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# Woody species diversity, structure and biomass carbon of parkland agroforestry practices in Gindeberet District, West Shoa Zone, Oromia Regional State, Ethiopia

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**Parkland agroforestry woody species are prominent features in many landscapes worldwide, and their ecological, social and economic importance is widely acknowledged. It is the traditional agroforestry systems from different countries and is almost a universal occurrence in Ethiopia. This study was conducted in Gindeberet District, West Shoa Zone, Oromia Regional State, Ethiopia to assess the parkland agroforestry woody species composition, diversity, structure and biomass carbon. Woody species inventory was carried out on 103 plots (each, 50 m x10 0m) in the crop field laid along 7 transects. For woody species ≥ 5 cm DBH, measurements of DBH and tree height were taken. A total of 61 woody species belonging to 35 families were recorded. The study indicated that the woody species Shannon and Simpson diversity indices were higher at lowland than midland agro-ecology. The species richness was significantly different between the two agro-ecological zones ($X^2$ = 8.5, p = 0.003). This study showed low carbon storage potential in living biomass of woody species; it is recommended to develop a policy on the woody species management, conservation and regeneration to increase the carbon storage potential in living biomass of woody species.**

**Key words:** Parkland agroforestry, woody species, latitude, diversity index, biomass carbon.

## INTRODUCTION

Many useful indigenous plant species are kept within the crop fields and form a prominent component of the farmland. This land use system, commonly known as the agroforestry parkland systems, has been successively described as farmed parkland by Pullan (1974) then, subsequently, as one of the many agroforestry systems observed all over the world (Nair, 1985). It is characterized by well-grown scattered trees on cultivated and recently fallowed land. These parklands develop when crop cultivation on a piece of land becomes more

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permanent (Verheij, 2003).

Parkland agroforestry woody species are prominent features in many landscapes worldwide, including natural, cultural and recently modified landscapes and their ecological, social and economic importance are widely acknowledged (Munzbergova and Ward, 2002; Plieninger et al., 2003; Manning et al., 2006). Woody plants integrated with the agricultural crops of smallholders characterize various forms of traditional agroforestry systems from different countries and is almost a universal occurrence in Ethiopia (Mohammed and Zemede, 2015). Woody plants of the farmed landscapes in Ethiopia have been part of the farmed commodities as they serve a wide range of economic, socio-cultural and ecological functions within the traditional farming systems (Kassa et al., 2011).

These agroforestry parkland systems have been described as good examples of traditional land use systems and biodiversity management practices (Boffa, 1999; Schreckenberg, 1999; Lovett, 2000); regulation of nitrogen dynamics and carbon sequestration (Barton et al., 2016; Hartel et al., 2017). The carbon (C) sequestration potential of agroforestry systems has been shown to vary with species composition, age, geographical location of the system (Jose, 2009), previous land use (Mutuo et al., 2005, Sauer et al., 2007), climate, soil characteristics, crop-tree mixture, and management practices (Dossa et al., 2008; Schulp et al., 2008).

Most of the carbon in trees and shrubs is accumulated in aboveground biomass (AGB) and 50% of the total biomass is taken as carbon stock. Aboveground carbon stock is the amount of carbon that is assumed to be 50% of the total vegetation biomass made up by carbon (Nair et al., 2009; Kumar and Nair, 2011). The belowground biomass of vegetation is considered as a fraction that takes about 25-30% of aboveground biomass depending on the nature of a plant, its root system and ecological conditions (Nair et al., 2009; Kumar and Nair, 2011).

Moreover, understanding of the roles of trees on farms and diversification of the farm in terms of species richness, as well as evenness through increase in number of trees of rare species, or through replacement of more common species are the best options for preventing degradation of agroforest ecosystems on farms (Kindt and Coe, 2005).

Even if the woody plants of parkland agroforestry have many benefits, unfortunately in natural, cultural and recently modified landscapes, it is facing some threats in these environments as well as some threats that are unique to particular ecosystems. The most direct threats to all those plants are clearing by humans, that is most of them are human driven and anthropocentric in origin. For example, the legal and illegal removal of scattered trees is widespread in every landscape worldwide (Gibbons and Boak, 2002; Aguilar and Condit (2001).). Parkland agroforestry degradation reduces both richness and abundance of useful trees and shrubs leaving the rural poor with fewer options to improve their health, nutrition and income. In addition, it reduces available habitat for other native plants and animals that figure importantly in local diets, medicines, etc.

However, to date there are no data in the literature about the study area which could help to provide the status of the woody species diversity of parkland agroforestry systems. Therefore, this study aims to assess the composition, diversity, structures and biomass carbons of woody species of parkland agroforestry in Gindeberet District, West Shoa Zone, Oromia Regional State, Ethiopia.

## MATERIALS AND METHODS

### Study area

The study was conducted in Gindeberet District, West Shoa Zone, Oromia Regional State, Ethiopia. Gindeberet District is located between 9° 21' to 9° 50' N Latitude and 37° 37' to 38° 08' E Longitude (Figure 1) and 193 km distance in the West of Addis Ababa, the capital city of Ethiopia (PEDOWS, 1997).

According to WQMBAG (2004), the total area of Gindeberet District is estimated to be about 119,879 $km^2$ and it is divided into 31 kebeles. Land is exclusively used for agriculture. The Oromo people of the study area categorize their surroundings by local language, Afan Oromo into different land-use/land-cover systems: home-garden (oddoo), crop field (lafa qonnaa/oyiruu), grazing land (lafa kaloo), forestland (bosona), fallow land (laf-bayii) and shrub lands (miciree). Out of the total area of Gindeberet district, 50,494 $km^2$ (42.1%) is used for agricultural purposes, 39,791 $km^2$ (33.1%) is used for grassland, 4,248 $km^2$ (3.5%) is covered by forest, 10,389 $km^2$ (8.7%) is covered by shrubs and water bodies like river, wetland and 6,972 $km^2$ (5.8%) is not used for any development purposes, 2,670 $km^2$ (2.2%) religious organizations and 5,315 $km^2$ (4.4%) residential areas (WQMBAG, 2013).

Two agro-ecological zones can be found in Gindeberet, with, 43 and 57% of the land area classified as midland (Weinadega) and lowland (Kola), respectively. The mean monthly minimum and maximum temperature and rainfall for the agro-ecological zones of the study area are shown along with altitudinal variations in Table 1. The variability of the rainfall regime of the study areas affects cultivation, planting and harvesting activities.

### Sampling size and sampling techniques

#### *Selection of the study sites*

The study district was stratified into two agro-ecological zones: namely Weinadega (midland) and Kola (lowland) based on their altitudinal range. To select representative study sites within each agro-ecological zone, administrative units were used. The smallest administrative unit in the district is locally called ganda or kebele, which means Peasant Associations (PAs). Five PAs were selected purposively from both of the agro-ecology, three from lowland and two from midland based on the woody vegetation coverage. Farmlands (crop fields) were considered to lay down the plots in the parkland agroforestry in each kebele.

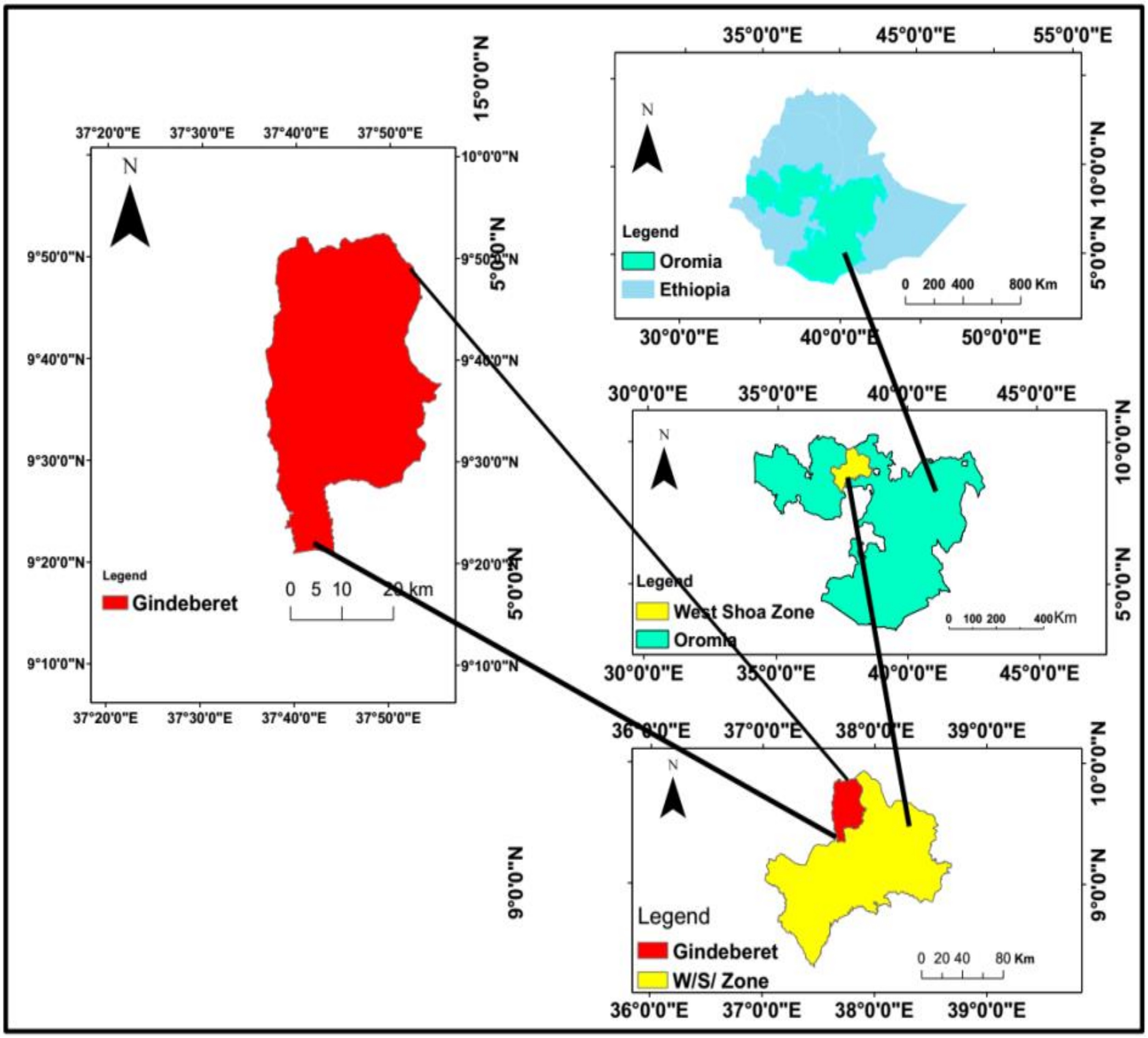


**Figure 1.** Location of the study area.

**Tree inventories**

Before starting field survey, reconnaissance was carried out for one week in the selected kebeles to get first-hand information about the study area. A total of 7 transect lines were established for the inventory in the farmland. Along the transect lines 103 plots of 100 m x 50 m (5000 $m^2$) size were laid in the farmland. A systematic sampling method was applied to locate the sample plots to collect woody species structure and composition. The data were collected following the transect line by excluding non-targeted habitats (e.g. rivers, rocky hills, farmers' compounds). The distance between each of the transects and plots was 500 and 400 m, respectively. All woody species found in the plots, with individuals having diameter at breast height (DBH) ≥ 5 cm, were recorded at 1.3 m height from ground level. The diameters were measured using tree caliper and diameter tape, and height was measured using a Suunto clinometer and approximately estimated in those cases where the topography and canopy conditions were not suitable to measure by a Suunto clinometer. Samples of all trees and shrubs species encountered in the plots were recorded by their local names, and specimens were collected for further identification. For specimen identification, Fichtl and Admasu (1994) and Azene (2007) were used, supported by expertise. The geographical position of plots was recorded with a GPS (Global positioning system) allowing their accurate location to allocate the x-y axis of each plot.

**Data analysis**

***Diversity analysis***

The species diversity in the parkland agroforestry was estimated using species richness, Shannon diversity index, Simpson diversity index and Shannon evenness (Kent and Coker, 1992). The Species richness is the total number of species in the community (Krebs,

**Table 1**. Agro-climatic description of the study areas.

| Agro-ecology | Temperature range (°C) | | Altitude range (m) | | Annual rainfall (mm) | |
|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max |
| Weinadega | 5 | 25 | 1501 | 2404 | 700 | 1400 |
| Kola | 10 | 30 | 1000 | 1500 | 300 | 850 |

Source: Gindeberet District Agricultural Office (WQMBAG, 2004).

1999). It was analysed by using Jack knife software version 7.2 (Chorles and Krebs, 2011).

Shannon diversity index is calculated as: $H' = -\sum p_i (\ln p_i)$
Where, H' = Shannon diversity index, $P_i$ = proportion of individuals found in the $i^{th}$ species; or the number of individuals of one species/total number of individuals in the samples.
The evenness of a population was calculated by (Krebs, 1999):

$$E = \frac{H'}{Hmax} = \frac{H'}{\ln (S)}$$

with Hmax = ln (S)

Where, E = Evenness, H ′ = Calculated Shannon-Wiener diversity, H max = ln(S) [species diversity under maximum equitability conditions]; S = the number of species; Simpson's diversity index (D) was calculated as:

$$D = 1 - \left(\frac{\sum n(n-1)}{N(N-1)}\right)$$

Where, D = Simpson's index, n = The total number of organisms of a particular species, N = The total number of organisms of all species.

At the end, the diversity indexes were converted to true diversity (effective number of species by using the formula $T_D = e^H$
Where $T_D$ = True diversity, e = Base of natural logarithm and H= Shannon diversity index.

To measure the similarity between the vegetation samples, Sorensen's coefficient of similarity ($S_s$) was used. It is given by the formula of Kent and Coker (1992):

$$S_s = \frac{2a}{2a + b + c}$$

Where, Ss= Sorensen similarity coefficient, a = number of species common to both samples, b = number of species in sample 1 and c = number of species in sample 2.

The coefficient is multiplied by 100 to give a percentage.

### Structural analysis

#### *Basal area*

Basal area is the cross-sectional area of woody stems at breast height. It measures the relative dominance (the degree of coverage of a species as an expression of the space it occupies) of a species in an area. Basal area was calculated for each woody species with diameter ≥ 5 cm as:

$$BA = \frac{\pi (DBH)^2}{4}$$

BA = basal area ($m^2$)
Where, π = 3.14 and DBH = diameter at breast height (cm).

Diameter and height classes were arbitrarily recognized in each of the two agro-ecologies of parkland agroforestry. For this, seven diameter classes (<10, 10-20, 21-30, 31-40, 41-50, 51-60, and >6), and five height classes (<5, 5.1-10, 10.1-15, 15.1-20 and > 20) were classified in each of the agro-ecological zones

#### *Density*

Density was calculated by summing up all stems across all area and converting into hectare basis.

$$\text{Density} = \frac{\text{Total number of individual species}}{\text{Sample area (ha)}}$$

#### *Relative density*

$$= \frac{\text{Number of individual of species}}{\text{Total number of individuals}} * 100$$

#### *Relative dominance*

$$= \frac{\text{Dominance of aspecies}}{\text{Total dominance of all species}} * 100$$

#### Frequency

$$= \frac{\text{Area of the plot in which species occurs}}{\text{Total number of sample plots}}$$

#### *Relative frequency*

$$= \frac{\text{Frequency of a species}}{\text{Frequency of all species}} * 100$$

#### *Importance value index*

The importance value index (IVI) indicates the importance of species in the system and it is calculated with three components

(Kent and Coker, 1992).

Importance value for each woody species was calculated by using the formula:

IVI= Relative frequency + Relative density + Relative dominance

### *Trees/shrubs biomass carbon estimation*

Woody species carbon was estimated for different woody species available in parkland agroforestry using non-destructive methods. Particularly, biomass carbon estimation was done as per the method adopted by Pandya et al. (2013); where he used the same formula for estimation of biomass carbon for 25 tree species.

### *Tree bio-volume ($T_{BV}$)*

Height and diameter of trees within each species were converted into bio-volume as follows:

Bio-volume ($T_{BV}$) = 0.4 x $(D)^2$ x H (Pandya et al., 2013).
Where, H = Height of the tree (m) and D = Diameter (cm)

### *Aboveground biomass (AGB)*

Aboveground biomass was calculated by using the following formula:

Aboveground biomass = $T_{BV}$ x P
Where, P = Wood density and $T_{BV}$ = Tree bio-volume
In this case for woody density, Global Woody Density Bases of Carsan et al. (2012) and Goldsmith and Carter (1981) were used.

### Belowground biomass (BGB)

The belowground biomass was calculated by multiplying the aboveground biomass (AGB) by 0.26; a factor expressing the root: shoot ratio (Hangarge et al., 2012).
BGB = AGB x 0.26

### Total biomass

Total biomass is the sum of above and belowground biomass (Sheikh et al., 2011).
In this study, the equation for total biomass was: (TB) = Aboveground biomass (excluding litter) + Belowground biomass (Excluding Soil Organic Matter).

### Carbon estimation

Generally, for any plant species 50% of its biomass is considered as carbon (Pearson et al., 2005) that is Carbon Storage = Biomass x 50%.

### Statistical data analysis

After the data were collected, species composition, species richness, species diversity, structures and biomass carbon estimate were analyzed using SPSS, version 20 and Microsoft Excel version 2010. These data were summarized and discussed using descriptive statistics such as frequencies, percentage and crosstabs.

## RESULTS AND DISCUSSION

### Woody species composition

Totally, 61 woody species (54 to species level, 6 to genus level and 1 unidentified) were collected from the two agro-ecological zones of the parkland agroforestry of Gindeberet (Appendix 1). Out of this, 31 species were collected from the midland parkland agroforestry; while 53 species were collected from the lowland parkland agroforestry. Twenty-three woody species were common for both agro-ecological parkland agroforestrys. The species richness was significantly different between the two agro-ecological zones ($X^2$ = 8.5, p = 0.003).

The collected species belonged to 35 families, excluding unidentified species. Fabaceae, Moraceae and Myrtaceae were the most dominating families. They were diverse in terms of species number being 12 for Fabaceae and 4 for Moraceae and Myrtaceae, each. Bajigo and Tadesse (2015) and Worku et al. (2011) reported that Fabaceae was the family with a higher number of woody species in Gununo Watershed in Wolaita Zone and Debre Zeit, central rift valley of Ethiopia.

The total number of woody species individuals from midland and lowland agro-ecological parkland agroforestries was 492 and 951, respectively; indicating a significant difference ($p < 0.05$) between the two agro-ecological zones in terms of agroforestry tree and shrub species abundance. In terms of habit classification, 73.8% were trees and 26.2% were shrubs with 93.4% indigenous and 6.6% exotic species. Comparison of the woody species richness of the present study site with other sites indicated that it is higher in most cases. For example, Nikiema (2005) reported 41 in Burkina Faso while Motuma (2006) reported 32 in Arsi Negelle. Likewise, Worku et al. (2011) reported only 7 species in Debre Zeit and Bajigo and Tadesse (2015) reported 11 in Gununo of Woliata District. In all the above cases, we can see that there was a significant difference ($p < 0.05$) between our study site and study sites reviewed in the literature. Such differences in the farmlands could exist as agro-ecological characteristics; or other factors such as: site, socio-economic, culture and management strategy of the farmers.

### Diversity of woody species

In order to get a better picture on extent of woody species diversity, the Shannon, Simpson and evenness indices were employed. The values of the indices for evenness, Shannon’s and Simpson’s, respectively, were: 0.478, 2.96, 0.935 (midland parklands) and 0.467, 3.2, 0.937 (lowland parklands) as shown in Table 2.

Similarly, the value of woody species richness at midland altitude and lowland altitudes parkland agroforestry were 61 and 105, respectively. The values of diversity indices of woody species (Shannon and Simpson's diversity indexes) in the lowland parkland agroforestry were greater than the midland parkland agroforestry, but the evenness value of lowland parkland agroforestry was lower than the midland parkland agroforestry.

In the present study, the Shannon and Simpson diversity indices showed high value in the lowland agro-ecological parkland agroforestry as compared to the midland parkland agroforestry. This may be due to the high number of species richness in the lowland agro-ecological parkland agroforestry compared to the midland parkland agroforestry. The species richness also showed the variation between the two agro-ecological parkland agroforestries. The lowland agro-ecology supported higher numbers of woody species richness than midland agro-ecology. This may be due to agro-ecological or site characteristics, altitudinal variation, socio-cultural and farmer's management strategy.

The study by Getahun (2011) on the diversity and management of woody species in home-garden agroforestries in Gimbo District, South west Ethiopia shows that the site, socio-economic, culture and management strategy could be the factors for woody species variation. As the study conducted by Hodel and Gessler (1999) stated, besides altitude and temperature, soil quality is another agro-ecological factor that generates variation of plant diversity. According to Dossa et al. (2013), there is a decline in tree species richness with increasing altitude, because of a greater role of environmental filtering at higher elevations (e.g. cooler temperatures, fog, reduced light incidence and higher relative humidity). Maghembe et al. (1998) also reported the influences of socio-cultural factors on woody species management and diversity. This is demonstrated both as encouraging and discouraging of woody species retention or their planting on farmlands.

The true diversity (effective number of species) of woody species in lowland parkland agroforestry and midland parkland agroforestry estimates were: 24.5 and 19.3, respectively (Table 2). From this, it is also possible to conclude that lowland parkland agroforestry was more diverse than the midland parkland agroforestry.

## Similarity index

The similarity in woody species composition between the two agro-ecological parkland agroforestries was 35.4% (Table 2). The low similarity could be due to the differences in agro-ecology and species growing requirements. Woody species adapted to midland agro-ecology may not adapt to lowland agro-ecology and vice-versa.

In this study, more numbers of woody species were recorded in lowland agro-ecologies as compared to the midland agro-ecologies. And also, the presence of a low number of woody species in midland agro-ecologies could be due to the fact that the midland agro-ecologies had relatively more infrastructures like roads and markets as compared to lowland agro-ecologies. According to Tesfaye (2005)'s report there was low woody species diversity and a low number of species richness in farms located near roads and access to markets. Also, as aforementioned agro-ecological or site characteristics, socio-cultural and farmer's management strategy could be the cause for the variation of woody species between the two agro-ecological zones.

## Structure of woody species

### *Basal area*

The total basal area of all woody species in the midland and lowland agro-ecologies of the parkland agroforestry were calculated from the diameter at breast height (DBH) of the individual tree/shrub species.

The mean basal area of midland parkland agroforestry (3.62 ± 1.3) was higher than the lowland parkland agroforestry (2.64 ± 0.92) (Table 3). However, there was no statically significant difference between the two means for basal areas of parkland agroforestries.

### *Frequency of woody species*

Frequency of woody species is one of the structural parameter which was measured in the two agro-ecological zones, and the top five frequent woody species in the two agro-ecological zones is listed in Table 4.

In the midland parkland agroforestry, the most frequent species were *Maytenus obscura*, *Rhus vulgaris*, *Acacia abyssinica Erthyrina brucei, Prunus africana,* being 47.1%, 38.2%, 26.5%, 26.5% & 23.5%, respectively (Table 4). In the lowland parkland agroforestry, the most frequent woody species were *Croton macrostachyus* (63.8%), *Faidherbia albida* (37.7%), C. africana (27.5) and *Albizia schimperiana* (27.5%).

### *Density of woody species*

Overall, 1443 individual woody species were collected from 51.5 ha from the two agro-ecological zones of the parkland agroforestry of Gindeberet. The mean density of midland parkland agroforestry (1.04 ± 0.35) was significantly lower than lowland parkland agroforestry (1.87 ± 0.22) at ($p < 0.05$) (Table 4). In general, the two agro-ecological parkland agroforestries have the lower mean density per hectare. This is because of the

**Table 2**. Diversity indices and species richness of woody species in the parkland agroforestry practices at the two agro-ecological zones.

| Agro-ecological altitude | Number of Plot | Species richness | Diversity index value | | | True diversity | Sorensen Similarity percentage |
|---|---|---|---|---|---|---|---|
| | | | Evenness | Shannon diversity | Simpson diversity | | |
| Midland | 34 | 61 | 0.478 | 2.96 | 0.935 | 19.3 | |
| Lowland | 69 | 105 | 0.467 | 3.20 | 0.937 | 24.5 | 35.4 |

**Table 3**. Mean ± Standard Deviation of the two agroforestry parkland structures.

| Parameter | Agro-ecology | Mean ± Standard Deviation | p-value |
|---|---|---|---|
| Diameter at breast height (cm) | Midland | 32.91 ± 4.19 | |
| | Lowland | 25.44 ± 3.11 | 0.153 |
| Height (m) | Midland | 9.79 ± 0.82 | |
| | Lowland | 9.51 ± 1.40 | 0.883 |
| Density (ha$^{-}$) | Midland | 1.04 ± 0.35 | |
| | Lowland | 1.87 ± 0.22 | 0.041 |
| Basal area ($m^2$) | Midland | 3.62 ± 1.38 | |
| | Lowland | 2.64 ± 0.92 | 0.543 |

**Table 4**. Top five frequent woody species in the two agro-ecological zones of Gindeberet in their descending order.

| Agro-ecological zones | Scientific name | % in frequency |
|---|---|---|
| Midland parkland agroforestry | *Maytenus obscura* | 47.1 |
| | *Rhus vulgaris* | 38.2 |
| | *Acacia abyssinica* | 29.4 |
| | *Erythrina brucei* | 26.5 |
| | *Prunus africana* | 23.5 |
| Lowland parkland agroforestry | *Croton macrostachyus* | 63.8 |
| | *Faidherbia albida* | 37.7 |
| | *Cordia africana* | 27.5 |
| | *Albizia schimperiana* | 27.5 |
| | *Vernonia amygdalina* | 24.6 |

continuous cultivation of farmland and low regeneration potential of species in the study area. The research conducted by Worku et al. (2011) in the parkland agroforestry of Debre Zeit also revealed that, due to the continuous cultivation of farmland and no fallow practices that could enable species to regenerate and grow to big size contributes to the low density of species in farmland.

***Diameter class distribution***

Seven diameter classes were arbitrarily recognized in each of the two agro-ecologies of parkland agroforestry to see the distribution of diameter classes (Figures 2 and 3). In the midland agro-ecology the higher diameter class (>60 cm) was dominated by *Ficus sur, Erythrina brucei* and *Prunus Africana*; whereas, the lowest diameter class (<10 cm) was dominated by *Acacia abyssinica* and *Vernonia auriculfera* species in terms of DBH.

The rest of woody species have low juvenile populations, but this increases at the middle diameter classes and then decreases toward the larger diameter class in the midland parkland agroforestry. The distribution of population structure of these woody species

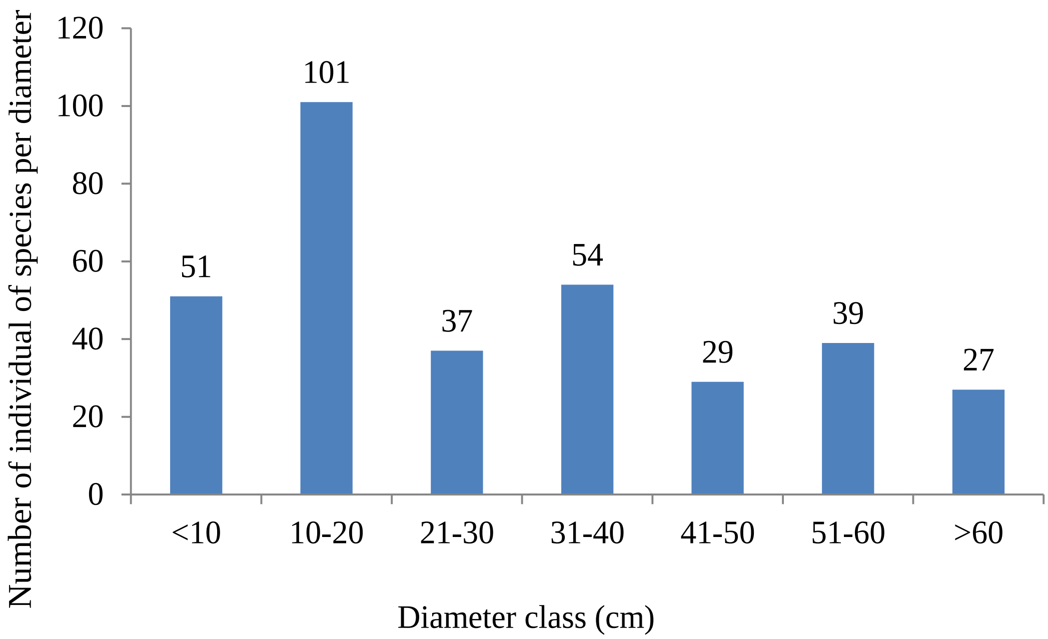


**Figure 2**. Diameter class distribution in midland parkland agroforestry of Gindeberet.

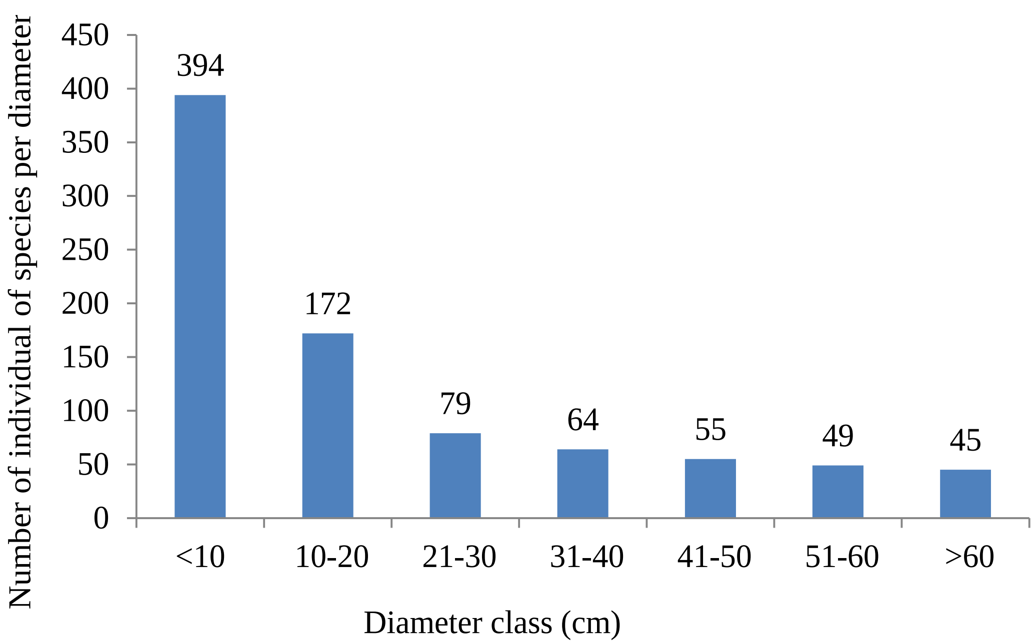


**Figure 3.** Diameter class distribution in lowland parkland agroforestry of Gindeberet.

species resembles close to a bell shape curve, which shows a high number of intermediate classes, but a very low number in the small and large diameter classes (Figure 2).

In the lowland parkland agroforestry (Figure 3), the total number of woody species in each DBH class decreased with increasing diameter classes. This was a normal DBH distribution pattern, when viewed from the whole set of plant communities, confirming a reversed J-shape plot (Figure 3). About 45.9% of the total populations were found in the first lower DBH class showing the dominance of small trees in the parkland agroforestry due to some

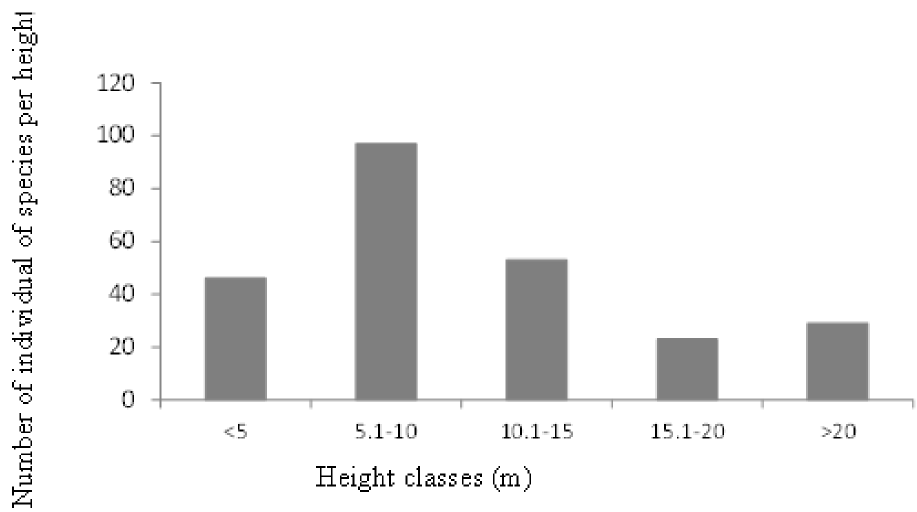


**Figure 4.** Height class distribution in midland parkland agroforestry of Gindeberet.

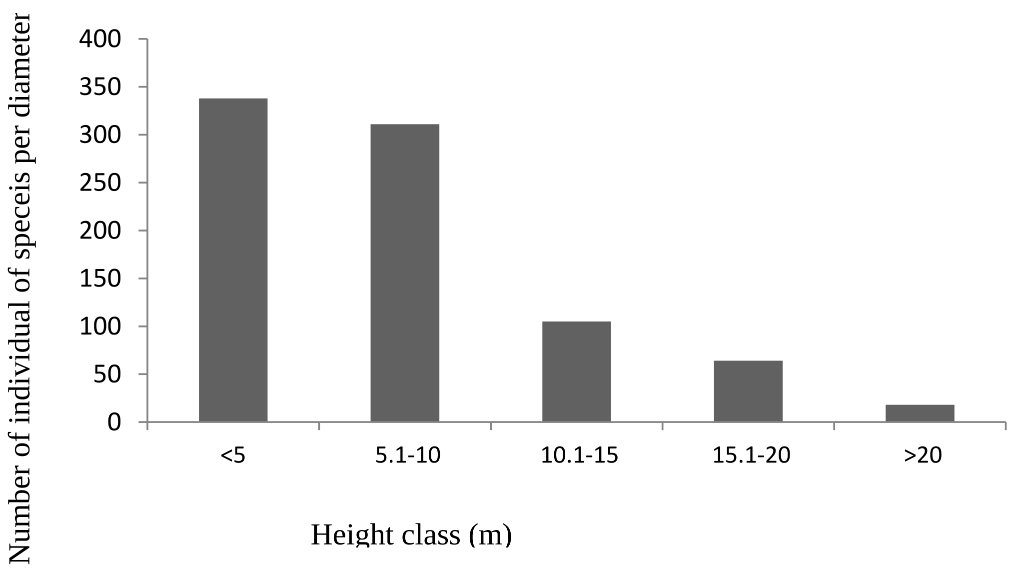


**Figure 5.** Height class distribution in the lowland parkland agroforestry of Gindeberet.

species were regenerating and some species were sprouting from the old trees that were coppiced, while the rest were distributed in all the remaining DBH classes. This diameter distribution pattern is similar with an earlier report by Yemenzwork (2014).

### Height class distribution

Generally, five height classes were identified in each of the agro-ecological zones (Figures 4 and 5). In the midland agro-ecology, the most dominant woody species with the higher height classes (>20 m) were *Ficus sur, Erythrina brucei* and *Prunus africana*; whereas *Acacia abyssinica* was the dominant species in the lowest height classes (<5.1 m).

In the lowest class, *Acacia abyssinica* was naturally regenerating better than the other woody species. This is due to the management practices like coppicing and lopping. The height attained was in the lower height classes. The height distribution structure of woody species in midland looks like a bell-shaped distribution, which shows a high number of intermediate classes, but a very low number in the small and large height classes

**Table 5**. The top five woody species with the highest importance value index in the two agro-ecological parkland agroforestry of Gindeberet.

| Agro-ecology | Scientific name | Relative. Frequency % | Relative Density % | Relative Dominance % | Importance Value Index |
|---|---|---|---|---|---|
| Midland | *F. sur* | 3.31 | 2.03 | 35.18 | 40.52 |
| | *M. obscura* | 13.22 | 12.4 | 7.93 | 33.55 |
| | *R. vulgaris* | 10.74 | 10.16 | 10.04 | 30.95 |
| | *E. brucei* | 7.44 | 8.74 | 12.9 | 29.08 |
| | *A. abyssinica* | 8.26 | 10.16 | 2.63 | 21.05 |
| Lowland | *C. macrostachyus* | 17.88 | 15.12 | 28.39 | 61.39 |
| | *F. albida* | 5.36 | 8.93 | 11.67 | 25.97 |
| | *F. vasta* | 2.00 | 5.15 | 17.03 | 24.18 |
| | *A. schimperiana* | 7.15 | 6.53 | 5.44 | 19.12 |
| | *C. africana* | 3.68 | 6.53 | 7.87 | 18.08 |

(Figure 4).

In the lowland agro-ecologies (Figure 5), the total number of woody species in each height class showed a decreasing trend with increasing height classes. This is also similar with the DBH class distribution in lowland agro-ecologies. This is a normal height distribution pattern, when viewed from the whole set of plants in a community, confirming a reversed J-shape plot (Figure 5).

The majority of the populations were found in the first height class showing the dominance of small trees in the parkland agroforestry. This is due to the management practices, i.e. lopping and coppicing. When the average mean height of trees in lowland parkland agroforestries (9.79 ± 0.82 m) is compared with the average mean height of midland agroforestry (9.51 ± 1.40 m), there is a slight difference. The difference may be due to the difference in management practices carried out at two locations. However, statistically, the independent t-test value revealed no significant difference (Table 3).

## Importance value index (IVI)

In the two agro-ecological zones, the importance value index of all woody species was assessed. However, the top five important woody species were briefly discussed here in terms of their importance value index (Table 5). Accordingly, *F. sur, M. obscura, R. vulgaris, E. brucei* and *A. abyssinica* were the top five ranked woody species, and had mean IVI values of 40.52, 33.55, 30.95, 29.08 and 21.05, respectively, in midland parkland agroforestries.

In the lowland parkland agroforestries, *C. macrostachyus, F. albida, F. vasta, A. schimperiana* and *C. africana* were the top five ranked woody species with the mean IVI values of: 61.39, 25.97, 24.18, 19.12 and 18.08, respectively. *C. macrostachyus* ranked first at lowland and F. sur ranked first at midland agro-ecologies. IVI is used to determine the overall importance of each species in the community structure. Species with the greatest importance value are the primary dominant species of a specified vegetation (Simon and Girma, 2004).

## Estimate of the aboveground and belowground biomass and biomass carbon

This study estimated the above and belowground biomass, total biomass and biomass carbon of the woody species in the two agro-ecological zones of parkland agroforestries in Gindeberet. The total woody biomass and the biomass carbon of lowland parkland agroforestries were considerably higher (38.33 Mg/ha) and (19.17 MgC/ha) than at midland parkland agroforestry (20.28 Mg/ha) and (10.14 MgC/ha), respectively (Table 6). This could be due to the difference in altitude, species richness, and structure of woody species in the area.

Since the aboveground biomass depends on the height and diameter of woody species, the aboveground biomass increases with increasing diameter and height. The structure and composition of vegetation (tree species, density, diameter at breast height size and height, etc.) affects the aboveground biomass carbon (Unruh et al., 1993; Weifeng et al., 2011). According to Leuschner et al. (2013), the aboveground biomass of vegetation decreased with increasing altitude. The relationship between height and diameter is also related to species, climatic, soil characteristics, region and even tree diversity (Imani et al., 2017). With regard to taxonomic characteristics, species richness has been associated with aboveground biomass.

**Table 6**. Estimate of the above and belowground biomass, total biomass and biomass carbon estimation in the two agro-ecology zones of Gindeberet (Mg/ha).

| Agro-ecology | Aboveground biomass | Belowground biomass | Total biomass | Total biomass carbon |
|---|---|---|---|---|
| Midland | 16.09 | 4.18 | 20.28 | 10.14 |
| Lowland | 30.42 | 7.91 | 38.33 | 19.17 |

Environmental parameters, such as climate and soils also affect aboveground biomass (Lewis et al. 2013; Poorter et al., 2015).

## Conclusions and Recommendations

Even though Gindeberet District is among the most severely deforested parts of West Shoa Zone in Oromia Regional State, Ethiopia; parkland agroforestry woody species still exist, although within various challenges.

However, the differences exist in the diversity and composition of woody species in the parkland agroforestry among the agro-ecological zones. Lowland parkland agroforestry supports higher number of woody species with higher diversity indices than midland parkland agroforestry. This set of parkland agroforestry practices was less complex structurally and had low storage of woody biomass and biomass carbon as compared to the other parkland agroforestry practices.

In general, even if the diversity of species is better in the study area as compared to the other parkland agroforestries, it needs improvements in management to support socio-economic and environmental sustainability.

To ensure the regeneration and to save the species, even from becoming extinct, direct sowing and preserving the desired species in the parkland agroforestry is the solution to overcome the problems.

Since this study showed low carbon storage potential in living biomass of woody species, it is recommended to develop a policy on the woody species management, conservation and regeneration to increase the carbon storage potential in living biomass of woody species to accomplish the goal of the Climate Resilient Green Economy Policy of the country by considering parkland agroforestry practices as one part for its achievement.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

### REFERENCES


Aguilar S, Condit R (2001). Use of native tree species by Hispanic community in Panama. Economic Botany 55(2):223-235.

Azene B (2007). Useful trees and shrubs of Ethiopia: Identification, propagation, and management in 17 Agro-ecological zones. Nairobi: RELMA in ICRAF Project P 552.

Barton DN, Benjamin T, Cerdán C, Declerck F, Madsen A, Rusch G, Villanueva C (2016). Assessing ecosystem services from multifunctional trees in pastures using Bayesian belief networks. Ecosystem Services 18:165-174.

Bajigo A, Tadesse M (2015). Woody Species Diversity of Traditional Agroforestry Practices in Gununo Watershed in Wolaita Zone, Ethiopia. Forest Research 4(4):2168-9776.

Boffa JM (1999). Agroforestry parklands in Sub Saharan Africa. FAO conservation guide 34. Food and Agriculture Organization of the United Nations, Rome, Italy.

Chorles J, Krebs M (2011). Programs for ecological methodology second Edition.

Dossa E L, Fernands EC M, Reid WS, Ezui K (2008). Above and belowground biomass, nutrient and carbon stocks contrasting an open-grown and a shaded Coffee plantation. Agroforestry Systems 72:103-115.

Dossa O, Paudel E, Fujinuma J, Yu H, Chutipong W, Zhang Y (2013). Factors determining forest diversity and biomass on a tropical Volcano, Mt. Rinjan Lombok, Indonesia. PLoS ONE 8(7):67720.

Fichtl R, Admasu A (1994). Honey bee Flora of Ethiopia: The National Herbarium, Addis Ababa University, Deutscher Entwicklungsdienst (DED). Margraf Verlag, Germany P 510.

Getahun Y (2011). Diversity and Management of Woody Species in Home-gardens Agroforestry. M.Sc. Thesis in Gimbo district, South West Ethiopia: Wondo Genet College of Forestry and Natural Resources. Hawassa, Ethiopia P 83.

Gibbons P, Boak M (2002). The value of paddock trees for regional conservation in an agricultural landscape: Ecological Management and Restoration 3(3):205-210.

Hartel T, Réti K, Craioveanu C (2017). Valuing scattered trees from woody pastures by farmers in a traditional rural region of Eastern Europe. Agriculture, Ecosystems and Environment 236:304-311.

Hodel U, Gessler M (1999). In situ conservation of plant genetic resources in home gardens of southern Vietnam: A report of home garden surveys in southern Vietnam, December 1996-May 1997.

Imani G, Boyemba F, Lewis S, Nabahungu N, Calders K, Zapfack L (2017). Height-diameter allometry and above ground biomass in tropical montane forests: Insights from the Albertine Rift in Africa. PLOS ONE 12(6):0179653.

Jose S (2009). Agroforestry for ecosystem services and environmental benefits: an overview. Agroforestry Systems 76:1-10.

Kassa H, Bekele M, Campbell B (2011). Reading the landscape past: Explaining the lack of on-farm tree planting in Ethiopia. Environment and History 17(3):461-479.

Kindt R, Coe R (2005). Tree diversity analysis. A manual and software for common statistical methods for ecological and biodiversity studies. Nairobi: World Agroforestry Centre (ICRAF). List of species and commodity grouping. Resources of Tropical Africa.

Kent M, Coker P (1992). Vegetation Description and Analysis: A practical approach. John Wiley and Sons, Chichester P 363.

Kumar BM, Nair PKR (2011). Carbon Sequestration Potential of Agroforestry Systems: and Challenges. Springer Science+ Business Media 8:326.

Krebs J (1999). Ecological Methodology: Second Edition, Benjamin Cummings. Menlo Park P 620.

Leuschner C, Zach A, Moser G, Homeier J, Graefe S, Hertel D (2013). The carbon balance of tropical mountain forests along an altitudinal

transects. Ecological Study 22(1):117-139.
Lewis S, Bonaventure S, Terry S, Serge K, Gabriela L, Geertje M, Van H (2013). Aboveground biomass and structure of 260 African tropical forests. Philosophical Transactions of Royal Society 36(8):20120295.
Lovett PN, Haq N (2000). Evidence for anthropic selection of the shea nut tree (Vitellaria paradoxa). Agroforestry Systems 48:273-288.
Manning A, Fischer J, Lindenmayer D (2006). Scattered trees are keystone structure. Implication for conservation. Biological Conservation 13(2):311-321.
Mohammed H, Zemede A (2015). Smallholder farmers' perceptions, attitudes, and management of trees in farmed landscapes in Northeastern Ethiopia. USA: USAID P 51.
Motuma T (2006). Woody Species Diversity of Agricultural Landscapes in Arsi Negelle District, Ethiopia. Msc. Thesis Submitted to the Graduate Studies of University of Hawassa, Wondo Genet College of Forestry: Wondo Genet, Ethiopia P 78.
Munzbergova Z, Ward D (2002). Acacia trees as keystone species in Negev desert ecosystems. Journal of Vegetation Science 13(2):227-236.
Mutuo PK, Cadisch G, Albrecht A, Palm C A, Verchot L (2005). Potential of agroforestry for carbon sequestration and mitigation of greenhouse gas emissions from soils in the tropics. Nutrient Cycling in Agro-ecosystem 71:43-54.
Nair PKR (1985). Classification of agroforestry systems. Agroforestry Systems 3(2):97-128.
Nair PKR, Kumar BM, Vimala DN(2009). Agroforestry as a strategy for carbon sequestration. Journal of Plant Nutrient Soil Science 172:10-23.
Nikiema A (2005). Agroforestry Parkland Species Diversity: Uses and Management in Semi-Arid West Africa (Burkina Faso). PhD Dissertation, Wageningen University, Wageningen. ISBN 90-8504-168-6.
Planning and Economic development Office for West Shoa Administrative Zone (PEDOWS) (1997). Ambo, Ethiopia, Printing section of the Ministry of Economic Development and Cooperation. 1st edition.
Plieninger T, Pulido F, Konold W (2003). Effects of land use history on size structure of holm oak stands in Spanish dehesas: implications for conservation and restoration. Environmental Conservation 30(1):61-70.
Poorter L, Van der Sande M, Thompson J, Arets E, Alarcón A, Álvarez-Sánchez, J (2015). Diversity enhances carbon storage in tropical forests. Global Ecological Biogeography 24(11):1314-1328.
Pullan RA (1974). Farmed parkland in West Africa. Savanna 3(2):119-151.
Sauer JT, Cambardella A C, Brandle RJ (2007). Soil carbon and tree litter dynamics in red cedar-scotch pine shelterbelt. Agroforestry Systems 71:163-174.
Schreckenberg K (1999). Products of managed landscape: Non-timber forest products in the parklands of the Bassila region, Benin. Global Ecology and Biogeography 8:279-289.
Schulp JEC, Nabuurs JG, Verburg HP, De Waal WR (2008). Effect of tree species on carbon stocks in forest stocks in forest floor and mineral soil and implications for soil carbon inventories. Forest Ecology and Management 256:482-490.
Simon SH, Girma B (2004). Composition, Structure & Regeneration Status of Woody Species in Dindin Natural Forest, Southeast Ethiopia: An Implication for Conservation. Ethiopian Journal of Biological Sciences 3(1):15-35.
Tesfaye A (2005). Diversity in home-garden agroforestry systems in Southern Ethiopia. Ph.D. Thesis, Wageningen University, Wageningen, Netherland P 143.
Unruh JD, Houghton RA, Lefebvre PA (1993). Carbon storage in agroforestry: An estimate for sub-Saharan Africa. Climate Research 3(1):39-52.
Verheij E (2003). Agroforestry, third edition: Agrodok 16, Agromisa Foundation, Wageningen. ISBN: 90-72746-92-9.
Weifeng W, Xiangdong L, Zhihai M, Kneeshaw DD, Changhui P (2011). Positive Relationship between Aboveground Carbon Stocks and Structural Diversity in Spruce Dominated Forest Stands in New Brunswick, Canada 57:506-515.
Worku B, Yitebetu M, Zebene A (2011). Structure, Diversity, Carbon Stocks& Management of Agroforestry Parkland in Debre Zeit, Central Rift Valley of Ethiopia: Implication for climate change mitigation and adaptation. Proceedings of the 2nd National Symposium on Science for Sustainable Development Organized by Arba Minch University in 2015, 2:343-354. Available at: http://hdl.handle.net/123456789/252
WQMBAG (2004 and 2013) (Strategic Action Plan for Agriculture and Rural Development of Gindeberet District) (Translated from Local Language Afan Oromo). Unpublished document.
Yemenzwork E (2014). Assessment of tree species, diversity distribution pattern and socio-economic uses on farmland in Oromia Regional State: The case of East Shoa Zone. M.Sc.Thesis Addis Ababa University. Addis Ababa, Ethiopia, 73pp.

**Appendix 1**. List of woody species in Gindeberet.

| S/N | Scientific name | Family name | Vernacular name in Afan Orormo | Habit |
|---|---|---|---|---|
| 1 | *Acacia abyssinica Hochst. ex Benth.* | Fabaceae | *Laaftoo* | T |
| 2 | *Acacia sp1.* | Fabaceae | *Laaftoo* | T |
| 3 | *Acacia sp2.* | Fabaceae | *Doddota* | T |
| 4 | *Acacia tortilis Forsk.* | Fabaceae | *Laaftoo* | T |
| 5 | *Albizia gummifera J.F.Gmel.* | Fabaceae | *Muka-arbaa* | T |
| 6 | *Albizia schimperiana Oliv.* | Fabaceae | *Imalaa* | T |
| 7 | *Albizia sp.* | Fabaceae | *Gaafatoo* | T |
| 8 | *Allophylus abysinicus (Hochst) Radlk.* | Sapindaceae | *Sarara* | T |
| 9 | *Apodytes dimidiata E. Mey ex Arn.* | Icacianaceae | *Calalaqaa* | T |
| 10 | *Bersama abyssinica Fresen.* | Melianthaceae | *Lolchiisaa* | S |
| 11 | *Brucea antidysenterica J.F. Mill.* | Simarobiaceae | *Qomonyoo* | S |
| 12 | *Buddleja polystachya Fresen.* | Buddlejaceae | *Anfaara adii* | T |
| 13 | *Calpurnia aurea (Lam.) Benth.* | Fabaceae | *Ceekaa* | S |
| 14 | *Carissa spinarum L.* | Apocynaceae | *Hagamsa* | S |
| 15 | *Celtis africana Brum. F.* | Ulmaceae | *Mata qoma* | T |
| 16 | *Coffea arabica L.* | Rubiaceae | *Buna* | S |
| 17 | *Cordia africana Lam.* | Boraginaceae | *Waddeessa* | T |
| 18 | *Croton macrostachyus Hochst. Ex.A.Rich.* | Euphorbiaceae | *Bakkaniisa* | T |
| 19 | *Cussonia arborea A. Rich.* | Araliaceae | *Gatamaa* | T |
| 20 | *Dombeya torrida D. goetzenii.* | Sterculiaceae | *Daannisa* | T |
| 21 | *Dovyalis abyssinica A. Rich.* | Flacourtiaceae | *Koshommii* | T |
| 22 | *Dracaena steudneri Engl.* | Dracaenaceae | *Merqoo* | T |
| 23 | *Ekebergia capensis Sparrm.* | Meliaceae | *Somboo* | T |
| 24 | *Erythrina brucei Schweinf.* | Fabaceae | *Walensuu* | T |
| 25 | *Eucalyptus camaldulensis Dehnh.* | Myrtaceae | *Baarzaafii Wallaggee* | T |
| 26 | *Eucalyptus globulus Habill.* | Myrtaceae | *Baarzaafii* | T |
| 27 | *Eucalyptus saligna Smith.* | Myrtaceae | *Baarzaafii wallagge* | T |
| 28 | *Euclea racemosa L.* | Ebenaceae | *Miheessaa* | S |
| 29 | *Euclea sp.* | Ebenaceae | *Jimaa* | S |
| 30 | *Faidherbia albida Del.* | Fabaceae | *Garbii* | T |
| 31 | *Ficus sp.* | Moraceae | *Qilinxoo* | T |
| 32 | *Ficus sur Forsk.* | Moraceae | *Harbuu* | T |
| 33 | *Ficus thonningii Bl.* | Moraceae | *Dambii* | T |
| 34 | *Ficus vasta Forsk.* | Moraceae | *Qilxuu* | T |
| 35 | *Grevillea robusta A. Cunn. ex R. Br.* | Proteaceae | *Giravillaa* | T |
| 36 | *Grewia ferruginea Hochst. Ex. A. Rich.* | Tiliaceae | *Dhoqonuu* | S |
| 37 | *Justicia schimperiana T.anders.* | Acanthaceae | *Dhummuugaa* | S |
| 38 | *Maesa lanceolata* | Myrsinaceae | *Abbayii* | S |
| 39 | *Maytenus obscura (A. rich) Cuf.* | Celastraceae | *Kombolcha* | T |
| 40 | *Maytenus sp.* | Celasteraceae | *Kombol biitee* | S |
| 41 | *Millettia ferruginea Hochst.* | Fabaceae | *Birbirraa* | T |
| 42 | *Nuxia congesta R.Br. ex Fresen.* | Loganiaceae | *Anfaara gurraacha* | T |
| 43 | *Olea europaea L.* | Oleaceae | *Ejersa* | T |
| 44 | *Olinia rochetiana A.Juss.* | Oliniaceae | *Soolee* | T |
| 45 | *Pavetta oliveriana Hiern.* | Rubiaceae | *Buruurii* | S |
| 46 | *Phoenix reclinata Jack.* | Arecaceae | *Meexxii* | T |
| 47 | *Podocarpus falcatus (Thunb.) C. N. Page.* | Podocarpaceae | *Birbirsa* | T |
| 48 | *Premna schimperi Engl.* | Verbenaceae | *Urgeessa* | T |
| 49 | *Prunus africana (Hook.) Kalkm.* | Rosaceae | *Gurraa* | T |
| 50 | *Rhamnus prinoides L. Herit.* | Rhamnaceae | *Geshoo* | S |

**Appendix 1**. contd.

| | | | | |
|---|---|---|---|---|
| 51 | *Rhus glutinosa A.Rich.* | Anacardiaceae | *Xaaxessaa* | T |
| 52 | *Rhus vulgaris Meikle.* | Anacardiaceae | *Dabobessaa* | T |
| 53 | *Ricinus communis L.* | Euphorbiaceae | *Kobboo* | S |
| 54 | *Rumex nervosus Vahl.* | Polygonaceae | *Dhangaggoo* | S |
| 55 | *Salix subserrata* | Salicaceae | *Aleltuu* | T |
| 56 | *Sesbania sesban (L.) Merr* | Fabaceae | *Inchinnii* | S |
| 57 | *Syzygium guineense (Wild) D.C.* | Myrtaceae | *Baddeessaa* | T |
| 58 | *Teclea nobilis Del.* | Rutaceae | *Hadheessa* | T |
| 59 | *Vernonia amygdalina Del.* | Asteraceae | *Dheebicha* | T |
| 60 | *Vernonia auriculfera Heirn.* | Asteraceae | *Reejjii* | S |
| 61 | - | - | *Coocingaa** | S |

*Local name by Afan Oromo.