Black Sea Journal of Agriculture
Open Access Journal
e-ISSN: 2618 - 6578

BS Publishers

Research Article
Volume 3 - Issue 1: 6-16 / January 2020

# FLORISTIC COMPOSITION AND VEGETATION STRUCTURE OF GATIRA GEORGE'S FOREST IN HABRU WOREDA IN NORTH WOLLO, ETHIOPIA

**Andualem AYALEW[1]***

[1]*Sirinka Agricultural Research Center, P.O.Box 74, Woldiya, North Wollo, Ethiopia*

***Received:*** *August 14, 2019;* ***Accepted:*** *October 01, 2019;* ***Published:*** *January 01, 2020*

## Abstract

The study was conducted on Gatira Georges forest in, North Eastern Ethiopia to determine the floristic composition and vegetation structure. Systematic samplings of 9 (20 m × 20 m) plots were sampled along three line transects. In each main plots, nested plot (5m × 5m) and 2m×2m distributed were laid down to sample trees, shrubs and their seedlings and saplings. All plots were laid at a distance of 50 m along the transect lines. Community classification was performed using R-Free Statistical Software. Results showed that a total of 34 woody plant species representing 34 genera and 27 families were identified. The result of hierarchical cluster analysis of the forest revealed two communities identified having 85.7% similarities. The highest species diversity and evenness was 2.78 and 0.88 recorded in *Juniperus procera -Calpurnia aurea* community. The forest was dominated by lower diameter at breast height class and in the lower canopy indicating that it is in the stage of secondary development. Important value index ranges between 1.2 (0.42%) to 48.4(15.78%). Based on the results, nursery and plantation establishment, regeneration status and medicinal values of the forest and appropriate conservation measures for sustainable use of the forest resources are recommended.

**Keywords:** Diversity, Plant community, Gatira Georges Forest, Important Value Index, Sustainable use of forest

***Corresponding author:** Sirinka Agricultural Research Center, P.O.Box 74, Woldiya, North Wollo, Ethiopia
**E mail:** andualemayalew2010@gmail.com (A. AYALEW)
Andualem AYALEW https://orcid.org/ 0000-0002-1750-8914

**Cite as:** Alalew A. 2020. Floristic composition and vegetation structure of Gatira George's forest in Habru Woreda in north Wollo, Ethiopia. BSJ Agri, 3(1): 6-16.

## 1. Introduction

Ethiopia is one of the top 25 biodiversity-rich countries in the world as the major center of diversity and endemism for several plant species, due to its great geographical diversity, elevation, vegetation (Abiyou, 2013). Woody plants constitute about 1000 species out of which 300 are trees (Bekele, 2016). Biodiversity measurement typically focuses on the species level and species diversity is one of the most important indices for sustainable land use practice to reverse the decline of biodiversity by evaluating ecosystems at different scales (Shackelton, 2000; Ardakani, 2004). According to MEFCC (MEFCC, 2016), current Ethiopia's forest cover is 15.5 % which includes enormous areas of forest, dense wood lands, bamboo and plantation forests of the country.

Deforestation and forest degradation activities has accelerated the loss of biological diversity (Sagar and Singh, 2006). The annual deforestation rate in Ethiopia ranges from 80,000 to 200,000 ha per year (Temesgen, 2015). According to the report of Desta (2001), about 20,000 ha of forests are annually harvested in Amhara region for fuel, logging, and construction purposes. This

has contributed to the current low forest area, i.e.; only 60,688 ha state natural forest and 2.4 million ha public forests, which are not properly demarcated and managed (DHV consultants, 2001).

Remaining forests are only small remnant patches mostly confined to inaccessible areas (steeply and mountainous areas and sacred places (churches, monasteries and mosques) (Alemayehu et al., 2005). Church forests are serving as in- situ conservation and hotspot sites for biodiversity resources (Aerts et al., 2006; Abiyou et al., 2015). With the prevailing alarming rate of deforestation, the remaining natural forests could disappear within a few decades, unless appropriate and immediate measures are taken. Remnant trees are spared from cutting when forests cleared for agricultural or grazing. They have a clear effect on the species diversity, composition, and ecology of the surrounding woody vegetation (Manette and Robin, 2014). Moreover, Juniperus procera currently included in the International Union for Conservation of Nature in the red list of threatened species are common to abundant to church forest (IUCN, 2006).

Most of the remaining natural forests in Ethiopia are found in the southern and southwestern parts of the country, and the forests have almost disappeared from the rest of the country except a few scattered and relatively small areas of forest cover that remained in the northern, central and eastern parts of the country (Getahun and Anteneh, 2015). The flora of North Wollo is the least known still now, mainly due to lack of access (Cardelus et al., 2003). Woody species diversity and structure in the study areas are vital to know past management and to set management intervention (Ermias, 2011). The knowledge of the floristic composition of an area is a prerequisite for any ecological, phyto-geographical studies and conservation management activities (Jafari and Akhani, 2008). Structural analysis and species diversity are essential to provide information on species richness, forest management, forest ecology and ecosystem functions (Pappoe et al., 2010). Thus, assessment of floristic composition and vegetation structure of remnant natural forests ensures the conservation and management of the remaining remnant forests of North Wollo.

The management and conservation of forests in all areas throughout the country has been becoming a big challenge. Since most of the activities did not involve the local community (Dessalegn, 2001). Currently, forest species management on a sustainable basis is the main aim of conservation biodiversity (Myers and Harm, 2009).

In Northern Ethiopia mostly the Christian population is distributed following settlement pattern within the range of 1500 to 3500 m.a.s.l. (Alemayehu, 2007). Nowadays, even the remnant natural forest is continuously threatened by human activities. Gatira George's forest is one of the remaining forests in Northern Ethiopia. In order to ensure the conservation, management and sustainable utilization of this forest, describing the vegetation is urgently needed. Therefore; this study is designed to look in to the existing woody species diversity, structure and regeneration status in Gatira George's forest. So far, no studies have been reported on this forest. Therefore, this study was undertaken to describe and provide valuable information on floristic composition and vegetation structure of woody species in the forest. This intern helps to undertake appropriate conservation and management measures.

## 2. Material and Method

### 2.1. Description of the Study Area

The study area is located in Habru District, in North Wollo, Amahra Region at the distance of 478 km far from Addis Ababa along Dessie to Woldiya road (Figure 1). It is found at 23 km from Habru district at Wurgessa town. The forest is located between UTM zone 37 N 50° 00' 00"- 62° 30' 00" E longitude and latitude 11° 40' 00"-12°20' 00" N latitude. Gatira George's church forest is estimated to cover an area of 2.4 hectare. The altitudinal range is from 2024 to 2061 meters above sea level (m.a.s.l.) The annual mean temperature of study area is 27 ˚c with mean annual rain of 923 mm and its rainfall distribution is bimodal with the main rainy season July to September and the small rainy season at end of February to end of April (Shimelse, 2007).

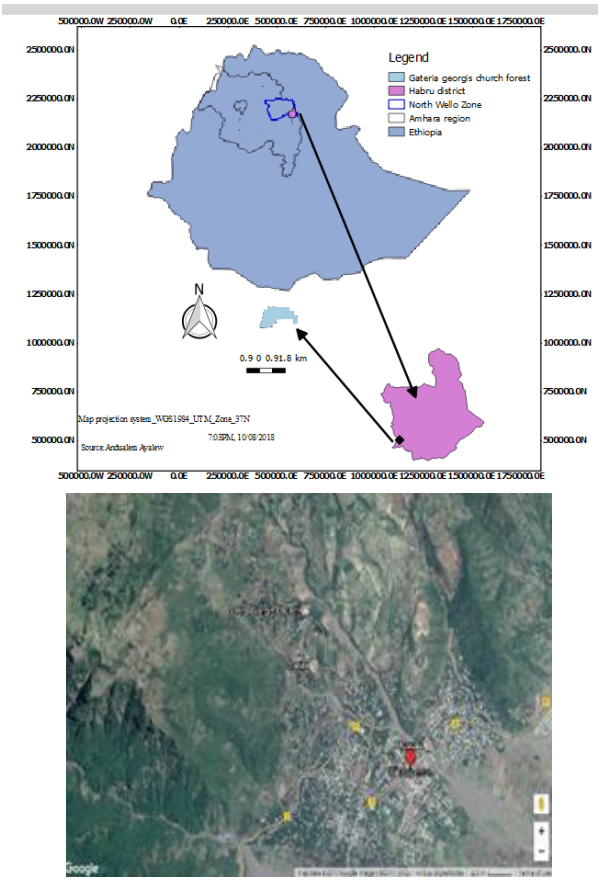


**Figure 1.** Map of the study area constructed by taking GPA points and located using QGIS 2.1.8.

**2.2. Sampling Design**

A systematic sampling method was employed for vegetation data in Gatira George's forest. Sample plots along three line transect in church forest were laid systematically in a concentric way at every 50 m along transect lines, which were 50 m apart from each other. The first transect line was laid starting from the lowest altitude of the study area by entering about 20 m from edge of the forest to avoid the "edge effect". Thus, for the census of mature plants, nine of the total quadrats of nested plot design were considered while for the purpose of shrub, seedling and sapling inventory, five sub quadrats of 5 m × 5 m and × 2 m were laid at the four corners and at the center of each main quadrat. Sample plot of 20 m× 20 m (400 $m^2$) was used for trees at height >5m and DBH>10cm. Five sub plot of 5mx5m (25 $m^2$) were laid for shrubs with height 0.5-5m (FRA, 2015; Amare and Bhardwaj, 2016). Five smaller plot of 2mx2m (4 $m^2$) also used for seedling DBH <2.5 and height < 2m and sapling >2m with DBH <10cm (FRA, 2015; Amare and Bhardwaj, 2016; Feyera, 2006) at the four corners and one at the center for tree regeneration study.

**2.3. Data Collection and identification**

**2.3.1. Floristic data collection**

Every plant species encountered in each quadrate was recorded using local name (vernacular names). For those species difficult to identify and give scientific name in the field, plant specimen was collected, pressed and brought to the national herbarium of Ethiopian, Addis Ababa University for taxonomic identification using published volume of the flora of Ethiopia and Eritrea (Edwards and Hedberg, 1989) and NDA (Natural Database for Africa) software. Moreover, for specimens being difficult to identify in the field, voucher samples were collected, pressed, and submitted for proper identification and botanical nomenclature at the National Herbarium, at Addis Ababa University. For basal area calculation, tree species with diameter at breast height (DBH) >2 cm were selected for comparison of remnant forests.

**2.3.2. Structural data collection**

The tree density, DBH, frequency, basal area and IVI were measured, recorded and used for description of vegetative structure. For the purpose of the study "seedlings", "saplings" and "mature trees/shrubs" were defined as plants with heights < 2 m and DBH< 2.5 cm, 2-5 m and DBH<10 cm and >2 m and DBH >10 cm (FRA, 2015; Amare and Bhardwaj, 2016; Feyera, 2006) at the four corners and one at the center for tree regeneration study respectively.

Accordingly, Sample plot of 20 m× 20 m (400 $m^2$) were laid for tree inventory in the main quadrat. While, 2 m x 2 m (4 $m^2$) for seedling and 5 m × 5 m (25 $m^2$) for sapling were laid at the four corners and at the center of each main quadrat respectively.

Seedling and saplings of trees and shrubs were counted to estimate the regeneration status of the forest.

**2.4. Data Analysis**

**2.4.1. Vegetation classification**

Cluster analysis was used for the purpose of vegetation classification into different community types using the statistical software R-package for windows version 2.15.0 (Venables and Smith, 2012). The Indicator Species Analysis was made to compare the species present in each community.

Hierarchical cluster analysis was conducted to identify vegetation samples that are similar in terms of their woody species composition. The cover abundance data of species were used for the analysis. The plant community types were named after two or three dominant species selected using the relative magnitude of their mean cover abundance values.

Of the total 34 plant species recorded from the study area, hence, 34 plant species were used for structural data analysis. The DBH, basal area, tree density, height, frequency and important value index were used for description of vegetation structure.

**2.4.2. Diversity index**

Species diversity and evenness are often calculated using shannon-wiener diversity index (Kent and Coker, 1992).

$$H' = -\sum \frac{ni}{N} \times ln \frac{ni}{N} \quad (1)$$

where "*H*" is Shannon diversity index, "$n_i$" is the total number of individuals of species "*I*" and "*N*" is the total number of individuals of all species in that stand & *ln*=natural logarithm. Possible values of the $H'$ range between 1.5 and 3.5 and only rarely exceed 4.5, where high values indicate high diversity.

Species evenness was calculated as;

$$J = \frac{H'}{Hmax} = \frac{H' = -\sum \frac{ni}{N} \times ln \frac{ni}{N}}{\ln s} \quad (2)$$

where $J$ is species evenness $H'$ is observed Shannon diversity index; $S$ is the number of species. *Hmax* is the maximum level of diversity.

The Sorenson's Coefficient of Similarity (SC) was also computed (Sorensen, 1948) as;

$$SC = \frac{2c}{a+b+2c} \times 100 \quad (3)$$

where $C$ is the number of species common to both forest sites; $a$ and $b$ are the number of species at forest sites $a$ and $b$.

**2.4.3. Stand characteristics of the forest**

To describe the horizontal stand structure of the forest, basal area, density, frequency, height, DBH, floristic composition, importance value index and basal area were calculated following.

**2.4.3.1. Basal Area**

It is the cross-sectional area of all of the stems in a stand at breast height (1.3m above ground level). This basal

area per unit area is used to explain the crowdedness of a stand of forests. It is expressed in square meter/hectare (Jim and Becky, 2012). The basal area was computed as;

$$BA = \sum \frac{3.14*DBH2}{4} \quad (4)$$

where, *BA* is basal area, *DBH* is average diameter at breast height. Therefore, Relative basal area (RBA) was computed as;

$$RBA = \frac{Total\ basal\ area\ of\ aspecies}{Total\ basal\ area\ of\ all\ species} \times 100 \quad (5)$$

Density is defined as the number of plants of a certain species per unit area.

$$Density = \frac{Total\ number\ of\ individual\ species}{n \times Plot\ area} \quad (6)$$

For density/ha calculation, the sum of individuals per species were calculated and analyzed following methods (Mueller-Dombois and Ellenberge, 1974).

Relative density (RD) is the study of the numerical strength of a species in relation to the total number of individuals of all the species.

$$RD = \frac{Density\ of\ individual\ species}{Total\ desnity\ of\ all\ species} \times 100 \quad (7)$$

Frequency is defined as the chance of finding a plant species in a given sample area or quadrat (Kent and Coker, 1992). It is calculated with the formula;

$$Frequency = \frac{TNQ\ in\ w/c\ the\ species\ occur}{TNQ\ studied} \times 100 \quad (8)$$

here, *TNQ* denotes the total number of quadrats.

Relative frequency (RF) is the degree of dispersion of individual species in relation to the number of all the species occurred. It was computed;

$$RF = \frac{frequency\ of\ individual\ species}{Toal\ frequency\ of\ all\ species} \times 100 \quad (9)$$

Importance value index (IVI) was computed using (Krebs, 1989);

$$IVI = RBA + RD + RF \quad (10)$$

## 3. Results and Discussion

### 3.1. Floristic Composition

Only 34 woody species belonging to 34 genera and 27 families were identified during this study showing the low species richness of the Forest ecosystem. The most frequent families are *Boraginaceae, Euphorbiaceae, Fabaceae, Oleaceae, Rosaceae, Sapindaceae* and *Tiliaceae* (2 species each) accounts 25.9%, and 20 families represented by (1 species each) accounts 74.1% share in the study area respectively (Figure 2). The 34 species recorded in the study area was lower than that Yemrehane Kirstos church forest which was 39 reported by (Lamprecht, 1989; Amanuel, 2016), Tara Gedam and Sesa Mariam 113 each (Haileab et al., 2011; Birhanu et al., 2015).

The number of families recorded is greater than the works of Kitessa and Bishaw (Kitessa and Bishaw, 2008). This might be due to the more percentage of trees than shrub species. Woody species belongs to shrub and trees account 48.3% and 51.7 % respectively. The total number of tree species recorded from remnant forest of North Wollo also comparable with remnant forest of Zengena remnant forests reported by (Desalegn et al., 2014).

### 3.2. Vegetation Classification

From cluster analysis of the forest, each community was named by the species having higher indicator value. Each community was named after two dominant species within the group (Desalegn et al., 2014). The dominant species were those with highest mean cover- abundance value for a given community (Table 1). Vegetation classification within Gatira George's monastery forest patch was performed using cover abundance values as class labels. Object group averages, product moment correlation and squared distance were used to quantify dissimilarities among different quadrats. Agglomerative hierarchical classification using R-software (version 2.15.0) at 1.5 to 2.0 dissimilarity levels was used to classify the vegetation into communities. The name for each community type was given based on high synoptic values of tree and/or shrub species. Accordingly, two plant communities were identified in Gatira George's forest as displayed in (Figure 3) described as *Juniperus procera – Calpurnia aurea* (Community type 1) and *Podocarpus falcatus - Olea capensis* (Community type 2).

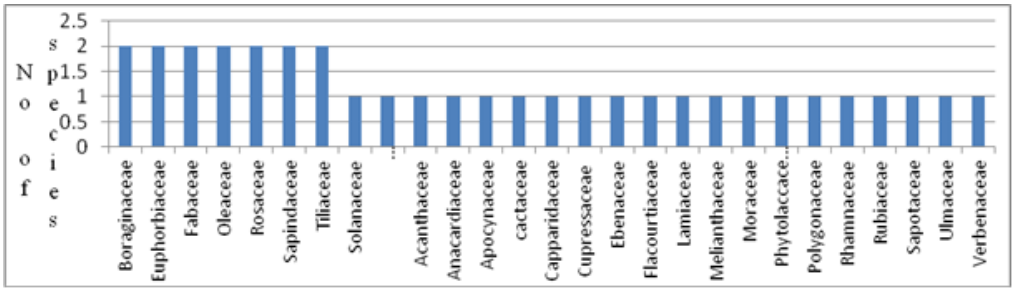


**Figure 2.** All woody species per families across Gatira Georg's forest.

**Table 1.** Synoptic values for species having values >1 in at least one community type and values in bold refer to indicator species of the community

| Species | Community type 1 | Community type 2 |
|---|---|---|
| *Juniperus.procera* | 7.75 | 4 |
| *Calpurnia.aurea* | 4.38 | 2 |
| *Olea.europea* | 4 | 0 |
| *Justica.shmepriana* | 3.62 | 0 |
| *Celtis.africana* | 3 | 0 |
| *Grewia.ferruginea* | 2.25 | 0 |
| *Euclea.schimperi* | 2 | 0 |
| *Podocarpus.falcatus* | 2 | 32 |
| *Olea.capensis* | 2.5 | 8 |
| *Carrisa.spanarium* | 1.88 | 0 |
| *Ehertia.cymosa* | 1.75 | 5 |
| *Rhus.natalensis* | 1.25 | 0 |
| *Euphorbia.candbalrium* | 1.12 | 0 |
| *Pterolbium..stellatum* | 0.88 | 0 |
| *Pavetta.oliveriana* | 0.75 | 0 |
| *Codia.africana* | 0.62 | 1 |
| *Maytenus..arbitifolia* | 0.62 | 0 |
| *Ocimum.urticifolium.Roth* | 0.62 | 0 |
| *Premna.schmperi* | 0.5 | 0 |
| *phytolacca.dodecandra* | 0.38 | 0 |
| *Solanium.incanum* | 0.38 | 0 |
| *Poutria.altissma* | 0.25 | 0 |
| *Bersama.abyssinica* | 0.12 | 0 |
| *Dodonea.angustifolia* | 0.12 | 0 |
| *Ekebrgia.capensis* | 0.12 | 2 |
| *Opuntia.ficus.indica* | 0.12 | 0 |
| *Rhamnus.prinodes* | 0.12 | 0 |
| *Rosa.abyssinica* | 0.12 | 0 |
| *Rumex.nervosus* | 0.12 | 0 |
| *Capparis.tomentosa* | 0 | 1 |
| *Dovayalis.abyssinica* | 0 | 1 |
| *Ficus.ovata* | 0 | 1 |
| *Prunus.africana* | 0 | 1 |

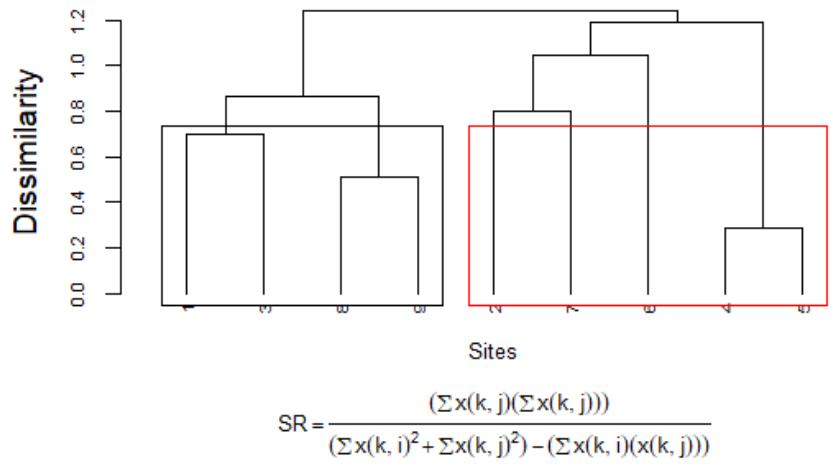


**Figure 3.** Dendrogram showing the two plant community types in Gatira George's forest (Agglomerative Hierarchical Classification using SR).

***Juniperus procera - Calpurnia aurea* Community type**

This community in Gatira George's forest is located between the altitudinal ranges of 2024 m -2061 m a.s.l. It was represented by 7 plots and 22 species. Two species were found to be indicator species (*Juniperus procera* and *Calpurnia aurea*). Other associated tree species include *Olea europea, Justica shmepriana, Celtis. africana, Grewia ferruginea, Euclea. schimperi, Podocarpus falcatus* and *Olea capensis* (Table 1).

***Podocarpus falcatus - Olea capensis* Community type**

This community in Gatira George's forest is located between the altitudinal ranges of 2024 m -2061 m a.s.l. It was represented by 7 plots and 26 species. Two species were found to be indicator species (*Podocarpus falcatus* and *Olea capensis*). Other associated tree species include *Ehertia cymosa, Juniperus procera, Calpurnia aurea* and *Ekebrgia capensis* (Table 1).

### 3.3. Vegetation Species Diversity and Richness

Among the two communities, *Juniperus procera - Calpurnia aurea* community is found to be the most diverse with even distribution of individual species (Table 2).

This lower value of diversity index in *Podocarpus falcatus - Olea capensis* community could be due to the order of dominance of only certain trees and shrubs species such as *Juniperus procera, Ehertia cymosa, Calpurnia. aurea , Ekebrgia capensis, Codia africana, Ficus ovata Prunus africana, Capparis tomentosa* and *Dovayalis abyssinica*. The Shannon weiner diversity and species richness was lower than reported (Getinet et al., 2015) from Alemsaga Forest, North Western Ethiopia (Table 2).

Species diversity, evenness and species richness was higher than Ascha and Hiruy reported by (Alemayehu, 2003) from the Case of Churches in South Gonder, Northern Ethiopia. However, the species diversity and richness is lower than reported by (Alemnew et al., 2007) from the peninsula of Zegie, northwestern Ethiopia. This is due to the difference in the size of the church forests and the level of conservation measures taken by the forest societies in the respected forests (Table 3).

### 3.4. Similarity among the Plant Community Types

The two Communities share 85.7% of similarity ratio (Table 4). This was probably due to similarity in altitudinal range and the existence of most quadrats adjacent to each other that show similar adaptation mechanisms and requirements for species occurring in both communities. Hence, similarities in woody species composition are expected between the plant communities are high.

**Table 2.** Shannon weiner diversity index(s), species richness(R) and evenness (E) of each plant community

| Plant community | Shannon weiner diversity | Species richness | Evenness |
|---|---|---|---|
| *Juniperus procera - Calpurnia aurea* | 2.74 | 22 | 0.88 |
| *Podocarpus falcatus - Olea capensis* | 2.21 | 26 | 0.68 |

**Table 3.** Comparison of species diversity index and species richness measures for the study area and other forests in Ethiopia

| Forest site | Forest area (ha) | No of plot (plot area $ha^{-1}$) | Diversity index | Species evenness | Species richness | Source |
|---|---|---|---|---|---|---|
| Gatira George's | 2.4 | 9(0.36) | 2.88 | 0.82 | 34 | Present study |
| Ascha | 1.6 | 7(0.28) | 2 | 0.63 | 22 | (Alemayehu, 2003) |
| Hiruy | 4 | 14(0.56) | 2.6 | 0.75 | 31 | |
| Zegie | 132 | 132(5.28) | 3.72 | 0.84 | 113 | (Alemnew et al., 2007) |

**Table 4.** Sorenson's similarity between plant communities

| Plant community type | *Juniperus procera - Calpurnia aurea* | *Podocarpus falcatus - Olea capensis* |
|---|---|---|
| *Juniperus procera - Calpurnia aurea* | 1 | |
| *Podocarpus falcatus - Olea capensis* | 85.7 | 1 |

### 3.4. Vegetation Structure

#### 3.4.1. Tree density

The total densities of woody plant species in all the nine sample quadrats of the study area was 1156 individuals per hectare. The species with the highest density was *Juniperus procera* (15.9%) followed by *Olea europea* (10.1%), *Calpurnia aurea* (7.9%), *Olea capensis* and *Justicia schimperiana* (7.7% each), *Grewi ferruginea* and *Euclea schimperi* (6% each ), *Ehretia cymosa* (5%), *Celtis Africana* (4%) and *Podocarpus falcatus* (3.8%), and These species constituted 74.1% of all stems in all sampling quadrats of the study area. For the 34 selected woody species, the density distribution was as shown in (Table 5).

**Table 5.** Density of matures woody species of the study area at different DBH ranges

| DBH(cm) | Density ha$^{-1}$ | Percentage |
|---|---|---|
| 2<DBH<10cm | 1009 | 87.3 |
| 10cm<DBH<20cm | 90 | 7.8 |
| DBH>20cm | 57 | 4.9 |
| Total | 1156 | 100 |

The ratio of tree density DBH ≥10 cm and ≤20 cm to DBH >20 cm is taken as a measurement of the size class (Grubb et al., 1963). The ratio at these densities in this monastery was 1.58. This shows the presence of relatively large deference in abundance between individuals of DBH ≤20 cm and DBH >20 cm. When this value is compared with two churches natural Afromontane forests found in other parts of Ethiopia, it is medium, which confirms the forest is relatively dominated by small size woody species (Table 6).

**3.4.2. Diameter at breast height (DBH) distribution**

Woody species with DBH greater than 2.5cm were measured to analyze the DBH and height class distribution in the forests. The DBH size classes were defined as to nine class intervals (<2.5 cm, 2.5-5 cm, 5.1-10 cm,10.1-15 cm,15.1-20 cm, 20.01-25 cm, 25.01-30 cm, 30.1-35 cm and >35cm. Individuals with DBH less than 2.5 cm and height less than 2m were counted (Figure 4).

The number of tree species in DBH class less than 2.5cm, 2.5-10cm and >10cm were represented by 444 stems ha$^{-1}$ (38.4%), 565 stems ha$^{-1}$ (49%) and 147 stems ha$^{-1}$ (12.6%) found at Gatira George's forest respectively. This implies the number of sapling ha$^{-1}$ is the highest followed by seedling implies the forest is in the state of good regeneration status (Figure 5). The dominance of small size (DBH<10cm) individuals in the Gatira George's forest is largely due to the high density of *Juniperus procera* (183stem ha$^{-1}$) followed *Olea europea* (117stems ha$^{-1}$).

The density of woody species also decrease as the DBH class increases, implies the number of individual's ha$^{-1}$ is highest in the lower DBH class. A similar result was reported by (Birhanu et al., 2015; Kitessa and Bishaw, 2008; Desaleng et al., 2014; Alemnew et al., 2007; Getinet et al., 2015). The density of plant species with DBH class as their contribution of the numbers of species were given in (Table 7). The density of woody plant species increases with increasing number of species. So the general pattern of DBH class size distribution forms an irregular inverted J-shape (Figure 5) for the most selected dominant trees species. This might be associated with presence of tree species with no seed source to continue its generation.

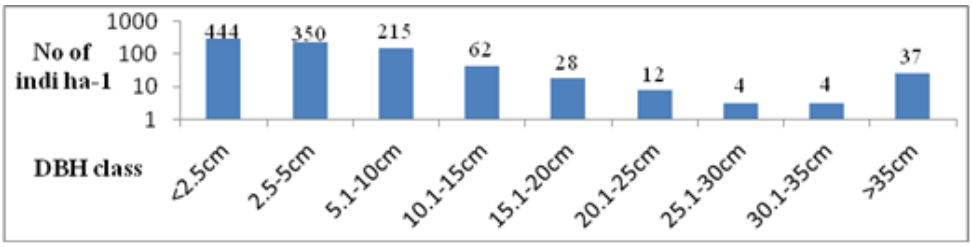


**Figure 4.** The DBH class of Gatira Georgis forest.

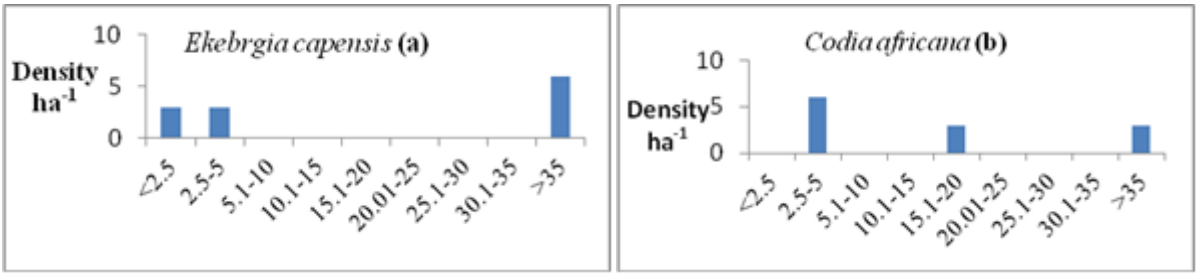


**Figure 5.** The distribution of Ekebergia capensis (a) and Cordia Africana (b) DBH class distribution showing an irregular shape.

**Table 6.** Comparison of tree densities with DBH between 10 and 20(a), and >20 cm (b) of the study area with other forests in Ethiopia arranged in an increasing order of a/b values

| Forests | a)10cm<DBH<20cm | b)DBH>20cm | a/b | Vegetation type | Source |
|---|---|---|---|---|---|
| Gatira Georgis | 90 | 57 | 1.58 | Dry Afromontane | Present study |
| Sesa Mariam | 431.86 | 578.9 | 0.75 | Dry Afromontane | (Haileab et l., 2011) |

**Table 7.** DBH class, the density of plant species and basal area (BA) in Gatira George's forest

| DBH Class | Aver. DBH (m) | No. Species | Density ha$^{-1}$ | BA(m2 ha$^{-1}$) |
|---|---|---|---|---|
| <2.5cm | 0.01 | 28 | 444 | 0.03 |
| 2.5-5cm | 0.04 | 17 | 350 | 0.44 |
| 5.1-10cm | 0.07 | 15 | 215 | 0.83 |
| 10.1-15cm | 0.12 | 10 | 62 | 0.70 |
| 15.1-20cm | 0.18 | 5 | 28 | 0.71 |
| 20.1.-25cm | 0.23 | 3 | 12 | 0.50 |
| 25.1-30cm | 0.30 | 3 | 4 | 0.28 |
| 30.1-35cm | 0.32 | 3 | 4 | 0.32 |
| >35cm | 0.68 | 6 | 37 | 13.43 |

The density of all woody species in Gatira George's forest sites based on DBH greater than 10 cm (a) was found to be 10 individuals per hectare. While it was 15 individuals per hectare on DBH greater than 20 cm (b). The result disagrees from Zegie, North Western Ethiopia also reported (Alemnew et al., 2007). The highest basal area is recorded in DBH class (DBH>10 and DBH > 20). This indicates the forest is well protected due to the perception of peoples around church' to cut a tree from church brings punishment from God.' The ratio of DBH greater than 10 cm (a) to DBH greater than 20 cm (b) was found to be 1.58. So, this ratio is used as a good indicator as to the status of a particular forest. In this regard, compared many forests, the Gatira George's forest sites showed a high ratio implies the predominance of small size trees and shrubs. Hence, it could be considered as a regenerating forest.

The present study implies decline of density ha-1 and number of stems from the lower DBH class to the higher DBH class is similar to reported by (Birhanu et al., 2015) from Sesa Mariam Monastery, North western Ethiopia.

As shown in (Figure 5a and b), two different patterns of DBH distribution were recognized in Gatira George's forest. The first pattern is described as irregular shape displayed in 'a and b' where no defined pattern observed across the DBH class. *Ekebergia capensis* and *Cordia africana* are representative for an irregular shape in DBH distribution.

The second pattern is described as an inverted J shape displayed in 'b' where more number of species found in the lower DBH class and decrease as DBH class increases (Figure 6) *Celtis africana* is representative for an inverted J shape in DBH distribution. Such pattern is normal population structure and shows the existence of species in healthier condition and recruitment capacity (Krebs, 1989).

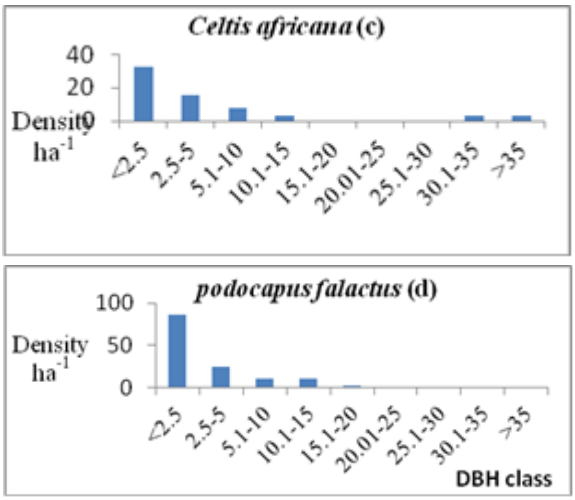


**Figure 6.** The distribution of *Celtis Africana* (c) and *Podocarpus falactus* (d) DBH class distribution showing an inverted J shape.

### 3.4.3. Basal area

The normal value of basal area in Africa is expected to be between 23-37m$^2$ha$^{-1}$ reported by Lamprecht (1989). In this regards, the total basal area of Gatira George's forest sites were recorded (7.84 m$^2$ha$^{-1}$) (Table 8). The total basal area of the study area is larger than reported by (Alemayehu, 2003) from churches of South Gonder, Northern Ethiopia. However, the total basal area recorded in the study areas are less than Tara Gedam (115.36 m$^2$ha$^{-1}$) (Haileab et al., 2011) and Sesa Mariam monastery (94.81 m$^2$ha$^{-1}$) (Birhanu et al., 2015). This difference is due to the present study area forest site is close to the natural forest site which inurn helps to the abundance of many ingenious tree species niche which have larger in DBH than Gonder church forest with no nearby forest site. While the present study area is lower in basal area compared to Tara gedam which has a huge natural forest site nearby it contributed to the forest site having larger basal area.

**Table 8.** Comparison of Basal area distribution of Gatira George's forest with other forests in Ethiopia

| Forest site | Basal area ($m^2ha^{-1}$) | Source |
|---|---|---|
| Gatira Georgis forest | 7.84 | Present study |
| Ascha | 3 | (Alemayehu, 2003) |
| Hiruy | 2 | (Alemayehu, 2003) |

**3.4.4. Importance value index (IVI)**

The highest IVI value was contributed by *Ekebrgia capensis* in Gatira George's forest and its basal area contribution was highest ($3.48m^2ha^{-1}$). As indicated in IUFRO classification scheme (Krebs, 1989). IVI value is used for comparison of ecological significant of species in which high IVI values indicate that the species structure in the community is high. In the present study, IVI of species varied from 1.2 (3.2% of the total IVI) to 48.4 (16.1%) and only three species contributed 35.7% of the IVIs (Table 9). Other study also showed IVI values are good indicator for vegetation characteristics of a given habitat and the ecological significance of the species (Simon and Girma, 2004).

According to Simon and Girma (2004), Species with less than 10 ranks in the IVI values deserve appropriate conservation measures. In this regards, the least IVI value of 1.3 was recorded for species such as *Capparis tomentosa, Prunus africana, Rumex nervosus, Rosa abyssinica, Rhamnus prinodes, Dodonea angustifolia, Dovayalis abyssinica* and *Ficus ovate* and species identified less than ten in IVI values deserve appropriate conservation measures.

**Table 9.** Frequency, relative frequency, density, relative density, basal area, relative basal area and IVI values of woody species (DBH>2cm) in Gatira George's Forest according to decreasing order of the importance value index (IVI)

| Species | Mean Basal area | Density ($ha^{-1}$) | Relative density | BA ($ha^{-1}$) | Relative BA (%) | Frequency | RF (%) | IVI (%) |
|---|---|---|---|---|---|---|---|---|
| *Ekebrgia capensis* | 0.314 | 11.1 | 1 | 3.48 | 44.4 | 33.3 | 3 | 48.4 |
| *Juniperus procera* | 0.0064 | 183.3 | 15.9 | 1.17 | 14.9 | 66.7 | 6.1 | 36.9 |
| *Olea europea* | 0.0052 | 116.7 | 10.1 | 0.6 | 7.7 | 44.4 | 4 | 21.8 |
| *Celtis africana* | 0.011 | 41.7 | 3.6 | 0.45 | 5.7 | 66.7 | 6.1 | 15.4 |
| *Olea capenis* | 0.00104 | 88.9 | 7.7 | 0.09 | 1.1 | 66.7 | 6.1 | 14.9 |
| *Codia africana* | 0.0387 | 16.7 | 1.4 | 0.64 | 8.2 | 55.6 | 5.1 | 14.7 |
| *Ehretia cymosa* | 0.0032 | 52.8 | 4.6 | 0.1697 | 2.2 | 55.6 | 5.1 | 11.9 |
| *Justica shimperiana* | 0.00012 | 88.9 | 7.7 | 0.01 | 0.1 | 44.4 | 4 | 11.8 |
| *Euclea schimperi* | 0.00197 | 69.4 | 6 | 0.14 | 1.8 | 44.4 | 4 | 11.8 |
| *Calpurnia aurea* | 0.00051 | 91.7 | 7.9 | 0.05 | 0.6 | 33.3 | 3 | 11.5 |
| *Podocarpus falcatus* | 0.0065 | 44.4 | 3.8 | 0.29 | 3.7 | 44.4 | 4 | 11.5 |
| *Grewia ferruginea* | 0.00053 | 72.2 | 6.3 | 0.04 | 0.5 | 44.4 | 4 | 10.8 |
| *Rhus natalensis* | 0.00095 | 47.2 | 4.1 | 0.04 | 0.5 | 44.4 | 4 | 8.6 |
| *Euphorbia candelabrum* | 0.0047 | 36.1 | 3.1 | 0.17 | 2.2 | 33.3 | 3 | 8.3 |
| *Croton macrostachyus* | 0.0158 | 16.7 | 1.4 | 0.26 | 3.3 | 33.3 | 3 | 7.7 |
| *Premna schimperi* | 0.0002 | 13.9 | 1.2 | - | - | 55.6 | 5.1 | 6.3 |
| *carissa spinarium* | 0.00083 | 30.6 | 2.6 | 0.03 | 0.4 | 22.2 | 2 | 5.0 |
| *Pavetta oliveriana* | 0.00005 | 22.2 | 1.9 | 0.001116 | 0.01 | 33.3 | 3 | 4.9 |
| *Poutria altissma* | 0.00038 | 19.4 | 1.7 | 0.01 | 0.1 | 33.3 | 3 | 4.8 |
| *Ocimum lamifolium* | 5.28E-05 | 13.9 | 1.2 | - | - | 33.3 | 3 | 4.2 |
| *Maytenus arbitifolia* | 0.00029 | 19.4 | 1.7 | 0.01 | 0.1 | 22.2 | 2 | 3.8 |
| *Bersama abyssinica* | 0.06422 | 2.8 | 0.2 | 0.18 | 2.3 | 11.1 | 1 | 3.5 |
| *Pterollobiumstellatum* | 0.00025 | 13.9 | 1.2 | - | - | 22.2 | 2 | 3.2 |
| *Solanium incanum* | 0.000127 | 8.3 | 0.7 | - | - | 22.2 | 2 | 2.7 |
| *phytoacca dodecandral* | 0.001256 | 5.6 | 0.5 | 0.01 | 0.1 | 22.2 | 2 | 2.6 |
| *Opuntia ficus indica* | 0.0005 | 5.6 | 0.5 | - | - | 22.2 | 2 | 2.5 |
| *Dodonea angustifolia* | 0.00049 | 2.8 | 0.2 | - | - | 11.1 | 1 | 1.2 |
| *Prunus africana* | 0.00025 | 2.8 | 0.2 | - | - | 11.1 | 1 | 1.2 |
| *Rhamnus prinodes* | 0.000201 | 2.8 | 0.2 | - | - | 11.1 | 1 | 1.2 |
| *Rosa abyssinica* | 0.000201 | 2.8 | 0.2 | - | - | 11.1 | 1 | 1.2 |
| *Dovayalis abyssinica* | 0.00013 | 2.8 | 0.2 | - | - | 11.1 | 1 | 1.2 |
| *Ficus ovata* | 5.67E-05 | 2.8 | 0.2 | 0.0002 | 0.003 | 11.1 | 1 | 1.2 |
| *Rumex nervosus* | 0.000064 | 2.8 | 0.2 | - | - | 11.1 | 1 | 1.2 |
| *Capparis tomentosa* | 0.000028 | 2.8 | 0.2 | - | - | 11.1 | 1 | 1.2 |
| Total | 0.47951 | 1155.6 | 100 | 7.841016 | 100 | 1100 | 100 | 300.0 |

**3.4.5. Forest canopy layers**

The implication of having 94.4% lower canopy, 5% middle and <0.59% upper canopy of the study area is related to the similarity of tree and shrubs species and their growth nature. Most of the visible gaps were filled up with the under story species canopy mainly covered by trees and shrub species. In addition, density ha-1 decrease from lower to upper strata. The canopy layers structure is similar to remnant dry afromontane natural forest patch within Deberiabones Monastery reported by (Getachew et al., 2013). The highest mean height also recorded in the upper canopy followed by middle canopy layers. However, the highest densities were recorded in the lower canopies followed by middle canopies implies the most number of trees and shrubs are found in the lower canopy (Table 10). The ratio of upper canopy relative to the middle and lower canopy is also less than 12%. It is similar to Nigerian strict nature reserve reported by Adekunle et al. (2013).

**Table 10.** The mean height, density, species number and individual to species ratio by canopy story in the study area

| Forest site | Forest strata | Mean Height (m) | Density Number $ha^{-1}$(a) | Species Number (b) | Ratio $Ab^{-1}$ |
|---|---|---|---|---|---|
| Gatira george's | Upper | 29.3 | 5 | 2 | 2.8:1 |
| | Middle | 14.4 | 39 | 9 | 5.2:1 |
| | Lower | 3.5 | 744 | 32 | 27.8:1 |

## 4. Conclusions and Recommendations

The data derived from floristic composition and vegetation structure of Gatira George's forest indicated that the forest is the source of many indigenous woody species.

Gatira George's forest is a spiritual place and biodiverse native of natural forest managed by the local community around the church. It consists of 34 woody species representing 34 genera and 27 families. Among these species *Ekebergia capensis* and *Juniperus procera* were found to be the densest and the most dominant and frequent species with higher IVI in the forest.

The highest species diversity and evenness is attained in *Juniperus procera - Calpurnia aurea* community type as a good source of forest products and needs conservation priority.

Based on the findings the following recommendation was forwarded:

Species with low IVI needs to be prioritized for conservation.

To prevent local extinction of rare species, effort of nursery establishment and plantation of indigenous species should be practiced.

Detailed ethno botanical studies are required to explore the wealth of indigenous knowledge on the diverse use of plants and their implication to conservation.

Sustainable protection and management of the forests needed through the collaborative effort of the government, NGO and the local community.

Regeneration and soil status of the forest should be further investigated from remnant forest on suitable basis.

**Conflict of interest**

The author declare that there is no conflict of interest.

**Acknowledgements**

I acknowledge the Amhara Agriculture Research Institute as well as Sirinka Agriculture Research Centre for financing the research activities and Tesfaye Mitkeya, Binayam Tefera and Habetamu Yimer, church guard (Wurgessa), Gezagehgn Getachew, Solomon Wondatitor, Addisie Degu and Tesfaye Wubu (Sirinka Agricultural research center), Mistre Yefru, Endale Abay and Gaurema Gerbaba from Addis Ababa University who helps in identifying scientific names of plants also acknowledged. Finally, I would like to acknowledge and appreciate the encouragement and patience of my lovely wife, during the whole study period.

## References

Abiyou T, Teshome S, Ensermu K. 2015. Structure and Regeneration status of Menagesha Amba Mariam Forest in Central Highlands of Shewa, Ethiopia, 185.

Abiyou T. 2013. The contribution of Ethiopian Orthodox Tewahido Church in forest management and it's best practices to be scaled up in North Shewa Zone of Amhara Region, Ethiopia.

Adekunle VAJ, Olakoge AO, Akindele SO. 2013. Tree species diversity and structure of a Nigerian strict nature reserve. Tropical Ecol, 54(3): 275-289.

Aerts R, Van-Overtveld K, Deckers J. 2006. Species composition and diversity of small Afromontane forest fragment in northern Ethiopia. Plant Ecol, 187: 127-142.

Alemayehu W, Demel T, Powell N. 2005. Church forests in North Gondor Administrative Zone, Northern Ethiopia. Forests Trees Livelihood, 15(4): 349-374.

Alemayehu W. 2003. Opportunities, constraints and prospects of the Ethiopian Orthodox Tewahido Churches in conserving forest resources: The Case of Churches in South Gonder. Northern Ethiopia.

Alemayehu W. 2007. Ethiopian Church Forest opportunities and challenges for restoration ISBN: 978-90-8504-768-1.

Alemnew A, Demel T, Yemshaw Y, Edwards S. 2007. Diversity and status of regeneration of woody plants on the peninsula of Zegie. Northwestern Ethiopia, ISSN 0564-3295.

Amanuel A. 2016. Woody Species diversity, structure and regeneration status of Yemrehane Kirstos Church Forest of Lasta Woreda, North Wollo Zone, Amhara region, Ethiopia. A Thesis Submitted to the Centre of Environmental Science. Addis Abeba University.

Amare T, Bhardwaj D. 2016. Study on natural regeneration of

Quercus glauca Thunberg forest and its relation with site Condition ALST-vol.662018.

Ardakani MR. 2004. Ecology. Tehran University Press, 340p.

Bekele T. 2016. Review on woody plant species of Ethiopian high forests. vol: 27, ISSN 2422-8397.

Birhanu W, Berhanu A, Belay B. 2015. Survey on composition of perennial vegetation in Sesa Mariam Monastery. Northwestern Ethiopia, doi: 10.1186/s13104-015-1562-5.

Cardelus C, Peter SP, Hair J, Baimas GM, Lowman M, Alemayehu W. 2003. A preliminary assessment of Ethiopian sacred grove status. Landscape Ecosystem Scal, 5: 320.

Desalegn T, Ermias L, Destaw D, Adane A. 2014. Floristic diversity and regeneration status of woody plants in Zengena forest, a remnant montane forest patch. Northwestern Ethiopia, 25(2): 329-336.

Dessalegn R. 2001. Environmental change and state policy in Ethiopia: lessons from past experience. Addis Ababa. Ethiopia, 10-108.

Desta H. 2001. Research methods in forestry, Principles and Practices with particular references to Ethiopia. Larenste in University, Deventer. The Netherlands, 682.

DHV consultants. 2001. The resources of North Wollo Zone Amhara National Regional State. Environmental support project component and Ministry of Agriculture and Ministry of water resources, Ethiopia.

Edwards S, Hedberg I. 1989. Flora of Ethiopia. Vol: 3, Addis Ababa and Asmara, Ethiopia and Uppsala, Sweden.

Ermias A. 2011. Forest diversity in fragmented landscapes of northern Ethiopia and implications for conservation, Ph.D. Dissertation, Bonn. doi: 10.1.1.407.2442.

Feyera S. 2006. Biodiversity and ecology of Afro mountain rain forest with wild coffee arabica L, population in Ethiopia, Ecology and Development Serious No: 18.1449.

Forest resource assessment (FRA). 2015. Terms and definitions, Forest resources Assessment Working Paper, 180.

Getachew D, Mulugeta L, Satishkumar B. 2013. Plant community types, vegetation structure and regeneration status of remnant dry Afromontane Natural Forest Patch within Debrelibanos Monastery. Ethiopia, doi: 10.7392/open access.70081972.

Getahun Y, Anteneh F. 2015. Diversity and regeneration status of woody species: The Case of Keja Arabaand Tula Forests, South West Ethiopia, doi: 10.4236/oalib.1102576.

Getinet M, Teshome S, Ensermu K. 2015. Status and species diversity of Alemsaga Forest. Northwestern Ethiopia ISSN 2224-7181 (Paper) ISSN 2225-062X (Online) Vol.34.

Grubb PJ, Lloyd JR, Penigton TD, Whitmore TC. 1963. A comparison of Montane and lowland rainforests in Ecuador. Journal of Ecology, 51: 567-601. doi: 10.2307/2257748.

Haileab Z, Demel T, Ensermu K. 2011. Diversity and regeneration of woody species in Tara Gedam and Abebaye forest. North Western Ethiopia, doi: 10.1007/s11676-011-0176-6.

International Union for Conservation of Nature (IUCN). 2006. IUCN Red List of Threatened Species.

Jafari SM, Akhani H. 2008. Plants of Jahan name protected area, Golestan province, N. Iran. Pakistan J Botany, 40(4): 1533-1554.

Jim E, Becky B. 2012. Basal area: A measure made for management, school of Forestry and Wildlife sciences, Auburn University, ANR-1371.

Kent M, Coker P. 1992.Vegetation description and analysis a practical approach. John Wiley and Sons, New York Károly RÉDEI, Irina VEPERDI.

Kitessa H, Bishaw D. 2008. Woody species composition and structure of the GurraFarda Forest, SNNPR, South Wastern Ethiopia, 3(2).

Krebs C. 1989. Ecological methodology, Harper Collins Publishers, New York.

Lamprecht H. 1989.Sericulture in the tropics. Tropical forest ecosystems and their tree species possibilities and methods are the long-term utilization. T2-verlagsgeslls chaft, RoBdort, Germany, PP. 296.

Manette ES, Robin LC. 2014. Remnant trees affect species composition but not structure of tropical second-growth forest. PLoS ONE, 9(1): e83284. doi: 10.1371/journal.pone.0083284.

Ministry of Environment, Forest and Climate Change (MEFCC). 2016. Ethiopia's Forest Reference Level Submission to the UNFCCC.

Mueller-Dombois D, Ellenberge H. 1974. Aims and methods of vegetation ecology (p. 304). New York, NY: John Wiley and Sons.

Myers J, Harms K. 2009. Seed arrival, ecological filters, and plant species richness: a meta-analysis. Ecology Letters, 12(11): 1250–1260.

Pappoe A, Armah F, Quay E, Wake P, Buxton G. 2010. Composition and stand structure of a tropical moist semi deciduous forest in Ghana. Inters J Plant Sci, 1: 95-106.

Sagar R, Singh JS. 2006. Tree density, basal area and species diversity in a disturbed dry tropical forest of northern India: implications for conservation. Environ Conserv, 33: 256-262.

Shackelton CM. 2000. Comparison of plant diversity in protected and communal lands in Bushbuck Ridge Lower Savannah, South Africa. Biol Conserv, 94: 273-285.

Shimelse M. 2007. Land policy and tenure insecurity in Habru district, northeastern Ethiopia Msc Thesis, Norwegian University of life sciences, Norway.

Simon S, Girma B. 2004. Composition, structure and regeneration status of woody species in Dindin natural forest, Southeast Ethiopia: An implication for conservation. Ethiopian J Biol Sci, 1(3): 15-35.

Sorensen T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content and its application to analyses of the vegetation. Danish Commons, 5: 1–34.

Temesgen G. 2015. Forest degradation in Ethiopia: Extent and conservation effort.

Venables WN, Smith DM. 2012. Introduction to the R packaging system.