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RESEARCH PAPER

Structure and Regeneration Status of Woody Plants in Jiga Bushe Forest, Jaldu District, Central Ethiopia

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Abstract

Ecological study was done on the structure and regeneration status of woody plants in Jiga Bushe Forest, Jaldu District, and Central Ethiopia. Data of woody plant species were collected using systematic sampling method by laying 9 transects and 50 quadrats each with 20 m x 20 m for trees. Inside the main quadrats, there are 5 m x 5 m sub-quadrats for shrubs, and 1 m x 1 m sub-quadrats for seedlings and saplings both for structural and regeneration status determination. Structural data like DBH, height, total density, basal area were analyzed in descriptive statistics. The result revealed that 64 woody plant species belong to 60 genera and 44 families were recorded. Trees had the highest composition followed by Shrubs and lianas. The largest species rich families were Fabaceae, followed by Rosaceae, Acanthaceae and Asteraceaea. Generally, both diameter and height class distributions of the population in the Jiga Bushe Forest exhibited inverted J-shape. The total density and basal area of woody plant species in the study area were 1,272 ha^{-1} and 25.6 m^2 ha^{-1} respectively. Analysis of the importance value index indicated that Olinia rochetiana had the highest value (17.69). Regeneration status of the forest based on the number of seedlings, saplings and mature trees were in good condition.

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Keywords: Jiga Bushe Forest, Regeneration Status, Total Density, Vegetation Structure

Introduction

Ethiopia is one of the countries in the world gifted with rich biological resources (Bekele, 2017). One of these resources is natural vegetation where floristic and faunistic life forms dynamic ecosystems (Balcha, 2004; Azamal *et al*., 2012; Erenso *et al*., 2014). The country also has around 6027 species of higher plants, of which about 10% are endemic (Kelbessa & Demissew, 2014). These makes Ethiopia important regional center for biological diversity due to the broad ranges of altitude, as well as its great geographical diversity, which includes high and steep mountains, flat-topped plateaus and deep gullies, incised river valleys, and rolling plains (Kelbessa *et al*., 1992). However, these rich biodiversity resources, including forests, are highly declined due to human related disturbances (Lulekal *et al*., 2016) and the forest cover of Ethiopia also declined from 13.78% to 11.40% from 1990 to 2015 because of widespread deforestation (FAO, 2015). Therefore, the average annual deforestation rate was about 1%, high compared to other Sub-Saharan African countries which had 0.8% (FAO, 2010).

Previous documents also indicated that Ethiopia had experienced substantial deforestation, soil degradation and a rise in bare land over the years. The requirement for fuel wood, expansion of agricultural land, grazing areas are indicated as the main causes of forest degradation; frequently resulting in loss of forest cover and biodiversity, erosion, desertification and reduced water resources (Kelbessa & Soromessa, 2008). The high level of dependency of the local people on agriculture (more than 90%) and high rate of population growth have also accelerated the problems (EFAP, 1994; Woldemariam, 2003; Shibru & Balcha 2004; Senbeta, 2006).

Various studies have indicated the intractable loss of forests in Ethiopia in different parts of the Ethiopia in various forest types ranging from lowland woodlands to southeastern and southwestern dense forests (Kelbessa & Soromessa, 2008; Gurmessa *et al.*, 2012; Soromessa, 2013; Soromessa & Kelbessa, 2013a, Soromessa & Kelbessa, 2013b; Soromessa & Kelbessa, 2014; Gedefaw *et al.*, 2014; Soromessa, 2015).

Assessment on species composition, structure and regeneration studies of a forest are useful for forest management and helps in understanding forest ecology and ecosystem functions (Pappoe *et al*., 2010; Kuma & Shibru, 2015; Mammo *et al.,* 2016; Mammo & Zhang, 2018). Knowledge of natural regeneration trends is essential for addressing the fundamental question of forest management (Chazdon & Uriarte, 2016).

Jiga Bushe Forest is a dry evergreen montane forest that is found in the high lands of Shewa. It is one among the preserved forest areas under Environment, Forest and Climate Change Authority Office (JDEFCCAO) of Jaldu District with an area of about 153 ha (JDEFCCAO, 2021). The aim of this study was to assess the structure and regeneration status of woody plant species in Jiga Bushe Forest which is found in Jaldu District, Centeral Ethiopia. The results of this study will help conservation practitioners the protection and design of appropriate options for conservation and management within the natural resources of the area.

Materials and Methods

Description of the Study Areas

Geographical Location

Jiga Bushe Forest is located in Jaldu District, Central Ethiopia. It lies approximately between 10° 15' to 10° 20' N and 38° 80' to 39° 50' E with a total area of 153 ha contagious block forest (JDANRMO, 2021) (Figure 1). The District has an elevation range between 1900 m and 3206 m above sea level (JDANRMO, 2021).

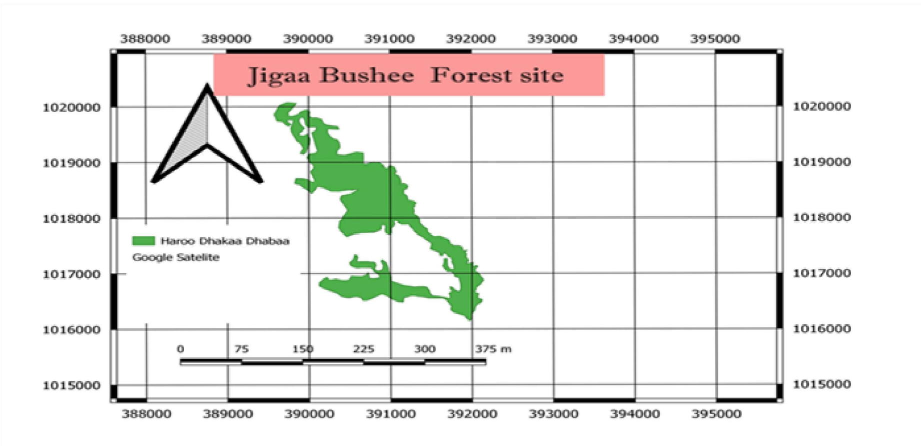

Figure 1: Map of the Study Area

Climate

The information obtained from NMSA (2021), indicated that the mean minimum temperature of Jaldu District is 6.7 °C and the maximum is 24.23°C.The average ten years rainfall ranges of the area is between 1090.5-1511.8 mm. High rain falls during the month of June up to September, but low rain is also falls during the month of October up to May (NMSA, 2021).

Vegetation

The natural vegetation of the Jaldu District belongs to the dry evergreen montane vegetation type which is dominated by remnant trees such as *Juniperus procera, Hagenia abyssinica, Podocarpus falcatus, Acacia abyssinica, Cordia africana, Ficus species, Erytrina brucei, Croton macrostachyus*, *Olea europaea* subsp *cuspidata.*

Sampling Design and Data Collection

Reconnaissance Survey and Study Site Selection

Reconnaissance surveys was made in October 2020 across the Jiga Bushe Forest to obtain an idea of site conditions, physiognomy of the vegetation, collect information on accessibility and categorize sampling sites. The forest's altitude range and transect path were then determined and transects were laid from the lowest to highest altitude (Alves *et al*., 2010).

Sampling Design

A systematic sampling method was used to conduct the vegetation sampling. In order to collect vegetation data, a total of nine transect lines which are 200 m a part were laid. On the transect lines, 50 quadrats each with the size of 20 m x 20 m at an interval of 100 m were laid along the established. For shrubs data collection five sub plot of 5 m x 5 m (25 m^2) at the four corners and at the center of main quadrat were taken and for the purpose of seedling and sapling data collection a total of 5 sub plots with the area of 1 m x 1 m were laid at four corners and at the center of main quadrat 20 m*20 m. It is strategically placed in areas with rapid changes in vegetation and various environmental gradients (Kent & Coker, 1992).

Data Collection Methods

The primary data was obtained through field measurements. For the purpose of this study, "seedlings", "saplings" and "mature trees/ shrubs" were defined as plants with heights less than 1 m, 1-3 m and greater than 3 m respectively. In each sample plot, woody plant species were registered and coded with vernacular and or/scientific names. Species identification was accomplished by the use of published volumes of the Flora of Ethiopia and Eritrea and Useful trees and shrubs for Ethiopia (Bekele, 2007).

Tree and shrub diameter (DBH) was measured by using caliper and height was measured by use of hypsometer. Trees and shrubs in the quadrat's boundary were included if more than 50% of their basal area was within the quadrat and removed if more than 50% of their basal area was outside the quadrat (Bhishma *et al*., 2011). Trees that overhung the quadrat were excluded, but trees with trunks within the quadrat and branches outside were included. In all quadrats, additional trees and shrubs outside the quadrat boundaries but within 10-15 m are collected and noted as present but was not used in the subsequent vegetation data analyses (Bekele, 1994). A woody plant which had multiple stems at 1.3 m height, all individual stems were measured and the average DBH was taken during data collection (Kent & Coker, 1992).

Data Analysis

Structural Data Analysis

The tree/shrub density, diameter at breast height (DBH), basal area, frequency and important value index were used to describe the structure of the vegetation. DBH: measurement was taken at about 1.3 m from the ground using a measuring tape and caliper (Kent & Coker, 1992).

Basal Area

It is the cross-sectional area of all of the stems in a stand at breast height (1.3 m above ground level (Kent & Coker, 1992). Basal Area is expressed in hectare.

Basal Area = π $DBH^2/4(0.785DBH^2$ ….. (Eq.1)

Where): DBH is diameter at breast height, π = 3.14.

Relative dominance of plant species

$$\text{Relative Dominance} = \frac{\text{Total Basal Area for a species A}}{\text{Total Basal Area for all species}} \text{ X } 100 \ldots\ldots.\ldots\ldots\ldots\ldots\ldots.(\text{Eq. }2$$

Density

Density is a count of the numbers of individuals of a species within the quadrat (Kent & Coker, 1992).

$$\text{Density} = \frac{\text{Number of individual}}{\text{Area sampled}} \text{ X } 100 \ldots\ldots\ldots.\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\text{Eq. }3)$$

$$\text{Relative Density} = \frac{\text{Number of individuals of species A}}{\text{Total number of individuals}} \text{ X } 100 \ldots\ldots\ldots (\text{Eq. }4)$$

Frequency

Frequency is the number of times a particular species is recorded in the sample area (Kent & Coker, 1992).

$$Frequency = \frac{Number\ of\ plots\ in\ which\ a\ species\ A\ occur}{Total\ number\ of\ plots} \text{ X } 100 \ldots.\ldots.\ldots\ldots\ldots (\text{Eq. }5)$$

$$\text{Reletive frequency} = \frac{\text{Frequency of Tree species}}{\text{Frequency of all Tree species}} \text{ X } 100 \ldots\ldots\ldots (\text{Eq. }6)$$

Importance Value Index (IVI)

It is parameters or an index computed from Relative Density, Relative Dominance and Relative Frequency, which describes the structural role of a species in a stand. It is useful for making comparisons among stands in reference to species composition and stand structure (Bekele, 1993; Shibru & Balcha, 2004).

Importance Value Index (IVI) = *(Relative density + Relative frequency +* Relative dominance*)* .... *(Eq.7)*

Regeneration Status Analysis of Species

In general Regeneration status of the forest is analyzed by comparing the number of saplings and seedlings with the matured trees. According to Chauhan et al. (2008), the regeneration status is in good condition, if seedling is greater than sapling and adult (seedling > sapling >adults density); Fair regeneration, if seedling > sapling ≤ adults; poor regeneration, if a species survives only in the sapling stage, but has no seedlings (even though saplings may be <, >, or = mature); If a species is present only in an adult form, it is considered as not regenerating, new, if a species has no mature, but only sapling and/ or seedling stages.

Results and Discussions

Vegetation Structure

A total of 64 woody plant species belonging to 60 genera and 44 families were recorded from Jiga Bushe Forest (Appendix 1). The vegetation structure of the study forests is here explained under different parameters including density, frequency, DBH (Diameter at Breast Height), height and the importance value index (IVI) of trees and shrubs.

Density of Woody Species

The average overall density of Jiga Bushe Forest was estimated around 1272 individuals' ha^{-1}. Of these, *Olinia rochetiana Rubus steudneri*, *Mytenus arbutifolia*, *Juniperus procera* and *Croton macrostachyus,* respectively were the predominant species in the studied forest. Whereas *Jasminum abyssinicum, Osyris quadripartita, Buddleja polystachya, Clausena anisata, Schefflera abyssinica, Vernonia amygdalina, Englerina woodfordioides*, *Eucalyptus globulus* and *Cassipourea malosana* were the least predominant species in decreasing order. This value is almost similar to the mean density of trees and shrubs in the Dida Hara Forest Borana lowland (1274 ha-^{1}) (Dalle *et al.,* 2005).

However, densities of the present studies are low compared to some other dry afromontane forests in Ethiopia. For example, Kimphe Forest (3059 stems ha^{-1}) (Senbeta & Teketay, 2003); Dindin Forest (1750 stems ha^{-1}) (Shibru & Balcha, 2004); Oda Forest (4745 individuals ha^{-1}) (Kuma & Shibru, 2015) and Sideni in Tehuledere District in Wollo (2737.50 individuals ha^{-1}) (Gedefaw & Giacomo, 2017). This could be attributed to variations in landscape topographic gradients as well as habitat qualities linked to ecological requirements of component tree and shrub species in the respective forests. However, it had been higher than Dodola Forest (521 individuals ha^{-1}) Hundera and Gadissa (2008); Boditi Forest (498 individuals ha^{-1}) Yineger *et al*. (2008); Kurib Forest (152.53 individual ha^{-1}) Belay (2016) and Wanzaye Natural Forest (482 individuals ha^{-1}) (Getnet, 2018).

DBH Class Distribution of Jiga Bushe Forest

The DBH class distribution of the trees/shrubs in Jiga Bushe Forest was ordered in to ten classes, 1) 2.5-5 cm, 2) 5.1-10 cm, 3) 10.1-15 cm, 4) 15.1-20 cm, 5) 20.1-25 cm, 6) 25.1-30 cm, 7) 30.1-35 cm, 8) 35.1-40 cm, 9) 40.1-45 cm and 10) >45 cm (Table 2). The last DBH class (class 10) was added together as only few numbers of high DBH plants were found (Table 1).

Table 1. The number of individuals selected in DBH classes (cm) in Jiga Bushe Forest

DBH classes	Class intervals	Density	%
1	2.5 -5 cm	1006	39.54
2	5.1-10 cm	578	22.72
3	10.1-15 cm	297	11.67
4	15.1-20 cm	178	6.99
5	20.1-25 cm	123	4.83
6	25.1-30 cm	71	2.79
7	30.1-35 cm	75	2.95
8	35.1-40cm	61	2.4
9	40.1-45 cm	56	2.2
10	>45 cm	99	3.89

As demonstrated from the tables 1 above, more number of individual were found in DBH in class 1 (39.54%). The second highest number was recorded from DBH class 2 (22.72 %), while the least number of individuals were found in DBH class 9 (2.2%). Except for the largest DBH class, number of individuals in DBH classes revealed a decrease in the number of individuals as they moved up from lower DBH class to higher DBH classes. This showed that the quantity of tree/shrub reduced with an increase with DBH size and the density of tree/shrub were higher in lower DBH class. The highest DBH was recorded for *Ficus sur* with the mean DBH of 53.46 cm followed by *Prunus africana* and *Ekebergia capensis* with mean DBH value of 48.5 cm and 46.7 cm respectively. The least mean DBH recorded for *Calpurnia aurea* was a mean value of 5.22 cm followed by *Myrsine africana* and *Grewia ferruginea* with the value of 5.41 cm and 5.78 cm, respectively.

The analysis of DBH and height distribution of trees and/shrubs in Jiga Bushe Forest were showed that the majority of species had more individuals in the lower DBH and height classes, because it was secondary forest. In this study, secondary forest is the forest restored after a long period destruction. As the analysis clearly demonstrated, the number of individual tree was high in the first and second DBH classes, but relatively low in the remaining eight classes. The cumulative distribution of DBH classes exhibited a relatively inverted J-shaped distribution. Similar findings have been documented in the Chilimo and Menagesha forests of Ethiopia's centeral Plateau (Bekele, 1994), in Menagesha Amba Mariam Forest (Tilahun, 2009), as well as in the Denkero Forest (Ayalew, 2003) and in Gedo Forest (Kebede *et al*., 2016).

Height Class Distribution of Jiga Bushe Forest

Height can be used as an indicator of the age of the forest. About 58 woody species having 2,544 individuals were used to describe the structure of Jiga Bushe forest. This study site's height distribution was divided into seven categories. 1) 1.5–5 m, 2) 5.1–10 m, 3) 10.1–15m, 4) 15.1–20 m, 5) 20.1–25 m, 6) 25.1–30 m, and 7) >30 m) (Table 2).

Table 2. The number of individuals selected in height classes (m) in Jiga Bushe Forest

Height classes	Class intervals	Density	%
1	1.5-5 m	1390	56.4
2	5.1-10 m	807	31.7
3	10.1-15 m	176	6.92
4	15.1-20 m	60	2.36
5	20.1-25 m	29	1.14
6	25.1-30 m	31	1.22
7	>30 m	51	2

In general, height of trees in class 1 was found to be dominant followed by class 2, 3, 4, 7, 6, 5, respectively (Table 2). The maximum height value in the studied forest was recorded for *Prunus africana* with the height value of 36 m followed by *Ficus sur* and *Ekebergia capensis* with the height value of 33 m and 30 m respectively. The least height was recorded for *Myrsine africana* with the value of 2.16 m followed by *Grewia ferruginea* and *Calpurnia* *aurea* with the value of 2.47 m and 2.8 m (Table 2).

In the study forest, the cumulative distribution of height classes exhibited a relatively inverted J-shaped distribution. This arrangement indicated that the lower height classes had the highest number of individuals counted, while the middle and higher height classes had a decreasing density. This indicated that the study site had a high potential for regeneration. Similar findings have been documented in some Dry Evergreen Forests of Ethiopia (Bekele, 1994; Tilahun, 2009; Ayalew, 2003; Kebede *et al*., 2016).

Vertical Structure

The vertical structure of trees in Jiga Bushe Forest was described following the International Union for Forestry Research Organization (IUFRO) classification scheme, the tree height was divided into three: upper store, middle store and lower store (Lamprecht, 1989). Upper store, where the tree height is greater than 2/3 of the top height. Middle store, where the tree height is between 1/3 and 2/3 of the top height; and lower store, where the tree height was less than 1/3 of the top height, since the tallest tree in Jiga Bushe Forest was *Prunas africana*, which peaked at 36 m, trees in the lower, middle, and upper stores were in the height ranges of 12 m, 12-24 m, and > 24 m, respectively (Table 3).

Table 3. The total number of species and the corresponding mean density of individual's ha^{-1} in a vertical distribution.

Store	Density of individuals ha^{-1}	%	Number of species	%
Upper	3.5	0.3	3	5.17
Middle	98	7.7	7	12.1
Lower	1170.5	92	48	82.76
Total	1272	100	58	100

Tree species that occupied the upper store in Jiga Bushe Forest include *Prunas africana*, *Apodytes dimidiata and Ficus sur*. The upper store was occupied by a very small number of individuals as the ratio of an individual to species is lower (Table 3). The middle layer of the study forest was dominated by species like *Salix mucronata sub.sp.serrata, Podocarpus falcatus*, *Ekebergia capensis*, *and Myrica salicifolia.* Shrubs and small trees dominated the lower store. *Olea europaea* subsp. *cuspidata* and *Podocarpus falcatus* were the species in the study forest have not representative from the upper store, indicating that the species may had experienced selective cutting for their use in the forest. Human factors can modify the vertical structure of the study forest, through selective logging for fuel wood, construction and illegal wood harvest for timber production as it was existed in different stages of secondary development. These human activities may have played a role in the forest's decline, especially in the upper store trees. This agrees with the work of Ayalew (2003) in Denkoro Forest and Kebede *et al*. (2016) in Gedo Forest.

Basal Area

In Jiga Bushe Forest, the total basal area of all woody plant species was 25.6 m^2 ha^{-1}. *Ficus sur* has the highest basal area which covered 11.6 % followed by *Prunus africana, Ekebergia capensis, Apodytes dimidiata* and *Salix mucronata subsp. serrata* which has basal area coverage of 11.1%, 10.2 %, 9.84 % and 6.33 % respectively. On the other hand, the lowest (basal area below 0.05 m^2 ha^{-1}) was recorded for most species like *Grewia ferruginea, Calpurnia aurea, Brucea antidysenterica, Vernonia auriculifera* and *Schefflera abyssinica.* This might be due to the nature of the plants not to grow to higher basal area. It's fair to say that species with the largest basal area don't always have the highest density, meaning that there's a size gap between them (Kebede *et al*., 2016). As a result, the species with the highest basal area may be considered the forest's most valuable species. According to Tamirat (1994), basal area provides a better indicator of relative value of the species than simple stem count.

In Africa, the average basal area of virgin tropical forests is 23–37 m^2 ha^{-1} (Dawkins, 1959 cited in Lamprecht, 1989). As a result, the basal area value of Jiga Bushe Forest (25.6 m^2 ha^{-1}) is within the standard range for virgin tropical forest basal area values in Africa. When we compared the basal area of Jiga Bushe Forest with the basal area of other Ethiopian forests, the present study forest has lower than Tara Gadam Forest (115.4 m^2 ha^{-1}) by Zegeye *et al* .(2011); Yemrehane (72 m^2 ha^{-1}) by Ayana (2016); Gedo Forest (35.5 m^2 ha^{-1}) by Kebede *et al*. (2016); Chilimo (30.19 m^2 ha^{-1}) by Bekele (1994) and more or less comparable with Adelle Forest (26 m^2 ha^{-1}) by Yineger *et al*. (2008). On the other hand, the basal area of Jiga Bushe Forest has higher than the basal area of Boditi (23 m^2 ha^{-1}) by Yineger *et al*. (2008); Wanzaye Forest (23.3 m^2h^{-1}) by Getnet (2018); Beschillo and Abay (12.6 m^2 ha^{-1}) by Belachew (2006) and Yangudi-Rassa (3.12 m^2 ha^{-1}) by Beyene (2010).

Frequency

Frequency is the number of quadrats in which a given species occurred within the study area. Frequency is an indicator of the homogeneity and heterogeneity of a given vegetation. A higher number of species in higher frequency classes and a low number of species in lower frequency classes indicates similar species composition, while a large number of species in lower frequency classes and a small number of species in higher frequency classes indicates higher heterogeneity (Lamprecht, 1989)).

The study area's woody plant species were classified into five frequency groups. These frequency classes are as follows: A=0-20%, B=21- 40%, C=41- 60%, D=61- 80% and E=81-100%, Accordingly, the foremost frequently observed species were in class 'D' and 'E' (i.e, *Rubus steudneri* 42 times out of fifty quadrats possessing 84 individuals and 5.92 relative frequencies, *Olinia rochetiana* with 80 individuals and 5.63 relative frequencies, *Juniperus procera* was individuals and 5.1 relative frequency and *Maytenus arbutifolia* with 62 individuals and 4.4 relative frequencies).

On the other hand, the smallest amount frequently occurred species were in class 'A' (i.e, *Buddleja polystachya, Clausena anisata, Osyris quadripartita, Eucalyptus globulus, Jasminum abyssinicum, Schefflera abyssinica* and *Cassipourea malosana*), each constituting less than 4 and 0.282 frequency and relative frequency respectively. The study's findings also revealed that the difference in species frequency ranged from 2 to 84 %.

In the present study, high frequency values were obtained in lower frequency classes whereas low-frequency values were obtained in higher-frequency classes indicating the existence of woody plant heterogeneity. The same result is also obtained in Weiramba Forest (Teshager, 2017). *Rubus steudneri, Olinia rochetiana, Juniperus procera, Maytenus arbutifolia* were found to be attributed to its usual occurrence of plant species at wide range of altitude, seed dispersal capacity, and germination vigor and resistant to pests and pathogens are perhaps a number of the factors contributing for the higher frequency of the species. Furthermore, a species with high frequency is often dependent on habitat preferences, adaptation, and the availability of suitable conditions for regeneration (Kenea, 2008). The species with the least occurrence include *Buddleja polystachya, Clausena anisata, Osyris quadripartita, Eucalyptus globulus, Jasminum abyssinicum, Schefflera abyssinica* and *Cassipourea malosana.* These are due to low habitat preferences, adaptation, and less availability of suitable conditions for regeneration (Kenea, 2008).

Important Value Index (IVI)

The dominant and ecologically most significance tree species in Jiga Bushe Forest based on their IVI value were *Olinia rochetiana* (17.99), *Rubus steudneri* (15.99), *Maytenus arbutifolia* (15.83), *Prunus africana* (15.7), *Juniperus procera* (14.495), *Ekebergia capensis* (14.469), *Ficus sur* (13.8), *Croton* *macrostachyus* (12.6), *Apodytes dimidiata* (11.8) and *Pittosporum viridiflorum* (10.9). These dominant species accounted for over 143.28 (47.76) of the total 300 IVI of the Jiga Bushe Forest. A species having significance of IVI greater than 5.00 is considered dominant due to the relative environmental role it plays within the ecosystem (Gurmessa *et al*., 2012). These species are those well adapted to the high pressure disturbance, natural and environmental factors, and the effect of local communities. The most successful species in regeneration, pathogen resistance, choice by browsing animals (least preferred), attraction of pollinators, and attraction of seed predators that promote seed dispersal within the prevailing environmental conditions may also be the most dominant and ecologically significant species (Kenea, 2008).

On the other hand, about 30 species have IVI values of less than 1%, for example *Brucea antidysenterica, Celtis africana, Acanthus sennii, Buddleja polystachya, Phytolacca dodecandra, Maesa lanceolata, Urera hypselodendron, Grewia ferruginea and Dovyalis abyssinica.* This low abundance may also be due to adverse environmental factors or the random distribution of available resources within the forest.

The IVI assessment is used to determine environmental priorities (Gurmessa *et al*., 2012). The tree species in the study forest were classified into five groups based on their IVI values for conservation priority as shown below: 1) >15), 2) 10.1-15, 3) 5.1-10, 4) 1.1-5, 5) < 1 IVI. The IVI species classified as classes 4 and 5 (Table 4) should receive the highest conservation priority since they are threatened with local extinction. Those with higher IVI values, classified as class 1, 2, and 3, need management and monitoring.

Table 4: List of Species under each IVI Class

Class 5	Class 4
Solanum incanum	*Bersama abyssinica*
Asparagus africanus	*Eucalyptus globulus*
Clutia lanceolata subsp. lanceolata	*Buddleja polystachya*
Justicia schimperiana	*Albizia schimperiana*
Pterolobium stellatum	*Dombeya torrida*
Englerina woodfordioides	*Brucea antidysenterica*
Cassipourea malosana	*Celtis africana*
Clausena anisata	*Acanthus sennii*
Osyris quadripartita	*Nuxia congesta*
Schefflera abyssinica.	*Phytolacca dodecandra*
Class 3	*Maesa lanceolata*
Rhus vulgaris	*Urera hypselodendron*
Podocarpus falcatus.	*Grewia ferruginea*
Myrica salicifolia	*Dovyalis abyssinica.*
Salix mucronata subsp. serrata	*Vernonia auriculifera*

Carissa spinarum	*Maytenus gracilipes*
Ficus sycomorus	*Rumex nervosus*
Erythrina brucei	*Hypericum revolutum*
Olea europaea subsp. cuspidata	*Psychotria orophila*
Calpurnia aurea	*Hagenia abyssinica*
Dodonaea angustifolia	*Myrsine africana*
Allophylus abyssinicus	*Otostegia intergrifolia*
Acacia abyssinica	*Vernonia amygdalina*
Class 2	*Teclea nobilis*
Juniperus procera	
Ekebergia capensis	**Class 1**
Ficus sur	*Olinia rochetiana*
Croton macrostachyus	*Rubus steudneri*
Apodytes dimidiate	*Maytenus arbutifolia*
Pittosporum viridiflorum	*Prunus africana*
Rosa abyssinica	

Population Structure

Population structures of trees have important implications to their management, sustainable use and conservation (Shibru & Balcha, 2004). Analysis of the population structure of 58 common tree and shrub species revealed five different Patterns represented by one species from the group (Figure 2a-e).

The primary pattern was an inverted J-shaped distribution formed by species with high frequency distribution of individuals within the lower DBH classes followed by a gradual decrease towards the upper DBH classes (Figure 2a). This pattern was represented by *Acacia abyssinica, Juniperus procera, Erythrina brucei, Olinia rochetiana, Maytenus arbutifolia, Ficus sycomorus, Hypericum revolutum* and *Bersama abyssinica*. This suggested good reproduction and healthy regeneration potential of the species in the forest (Fayera, 2006).

The second trend was a bell-shaped distribution created by species in which the distribution of individuals within the lower and higher DBH classes was less than the distribution of individuals within the middle classes (Figure 2b). Species like *Croton macrostachyus, Dodonaea angustifolia* and *Celtis africana* were characterized by this distribution pattern within the forest. This pattern indicates the occurrence of a poor reproduction status (Fayera, 2006) and recruitment of species. This might be associated with over harvesting of seed-bearing individual. The lower and higher diameter classes are poorly represented may be due to selective removal of low and high sized individuals. The third pattern was created by species with an uneven distribution (irregular) throughout DBH classes, with some DBH classes having a small number of individuals and others having a large number of individuals (Figure 2c). This pattern of distribution was represented by *Olea europaea* subsp. *cuspidata, Myrica salicifolia, Ekebergia capensis, Podocarpus falcatus* and *Salix mucronata* subsp. *serrata*. Such trend demonstrates poor reproduction patterns (Fayera, 2006). This irregular pattern distribution was due to selective cutting by the local people for construction, firewood and overgrazing.

The fourth trend was formed by species with a J-shaped distribution, with a low distribution of individuals in the lower DBH classes, led by a gradual increase towards the upper DBH classes (Figure 2d). Species like *Rhus vulgaris, Apodytes dimidiata, and Prunus africana* were characterized by this distribution pattern. Such pattern shows poor reproduction patterns and hampered regeneration because either most trees are not producing seeds due to age or there are losses due to predators after reproduction (Fayera, 2006).

The final pattern (Figure 2e) was created by a small number of individuals in the first and second DBH classes, but no individuals' species were registered in the other DBH classes. This pattern of distribution was represented by *Carissa Spinarum*, *Dovyalis abyssinica, Asparagus africanus, Buddleja polystachya, Englerina woodfordioides, Brucea antidysenterica, Calpurnia aurea, Justicia schimperiana* and *Myrsine africana*. This is due to the nature of the plants not to grow to higher DBH classes due to removal of the plant for different activities

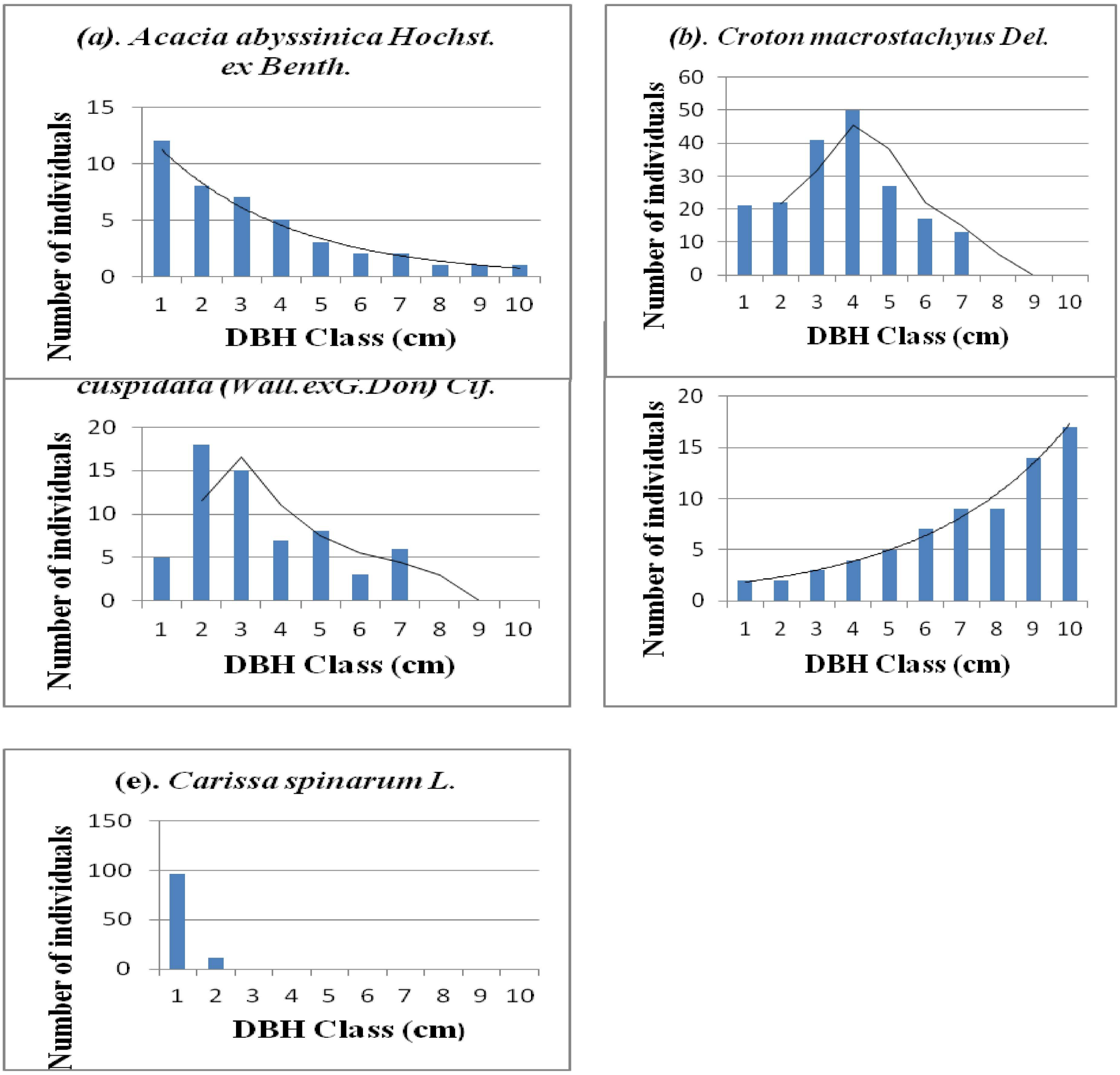

Figure 2 (a-e): Representative Patterns of species population structures in Jiga Bushe Forest Class 1 (2.5-5cm), 2 (5.1-10cm), 3 (10.1-15cm), 4 (15.1-20cm), 5 (20.1-25cm), 6 (25.1-30cm), 7 (30.1-35cm), 8 (35.1-40cm), 9 (40.1-45cm), 10 (>45cm).

Regeneration Status of Jiga Bushe Forest

The future composition of forests depends on the potential regeneration status of individual species within a forest stand in space and time (Henle *et al*., 2004). The existence of a sufficient population of seedlings, saplings, and adults in the population system indicates good regeneration of forest species and the presence of saplings under the canopies of adult trees also indicated the future composition of a community. Regeneration of a particular species is poor if seedlings and saplings are much less than the mature trees. The regeneration status of plant species is summarized based on the total count of seedling and sapling of each species across all quadrats (Tiwari *et al*., 2010). Accordingly, the percent of seedlings, saplings and mature trees in the study forest were 38.8 % 33.96 % 27.5 % respectively. This figure shows that the largest individuals found in the forests are seedlings and indicates that the forest was under good regeneration status.

Most of the species' proportions in the study area fall under group II with 25 species (43.1%) of the total species in the area and 20 species (34.5%) fall under class I. On the other hand, the number of species in class III was 4 species (6.896%). Similarly, about 9 (15.52%) were found in Class V. The ratio of seedlings to saplings, seedlings to mature trees and saplings to mature trees in the present study were, 1.15:1, 1.43:1 and 1.24:1. These show that the distribution of seedlings as a total is bigger than that of saplings and mature trees and saplings is higher than mature trees.

In general, the regeneration status of Jiga Bushe Forest can be considered to be in good condition. This was observed because the proportion of regeneration (combined seedling and sapling) is higher than that of the mature. This finding is similar with different pervious reviews by Kebede *et al*. (2016) in Gedo Forest; Sultan and Berhanu (2013) in Yegof mountain; Belay (2016) in Kurib Forest. It is also consistent with Sultan and Berhanu (2013) in that the presence of greater seedlings than saplings and saplings than mature trees is an indication of a success regeneration status of forest species.

The different woody species encountered in the forest have different density of seedlings and saplings. Accordingly, *Rubus steudneri, Olinia rochetiana, Bersama abyssinica, Acanthus sennii, Erythrina brucei, Acacia abyssinica and Juniperus procera* were with highest density of seedling ha^{-1}. *Pittosporum viridiflorum, Rosa abyssinica*, *Celtis africana, Maytenus arbutifolia, Osyris quadripartite, Brucea antidysenterica and Carissa spinarum* were with the highest number of saplings ha^{-1} in the study area.

All of the species encountered in this forest have been divided into four categories based on total seedling and sapling density to research the conservation status. Those species which can be completely absent within side the regeneration are grouped below IV, and others whose poor regeneration are categorized in group III. The others group whose regeneration statuses are good and fair categorized below group I and II respectively. Consequently, those in group IV need the primary priority conservation and group III second priority. Group II and I need monitoring and management (Table 5).

Table 5. The regeneration status of different woody plant species in Jiga Bushe Forest (Group I=Good, II= Fair, III= Poor and IV = No Regeneration)

II	**I**
Solanum incanum	*Rubus steudneri*
Asparagus africanus	*Olinia rochetiana*
Teclea nobilis	*Bersama abyssinica*
Myrsine africana	*Erythrina brucei*
Schefflera abyssinica	*Acacia abyssinica*
Prunus africana	*Juniperus procera*
Allophylus abyssinicus	*Clausena anisata*
Clutia lanceolata subsp. Lanceolata	*Justicia schimperiana*
Cassipourea malosana	*Acanthus sennii*
Croton macrostachyus	*Phytolacca dodecandra*
Ficus sur	*Rhus vulgaris*
Urera hypselodendron	*Ficus sycomorus*
Dovyalis abyssinica	*Rumex nervosus*
Vernonia auriculifera	*Pterolobium stellatum*
Ekebergia capensis	*Maytenus arbutifolia*
Myrica salicifolia	*Otostegia intergrifolia.*
Brucea antidysenterica	*Psychotria orophila*
Englerina woodfordioides	*Calpurnia aurea*
Hagenia abyssinica	*Jasminum abyssinicum.*
Hypericum revolutum	
Buddleja polystachya.	**IV**
Grewia ferruginea	*Albizia schimperiana*
Maytenus gracilipes	*Apodytes dimidiata*
Nuxia congesta	*Dombeya torrida*
Salix mucronata subsp. serrata	*Eucalyptus globulus*
III	*Olea europaea subsp Cuspidata*
Osyris quadripartita	*Podocarpus falcatus*
Celtis africana	*Vernonia amygdalina*
Pittosporum viridiflorum	*Dodonaea angustifolia*
Rosa abyssinica	*Carissa spinarum*

Conclusion

This study provides valuable information on the current state of structure and regeneration status of woody plant species in Jiga Bushe forest. The total densities of tree/shrub were recorded (1272 ha^{-1}) and indicated that the vegetation of the forest has more or less densely populated. The dominant trees were *Olinia rochetiana, Rubus steudneri*, *Mytenus arbutifolia*, *Juniperus procera* and *Croton macrostachyus* respectively with DBH and height of the trees/shrubs increasing with decreasing of the number of individuals. The total basal area of all woody plant species was 25.6m^2 ha^{-1}. It was found in between normal basal area value for virgin tropical forests in Africa (23-37 m^2 ha^{-1}). The basal area of the present study was relatively low when compared to other dry afromontane forest as the result of the low woody species density and illegal cutting of big trees for different purposes. Jiga Bushe Forest was grouped into five frequency classes. The high values in lower frequency classes and the low values in higher frequency classes. It was also indicated that the study forest has high woody plant species heterogeneity.

Population structures and vertical structure of present study was identified. Accordingly, population structures were categorized into five population distributions: Inversed J-Shape, Bell- Shape, Irregular shaped and low number of individuals within the first and second DBH classes but no any species was recorded in the other DBH classes. In contrast, the vertical structure of species in the current study was classified into three stores: lower, middle, and upper. Based on this, the number of individuals in the lower store is very high.

The importance Value Index (IVI) of the study area was calculated. Based on the result, species with a low Important Value Index (IVI) need intensive conservation efforts. The regeneration status on the study area was identified in good condition. Five species such as, *Rubus steudneri, Bersama abyssinica, Olinia rochetiana, Acacia abyssinica* and *Acanthus sennii* were the highest number of seedlings. On the other hand, some population structure and regeneration status of woody plant species in the forest revealed that there is requiring for conservation priority for species with poor and no regeneration status. Generally, woody plant species of Jiga Bushe Forest showed that the forest had high species diversity with good regeneration status.

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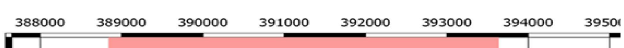

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