Floristic Composition, Structure and Regeneration Status of Woody Plants in Wonjeta St Micheal Church Forest, Northwestern Ethiopia

Amare Bitew Mekonnen
Bahir Dar University
Wubetie Adnew Wassie (wubet42@gmail.com)
Bahir Dar University

Research Article

Keywords: Church forest, Vegetation diversity, Structure, Regeneration, Conservation

Posted Date: November 11th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2243112/v1

Abstract

The study was conducted in Wonjeta St Micheal Church Forest, Northwestern Ethiopia. Fifty plots of 20m x 20m ($400m^2$) were laid along five-line transect for vegetation data collection. In addition, 5m x 5m subplots were laid within the main plot to sample seedlings and saplings. All plots were laid at a distance of 50m along the transect lines. The diversity and population structure of woody individuals of trees and shrubs with a diameter at breast height (DBH) ≥ 2.5cm and height ≥ 2m were measured and DBH < 2.5cm and height < 2m were counted as seedlings and saplings. All trees and shrubs recorded in the 50 plots were used for vegetation structure analysis. A total of 65 woody plant species in 53 genera and 33 families were recorded. Out of the total number of species three were found to be endemic to Ethiopia.The family Fabaceae had the highest number of species, followed by Moraceae, and then Euphorbiaceae with 14, 6, and 4 species respectively.The results of Shannon Wiener diversity and evenness indices of woody species were 2.8 and 0.68 respectively. Woody species densities for mature individuals were 2,202.5 stems ha^{-1}, seedling 2419.2 stems ha^{-1}, and sapling 1737.6 stems ha^{-1}. Priority for conservation should be given using population structure, important value index, and regeneration status as criteria. Results of the structural analysis revealed that the Forest is highly dominated by small-sized trees and shrubs indicating that it is in the stage of secondary development and there are species that require urgent conservation measures.

1. Introduction

Tropical forest is a biologically diversified ecosystem with large species richness, evenly distributed with highest net primary production (NPP) and biomass accumulation due to its favorable climate and other environmental condition (Chapin et al., 2011). However, it is highly threatened in the net loss of forest due to high anthropogenic pressure (FAO, 2010). Deforestation is still alarmingly high in the tropical region resulting in the formation of small patches of fragmented forests (FAO, 2016). Loss of forest cover and biodiversity due to anthropogenic activities is a growing concern in many parts of the world.Africa's forest cover is estimated to be 650 million hectare constituting 17% of the world's forests including a number of global biodiversity hotspots (Mittermeier et al., 2004).

Ethiopia is one of the top 25 biodiversity-rich countries in the world, and hosts two of the world's biodiversity hotspots, namely the Eastern Afromontane and the Horn of Africa hotspots. It is also among the countries in the Horn of Africa regarded as chief Centre of diversity and endemism for several plant species. The Ethiopian flora is estimated to about 6000 species of higher plants, of which 10% are considered to be endemic (Kelbessa & Demissew, 2014). Woody plants constitute about 1000 species (Hedberg et al., 2009). This richness in biodiversity is due to topographical diversity with flat-topped plateaus, high mountains, river valleys, deep gorges, rolling plains, and with great variation of altitude ranging from 116to 4620meter above sea level (m.a.s.l.) (Friis et al., 2011; IBC, 2014).

Many scholars also agree that the forest of Ethiopia become decreasing from time to time due to anthropogenic activities (Teshome, 2013;Mohammed et al.,2014).Lack of integration of the local people living around the conservation areas is the major constraint to the overall conservation effort in Ethiopia (Feyera and Demel, 2003). Because of this, it has now realized that unless the local community is involved in the conservation effort, the sustainability of forest resource will be under a question. Rapid human population growth, poverty, forest clearing for cultivation, over grazing, exploitation of forests for fuel wood and construction materials without replantation and lack of proper policy framework is some of the major factors that contribute to the loss of forest resources in Ethiopia (Dereje, 2007;Cardelús et al., 2019). Reduction in forest cover has number of consequences including soil erosion and reduced capacity for watershed protection with possible flooding, reduced capacity, and loss of biodiversity. This leads to instability of ecosystem and reduced availability of various forest products and services (Didita et al., 2010).

The northern and central highlands of Ethiopia are nearly devoid of forests due to deforestation and environmental degradation, where forests remain as small, isolated patches usually on the tops of mountains and heads of streams surrounding churches (Wassie 2002). These remnant natural forest fragments persist because of their sacred status under religious knowledge of forest conservation of the Ethiopian Orthodox Tewahido Churches (EOTC) (Wassie 2002; Cardelús et al. 2017).

Wonjeta St Micheal Church Forest is one of the few ruminant natural forests in Ethiopian upper Blue Nile basin, where most of the forest area is degraded and converted to agricultural land due to demographic pressure,sedentary farming, and exotic tree plantation. Theseinspired us to study the vegetation status, woody species composition, density, diversity, structures of vegetation, and regeneration status of the forest. Therefore, this study aimed to describe the opportunities and challenges of such church forest for upper Blue Nile basin, ecosystem wellbeing.

2. Materials And Methods

2.1. Description of the Study Area

The study was conducted in Wonjeta St Micheal Church Forest, Bahir Dar zuria district in Ethiopian upper Blue Nile basin, Northwestern Ethiopia (Fig. 1). Bahir Dar zuria is one of thedistrict in West Gojjam administrative Zone. The district is bounded in the south by Yelimanadensa District, on the southwest by Mecha, on the northwest by GilgelAbay River (tributary) separates it from SemienAchefer, on the north by Lake Tana, on the east by the Abay River that separates it from South Gonder Zone, in the west by Mecha and Achefer Districts. The study site is Wonjeta St Micheal Church Forest which is found in the reference of Longitude11.686410 and Latitude37.283097 with the elevation of 1820 m.a.s.l.

2.2. Methods of Sampling and Data Collection

2.2.1. Sampling Design

Systematic sampling design was used to collect vegetation data following Muller and Ellenberg (1974). Five line transects were laid at every 50m distance between them. The first line transect was started 50 meters inward from the edge of the forest to avoid “edge effect” (Christine et al., 2010; Cardelús et al., 2020). Along each transect, sample plots having an equal size of 20m x 20m ($400m^2$) were laid at distance of 50m from each other. A total of 50 plots were laid for woody speciesdata collection. Within the main plot 5m x 5m sub-plots were laid at four corners and one in the middle for seedling and sapling data collection.

2.2.2. Vegetation Identification and Data Collection

All woody plant species encountered in each plots were recorded by their local (vernacular) name and their cover abundance percentage was estimated following the Braun-Blanquet procedure. Local name of the woody species was provided by experienced and familiarized key informants selected from the nearby community. For those species difficult to identify in the field, their plant specimens were collected, pressed, and brought to Bahir Dar University botanists for taxonomic identification referring published volume of the flora of Ethiopian and Eritrea (Hedberg and Edwards 1989; Hedberg and Edwards, 1997; Hedberg et al., 2006).

2.2.3. Structural Data Collection

The diameter at breast height (DBH) and height of woody plants was recorded with measuring tape and calibrated stick respectively, which were used for description of vegetation structure (frequency, dominancy, basal area, and important value index).

In each plot, trees and shrubs with height ≥ 2m and DBH ≥ 2.5cm were measured and recorded at about 1.35m from the ground. For trees and shrubs that were branched around the breast height, the circumference was measured separately and averaged. For the purpose of regeneration assessment, from the five sub quadrats, the seedlings and saplings were counted for each species. In this study, a seedling was considered as woody individual with a DBH < 2.5cm and less than 1m hight; a sapling was considered as those woody individual with a DBH ≥ 2.5cm and a height of less than 2m.

2.3. Data Analysis

2.3.1. Vegetation Composition and Structure Data Analysis

The structural parameters were analyzed using the following formula:

Basal area of a tree = $\pi(\frac{\mathrm{DBH}}{2})^{2}$ Where, π = 3.142, DBH (Diameter at Breast Height) = (C/π).

$$Dominance = \frac{Basalareaofaspecies}{Areasampled}$$

$$Relativedominance = \frac{DominanceforspeciesA}{Totaldominanceofallspecies}$$

$$Density\,(D) = \frac{Numberofindividualsofaspecies}{Sampledareainha}$$

$$Relativedensity\,(RD) = \frac{NumberofIndividualsofaspecies}{Totalnumberofindividualsinha} x100$$

$$Frequency\,(F) = \frac{Numberofplotsinwhichaspeciesoccurs}{Totalnumberofplotssampled}$$

$$Relativefrequency\,(RF) = \frac{frequencyvalueforaspecies}{Totalfrequencyvalueforallspecies} x100$$

Important value = Relative density + Relative frequency + Relative dominance

Importance Value Index (IVI) analysis is used for setting conservation priority. It combines data for three parameters (relative frequency, relative density and relative abundance) or it often reflects the extent of the dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker, 1992).

The vertical stratification of species in the study area was examined using the IUFRO classification scheme (Lamprecht, 1989). According to this scheme, tree with > 2/3 height of the top represents upper story, trees with height between 1/3 and 2/3 of the top height represent the middle story, and the lower story is represented by trees with height < 1/3 of the top height.

2.3.2. Regeneration Data Analysis

Regeneration status of the forest was analyzed by comparing saplings and seedlings with the matured trees according to Dhaulkhandi et al. (2008); and Tiwari et al. (2010), i.e., Good regeneration, if seedlings > saplings > adults; Fair regeneration, if seedlings > or ≤ saplings ≤ adults; Poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults); and if a species is present only in an adult form it is considered as not regenerating.

2.3.3. Measurement of Species Diversity Indices

Shannon –Wiener diversity index

is used to evaluate the species diversity of the study area.It is popular measure of species diversity and evenness that is not affected by sample size

$$H' = -\sum_{i=1}^{S} Pi(ln(Pi))$$

H' = Shannon diversity index, S = the number of species;Pi = the proportion of individual woody plant species; ln = is the natural logarism.
The equitability or evenness of the species in each plot was computed using the formula:

$$\text{Evenness index (Equitability) } J = {}^{H'}/_{H\ max}$$

Where, J = Evenness, H' =Shannon diversity index, and H'max = lnS; S = the number of species.

Equitability assumes a value between 0 and 1, where 0 indicates the abundance of few species and 1 indicates the condition where all species are equally abundant.

3. Result And Discussion

3.1. Woody plant species composition

A total of 65 woody plant species in 53 genera and 33 families were identified from Wonjeta St Micheal Church Forest. Among the 65 recorded woody species 32 (49.23%) were shrubs, 29 (44.62%) were trees, and 4 (6.15%) lianas (Fig. 2).The results of the study revealed that the species richness of the forest was higher than some dry afromontane forests of Ethiopia such as Ambo State Forest with 58 species located in South Gondar Zone (Solomon and Belayneh, 2015), Wanzaye natural forest with 49 species in South Gondar (Ambachew, 2018) and Wogello natural forest 20 species in North Gonder (Ambachew, et al., 2019) and less than many dry afromontane Forests like Woynwuha Natural Forest with 69 species in East Gojjam (Temesgen et al., 2015), Chebera Churcura National Park with 106 species in Southern Ethiopia (Girma and Maryo, 2018).

The major families were Fabaceae represented by 14 species (21.53%) followed by the family Moraceae consisting 6 species (9.23%), and Euphorbiaceae including 4 species (6.15%), Oleaceae with 3 species (4.61%), Asteraceae, Acanthaceae, Celastraceae, Lamiaceae, Apocynaceae, Solanaceae, Malvaceae, Combretacae, Myrtaceae each with 2 species (3.08% each). Each of the remaining 20 families was represented by one species (30.76%) (Table 1). Different studies (Motuma et al., 2010; Birhanu, 2010; Mekbib, 2012) reported the dominance of Fabaceae, Poaceae and Asteraceae in Afromontane vegetation type but it is not true in this study area.

Table 1
The top 13 Families with their corresponding number of genera and species

No.	Family	Genera	%	Species	%
1	Fabaceae	10	18.87	14	21.54
2	Moraceae	1	1.89	6	9.23
3	Euphorbiaceae	4	7.55	4	6.15
4	Oleaceae	3	5.66	3	4.62
5	Lamiaceae	2	3.77	2	3.08
6	Combratiaceae	2	3.77	2	3.08
7	Myrtaceae	2	3.77	2	3.08
8	Apocynaceae	2	3.77	2	3.08
9	Acanthaceae	2	3.77	2	3.08
10	Celastraceae	1	1.89	2	3.08
11	Malvaceae	2	3.77	2	3.08
12	Solanaceae	1	1.89	2	3.08
13	Asteraceae	1	1.89	2	3.08
	Others	Each has one Genera	1.89	Each has one Species	1.54

3.2. Species diversity and evenness

The results of Shannon Wiener diversity and evenness indices of woody species were 2.8 and 0.68 respectively which means woody diversity and evenness was high with compare to Yegof forest 2.26 and 0.57, respectively (Mesfin et al., 2018). But the forest has lower value of diversity and evenness indices than zegie forest (H’ = 3.72 and J = 0.84) respectively (Alemnew et al., 2007) and Keja Araba and Tulu forest (H’ = 2.81, 3.14 and J = 0.79, 0.86) respectively (Yakob and Fekadu, 2016). According to Kent and Coker (1992), the Shannon Wiener diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. High diversity when it is above 3.0, medium when it is between 2.0 and 3.0, low between1.0 and 2.0, and very low when it is smaller than 1. The equitability (evenness) index has values between 0 (a situation in which the abundance of all species are completely disproportional) and 1 (all species are equally abundant) (Kent and Coker, 1992). The study forest has medium diversity may be due to harvesting of fuel wood and clearing of shrubs/trees for agriculture. The evenness index showed not that much evenly distributed of species in the forest, or an unbalanced distribution of the individuals of a species. The reason could be attributed to excessive disturbance, variable conditions for regeneration and over-exploitation of some species (Wassie et al., 2005). The diversity and evenness indices imply the need to conserve the forests from human disturbance.

3.3. Vegetation Structure

3.3.1. Vegetation Density

The overall density of mature woody species with DBH ≥ 2.5cm in Wonjeta St Micheal Church Forestwere 2202.5 stems ha^{-1}. This was classified into seven density classes: 1) < 5, 2) 5.01 -20, 3)20.01-35,4)35.01-50, 5) 50.01-65, 6) 65.01–80, 7) > 80 stems ha^{-1}.Nine species contributed 79.25% of the total density from the density class 7 which was due to the dominance of species *Carissa spinarum, Calpurnia aurea, Maytenusobscura, Grewia ferruginea, Capparistomentosa, Premnaschimperi, Rhusglutinosa, Pterolobiumstellatum* and *Croton macrostachyus*. From density class 1 *Stereospermumkunthianum, Ficussycomorus, Ficuspalmata, Dichrostachyscinerea, Acokantheraschimperi, Entadaabyssinica, Ficussur, Piliostigmathonningii*, and *Brideliamicrantha* contributed only 0.23% of the total density, and those which are represented with less number of species need conservation attention.

According to the result, the densities of tree individuals of Wonjeta St Micheal Church Forestwith DBH between 2.5 and 10cm,between 10cm and 20cm, and with DBH > 20cm were1950.5ha^{-1}, 221.5ha^{-1}, and 30.5ha^{-1} respectively.The ratio of density of individuals of Wonjeta St Micheal Church Forestwith DBH > 10 cm to DBH > 20 cm is very high (7.26). The comparison of the density ratio of the study site with other 4 forests' density ratio in Ethiopia is given by Table 2.The ratio a/b indicate that Wonjeta St Micheal Church Forest has more tree in lower DBH classes than in the higher classes when compared to Gedo, Menna Angetu, Chilmo, and Menagesha Forest. The reasons behind these are geographical location, the nature of the forest, altitude variation, age of the forest, degree of conservation and exposure to disturbance.

Table 2
Comparison of tree densities with DBH between 10 and 20, and > 20cm of Wonjeta St Micheal Church Forestwith other 4 Forests in Ethiopia

Forets	10 < DBH < 20 (a)	DBH> 20 (b)	a/b	Forest types	Source
Gedo	832	464	1.79	Dry Afromontane	(Birhanu, 2010)
Menna Angeu	292.59	139.78	2.08	Dry Afromontane	(Ermias et al., 2008)
Chilmo	638	250	2.6	Dry Afromontane	(Soromessa & Kelbessa, 2013)
Menagesha	484	208	2.30	Dry Afromontane	(Tamrat, 1993)
St. Micheal Church Forest	221.5	30.5	7.26	Dry Afromontane	Present study

3.3.2. DBH distribution

The distribution of plant species in different DBH classes is shown in Fig. 3. Matured woody plants of the study area were classified into seven DBH classes. Class A = 2.5-5cm, B = 5.01-10cm, C = 10.01-15cm, D = 15.01-20cm, E = 20.01-30cm, F = 30.01-40cm, G = > 40cm. Based on the result, the first class had the highest distribution of species density which was1326.5individuals ha^{-1}(60.23%), the second was624(28.33%) and the 3rd, 4th, 5th, and 6th takes 196.5 (8.92%), 25 (1.14%), 21 (0.95%), 2.5 (0.11%), finally the last class takes 7 (0.32%) respectively.

The DBH class distribution of all individuals showed inverted J-shape distribution pattern which means that the majority of the species had highest number of individuals in the lowest diameter class. This means form the potential source of recruitment to successively increasing diameter classes that ensures sustained future regeneration of the forest if it will be properly managed. However the density was decreased as DBH class increasing. This indicated that the predominance of small and medium sized individuals in the Forest such as *Carissa spinarum, Calpurnia aurea, Maytenusobscura, Grewiaferruginea* and *Capparistomentosa*. This could be attributed to high rate of regeneration but poor recruitment in the forest, which might have been caused by unsustainable exploitation of woody species in the forest by the local people some years before maturity.

3.3.3. Height class distribution

Individuals of woody species were classified into four height classes and their density ha^{1} was shown on this basis(Fig. 4). Based on the result, the height class distribution of woody plants of Wonjeta St Micheal Church Forestshowed a higher individualin the lowest height class, 1695.5ha^{-1}(76.98%) are in ≤ 5class height. As height increases from one class to the other the density of individuals were decreasing i.e. large proportion of woody plant species were distributed in the lowest height class. This clearly tells the dominance of small sized individuals and the presence of high regeneration but lower recruitment and absence of matured individuals. It might be due to anthropogenic factors.

3.3.4. Frequency

Based on the percentage frequency value, the result showed there are eight most frequent woody species in the study area ≥ 56% (Table 3).

Table 3
Frequency distribution of top 8 woody plant species of St.Micheal Church Forest

Number	Scientific name	Frequency in %
1	*Grewiaferruginea*	80
2	*Calpurnia aurea*	78
3	*Carissa spinarum*	76
4	*Maytenusobscura*	76
5	*Premnaschimperi*	74
6	*Croton macrostachyus*	70
7	*Rhusglutinosa*	62
8	*Acacia lahai*	56

3.3.5. Population Structure

In the present study, the general patterns of DBH distribution of the forest showedan inverted J shape distribution pattern. However some groups of individuals showed population dynamics and recruitment processes for a given species. The first type of pattern was inverted J- shape. It shows a high number of species in the lower DBH classes and reduction at the highest DBH classes. This pattern was exhibited by the species *Pittosporum viridiflorum* (Fig. 5A). Such pattern shows normal or healthy structural pattern with good reproduction and recruitment capacity of a given species (Feyera et al., 2007). The second type of population pattern was bell shaped and is characterized by the species *Croton macrostachyus* (5B). It shows a fairly high number of individuals of the species in the middle DBH classes but lower numbers of individuals of the species in the lower and higher DBH classes. This species has poor recruitment potential which might be due to intense competition between the other species found in its surroundings and also were use of this tree for making fencing, charcoal and other purposes. The third type of population pattern is represented by *Acacia persiciflora* (5C). In such pattern, the density of individuals increases with increasing DBH up to some point and then decreases with increasing DBH. The pattern continues with decreasing to some extent and increasing density as DBH increases. This population structure pattern showed irregular or zigzag type of distribution and is not healthy because of selective removal of the species for construction and fuel wood.

3.3.6. Basal Area

The total basal area of woody species in St Micheal Church Forest with DBH ≥ 2.5cm and height ≥ 2m was found to be 99.57m^2ha^{-1}. Comparison of the basal area and density in the DBH classes of the study sites revealed that occurrence of more number of individuals in the first DBH classes 2.5–5cm. However, their contribution to the basal area was very low. About 47.93% of the total basal area is distributed in the highest DBH Class (> 20cm) which was the presence of few but large sized individuals of the canopy trees which are *Ficus vasta, Sapium ellipticum, and Mimusops kummel*. The second highest basal area (28.5%) distribution is in DBH class 5.1-20cm which was due to the constitution of species *Acacai alahai, Croton macrosachyus, Calpurnia aurea* and *Rhus glutinosa*.

It was reported that BA provides a better measure of the relative importance of the species than simple stem count (Tamrat, 1994). Thus, species with largest contribution to the basal area in St Micheal Church Forest are *Acacia lahai, Syzygiumguineense, Calpurnia aurea, Premnaschimperi, Rhusglutinosa, Ficusvasta, Croton macrostachyus, Carissa spinarum, Grewiaferruginea*and*Euclearacemosa.*

The basal area of St Micheal Church Forestwas compared with the basal areas of other five forests in Ethiopia (Table 4). Based on the result, the Basal area of St Micheal Church Forestis much greater than Jibat, Menagesha, Gedo forest but smaller than Chilimo-Gaji forest and Belete forest. This may be due to variations in the conservation of the forests, exposure to deforestation and geographical location of the forests.

Table 4

Basal area (BA) Comparison of St Micheal Church Forestwith other five Afromontane forests (m^2ha^{-1})

Forest	**Basal area (m^2ha^{-1})**	**Forest types**	**Source**
Chilimo-Gaji	454.52	Dry Afromontane	(Mammo and Zhang, 2018)
Belete	103.5	Moist Evergreen Montane	(Kflay and Kitessa, 2014)
Jibat	49.8	Humid Afromontane	(Tamrat, 1994)
Gedo	35.45	Dry Afromontane	(Birhanu, 2010)
Menagesha	36.1	Dry Afromontane	Tamrat (1993)
Present study site	99.57	Dry Afromontane	Present study (2020)

3.3.7. Dominant Plant Species

The total dominance of woody species in the forest was $49.78m^2ha^{-1}$. From 61 total plant species, the most dominant species in St Micheal Church Forest was *Acacia lahai* which contributed 16.13% followed by *Syzygium guineense* which contributed 10.35% and *Calpurnia aurea* which contributed 7.87%. But the least dominant species was *Ficussur, Combretum collinum ,Piliostigma thonningii, Justica schimperiana, Entada abyssinica, Terminalia brownie, Stereospermum kunthianum, Helinumy stacinus, Ficus palmate, Acokanthera schimperi, Ficus sycomorus, Dichrostachys cinerea* which contributed 0.1% of the total dominance. According to Feyera et al. (2007), the high dominance and/or abundance of a few species in a forest could be attributed to a number of factors, such as the over-harvesting of the desired species, disturbance factors, succession stage of the forest and/or survival strategies of the species.

3.3.8. Vertical structure (Over story) of St Micheal Church Forest

The vertical stratification of the tree in the study area was examined using IUFRO classification cheme (Lamprecht; 1989). Based on this scheme the top height was used for the vertical structure of tree. According to the result of the study trees with 2/3 of the top height (height above 24m) represent upper story is 0.18% of the individuals; trees with height between 1/3 and 2/3 of the top height represent middle story contains 9.35% of the total individuals and trees with height < 1/3 of the top height represent lower story includes contains 90.47% of the individuals (Table 5). The highest tree distribution in the study area is the lower story class. This implies that the forest has been heavily influenced by the local anthropogenic activities through selective logging for fuel wood, construction, and illegal wood harvest for timber production. Currently, there were some long trees and short to medium individuals. The dominance of short-heighted individuals was the attribute of good regeneration but low recruitment.

Table 5
Over story classification of the forest

Vertical stratification of the trees	Number of individuals	Individuals in (%)
Upper Story	8	0.18%
Middle Story	412	9.35%
Lower Story	3985	90.47%

3.3.9. Regeneration Status

The result found the total densities of seedling, sapling, and mature plants of the forest were 2419.2ha^{-1}, 1737.6ha^{-1} and 2202.5ha^{-1} respectively. Out of the total analyzed tree and shrub fifteen (15) species were with no seedling and sapling and they are put in the first priority class as they are represented by no individual and if no urgent action is taken they will be locally extinct those are *Acokantheraschimperi, Stereospermumkunthianum, Sapiumellipticum, Ficussycomorus, Syzyguimguineense, Ficusthonningi, Ficus palmate, Mimusops kummel, Ficusvasta, Brideliamicrantha, Dichrostachyscinerea, Erythrinaabyssinica, Albiziagummifera, Entadaabyssinica*and *Ficus sur*.

The ratio analysis of woody species seedling to mature individuals in the forest gives that (1.10:1), seedling to sapling was (1.39:1) and sapling to mature (0.79:1). The result showed that there is more seedling than that of sapling and mature individuals implying the survival of seedling to reach sapling stage and according to Tiwari et al. (2010), the forest is now in a fair regeneration. However there are also species with no seedling and sapling that may be caused by due to the physical condition of their microhabitat and human impacts and need urgent measurement to be taken as they are in poor regeneration.

3.3.10. Importance Value Index

The species in the forest were grouped in to five IVI classes based on their IVI values for conservation priority. Priority class 1 (IVI < 1) should get 23 uppermost conservation priority since these species are at risk of local extinction. Those species with lower IVI values need high conservation efforts while those with higher IVI values (IVI > 14.1) need monitoring management. Based on their higher IVI value, there were nine (9) most dominant and ecologically most significant shrubs and trees species in St Micheal Church Forest were *Carissa spinarum* (29.9), *Calpurina aurea* (25.63), *Acacia lahai* (23.99), *Grewia ferruginea* (21.31), *Maytenus obscura* (20.78), *Premna schimperi* (19.0), *Rhus glutinosa* (17.02), *Capparis tomentosa* (15.47) and *Croton macrostachyus* (14.67). In contrast to this, *Phoenix reclinata, Phytolecadodecandra, Albizia gummifera, Acokanthera schimperi, Sapium ellipticum, Acacia venosa, Erythrina abyssinica, Justica schimperiana, Sida schimperiana, Ficus palmate, Piliostigma thonningii, Millettia ferruginea, Hibiscus macranthus and Stereospermum kunthianum* were species with low IVI value that need urgent feedback to regenerate. The possible reason for this could be either the selective cutting of these species by the local people or unfavorable conditions micro habitat. This indicates that the requirement of conservation and management of the forest as a whole.

4. Conclusion And Recommendations

4.1. Conclusion

From the result of species composition, coverage, and abundance of woody plants; it can be concluded that St Micheal Church Forest could be an opportunity to develop Ethiopian upper Blue Nile basin resources. In this study the result showed that the Forest is dominated by small sized tree and shrub species, indicating that the Forest was seriously exploited and affected in the previous periods, but currently good regeneration is shown.

Based on structural description of diameter and height class distribution on St Micheal Church Forest both DBH and height class shown similar trend, in that the density of tree and shrub species decrease with increasing DBH and height classes, which implied predominance of small sized individuals in the lower than the higher diameter classes indicating good reproduction potential and rare occurrence of large individuals.

The analysis of frequency class in St Micheal Church Forest showed that higher percentage number of species in the lower class than in the higher frequency classes. This indicates that the Forest is floristically heterogeneous.

From the analysis of structures of some selected tree species in the study site it can be concluded that some species such as *Acacia sieberiana ,Acacia venosa, Acokanthera schimperi, Albizia gummifera, Entada abyssinica, Erythrina abyssinica, Ficus sycomorus*, and *Ficus vasta* have abnormal population structure with no or few individual at lower size classes and also there are species with no seedling and sapling as example *Sapiumellipticum ,Ficusthonningii ,Ficus palmate, Syzygiumguineense, Mimusops kummel, Stereospermumkunthianu, Dichrostachyscinerea, Erythrinaabyssinica, Entadaabyssinica* and *Ficus sur*. These species need urgent conservation measures that will bring a healthy regeneration and consequently their sustainable use.

4.2. Recommendations

To conserve the church forest's genetic resources and to improve the natural diversity, and structure of church forest and to provide optimal support for development of Ethiopian upper Blue Nile basin for ecological, economical and spiritual benefits the following general recommendations were made:

- Complete ecological studies are vital like, soil nutrient, soil seed bank, anthropogenic impact, and others of the forest should be studied to identify the environmental factors responsible for the observed pattern.
- Analysis of IVI and species structure shows that some important tree species including *Sapium ellipticum ,Ficus thonningii ,Ficus palmate, Syzygium guineense, Erythrina abyssinica* and *Entada abyssinica* are poor in regeneration and recruitment conditions this may be due to anthropogenic factors from the local community surrounding the area through cutting, continuous grazing and traditional farming system; unless alternative measure and immediate attention are taken the species are in a heavy pressure.
- Governmental and non- governmental institution should provide priority to the conservation of vegetation of the forest in general for its rich biodiversity area.
- Raising public awareness of the local community and introduction of participatory management programs should be encouraged and implemented. This will provide opportunity for local community to be involved in the management and conservation of the area and become beneficiaries.

Declarations

Ethical Approval – Not applicable

Competing interests – The authors declare that they have no competing interests

Authors' contributions – Amare Bitew Mekonnen**:** Conceptualization, Administration, Data collection, Analysis, & Investigation.

Wubetie Adnew Wassie**:** Conceptualization, Data collection, Data curation, & Analysis.

All authors read and approved the final manuscript.

Funding: This work was supported by Bahir Dar University College of Science Research office [grant numbers 00130, 2019]

Availability of data and material: The data sets used and/or analyzed in the study are available from the text.

References

1. Alemnew A., Demel T., Yonas Y., and Sue E. (2007). Diversity and status of regeneration of woody plants on the peninsula of Zegie, north western Ethiopia. *Tropical Ecology* **48**(1): 37-49.
2. Ambachew G. (2018).Woody Species Composition, Diversity and Vegetation Structure of Dry Afromontane Forest, South Gondar, Ethiopia. *Journal of Agriculture and Ecology Research International* **16**(3): 1-20, 2018; Article no.JAERI.44922.
3. Ambachew G., Biazen E., Getnet K., and Tesfay S. (2019). Woody species diversity, richness and population structure of enclosed areas, north Gondar, Ethiopia, South *Asian Journal of Biological Research*, **2**(1): 14-29.
4. Birhanu K. (2010). Floristic Composition and Structural Analysis of Gedo Dry Evergreen Montane Forest, West Shewa Zone of Oromia National Regional State, Central Ethiopia, MSc. Thesis.Addis Ababa University, Addis Ababa.
5. CardelúsC.L., Mekonnen A.B., Jensen K.H., Woods C.L., Baez M.C., ... Scull P.R., Peck W.H. (2020). Edge effects and human disturbance influence soil physical and chemical properties in Sacred Church Forests in Ethiopia. *Plant and Soil;* 453:1
6. Cardelús CL, Scull P, Wassie A, Woods CL, Klepeis P, Kent E, Orlowska I (2017) Shadow conservation and the persistence of sacred church forests in northern Ethiopia. The Association for Tropical Biology and Conservation.Biotropica 49:726–733.
7. Cardelús, C. L., Woods, C. L., BitewMekonnen, A., Dexter, S., Scull, P., &Tsegay, B. A. (2019). Human disturbance impacts the integrity of sacred church forests, Ethiopia. *Plos One*, *14*(3), e0212430. https:// doi.org/10.1371/journal.pone.0212430
8. Chapin FS, Matson PA, and Vitousek PM (2011). Principles of terrestrial ecosystem ecology Second Edition: Springer New York Dordrecht Heidelberg London. Springer Science and Business Media;LLC, 233 Spring Street, New York, NY 10013, USA.
9. Christine, B.S., Denich, M., Demissew, S., IbFriis, and Juergen, H.B. (2010). Floristic Diversity in Fragmented Afromontane Rainforests: Altitudinal Variation and Conservation. Applied Vegetation Science, 13, 291-304.
10. Dereje D. (2007). Floristic Composition and Ecological Study of Bibita Forest (GuraFarda), Southwest Ethiopia.M.Sc. Thesis, Addis Ababa University, Addis Ababa.
11. Dhaulkhandi, M., Dobhal, A., Bhatt, S., & Kumar, M. (2008). Community Structure and Regeneration Potential of Natural Forest Site in Gangotri, India. *Journal of Basic and Applied Sciences*, Vol. 4, 49-52
12. Didita, M. Nemomissa, S.andGole, T. W. (2010). "Floristic and structural analysis of the Woodland the woodland vegetation around DelloMenna, Southeast Ethiopia," Journal of Forestry Research, vol. 21,

no. 4, pp. 395–408.

13. Ermias L., Ensermu K., Tamrat B., and Haile Y. (2008). Plant Species Composition and Structure of the Mana Angetu Moist Montane Forest, South-Eastern Ethiopia. Journal of East African Natural History **97**(2): 165–185.
14. FAO (2010). Food and Agriculture Organization of the United Nations Forestry Department; Global Forest Resources Assessment 2010; Country report, Ethiopia. Rome: Italy.
15. FAO (2016). Food and Agriculture Organization of the United Nations; Forestry Contribution to National Economy and Trade in Ethiopia, Kenya and Uganda. By Kilawe, E. and Habimana, D. Addis Ababa, Ethiopia.
16. Feyera S. and Demel T. (2003). Diversity, Community types and population.Structure of Woody plants in Kimchee Forest, a virgin Nature Resave in Southern Ethiopia.*Ethiopian Journal of Biological Science.***2(**2**):** 169-187.
17. Feyera S., Tadesse W., Demissew S. and Denichi M. (2007). Floristic Diversity and composition of Sheko, Southwest Ethiopia. Ethiopian Journal of Biological sciences 6: 11-42.
18. Friis, I., Sebsebe D., and van Breugel, P. (2011) Atlas of the potential vegetation of Ethiopia. 92-105pp.Addis Ababa University Press &Shama Books, Ethiopia.
19. Girma M. and Maryo M. (2018). The Diversity and Composition of Woody Plants in Chebera Churcura National Park (CCNP), Southern Ethiopia.*Open Journal of Forest*, **8**, 439-458. https://doi.org/10.4236/ojf.2018.84028.
20. Hedberg I., Friis I., and Person E. (2009). Flora of Ethiopia and Eritrea, Vol. 1. National Herbarium, Addis Ababa, university.
21. Hedberg, I. and Edwards, S. (Ed.) (1997). Flora of Ethiopia and Eritrea, Vol. 7: Poaceae
22. Hedberg, I. and Edwards, S. (Eds.) (1989) Flora of Ethiopia and Eritrea, Vol. 3: Pittosporaceae to Araliaceae. The National Herbarium, Addis Ababa and the Department of Systematic Botany, Uppsala.
23. Hedberg, I., EnsermuKelbessa, Edwards, S., SebsebeDemisew and Persson, E. (2006). Flora of Ethiopia and Eritrea, Volume 5.Gentianaceae to Cyclocheilaceae. Addis Ababa, Ethiopia; Uppsala, Sewden.
24. Kelbessa E and Demissew S (2014). Diversity of vascular plant taxa of the flora of Ethiopia and Eritrea. Ethiopian Journal of Biological Sciences 13: 37 – 45.
25. Kent, M. and Coker, P. (1992).Vegetation Description and Analysis. A practical approach, 363p.John Wiley and Sons, New York.
26. Kflay G., and Kitessa H. (2014). Species composition, Plant Community structure and Natural regeneration status of Belete Moist Evergreen Montane Forest, Oromia Regional state, Southwestern Ethiopia.*Momona Ethiopian Journal of Science* (MEJS), V **6**(1):97-101, 2014.
27. Lamprecht H. (1989). Silviculture in the Tropics: Tropical Forest Ecosystems and Their Tree Species-Possibilities and Methods for Their Long-Term Utilization. Federal Republic of Germany, Eschborn.

28. Mammo S. and Kebin Z, (2018).Structure and natural regeneration of woody species at central highlands of Ethiopia.*Journal of Ecology and the Natural Environment*. Vol. **10** (7), pp. 147-158, September 2018.
29. Mekbib F. (2012). Floristic Composition and Diversity Analysis of Vegetation of Awash MelkaKunture Prehistoric Archaeological Site, Ethiopia, Msc. Thesis. Addis Ababa University, Addis Ababa, Ethiopia.
30. Mesfin W., Zerihun W. and Ermias L. (2018).Species Diversity, Population on Structure and Regeneration Status of Woody Plants in Yegof Dry Afromontane Forest, North Eastern Ethiopia. *European Journal of Advanced Research in Biological and Life Sciences* Vol. **6** (4), 2018 ISSN 2055984. Progressive Academic Publishing, UK Page 20 www.idpublications.org.
31. Mittermeier R. A.,Robles G. P. and Hoffmann M. et al.(2004). *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Eco-Regions, CEMEX, Mexico City.*
32. Mohammed G., Teshome S., and Satishkumar Belliethathan, (2014). Forest Carbon Stocks in Woody Plants of Tara Gedam Forest: Implication for Climate Change Mitigation. Science, *Technology and Arts Research Journal* **3** (1): 101-107.
33. Motuma D., Sileshi N., & Tadess W. (2010). Floristic and structural analysis of the woodland vegetation around Dello Menna, Southeast Ethiopia. *Journal of Forestry Research*, **21**: 395-408.
34. Muller D., and Ellenberg H. (1974). Aims and methods of vegetation ecology. 546 pp. John Wiley and Sons, Inc., New York.
35. Soromessa T., and Kelbessa E. (2013). Diversity And Endemicity Of Chilimo Forest, Central Ethiopia.
36. Solomon M. and Belayneh A. (2016). Woody plant diversity, structure regeneration in the Ambo State Forest, South Gondar Zone, Northwest Ethiopia.
37. Tamrat B. (1993). Studies on remnant Afromontane Forests on the central plateau of Shewa, Ethiopia. Uppsala, Sweden.
38. Tamrat B. (1994). Phyosociology and Ecology of Humid Afromontane Forest on the Central plateau of Ethiopia. *J. Veg. Sci*. **5**: 87- 98.
39. Temesgen M., Belayneh A., and Yeshanew A. (2015). Woody Plant Species Diversity, Structure and Regeneration Status of Woynwuha Natural Forest, North West Ethiopia.*Asian Journal of Ethnopharmacology and Medicinal Foods*, **01** (01), 2015; 0719.
40. Teshome S.(2013). Ecological Phytogeography: A Case Study of Commiphora Species: *Science, Technology and Arts Research Journal* **2** (3): 93-104.
41. Tiwari, G.K., Tadele, K., Aramde, F &Tiwari, S.C. (2010). Community Structure and
42. Regeneration Potential of Shorea Robusta Forest in Subtropical Submontane Zone of Garhwal Himalaya, India. *Nature and Science*, **8:**70-74.
43. Wassie, A. (2002). Opportunities, Constraints and Prospects of EOTC in Conserving Forest Resources: The Case of Churches in SouthGondar, Northern Ethiopia. MSc thesis, Swedish University of Agricultural Sciences, Skinnskatterberg, Sweden.

44. Wassie, A., Teketay, D. and Powell, N. (2005) Church Forests in North Gondar Administrative Zone, Northern Ethiopia. Forests, Trees and Livelihoods, 15, 349-373. http://dx.doi.org/10.1080/14728028.2005.9752536
45. Yakob G. and Fekadu A. (2016). Diversity and Regeneration Status of Woody Species: The Case of Keja Araba and Tula Forests, South West Ethiopia. *Open Access Library Journal*, **3**: e2576. http://dx.doi.org/10.4236/oalib.1102576

Figures

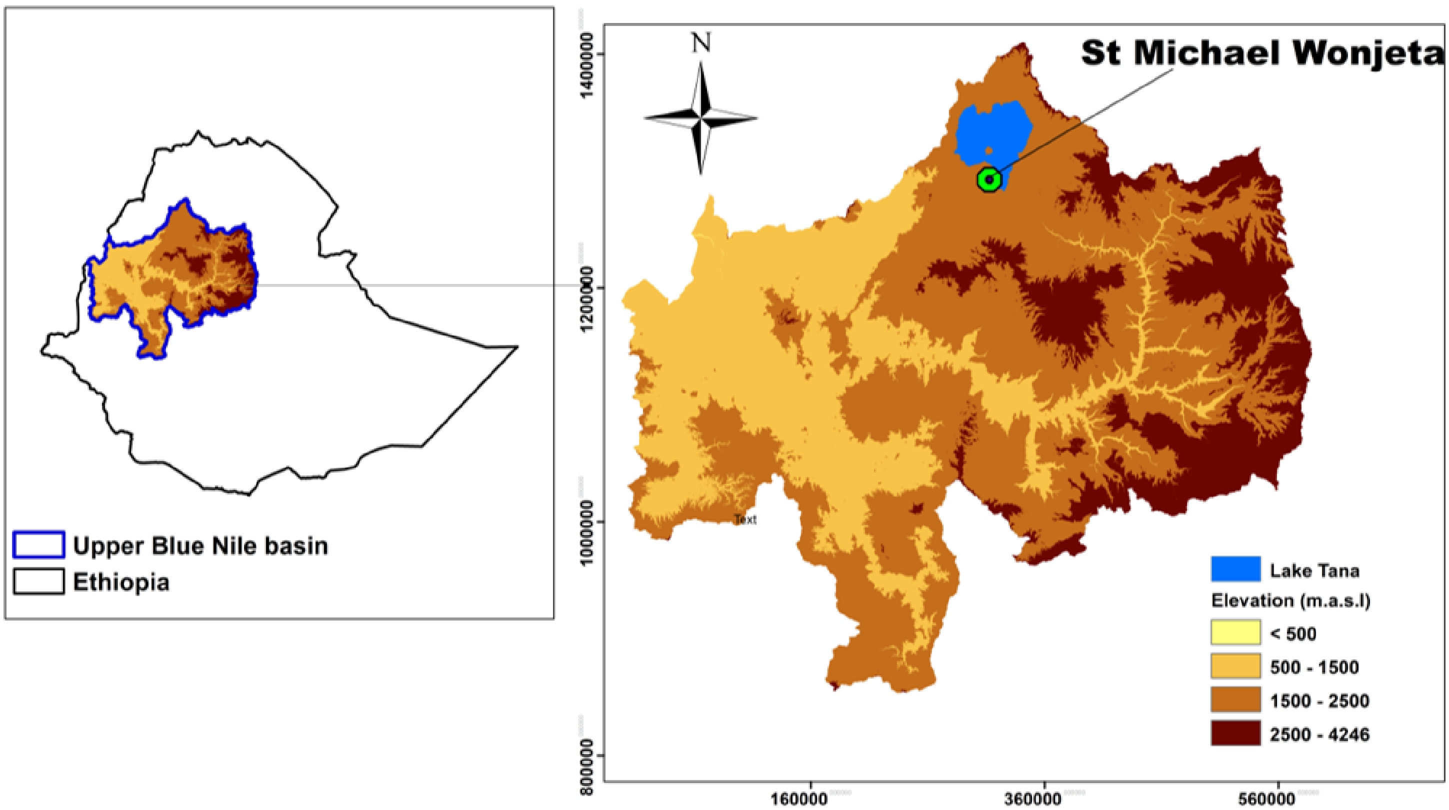

Figure 1

The study area map

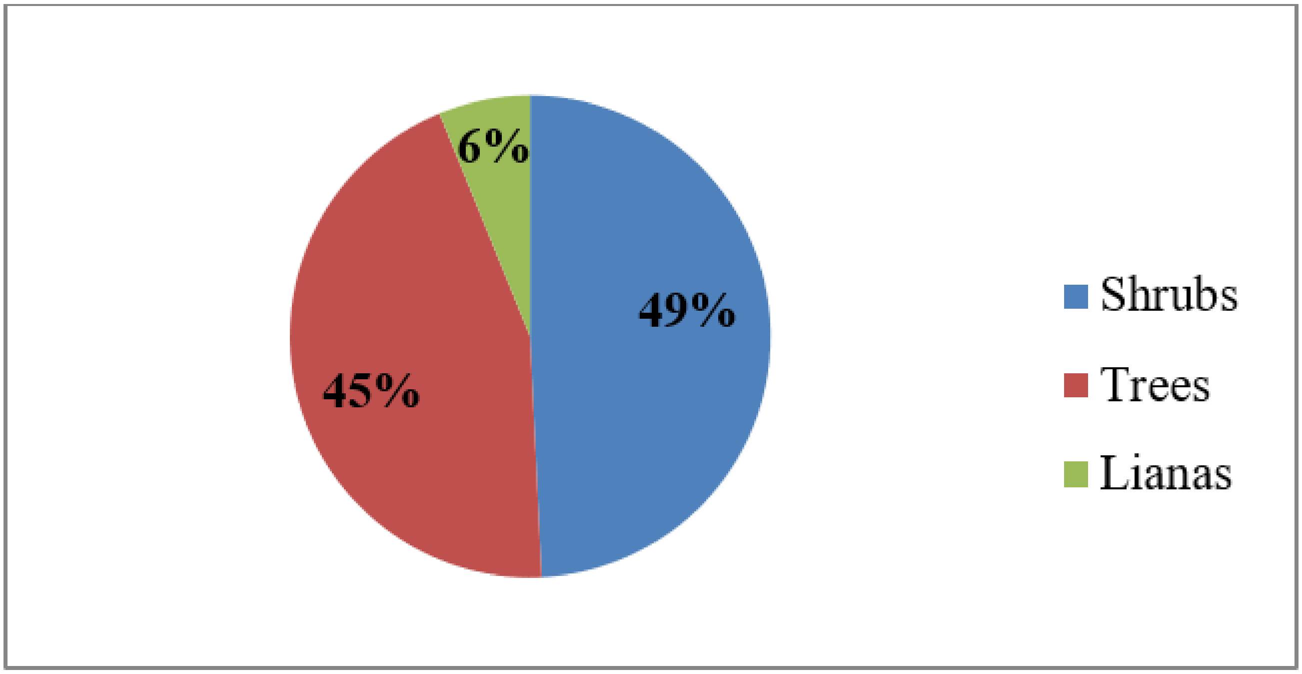

Figure 2

Distribution of woody plant species by their growth habits in Wonjeta St Micheal Church Forest.

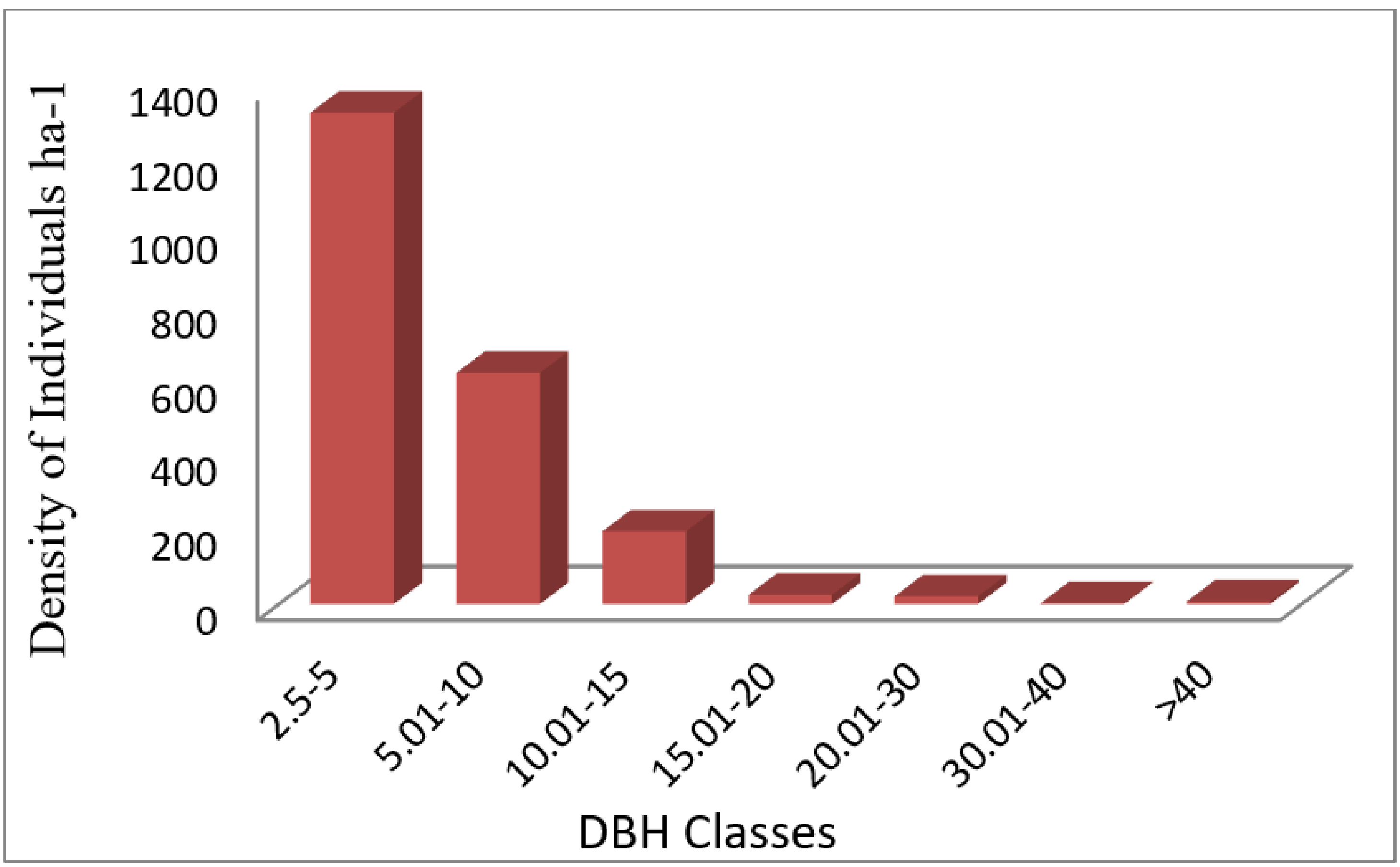

Figure 3

Distributions of woody plant individuals in the different DBH classes

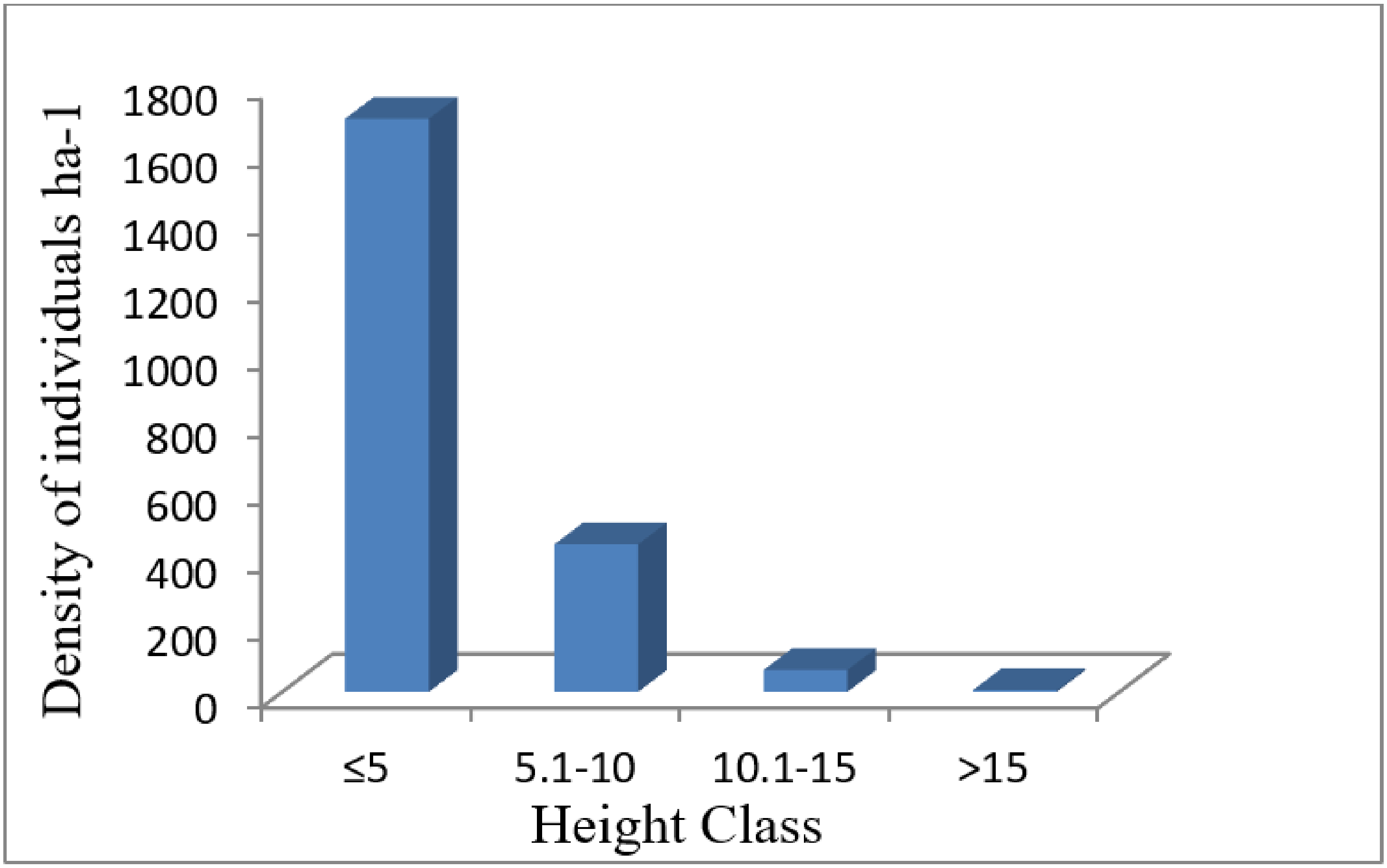

Figure 4

Distributions of woody plant individuals in the different height classes

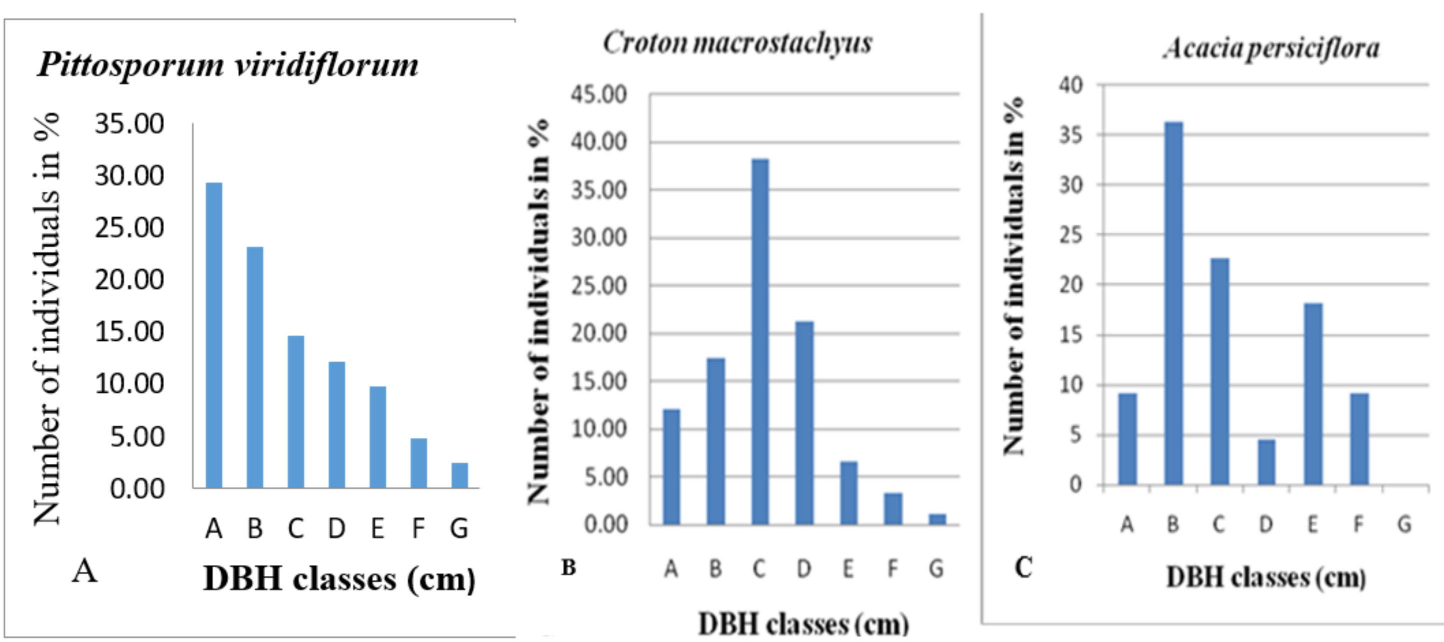

Figure 5

DBH distribution Patterns of some group of woody species; *Pittosporumviridiflorum*(5A) *Croton macrostachyus* (5B), and *Acacia persiciflora* (5C) of representative woody species. DBH classes: A= 2.5 – 5 cm, B = 5.1 – 10 cm, C = 10.1 – 15 cm, D =15.1 – 20 cm, E = 20.1 – 30 cm, F = 30.1- 40 cm, G = > 40 cm