Woody species diversity, Foristic Composition and Structure of Däbrä libanos monastery forests, Central Ethiopia

*Hingabu Hordofa Koricho**

መክብበ ጽሑፍ

የዚኽ ጥናት ዐላማ የዕፅዋት ዘር ብዝኀ ህይወት፣ ፍሎርስቲክ ተዋጽኦ (ስብጥር) እና የትልልቅ ዛፎች ዘር ሥርጭት በደብረ ሊባኖስ ደን ምን እንደሚመስል ማጥናት ነው፡፡ ሥነ ሕይወታዊ መረጃዎች 314 ሜ.ካሬ በሆነ መሬት ላይ 200ሜ.ካሬ ልዩነት ባላቸው 62 ክበባዊ የናሙና ቦታዎች እና 190 ሜ.ካሬ ስፋት ባላቸው ትራንሴክቶች ተሰብስበዋል፡፡ መረባዊ/Nested/ ክበባዊ ቦታዎች የተለያየ መጠን ያላቸውን ትልልቅ ዛፎችን ለመቁጠር ጥቅም ላይ ውላል፡፡ 340 ሜ.ካሬ የሚሸፍነው ዋነኛው ቦታ ደግሞ ዛፎችን ለመለካት ጥቅም ላይ ውላል፡፡ ከዋናው የናሙና ቦታ ውስጥ 28.26 ሜ.ካሬ የሚኸነው ንኡስ የናሙና ቦታ ሳፕሊንግ፣ ሽረቦችንና ትላልቅ የዛፍ ዝርያዎችን ለመሰብሰብ፣ 3.14ሜ.ካ. የሚሆነው ንዑስ ናሙና ቦታ ደግሞ ችግኞችን ለመሰብሰብ ተችላል። ለእጽዋት …በአጠቃላይ ወደ 70 የሚጠጉ የእንጨት ዝርያ ያላቸው በ43 ቤተሰብ እና 62 ጀነራ የሚመደቡ ዕጽዋት ተገኝተዋል፡፡ የዘር ተዋጽኦ በሶስቱ ደኖች ሲታይ 59 በቤተ ክርስትያን፣ 28 በመንግስት እና 32 በግል ሆናል፡፡

61 በመቶ የሚሆኑት ዛፎች ትልልቅ ሲሆኑ 33 በመቶ የሚሆኑት ደግሞ ትንንሽ ዛፎች ናቸው፡፡ በአጠቃላይ የቤተ ክርስትያን እንጨታማ ዕጽዋቶች ብዝኀ ሕይወት ከመንግሥትና ግል ደኖች ይበልጣል፡፡ ከዚህም በላይ ጥበቃና ትኩረት የሚሹ አናሳነት ያላቸው የዕጽዋት ዝርያዎችን ለመለየት ተችሏል፡፡ የዛፎች ሥርጭት በደብረ ሊባኖስ ደን ወጥነት ሲኖር በኦሊያ ዩሮፒያ ላይ ግን በጣም አናሳ የሆኑ በተፈጥሮ ሊበቅሉ የሚችሉ ችግኞች ተገኝተዋል፡፡ በመኾኑም በዚህ የዛፍ ዝርያ ላይ ትኩረት በመሥጠት እንዲያገግም ችግኞችን መትከል ያስፈልጋል፡፡

* Urban forestry and greening expert of Oromi Regional state, Addis Ababa

1. Introduction

1.1 Background and Justification

Ethiopia is a country that has varying agro-ecological zones. This has given rise to a botanical treasure house containing 7,000 different flowering plants out of which 12% are probably endemic.[1] This entire diverse flora is found in the natural forests which once covered 35% of the country's total land area,[2] but has now considerably shrunk. Different studies reveal that 3.1 million hectares of the total land of Oromia, excluding desert forest and bamboo, is covered by forest, which constitute 8.5% of the region's total land and 75% of the country's forest coverage. However, due attention has not been given to protection and conservation of it.[3] The Ethiopian Orthodox Tewahido parish churches give great value to preservation of natural forests as indicated by the presence of dense and attractive forests that are conserved by monasteries and churches.[4]

Despite being in a much better state than other lands, the forests in and around churches and monasteries are also declining. The land managed by the monasteries and churches has been shrinking in the course of the years due to different pressures. However, parish churches and monasteries have still managed to retain minor portions of the areas of the natural vegetation often limited to immediate vicinity of their compounds.[5]

Däbrä libanos's natural forest ecosystem is one of the larger and most significant of the existing Church forests. This study intends to present a general picture of the forests to assess their condition and the potential for further decision making on conservation and protection issues.[6]

At present, most of the remaining forests of Ethiopia are found in the south and south western parts of the country, in some inaccessible and remote areas of Ethiopia and around churches and monasteries.

Patches of forest and woodland, with a species composition similar to that of the remaining natural forests, are very common around church yards and religious burial grounds.[7] In some places, particularly in the northern part of the country, patches of forests are found only in monasteries and church compounds. In much of the landscape of northern Ethiopia, the lush vegetation on the sides of the hill surrounding a church or a monastery presents a sharp contrast to the surrounding bare ridges and mountain slopes.[8] The church forests are relatively intact, especially around the monasteries. Indigenous trees and shrubs, which in some places were completely destroyed elsewhere over the last century, are still found standing in the compounds of remote rural churches.[9]

The Däbrä Libanos Monastery forest where the current study was carried out is part of a forest conservation area that has been given special emphasis for conservation of natural forest resources.[10]

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1 kumilign Asmare, *estimation Of Sex−Related Genetic Diversity Of Hagenia Abyssinica (Bruce) j.f.gmel using random amplified polymorphic dna (rapd) markers.(* 2005).

2 Reusing, M. *Monitoring of natural high forests in Ethiopia*, MOA and GTZ, A.A, Ethiopia. (1998).

3 Oromia Forest and Wildlife Enterprise, (2011).

4 EOTC-MK (2009), Hamer the Ethiopian Orthodox Tewahido Church sandy school department of Mahibera Kidusan ,17th year volume 3 and pp.27-32.

5 Alemayehu Wassie, *Opportunities, constraints and prospects of the Ethiopian Orthodox Tewahido Church in conserving forest resources*, MSc thesis, Wondo Genet College of Forestry, Hawassa University, Ethiopia (2002).

6 EOTC-MK (2009), 27-32 p

7 Alemayehu Wassie (2002).

8 Taye Bekele, Kumelachew Yeshitela, Getachew Birhan and Sisay Zerfu (2001). *Forest Biodiversity Conservation: Perspectives of the Ethiopian Orthodox Tewahido Church*. A Paper presented to the 10th Workshop of BIO-REFOR-Sustainable Forest Management System and Biodiversity, 7-10 October 2001, Tokyo, Japan.

9 Alemayehu Wassie (2002).

10 EOTC-MK (2009), pp 27-32.

The Däbrä Libanos forest has three management categories: Church forest, Government forest and Private forest. The church forest is a strictly protected area for the conservation of the church natural forest. The government forest is part of the forest area managed by local government, while the wooded areas within private forest are managed for recreational and tourism purposes by private organizations, all are natural forest systems.

1.2 Objectives

General Objective

The general objective of the study was to investigate the species diversity, floristic composition and structure of woody species within the Däbrä Libanos forest, central Ethiopia.

Specific Objectives

- To assess the wood species diversity of Däbrä Libanos forest,
- To determine floristic composition and structure of woody species

1.3 Significance of the Study

The outcomes of the study will contribute to the development of sustainable forest management practices leading to the conservation of the biodiversity of the area. It will contribute to designing strategies for sustainable use of the forest by concerned bodies. Furthermore, the study is hoped to stimulate further scientific studies and conservation projects in the area.

2. Materials and Methods

2.1 Description of the study area

2.1.1 Location

Däbrä Libanos forest is located in North Šäwa Zone of the ᵓOromia Regional State, in central Ethiopia. It is situated at about 106 km from Addis Ababa and 14 km from Fiche town, the capital of North Šəwa zone, and in proximity to ᵓAbunä Täklä Haymanot Monastery. The total area of the study was about 178.03ha Church land, 26.26ha of government land, and the remaining 18.58ha is a private forest (according to *GPS of data survey*). This study was specifically carried out in the church, government and private forests bordering three settlements (Čagäl, Wəša Gädäl and the Monastery) which are situated within the borders of the two districts. The specific area is called ᵓAbunä Täklä Haymanot Monastery.

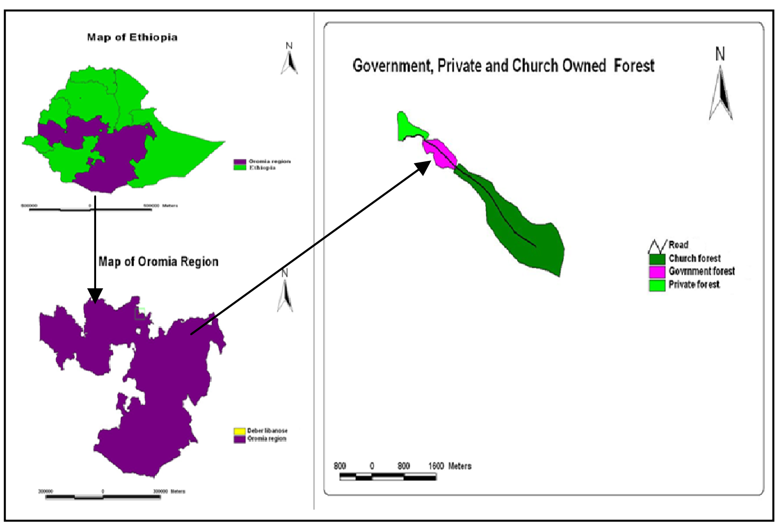


Figure 1: Location map of the study area (source: Internet and survey)

2.1.2 Vegetation

The vegetation of the study area is of the dry Afromontane type forest which has been recently explored in Ethiopia. The forest is dominated by afromontane forest tree species *Olea europae* and *Juniperus procera (personal observation)*. The monasteries and the settlement communities use the forest land for recreation, collection of wood for fuel, and income generation purposes.

2.13 Vegetation Survey

Based on the reconnaissance survey, the forests bordering three villages, namely Čagäl, Wəšagädäl and Səṭdäbər *(monastery)* were chosen. These areas were chosen because of their closeness to the settlements, the proximity of the church forest to the settlements and the comparatively extensive forest coverage of the government and private forests.

A systematic sampling design was used to locate sample plots in each forest system. The basic sampling unit was composed of three concentric circular plots each having 1m ($3.14m^2$), 3m ($28.26m^2$) and 10m ($314m^2$) radius (Fig. 2). The first transect line and the first plot was selected randomly. The circular plots were then laid out along an environmental gradient every 200m, while the subsequent trans-sectional lines were spaced every 190m from each other. A total of 62 circular plots were investigated in all forest systems, of which 34 plots in the church, 15 in the government and 13 in the private forests. A two stage sampling technique was employed to determine the statistically *(Confidence interval = 95%)* sufficient sample size to be completed in each forest.[11] Accordingly, eleven sample plots were taken in each management zone and the number of trees per plot was counted for the respective forest system. The sample variance for the number of trees was then computed using the following formula (stage 1):

$$S^2 = \frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}$$

Where, X_i =Number of trees in the i^{th} plot, $\overline{X}$ = Mean Number of trees in the eleven sample plots and S^2 = Sample variance.

The total number of plots (stage 2) to be taken in each forest system at 95% confidence interval was computed as:

$$N = \left(\frac{S^2 * t^2}{L^2}\right)$$

Where S^2 , = as defined above, $t^2 = \text{t value of } 0.05\ (1.96)$ L^2 =and Half confidence interval (± 2 trees)

The number of plots to be further sampled was taken to be the difference between the total numbers of plots (N) minus the number of plots sampled in the first stage (n).

The vegetation data was collected within the circular plots following the International Forestry Resources and Institutions Research (IFRI) Methodology.[12] IFRI protocol involves systematic collection of biophysical data within a framework that is common across the IFRI network. Accordingly, three set of vegetation data were collected within the basic sampling unit (Fig. 2).

[11] Ostrom, E. IFRI Field Manual Version 13,. International Forestry Resources and Institutions Research Program, Indiana University. Workshop in Political Theory and Policy Analysis. (2007).

[12] Ostrom, E. (2007).

Trees defined as woody plants having a diameter at breast height (dbh) of at least 10cm were recorded within 10m circular plots ($314m^2$). Saplings defined as woody plants having a dbh less than 10cm were recorded within 3m circular plots ($28.26m^2$). Shrubs and climbing woody plants (often called climbers) as their diameter was measured at any thickest point along their length were recorded within 3m circular plots. Seedlings were recorded within 1 m circular plots ($3.14m^2$). Seedlings are defined as woody plants having dbh of less than 2.5cm and that do not attain a height of at least 1m. Furthermore, clear and consistent definitions were attached to each growth form to carry out identification of plants without ambiguity. Accordingly, trees are considered to be woody plants that grow from a single main trunk and don't branch at or near the base of the plant. Shrubs are considered to be self-supporting woody plants that have several stems at or near the base of the plant.

Climbers are considered to be plants that grow over other plants. Climbers are considered to be woody when their stems produce woody or persistent tissue, otherwise herbaceous.

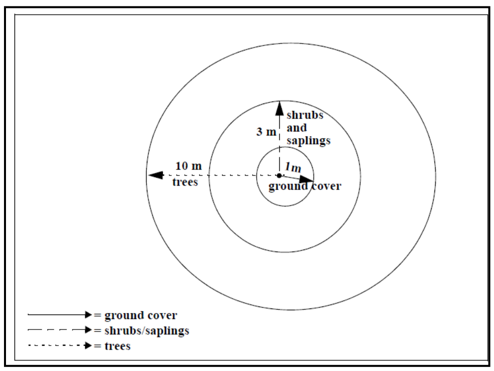


Figure 2: Layout of the sampling unit according to IFRI research protocol (Ostrom) 2009)

Tree caliber was used to measure the dbh of trees and saplings and the maximum stem diameter of shrubs and climbers. Diameter tape was used at times when the trunk of the trees to be measured exceptionally exceeded 50cm. Hypsometer was used to measure the height of trees, saplings and shrubs. Furthermore; the number of seedlings of each woody species was counted, soil color chart was used to identify the soil color. The geographical location of each plot was taken from the center in degrees using Garmin 72 GPS receiver. Likewise, the elevation of each plot was measured using GPS receiver while the aspect of each plot was recorded.

Plant identification was carried out both in the field and in the herbarium. Voucher specimens were collected for all plant species not identified in the field. The plant specimens were then properly pressed, dried, transported and deposited at the National Herbarium located in Addis Ababa University, Ethiopia, for subsequent identification. Nomenclature of species followed the published volumes of the Flora of Ethiopia and Eritrea.[13]

[13] Hedberg, I. and, S.Edwards (Eds.). *Flora of Ethiopia*. Vol.3. Pittosporaceae to Araliaceae. (Addis Ababa University, Addis Ababa, Uppsala University, Uppsala. 1989).p. 659.; Edwards, S., Tadesse, M. and I. Hedberg (Eds.).). *Flora of Ethiopia and Eritrea*. Vol 2, Part 2. Canellaceae to Euphorbiaceae. (Addis Ababa University, Addis Ababa and Uppsala University, Uppsala. 1995) p.456 ; Hedberg, I., Kelbessa, E., Edwards, S., Demissew, S. and Persson, E. (2006). *Flora of Ethiopia and Eritrea*, Vol. 5. Gentianaceae to Cyclocheilaceae. (Addis Ababa University, Addis Ababa and Uppsala University, Uppsala, 2006) p. 690.

2.14 Data analysis

Once the biophysical data representing the different forest systems was collected, vegetation data was entered using Excel. Statistical analyses were carried out using SPSS and Excel Bar graphs were drawn using Kyplot. Each forest was analyzed based on selected parameters and analysis tool pack employed by vegetation ecologists. Accordingly, diversity and floristic similarity indices, density, basal area, frequency, population structures and Importance Value Indices (IVI) were analysis for all and some woody species encountered within the studied forest systems.

Floristic Diversity

The floristic diversity indices used in data analysis were the Species richness, and the Shannon index. Furthermore, Shannon evenness index was used to evaluate the evenness of the distribution of species in each forest system. The species richness refers to the number of species per plots, area or community. In this study, it was used to mean the number of observed species across the whole sample plots in each studied forest system. The Shannon-Wiener function *(commonly referred as Shannon diversity index)* was calculated following.[14]

$$H' = -\sum_{i=1}^{s} p_i \times \ln p_i$$

Where, H' = Shannon diversity index, p_i = proportion of individuals found in the i^{th} species, s = the number of species, and = i 1, 2, 3…,.s

The Shannon evenness was calculated[15 16 17] accordingly to the following mathematical relation:

$$J = \frac{H'}{H'_{max}} = \frac{\sum_{i=1}^{s} p_i \times \ln p_i}{\ln s}$$

Where, J =Equitability (evenness) index, ,, H' p_i s and i as explained above.

The other popular diversity index used in this study was the Simpson's diversity index. It was calculated as:

$$D = 1 - \sum_{i=1}^{s} \frac{n_i (n_i - 1)}{N(N-1)}$$

Where, D= Simpson's diversity index, n_i = no. of individuals of species1 N,= Total number of species in community and s = as explained above.

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

[15] Krebs, C. J. . *Ecology: The Experimental Analysis of Distribution and Abundance.* (Harper & Row Publishers, New York. P. 800. 1985).

[16] Magurran, A. E.. *Ecological Diversity and Its Measurements*. (Chapman & Hall, London. 1988). P. 179.

[17] Kent, M. and Coker, P. (1992)

Floristic similarity

The Sorensen similarity index was used to examine the floristic similarity of the different forest systems. Like the other diversity indices used in this study, the Sorensen's diversity index was the popular one.[18] However, it measures how the floristic compositions of the different forest systems are alike. The Sorensen's similarity index was calculated following.[19] Accordingly, it was computed as:

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

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

Density

The density of woody species was one of the most important structural parameters considered during data analysis. The density per hectare of woody seedlings, saplings and shrubs (2.5cm<dbh<10cm) and trees (dbh>10cm) was calculated by summing up all stems across all sample plots and converting into hectare basis.

The ratio of the density of individuals having dbh of 2.5cm<dbh <10cm to that of the individuals having dbh> 10cm was computed and taken as a measure of distribution of the size classes. [20]

Basal area

The other most important structural parameter considered was the basal area. It measures the relative dominance of a species in a forest. Basal area was calculated for each tree having a dbh>2.5cm. It was calculated as:

$$BA = \frac{\pi * dbh^2}{4}$$

Where, dbh = diameter at breast height (cm). and π = 3.14

Frequency

Frequency is defined as the probability or chance of finding a species in a given sample area or quadrant.[21] Thus, it shows the presence or absence of a given species within each sample plot. Two sets of frequency were computed for each woody species encountered within the study plots: the absolute frequency and the relative frequency. Absolute frequency for each woody species was computed as:

$$\text{Absolute frequency} = \frac{\text{frequency of a Species}}{\text{Total number of sample plots}} \times 100 \ \%$$

[18] Kent, M. and Coker, P. (1992)
[19] Kent, M. and Coker, P. (1992)
[20] Grubb, P. J., Lloyd, J. R. Pennington, J. D. & Whitmore, J. C. . *A comparison of montane and lowland rain forest in Ecuador. I. The forest structure, physiognomy, and floristics*. J. Ecol. 51: 567-601, 1963.
[21] Kent, M. and Coker, P. (1992)

The absolute frequency of each species was then weighed by ACFOR scale.[22] Accordingly, the woody species were categorized under five frequency classes: A = 60-100% (abundant), C = 40-60% (common), F = 20-40% (frequent), O = 10-20% (infrequent) and R = 1-10% (rare). The relative frequency on the other hand shows the frequency of a species in relation to all other woody species constituting the forest under investigation. It was calculated as:

$$\text{Rel. frequency} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

Population structure

Population structure was computed for selected woody plants species. For the purpose of studying the population structure in the different forest systems, the diameter and height of all or individual woody plants were categorized into an arbitrary diameter/height classes. Accordingly, the woody species were grouped into five Dbh classes following:[23] Class: 1 = 2.5-5cm; 2 = 5- 11cm; 3 = 11-23cm; 4 = 23- 47cm and 5 = > 47cm) and seven height classes (1=1-5m; 2 = 5-10m; 3 = 10-15m, 4 = 15-20m; 5 = 20-25m; 6 = 25-30m; 7 = >30m). The relative distribution of individuals into different size classes was shown using bar graphs.

Statistical analysis

Descriptive statistics was used to compute the mean values (Mean ± SEM). One way Analysis of Variance with unequal replication was used to test the significance variation among different means. When variations among means were found to be significant, The Fisher Least Significant Difference (LSD) test was performed to test significance variations between any two means.

3. Results
Diversity and Structure of woody plant species
3.1.1 Floristic composition and Population Structure of woody plant species

A total of 70 species, representing 62 genera and 43 families were collected (Table 1) within all the studied forest systems. These 70 specimens were identified at species level.

Table 1: Number of family, genera and species encountered in the Däbrä Libanos forest, Ethiopia

Taxa	All forest systems	Church forest	Government Forest	Private forest
No. of families	43	37	21	22
No. of genera	62	49	26	28
No. of species	70	59	28	32
Genera/Family	1.44	1.32	1.13	1.27
Species/genera	1.12	1.20	1.11	1.14

[22] Kent, M. and Coker, P. (1992)
[23] Feyera Senbeta, *Biodiversity and ecology of Afromontane rainforest with wild Coffee arabica L. population in Ethiopia.* Ecology and Development Series No. 38. (2006). p. 144.

Considering the woody vegetation of the study area, *Fabaceae* and *Verbenaceae* were the most diverse families each represented by five species, followed by *Euphorbiaceae* and *Anacardiaceae* each represented by four species. Three families, namely, *Asteraceae, Moraceae* and *Acanthaceae* each was represented by three species); followed by seven families (Apocyanacae, *Rubiaceae, Oleaceae, Crassulaceae, Myrsinaceae, Lamiaceae* and *Santalaceae*), each represented by two species. The rest of the families were represented by one species each.

In the church forest, *Anacardiaceae* and *Verbenaceae* were the most diverse families each represented by four species; followed by *Euphorbiaceae* and *Acanthaceae* each represented by three species. Likewise, in the government forest, the most dominant families were *Fabaceae, Euphorbiaceae* and *Verbenaceae*, each represented by three species followed by *Apocyanacae* and *Moraceae* each represented by two species. The rest of the families were represented by one species each. Moreover in the private forest, the area was dominant by *Fabaceae* that was represented by four species, followed by *Euphorbiaceae* and *Verbenaceae* each represented by three and two species respectively.

The most dominant genera were *Rhus* and *Ficus* each represented by three species (*Rhus retinorrhoea, R. glutinosa* and *R. natalensis), F. vasta, F. sur* and *F. thonningi*, respectively, followed by two genera each represented by two species were *Acacia* and *Kalanchoe, (A. abyssinica* and *A. albida*; and *K. marnorota* and *K. sp.).*

The distribution of the genera among the different forests of Däbrä Libanos was not uniform. In the church forest, the most diverse genus was *Rhus,* represented by three species, followed by *Ficus* and *Lantana* each represented by two species.

In government forest, the most dominant genus was *Ficus*, which was represented by two species; while in the private forest, the most dominant genera were *Lantana* and *Acacia,* each represented by two species.

With regards to species distribution, church forest was the most species-rich comprising 59 species (84%), followed by the private forest which comprised 32 spp. (46%) the government forest comprised 28 species (40%). The woody plant species identified represented different life forms (Table, 2). Trees accounted for about 43 species (61%) being the most dominant growth form, followed by the shrubs and climbers comprised of 23 species (33%), and 4 species (6%), respectively (Table 2).

Table 2: Growth form composition of the different forest systems of Däbrä Libanos, Ethiopia

Growth form	All forest system		Church forest		Gov't forest		Private forest	
	No. of species	Percent	No. of species	Percent	No. of species	Percent	No. of species	Percent
Trees	43	61	34	57	18	64	20	63
Shrubs	23	33	21	36	8	29	10	31
Climbers*	4*	6	4	7	2	7	2	6
Total	70	100	59	100	28	100	32	100

Note: *All climbers are found in all forest and all are woody plants

The church forest harbored 34 tree species (57%) whereas the shrubs comprised 21 species (36%) and four species of climbers (7%). The government forest was composed mainly of tree species accounting for 64% of all the woody species recorded in it. The shrubs constituted nearly 29% while the climbers accounted for only 7% of the species composition of the forest (Table 2).

3.1.2 Diversity of woody species

The diversity of woody species varied among the different forest systems. The church forest was relatively the most diverse, with respect to woody species. It had the highest species richness, according to Shannon and Simpson diversity indices, while government and private forests had nearly similar number of species and diversity indices (Table 3).

Table 3: Diversity indices of woody species in the church, government and private forests of Debre Libanos

Debre Libanos Forest type	Species richness	Shannon diversity index (H')	Shannon evenness (E)	Simpson diversity index (1-D)
Church	59	3.135	0.768	0.917
Government	28	2.741	0.822	0.910
Private	32	2.775	0.801	0.890

3.1.3 Floristic similarity of woody species

The woody species found within the church forest were the remnants of the undisturbed forest. The woody species in the government forest were the result of natural forest regeneration. The private forest was planted and conserved by private organizations as recreational areas and thus to generate income.

In general, the floristic similarity between the different forest systems was not highly variable; however, the highest similarity index was observed between the church and the government forests (0.400) while the lowest similarity index was observed between the church and the private forests (0.336) (Table 4).

Table 4: Sorensen's Floristic Similarity indices and the number of common plant species under the three forest categories

Management category	Church	Government	Private
Church	-	0.400	0.336
Government		-	0.355
Private			-

Of the total 70 woody species identified in the different forest categories, about 27% (corresponding to 19 species) were common to all forest systems. However, the number of common woody species varied between the different forest systems. For instance, 34% (24 species) of the woody species were common to church and government, while 33% (23 species) were common to church and private forests, and 29% (20 species) were common to government and private forests (Fig.3).

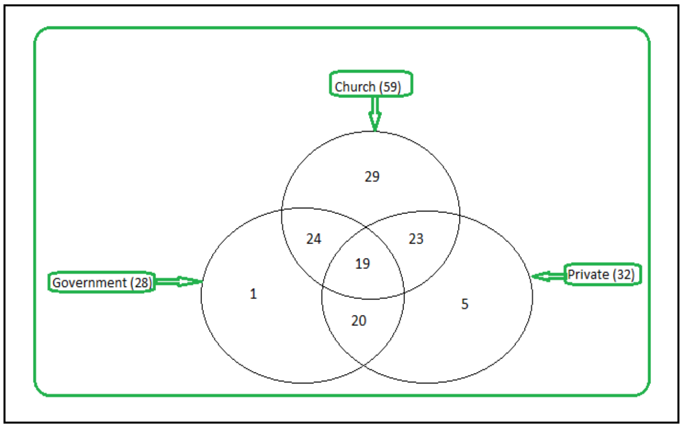


Figure 3: Venn diagram of the woody species richness pattern in the church, government and private forests of Däbrä Libanos

3.1.4 Population structure of woody species

3.1.4.1 Density

The total density of woody species inclusive of seedlings and saplings was 18,508, 13,115 and 6,961 individuals per hectare in the church, government and private forests, respectively (Table 5). Among the woody species encountered in the study, *A. abyssinica*, *J. procera*, *Aurea*, *C. spinarum*, *Maytenus senegalensis* were those that had relatively the highest relative density. Accordingly, in the church forest, *A. abyssinica*, *J. procera*, *C. spinarum*, *Aurea* and *Mytenus senegalensis* had the highest relative density (10.034, 10.034, 9.83, 6.8 and 6.29), respectively (Table 11). Similarly, in the government forest, *A. abyssinica*, *J. procera* and *M. senegalensis* were the three species that had the highest relative density of 19.81, 13.83 and 13.37, respectively. Likewise, in the private forest, *A. abyssinica*, *M. senegalensis* and *C. spinarum* were the three woody species with the highest relative density of 29.33, 11.33 and 8.0, respectively.

Table 5: Density of woody plant species ha^{-1} in the studied forest systems of Däbrä Libanos

Life forms	**Management Category**		
	Church	Government	Private
Small trees	18,006	12,666	6,675
Climber	52	27	118
Trees	450	422	168
Total	18,508	13,115	6,961

Note: Small trees: (1cm<dbh<10cm & height<8m), Climber Species: dependant trees, and Trees: dbh> 10cm

In terms of growth forms of woody species, small trees constituted much of the density of woody species in all the three forest types followed by trees. The highest density of small trees, trees and woody climbers was recorded in the church forest followed by the government forest with the private forest having the smallest densities of all the growth forms (Table 5).

Climbing species such as *Mermis sps, Cissapelos pareira L., Jesmminum sp.* and *Phytolacea dodecandra* contributed to about 52 (0.28%) in the density of church forest, 27 (0.2%) within government forest and 118 (2%) in the private forest (Table 5). Unlike in the church forest, the density of the tree layer in the government and private forests was accounted for by many more species.

The mean density per plot of small trees and trees (which means in 314m^2 area) in the church forest was significantly higher than that of the government and private forests, but that of climbers was not significantly different in all forest types (Table 6).

Table 6: The Mean ± SEM [24]of the density per plot of the woody species in the studied forest systems of Däbrä Libanos, Ethiopia

Density/plot	**Management category**				
	Church	Government	Private	All	p-value
No. of plots	34	13	15	62	
Small woody plants	13,208 ± 2,509^a	8,963 + 1893^{ab}	4,192 ± 908^b	10,335±1554	0.45
Shrubs	437 ± 76^a	629 ± 83^a	448 ± 117^a	480±53	0.49
Trees	450 ± 41^a	323 ± 55^{ab}	186 ± 26^b	365±30	0.12

Note: Small woody plants and shrubs: 2.5cm<dbh<10cm, Trees: dbh> 10cm at α =0.05. (The three α -value indicates that church, government & private)

3.1.4.2 Basal Area

The total basal area (expressed as the basal area of stems per hectare) of woody species with dbh > 2.5cm was 66m^2 ha^{-1}, 6.21m^2 ha^{-1} and 2.112m^2 ha^{-1} in the church, government and private forests, respectively (Table 7). Unlike the density of trees, basal area is a function of size of the trees rather than the simple stem counts. Hence, much of the basal area of the woody species was due to trees having a dbh greater than 10cm (Fig. 4a).

Table 7: Summary of basal area (m^2 ha^{-1}) of woody species in the study forest systems of Däbrä Libanos

Life forms	Management Category		
	Church	Government	Private
Small trees	16	0.21	0.112
Trees	51	6	2
Total	66	6.21	2.112

[24] SEM is represent the probability value multiplied by standard error of mean.

Note: Small trees are: (2.5cm>dbh<10cm), Tress: dbh>10cm

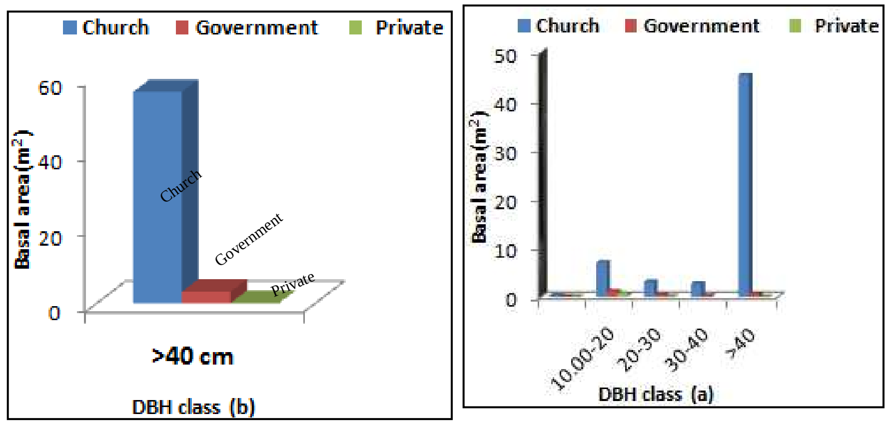


Figure 4: Basal area distribution by diameter class of all woody species within the church, government and private forests of Däbrä Libanos, *dbh Class: 1 = 1-10cm; 2 = 10- 20cm; 3 = 20-30cm; 4 = 30- 40cm and 5 = > 40cm*

About 12% (56 species) of the basal area in the church and 2.27% (3 species) in the government forest accounted for by trees having a dbh greater than 40cm (Fig. 4b).

Table 8: summary of basal area ha-1, Diversity indices, and density/ plot of three forest systems

Forest types	Plot	(H')	(E)	(1-D)	BA (m^2 ha^{-1})	Density (ha^{-1})
Church	34	3.135	0.768	0.917	53.61±17	14075±2626
Government	13	2.741	0.822	0.910	6.71±2.25	9915±2031
Private	15	2.775	0.801	0.890	2.11±0.35	4826±1051

Few tree species with relatively very few stems per hectare took the total basal area of their respective forest systems. However, *J. procera*, *O. europaea* and *F. sur* altogether accounted for about 46% (24m^2 ha^{-1}) of the overall basal area in the church forest. In the government forest, 24% (0.552m^2 ha^{-1}) of the total basal area of woody species was contributed by three species, (*J. procera*, *F. sur* and *A. abyssinica)* while the rest was accounted for by *A. abyssinica* about 15% (9.41m^2 ha^{-1}) of the total basal area of woody species in the private forest. Unlike in the church and government forests, *J. procera* dominated the basal area of woody species, in the private forest next to *A. abyssinica*.

The mean basal area per plot of small woody plant (dbh between 2.5cm and 10cm) was not significantly different in all the forest systems; while the mean basal area per plot of trees (dbh > 10cm) was significantly higher in the church than in the government forest. The mean basal area of trees in the church forest was significantly higher than those of the government and private forests (Table 9). However, there was no significant difference between the government and the private forests. Similarly, there were not significant differences in the mean basal area of small woody plants among all the three forest systems.

Table 9: The mean ± SEM of the basal area per plot of the woody species in the studied forest systems of Däbrä Libanos, Ethiopia

Basal area/plot	**Management**				
	Church	Government	Private	All	P-value
No of Plot	34	13	15	62	
Small woody plants	0.9 ± 0.52[a]	0.7 ± 0.25[a]	0.11 ± 0.04[a]	0.67±0.3	0.53
Trees	52.76 ± 16[a]	5.65 ± 2[b]	1.51 ± 0.31[b]	30.5±9.3	0.04

Note: woody plants (Small trees): 2.5cm<dbh< 10cm, Trees: dbh> 10cm at α =0.05. (The three p-value indicates that church, government and private)

3.1.4.3 Frequency

The woody species in the three forest systems were not evenly distributed throughout the study plots (Table 10). For instance, the frequency class distribution of the species in the church forest revealed that 8.5% of the species were abundant, 8.5% were common, 10% were frequent, 29% were infrequent and the rest 44% were rare. The most abundant and common woody species in the church forest were *Hypoestes triflora*, *C. spinarum*, *A. abyssinica*, *Aurea*, *Cultia abyssinica jaub and spach*, *C. macrostachyus*, *M. senegalensis* and *O. europaea*. Woody species which were frequent were *Brucea antidysenterica*, *Capparis tomentosa*, *Cordia africana*, *D. viscosa*, *Dombeya torrida*, *F. sur*, *Justicia schimperiana*, *Rhus glutinosa*, *R retinorrhoea*, Stereospermum *kunthianum* and *Viscum nervosum* were the typical examples of the species which fall within the infrequent frequency class. Woody species that were only recorded in a single study plot and were thus considered a typical example of rare species were *Vernonia amygdalina*, *Teclea noblis*, *Sesbania sesban*, *Senna aliexandrina*, *Rosa abyssinica*, *R. natalensis*, *Premna resinosa*, *Pouteria adolfi-friederidi*, *Phytolacea dodecandra*, *Myrsine africana*, *Mesea lanceolata*, *Galiniera coffeoides* and *Bersama abyssinica (Table 10).*

Table 10: Summary of the frequency class distribution of the woody species in the church, government and private forests of Däbrä Libanos, Ethiopia

Frequency Class	**Management Category**					
	Church		Government		Private	
	Number of species	Rel. abundance (%)	Number of species	Rel. abundance (%)	Number of species	Rel. abundance (%)
A	5	8.5	6	21	3	9
B	5	8.5	2	7	2	6
C	6	10	5	18	5	16
D	17	29	5	18	7	22
E	26	44	10	36	15	47
Total	59	100	28	100	32	100

Note: Frequency Classes: A=60-100 (Abundant), B= 40-60(Common), C=20-40 (Frequent), D=10-20 (Infrequent) and E= 1-10 (Rare)

The frequency class distribution indicated that the woody species within the government forest were represented by all frequency classes and some of the represented frequency classes were represented by six species, to the abundant frequency class. Five species (18%) namely, *C. spinarum*, *J. procera*, *M. senegalensis*, *Ocimum lamifolium*, and *R. glutinosa*, belonged to the frequent class and two species (7%) was represented in the common frequency class. Five species (*Capparis tomentosa*, *G. ferruginea*, *Premna angolensis*, *A. albida* and *R. abyssinica)* constituting 18% of the woody species belonged to the infrequent frequency class. The ten woody species (36%) were found to be rare and typical examples for this class were *Mermis species*, *C. africana*, *Dombeya torrida*, *Euphorbia abyssinica*, *F.sur*, *Lantana trifolia*, *Coffee arabica*, *Ekebergia capensis*, *Mangifera indica* and *Stereospermum kunthianum.*

Analysis of the woody species frequency class distribution within the private forest depicted that the first frequency classes was represented by three species (*M. senegalensis*, *A. abyssinica* and *Millettia ferruginea*) which is about 9% of the total. *Acacia albida* was the only woody species representing the rare frequency class, whereas *C. spinarum* and *Ocimum lamifolium* represented by two species (6%) of the common frequency class. *Aurea* and *C. macrostachyus* constitute the frequent frequency class.

The comparative patterns of the population structure (Stem diameter and height class distribution) of the whole woody species in the studied forest systems are presented in Fig. 5 and 6. Analysis of the diameter class distribution revealed similar pattern of distribution in all forest systems. Density of stems in general was very high at lower diameter classes and it drastically decreased as the diameter classes increased. For instance, 43% of the individuals were found in the dbh class: between (10-20cm) in the church forest, 55% (10-15cm) in the government forest and 52% also (10-15cm) in the private forest were found (Fig.5).

The higher diameter classes were comparatively represented by few individuals in the church forest (Fig.5). The number of individuals within the largest diameter class (>80cm) accounted for only 1% in the church forest. A tree with the biggest diameter at breast height, *J. procera* (381cm), was recorded within the church forest. The biggest trees recorded with a dbh more than 100cm were recorded only in the church forest by only *J. procera.*

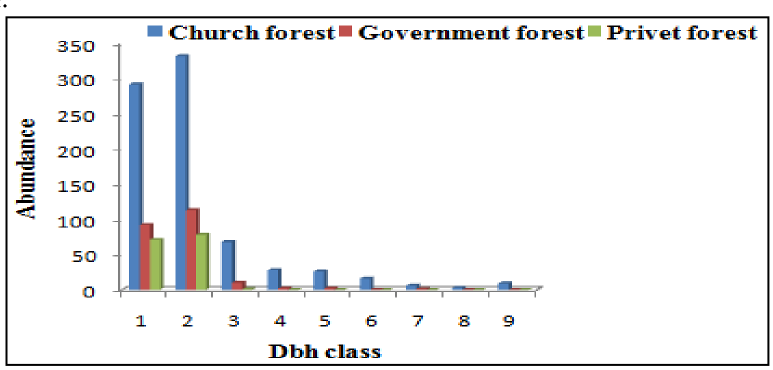


Figure 5: Diameter class abundance distribution of all woody species within the church, government and private forests of Däbrä Libanos Diameter at breast height (dbh) Class: 1 =1-10cm; 2 = 10- 20cm; 3 = 20-30cm; 4 = 30- 40cm, 5 = 40-50cm, 6 = 50-60cm, 7 = 60-70cm, 8 = 70-80cm and 9 = > 80cm

Analysis of the height class distribution patterns of the woody species under the different management systems revealed that the highest proportion of individuals were relatively concentrated in the lower height classes and the lowest proportion of individuals were in the highest height classes (Fig. 6). For instance, about 34%, 37%, and 51% of the individuals in the church, government and private forests respectively, represented in the height class of 5 to 10m, whereas only 1% of the individuals in the church, less than 1% in the government and no one in the private forests was represented in the height class of greater than 30m (Fig. 6).

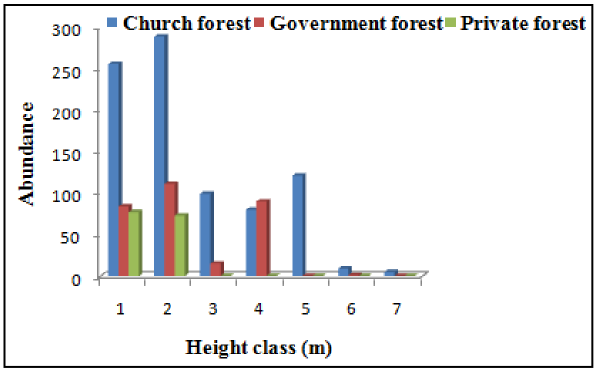
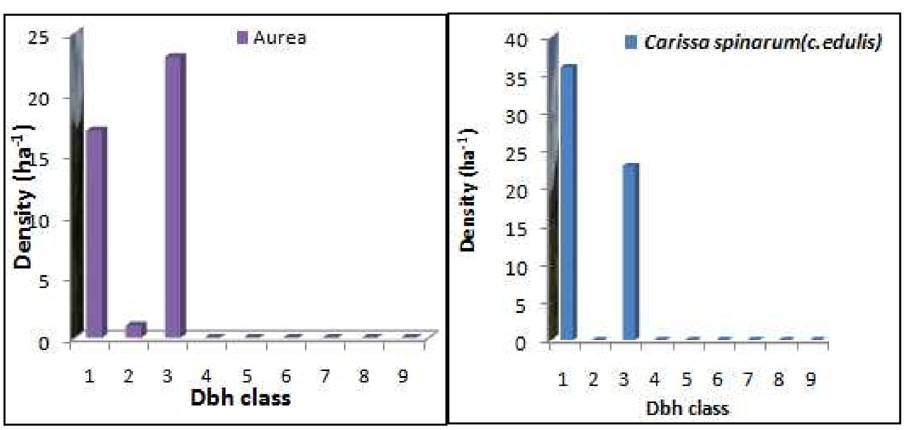


Figure 6: Height class distribution of all woody plants within church, government and private forests of Debre Libanos *Height class in m: 1=1-5m; 2 = 5-10m; 3 = 10-15m, 4 = 15-20m; 5 = 20-25m; 6 = 25-30m; 7 = >30m*

Population structure of selected woody species

The patterns of diameter class distribution indicate the general trends of population dynamics and recruitment processes of a given species. The evaluation of selected tree species in the church forest revealed four main patterns of population distribution (Fig. 7). These are almost near to Jshape (e.g., *Aurea*), an inverted Jshape (e.g., *Carissa spinarum)*, almost Ushape (e.g., *Juniperus procera*) and a broken inverted Jshape (*olea europaea*).



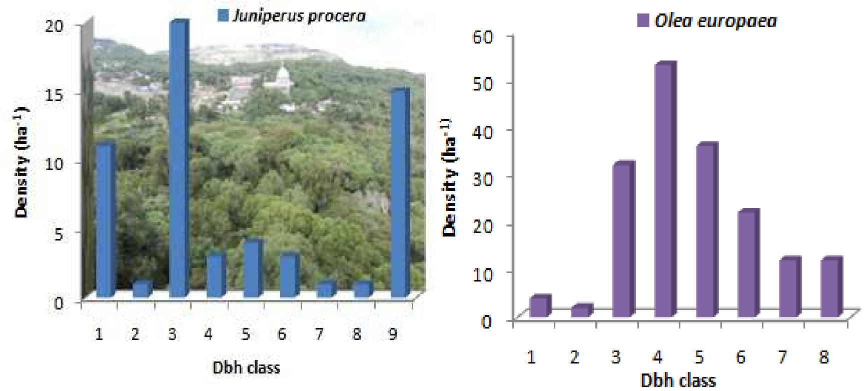


Figure 7: Diameter class distribution of selected tree species in the church forest of Däbrä Libanos *Dbh class: 1 = 1-5cm; 2 = 5- 10cm; 3 = 10-15cm; 4 = 15-20cm, 5 = 20 - 25cm, 6 = 25-30cm and 7 = >30cm.*

The evaluation of the population structure of woody species within government forest revealed two population structures (Fig.8). These are the inverted U-shape (e.g. *Acacia abyssinica*) and a J-shape population structure (e.g. *Croton macrostachyus*)

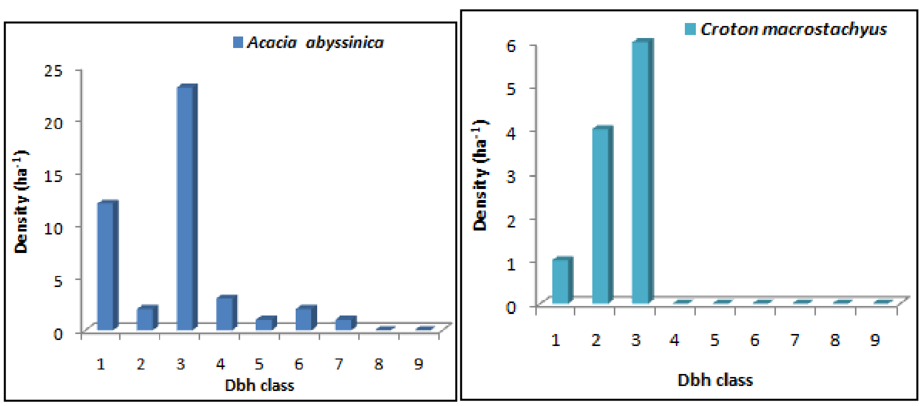


Figure 8: Diameter class distribution of selected tree species in the government forest of Debre Libanos Dbh *class: 1 = 1-5cm; 2 = 5- 10cm; 3 = 10-15cm; 4 = 15-20cm, 5 = 20-25cm, 6 = 25-30cm and 7 = >30cm*

Woody species population structures within private forest revealed two main patterns of population structures described for the private forest. For instance, *A. abyssinica* revealed Ushape with the first dbh and the third class was high; *Dodonea viscosa*, more J-shape with the third dbh classes (Fig. 9).

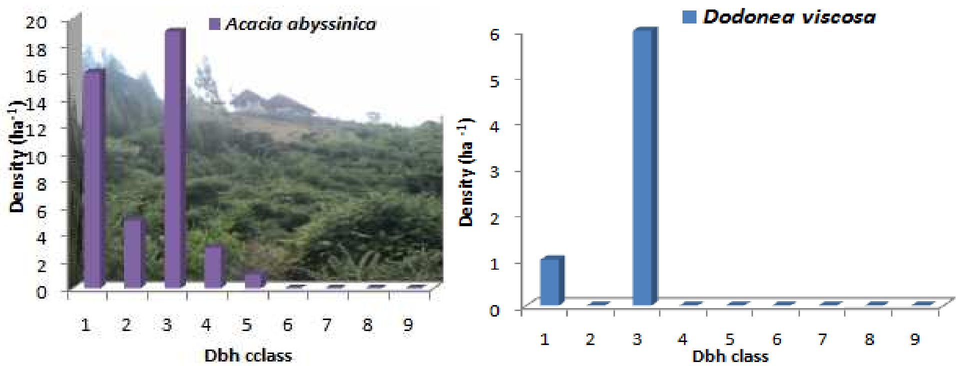


Figure 9: Diameter class distribution of selected tree species in the private forest of Däbrä Libanos *Dbh class: 1 = 1-5cm; 2 = 5- 10cm; 3 = 10-15cm; 4 = 15-20cm, 5 = 20- 25cm, 6 = 25-30cm and 7 = >30cm*

In general, the population structure of the selected woody species in the three forest systems depicted the presence of at least one unrepresented class except in the church forest where (e.g., *J. procera* and *O. europaea*) are represented by all diameter classes.

3.1.5 Importance Value Index (IVI) of woody species

The summary of the IVI of the woody plant species within the church, government and private forests is provided in Table 11 and the details are presented in. It showed that *J. procera* and *O. europaea* had IVI of 81.45% and 38.63%, respectively while *A. abyssinica* and *Carrissa spinarum* had nearly equal IVI. *Cultia abyssinica* had the smallest IVI. Few tree species had the highest IVI and accounted for much of the overall IVI of their respective forest type. For instance, 71% of the IV of the woody species in the church forest was accounted for by 10 species: *A. abyssinica*, *Aurea*, *C. spinarum*, *C.macrostachyus*, *C. abyssinica jaub & spac*, *F. sur*, *J. procera*, *M. senegalensis*, *O. europaea*, and *O. Compressa.* The rest 49 species (29%) contributed overall IV (Table 11).

Table 11: Summary of the IVI of 10 most common woody species in the church, government and private forests of Däbrä Libanos, Ethiopia (T – Tree, C – Climber, B- shrub, P - sapling and S –seedling)

Managment category	Botanical name	RF (%)	RDen (%)	RD (%)	IVI	Growth form
Church	Acacia abyssinic	5.882	10.034	0.625	16.542	T
	Aurea	5	6.802	0.381	12.183	T
	Carissa spinarum	6.764	9.863	0.366	16.995	T
	Croton macrostachyus	4.117	5.612	0.357	10.087	T
	Cultia abyssinica	4.117	2.380	0.012	6.511	P
	Ficus sur	1.764	2.551	3.033	7.349	T
	Juniperus procera	8.235	10.034	63.182	81.451	T
	Maytenus senegalensis	7.058	6.292	0.420	13.771	T
	Olea europaea	7.941	3.401	27.287	38.630	T
	Osyris compressa	4.117	3.911	0.194	8.223	T
	Total other species (49)	44.96	39.91	4.21	88.258	
	Total	100	100	100	300	
Government	Acacia abyssinica	11.93	19.81	22.451	54.19	T
	Carissa spinarum	6.422	3.687	2.327	12.43	T
	Croton macrostachyus	5.505	5.069	3.025	13.59	T
	Dodonea viscose	4.587	3.687	1.709	9.983	T
	Euclea racemosa	6.422	5.530	2.367	14.32	T
	Juniperus procera	9.174	13.83	43.051	66.05	T
	Maytenus senegalensis	9.174	13.37	6.221	28.76	T
	Ocimum lamifolium	8.257	7.834	0.350	16.44	B
	Osyris compressa	6.422	5.069	1.803	13.29	T
	Rhus glutinosa	7.339	7.834	4.405	19.57	T
	Total other species (18)	24.77	14.28	12.285	51.34	
	Total	100	100	100	300	
Private	Aurea	2.083	4.000	0.555	6.639	T
	Acacia abyssinica	15.625	29.33	38.788	83.75	T
	Carissa spinarum	8.333	8.000	9.6393	25.97	T
	Dodonea viscose	6.250	4.667	6.233	17	T
	Euclea racemosa	4.167	2.667	3.1488	9.982	T
	Lantana trifolia	4.167	2.667	0.257	7.090	T
	Maytenus senegalensis	10.43	11.33	10.732	32.48	S
	Ocimum lamifolium	7.292	6.667	0.6426	14.60	T
	Osyris compressa	6.250	4.667	5.2695	16.18	T
	Rhus glutinosa	5.208	3.333	4.177	12.71	S
	Total other species (22)	34.38	25.33	20.55	73.46	
	Total	100	100	100	300	

The majority of the IVI of woody species in the government forest was taken by *J. procera*, *A. abyssinica* and *M. senegalensis* and accounted for *J. procera, A. abyssinica* and *M. senegalensis* 66.05, 54.19 and 28.76 respectively. The species with the lowest IVI in the government forest was *D.viscosa* with IVI of 9.98. In general, the IVI of most of the 10 most common woody species in the government forest was higher than in the church forest. Next to *A. abyssinica*, and *J. procera* eight species (*C. spinarum*, *C. macrostachyus*, *D. Viscosa*, *Euclea racemosa*, *M. senegalensis*, *Ocimum lamifolium*, *O. Compressa* and *R. glutinosa)* override the IVI of the government forest accounted for about 83% of the IV (Table 11). The rest 18 species (17%) contributed to the overall IV of woody species.

In private forest, *A. abyssinica*, *M. senegalensis*, *C. spinarum*, *Osyris compressa* and *Ocimum lamifolium* were the five woody species with the highest IVI (83.75, 32.48, 25.97, 16.18 and 14.60, respectively) (Table 11).

4. Discussion

4.1 Diversity and structure of woody plant species

The variation in management intensities in the different forest systems caused variation in the floristic composition, diversity and similarity of the forests. The floristic composition in the church forest was greater than those of both the government and private forests. The church forests have been under management for a longer period of time than both the government and private forests, which might explain the higher floristic composition and diversity. Moreover, species such as *J. procera*, *O. europaea* and *C. spinarum* were introduced into the forest by the monastery administration.

The dominance of some families comprising certain tree species in the church forests may be deliberately retained within church forests, unlike the small trees and shrubs. For instance, *Rosaceae* is recorded only in government forest and *Asteraceae, Solanaceae, Arecaceae*, *Proteaceae* and *Hypericaceae* accounted in private forest the rest more diverse within church forest.

The small trees (sapling and shrubs) layer in the church forest was relatively occupied by more number of species than in the government and private forests. For instance, while 21 species of woody plants contributed to the overall density of the sapling and seedling layer in the church forest, while only nine and eight species in the government and the private forests, respectively contributed to the density of the sapling layer of their respective forest systems.

According to the current study, small trees constituted about 97%, 96% and 95% of the woody species composition in the church, the government and private forests, respectively. That is actually an indication of the status of the population, which seemed to be promising. For instance, the diameter class distribution of the most prominent species such as *A. abyssinica*, *C. spinarum*, *J. procera*, *Croton macrostachyus*, *Dodonea viscosa* displayed inverted Jshape or nearly so which means that there was a good level of recruitment of seedlings and saplings. However, from the current study, it was obvious that the population structure of one of the most important tree species, *O*. *europaea* was represented by higher diameter classes rather than the smaller ones. That is an indication of poor recruitment status and most of the trees are getting old. Generally, diversity values were comparatively very high in the church and very low in the government and private forests, which is indicative of the high dominance of a few species in both the government and private forest systems.

For instance, the relatively low Shannon diversity values of the government and the private forests are due to a numerical dominance of a *M. senegalensis* and *A. abyssinica* individuals.

The diversity of Däbrä Libanos church forest is (H' =3.135 & E =0.768) is lower than that of Zäge church forest (H' =3.74 & E =0.84) as reported by Alemayehu Wassie.[25] The variation in management adopted within the studied forest systems influenced the density, frequency, basal area and IVI of woody species. The density of the church forest was greater than those of the government and private forests. The comparatively very high density of woody species within the church forest could be due to the fact that the forest is set aside entirely for conservation purposes with almost no human interference over a long time. The other finding in Zäge (3,318) reported by Alemayehu [26]is less than that of the Däbrä Libanos forest. The impacts of forest management on the density of woody plants within government and private can be viewed by comparing their density against the density of woody species within the church forest. For instance, about 0.43% of the original density of small trees in the church forest was removed due to the purpose of fuel wood consumption in the monastery for the purpose of baking local bread called *Dabbe.* However, there are no significant variations in mean density per plot of small trees, climbers, saplings and shrubs among the studied forest systems. This is because of the conservation of woody plants in the sapling layer is compensated by increasing the density of small tree plants within the church and private forests. Furthermore, the selective removal or harvesting of *C. spinarum* tree species for monastery fuel wood in the church forest affected the density of trees (dbh> 10cm). For instance, about 0.43% of the original densities of woody plant species were removed due to intensive uses of fuel wood by monastery. The intensive use of *C. spinarum* for fuel woody also impacted on the density of seedlings.

The results of the present study depicted that the density of woody species in the church forest (18,508 ha^{-1}) is less than the ones reported in other Afromontane rainforests. It is less than the density of Yayu forest; undisturbed (69, 130 ha^{-1}) and other Afromontane rainforests such as Bonga (21, 540 ha^{-1}), Bərhane-Konṭər (24, 296 ha^{-1})[27] but by far greater than Zäge (3,318),[28] Haränna (8, 937 ha^{-1}) and Maji forest (7, 273 ha^{-1}).[29] This variation might be due to methodological differences in vegetation survey or else the better protection of the forest system that might have contributed to the hiked density at present.

The frequency distribution of woody species was also influenced by the variations in management of the three forest systems. *A. abyssinica* is the species belonging to the highest abundant frequency class in government and private forest systems. The predominance of the *O. europaea* within the church forest is mainly attributed to the intensive management of A. abyssinica.

[25] Alemayehu Wassie , *Opportunities, constraints and prospects of the Ethiopian Orthodox Tewahido Church in conserving forest resources*, MSc thesis, Wondo Genet College of Forestry, Hawassa University, Ethiopia. 2002.
[26] Alemayehu Wassie (2002).
[27] Tesfaye Gonfa, *Assessment of forest conditions under different management intensities*, MSc thesis, Wondo Genet College of Forestry, Hawassa University, Ethiopia, (2010).
[28] Alemayehu Wassie (2002).
[29] Feyera Senbeta. *Biodiversity and ecology of Afromontane rainforest with wild Coffee arabica L. population in Ethiopia. Ecology and Development Series* No. 38. (2006). P. 144.

But, the presence of abundant *O. europaea, C. spinarum J. procera,* and *Aurea* within the church forest is in agreement with the documents of monastery administration which stated that the Däbrä Libanos monastery forest is home for abundant especially in *O. europaea* populations. *J. procera* which belongs to the abundant frequency class in the government became common in the private forest. Rarity of woody species was more pronounced within the private (46%) and church (44%) than the government forests (33%).

The basal area ha^{-1} of individual stems of each species within the different management systems was calculated to evaluate the degree of dominance of each species in terms of the area m^2 it occupied. In the church forest system studied, large trees with a relatively fewer number of stems ha^{-1} predominate their respective basal area. Those tree species with the highest dominance values (for instance, *J. procera*, *M. senegalensis* and *O. europaea)* were common to both the church and the government forest. This could be due to a number of reasons which includes the economic and environmental reasons for which these species are highly valued, the fact that the two species may be among the remnants of the dry afromontane forest species that benefited from the protection activities of the two forest management strategies. The basal area ha^{-1} of the woody species varied from one forest system to another. However, the variation compared between the church forest and the government and the private forests was very large between the church and the government and private forests but very low between government and private forests. The basal area ha^{-1} of the woody species in the church on the other hand was higher than that of the government and the private forest by 89%.

This could be because the government and private forests were relatively younger than the church forest and or the level of disturbance in the government and private forests was higher than in the church forest as indicated by the outcome of the focus group discussion. Moreover, the private forest was established through planting very recently as indicated by the fact that most individuals in the forest were found in the lower size classes.

The basal area of the church forest of Däbrä Libanos ($66m^2$ ha^{-1}), was higher than that of Čələmo forest ($27.3m^2$ ha^{-1}) and that of Haränna forest ($49m^2$ ha^{-1}).[30] On the other hand, the basal area of the government and private forest (6.21 and $2.112m^2ha^{-1}$) respectively, were less than that of the Wäf-waša ($100.3m^2$ ha^{-1}).[31,32]

The relative importance of woody species as weighed by their abundance, dominance and frequency in relation to all other constituent of woody species in a forest is an important parameter to compare the relative ecological significance of a species. It enables to prioritize a species for conservation interventions. [33]

In all the forest systems considered in the current study, only a few species of woody plants dominated the IVI of their respective forest system which is indicative of their high ecological significance.

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[30] Feyera Senbeta. (2006)
[31] Feyera Senbeta. (2006)
[32] Tamrat Bekele. *Studies on Remnant Afromontane Forests on the Central Plateau of Shewa, Ethiopia. Acta Universitatis Upsaliensis, 1994.*
[33] Simon Shibru and Girma Balcha.. *Composition, structure and regeneration status of woody species in Dindin natural forest, South east Ethiopia: An implication for conservation*. Ethiopian Journal of Biological Science, 2: 31-48, (Addis Ababa, Ethiopia, 2004).

For instance, 71% of a species in the church, 83% in the government and 76% in the private forests contributed to the IVI of their respective forest systems. In church and government forests, *J. Procera* is by far the most important tree species as two forest management activities by nature and monastery community are gifted and the planting, and also maintaining of the plant within the forests. On the other hand, small trees and woody climbers were much more important within the church forest as compared to the government and private forests in which they were deliberately removed to promote the *C. spinarum*. However, the high IVI of few small trees and woody climbers in the forest systems was due to the abundance of their seedlings and their frequency of occurrence within the forests.

In all the forest systems, the aggregate pattern of forest structure indicates a high number of individuals in the lower size classes that drastically decreases towards the higher classes. Almost a similar inverted J-shape finding has been in Zäge reported by Alemayehu.[34] Thus, such a population structure gives the forest stand a more or less inverted J-shape which is indicative of good reproduction and recruitment potential of the forests. However, the population structures of individual woody species depict different patterns. For instance, *C. spinarum* is among a species in the church forest which have shown an inverted J-shape. *J. procera* and *O. europaea* in the church forest and *A. abyssinica* in the government forest depict a broken J shape population which shows hampered regeneration and good recruitment. The J shape population structure of *C. macrostachyus* in the government forest and *Dodonea viscosa* in the private forest shows the selective removal of medium sized trees.

In general, in the case of *J. procera* population which was dominated by individuals in the lowest size classes indicates that it was severely affected perhaps by logging. However, the future of the population seems to be promising. On the contrary, *O. europeae* was dominated by higher size classes which are an indication of poor regeneration and recruitment, and there form requires some action intervention.

5. Conclusions and Recommendations

5.1 Conclusions

From the investigations and analysis made during the current study the following conclusions were drawn:

- Among the forest types considered in the study, based on all the diversity indices calculated for the forests, the church forest was found to be the most diverse of the three followed by that of the government forest.
- The population structure of the church forest was generally found to have a pattern that is expected of any natural population characterized by the presence of most of its individuals in the lower size classes rather than the opposite. That is, the population displayed for most of the prominent species an inverted J–shape. However, it is emphasized here that *O. europaea* had populations with most of the individuals in the larger size classes rather than in the lower classes. The government and private forest also had similar patterns of size class distribution.
- The forests also displayed such features as dominance of a few species in population structural parameters as IVI, density, frequency and basal area. In the different forest types, different woody species dominated all the structural parameters.
- The floristic composition of the three forests also displayed different levels of similarity. The government and private forests were more similar in their species composition than the church forests.

5.2 Recommendations

- Active intervention in the form of enrichment planting should be carried out with particular emphasis to important tree species like *O. europaea* which have very low natural regeneration.
- The management of both the private and government forests of Däbrä Libanos is in urgent need of finding mechanisms to change the negative attitude of the local communities, in order to avert undesirable negative impact on the forests due to the activities of the surrounding communities.