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Plant Community Types, Vegetation Structure and Regeneration Status of Remnant Dry Afromontane Natural Forest Patch within Debrelibanos Monastery, Ethiopia

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Abstract: *The remnant forest patch within Debrelibanos monastery, a sacred isolated site, was studied to determine plant community types, vegetation structure and regeneration status of woody species and to provide information for sustainable management of the forest. Data was collected using a nested plot design (51quadrat of 20 x 20m size with five sub-quadrats of 3x3m within each major quadrat) was systematically laid across the forest. Diameter at Breast Height (DBH) and height was measured for all trees, shrubs and climbers with dbh and height greater than or equal to 2.5cm and 2m, respectively. Three community types and vertical structures (upper storey (>23.67m), middle storey (11.83 – 23.67m) and lower storey (<11.83 m)) were identified within the forest patch. In terms of population structure, most of the tree species showed a bell shaped with density of mature trees less than that of sapling and the saplings greater than seedling population. This implies that, the forest has poor regeneration and it requires urgent conservation and management actions as reiterated by nearly 73.34% of the respondent.*

***Keywords**: Population structure, Community type, Natural forest, DBH class, regeneration*

Introduction

Ethiopia is a biodiversity rich country located in the Horn of Africa, stretching from 3° to 15° N latitude and 33° to 48° E longitude. The country covers a total area of 1.13 million km^2 (EMA, 1988). Its flora and fauna diversity comprises about 6500 to 7000 plant species, 240 species of mammals, and 845 species of birds. About 12% of flora diversity, 22 species of mammals, 24 species of birds, 6 reptile and 30 amphibian species are known to be endemic to the country (Teketay, 2001; Lemenih and Teketay, 2004). This makes Ethiopia the fifth known among African countries for endemism of plant and animal species (Gebere Egziabher, 1991; Edwards and Ensermu, 1999; Demissew and Nordal, 2010). These are the result of suitable climatic condition, geographic location of the country (i.e. being tropical country) and geographical diversity (Yirdaw, 2001; Teklehaimanot and Healey, 2001 and 2002; Negash, 2002; Woldu, 1991; Haileab *et al.,* 2010).

The flora diversity of Ethiopia can be explained using different cover categories like forestland, woodland and bushland. However, this particular research study is concerned with the forest type categories.

Ethiopia is experiencing widespread deforestation and forest degradation with an estimated annual deforestation rate of 150,000 to 200,000 ha (EFAP, 1994; Reusing, 1998) which in turn causing the losses of forest biodiversity (FAO, 1997; 2010). According to the study of Bishaw (2001), Dessie (2007), Dessie and Johan Kleman, 2007 and Hundera and Deboch (2008), the possible causes of forest degradation that highly threatening the biological and ecological resources were uncontrolled exploitation, expansion of agricultural land, grazing land, replacement of natural forest by commercial plantation, expansion of infrastructure, forest fire, industrialization and urbanization.

There have been efforts (both government and community) to reverse situation, however it lacks coordination. The traditional community based forest management (CBFM) practices are among the efforts particularly widespread as the sacred forests around churches, monasteries, grave yards, which are providing essential refuge for a considerable forest species. The study of Wassie (2002, 2005, 2010), Bongers et al.,(2006) and Bekele (1994) remarked on this point that, the occurrence of isolated patches of forest that are seen around church, monasteries and religious burial grounds indicate that the Ethiopian churches and monasteries have a long standing tradition of preserving and conserving forests and animals.

There are few studies conducted on the roles of sacred sites in forest resource conservation and management within this study area. For instance the study of Teklehaimanot *et al.,* (2002) and Teklehaimanot (2004) was concerned with the discussion of forest composition and factors influencing the forest resources around 38 selected churches and monastery. Currently also study of Hordofa (2011) mainly concerned with woody species diversity, composition and their significance to Debrelibanos town. However, they lack detail on the forest community types, vertical and horizontal forest structure and regeneration status of the forest.

The overall aim of this study is to determine the community types, Vegetation structure, regeneration status of the forest patch and to make phytogeographical comparison of the forest with other similar forests in the country.

Material and Methods

Study site

The study was conducted at Debrelibanos monastery (which is commonly called Abune Teklehaimanot monastery) at north Shewa, Ethiopia with geographical location of 09^0 43' 0" N longitudes and 38^0 51' 0" E latitudes. It is found at 104 km from Addis Ababa and 14 km from Fiche town, the capital of North Shewa Zone, in the Oromiya Regional State (Figure 1). It has an altitudinal range of about 2400 m whilst the rim of the valley rises to over 2560 m.

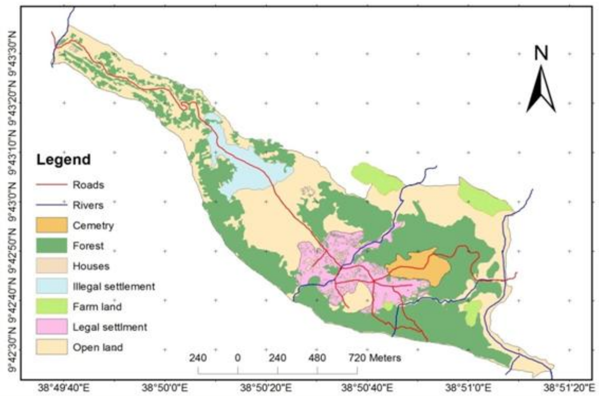

Figure 1: Location map of study area.

Its human population is estimated to be about 59,583(CSA, 2007). It has a mean minimum and maximum temperature of 5.7 ^{0}c and 22.90^{0}c respectively while the mean annual rainfall is about 1037mm (Fig. 2). The agricultural office of Debrelibanos reported that there are about three soils textural classes such as clay about 63%, sandy soil 10% and loam soil about 27% are found within the study area.

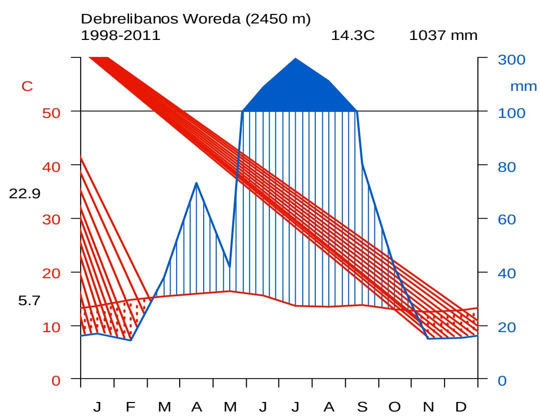

Figure 2: Climate graph of study area (Source: ENMSA, 2012)

The vegetation resources within the study area is one of the few remaining Dry Afromontane forests (has a total area of 85 ha) and it serve as the home for diverse highland birds and other animal species. However, currently it encountered a great challenge and diminished from year to year.

Methods

Study framework

The set of procedures followed in the collection and analysis of data were schematically summarized in figure 3 below. The detail of each method is presented in the paragraph below.

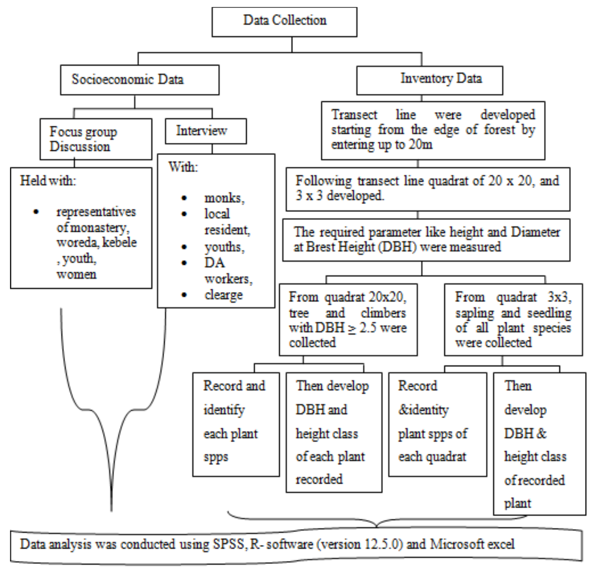

Figure 3: Study framework (DA = development agent)

Before actual data collection, reconnaissance survey was conducted to obtain information and impression on the general vegetation patterns of the study area. Following reconnaissance survey, the investigation of species diversity and density of woody plants within the study area was conducted using line transect survey. Accordingly, nested plot designs were developed and a total of fourteen transect lines and 51 quadrates of (20 x 20 m= 400 m^2 each) were laid systematically across the forest following Muller-Dombois and Ellenberg (1974) method (Fig.4). The distance between successive quadrats along the transect line were about 100m whereas between successive transect line were about 150m. The first transect line was laid randomly starting from the lowest altitude (bottom side) of the study area by entering to about 20m from edge of the forest to avoid the "edge effect".

Plant sample of different size were collected from the different size of the plots. In the main quadrat (400 m^2) all trees, shrubs and woody climbers with Diameter at Breast Height (DBH) greater than or equal to 2.5 cm and height ≥ 2 meter were recorded as mature tree (Alelign *et al.,* 2007). Following the method of Woldemariam (2003), within the major quadrat, five 3m x 3m sub-quadrats were laid to collect saplings of all trees, shrubs and climbers/lianas with height > 1 meter and seedlings of height ≤1 meters. For each quadrat, each plant was identified to species level and its DBH, total number as well as height were measured.

After a complete list of trees, shrubs and lianas were collected from each plot/quadrat; the identification was done with the aid of Flora of Ethiopia and Eritrea volume 1-8 and Bekele, (2007). However, those difficult for identification were collected following standard herbarium collection technique and taken to the National Herbarium of Ethiopia, Addis Ababa University were they have been identified.

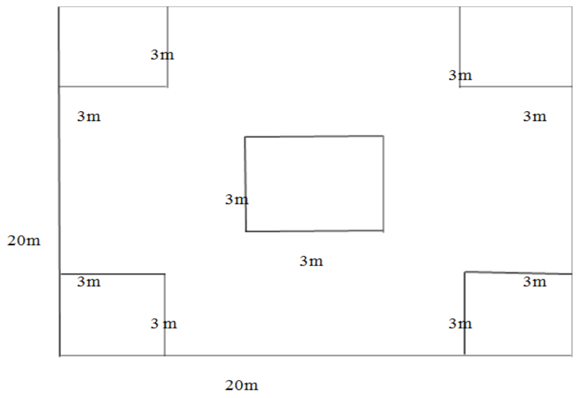

Figure 4: Layout of the study quadrat

To undertake the socio-economic survey, a total of sixty households were randomly selected and interviewed using semi-structured questionnaire. Focus group discussion was also made with representatives of monastery administration, development agents, kebele administration, woreda administration, local people, monks and youth representatives using close-ended questionnaire.

Data analysis

Plant Community Determination

The vegetation data analysis was made following Gauch (1982), Jongman *et al.* (1987) based on species abundances. Vegetation classification within Debrelibanos monastery natural forest patch was performed using cover abundance values as class labels. Object group averages; product moment correlation and squared distance were used to quantify dissimilarities among different quadrats. Agglomerative hierarchical classification using R-software (version 2.15.0) at 1.5 to 2.0 dissimilarity levels was used to classify the vegetation into communities. The name for each community type was given based on high synoptic values of tree and/or shrub species.

Vegetation Structure Analysis

All tree and shrub species identified in all quadrat (i.e. 51) were used in the analysis of the vegetation structure within the study area. Tree density (Kent and Coker, 1992), Diameter at breast height (DBH), basal area (Muller-Dombois and Ellenberg, 1974) and height were the parameters that were used in the description of vegetation structures in this study. Each of these parameters was measured as follow:

Diameter at Breast Height (DBH): DBH measurement is taken at about 1.3 m from the ground using caliper for smaller plant species where as for big tree measuring tape was used.

BA = (DBH/2)^2 * ∏ ………………… (eqn. 1)

Where, BA= Basal area in m^2 per hectare, DBH= Diameter at breast height (m) and ∏ = 3.14

$$\text{Density} = \frac{\text{No. of woody plant species}}{\text{Sampled area in ha}} \quad \ldots \text{(eqn.2)}$$

The vertical structure of remnant natural forest patch within the study area was determined following the International Union Forestry Research Organization (IUFRO) classification scheme (Lamprecht, 1989). To analyze the population structure of woody species, all individuals of each species encountered in the quadrats were grouped into arbitrary diameter classes and histograms were developed using the diameter classes versus the number of individuals categorized in each of the classes using SPSS Software (version 18.0) (Addo-Fordjour *et al.,* 2009).

Phytogeographical Comparisons

The similarity of plant species at each quadrat (communities), the association between Debrelibanos monastery natural forest patch and other similar dry afromontane forests were determined based on their species composition using Sorensen's index of similarity (Ss) (Kent and Coker, 1992). The index is given by;

$$Ss = \frac{2a}{(2a + b + c)} \quad \ldots\ldots\ldots \text{(eqn. 3)}$$

Where:

a = Number of woody species common to for both study area and other similar forest.

b = Number of woody species found only in the study area.

c = Number of species found only in the forest in comparison with Debrelibanos monastery woody natural forest patch.

Socio-economic analysis

The socio-economic data of the study area was analyzed using statistical package for social science (SPSS) software (Version 18) and Microsoft excel.

Results and Discussion

Plant Community Types

Three-plant community types (clusters) were identified from Agglomerative hierarchical classification using R-software (versions 2.15.0) at 1.5 to 2.0 dissimilarity levels (Figure 5). The data matrix contained fifty one (51) plots/sites with 60 species from Debrelibanos monastery remnant natural forest patch. The name for each community type was given based on high synoptic values of tree and/or shrub species (annex1).

1. ***Carissa spinarum - Olea europaea* subsp.*cuspidata* Community type**

This community is located within the altitudinal ranges between 2343 – 2361m a.s.l. It is represented by 21 plots (0.84 ha^{-1}) and 59 woody plant species. Besides the two dominant species used in naming of this community type, it also comprises species such as *Capparis tomentosa, Nuxia congesta, Acokanthera Schimperi, Asparagus flagellaris, Myrsine africana, Calpurina aurea, Osyris quadripartita, Juniperus procera, Grewia ferruginea, Ficus* *carica, Premna schimperi, Rhamnus prinoides, Triumfetta rhomboidea, Euclea racemosa* subsp.*schimperi and Cajanus cajan* in the tree and shrub layer of the community. The community type is dominated by tree and shrubs life forms.

Similar study conducted at Menagesha Amba Mariam by Tilahun (2009) identified five community types and the fist community type was similar with *Carrisa spinarum – Olea europaea* community types identified at Debrelibanos monastery Dry afromontane remnant natural forest patch. *Olea europaea subsp.cuspidata, Juniperus procera, Carissa spinarum* and *Myrsine africana* were common species found at Debrelibanos monastery natural forest patch and Menagesha Amba Mariam. This might be due to less anthropogenic disturbance, similarity of altitude and slopes, similarity in the level of management action undertaken.

Furthermore, the studies of Friis (1992) and Teketay (2001) suggested that the highlands of Ethiopia were once covered by diverse forest dominated by *Juniperus procera*, co-dominated by *Olea* presumed to be the natural vegetation of the Northern highlands of Ethiopia. Accordingly, this particular community type might confirm that church forest were co-dominated by these plant species showing that these forest patch represent the devoid natural vegetation of northern Ethiopia.

2. Acacia abyssinica* subsp.*abyssinica-Eucalyptus camaldulensis Community type

This community type is situated at elevation between 2365 – 2528 m a.s.l in the forest. It is represented by 24 plots (0.96 ha^{-1}) and 38 woody plant species. Some of the dominant trees within this community types include: *Eucalptus globulus, Juniperus procera, Ficus sur (F.capensis), Pittosporum viridiflorum, Crotona macrostachyus, Casuarina cunninghamiana, Osyris quadripartita, Brucea antidysenterica, Rumex nervosus, Nuxia congesta, Hypericum revolutum (H.ianceolatum), Discopodium penninervum, Dombeya torrida* subsp.*torrida (D.goetzenii),and Ekebergia capensis (E. rueppeliana).* The shrub layer was dominated by *Rhus gultinosa, Dodonea angustifolia, Ocimum urticifolium, Buddleia polystachya, Salix mucronata (S.subserrata), Carissa spinarum. Jasminum abyssinicum and Momordica foetida* are climbers that are found within this community type.

3. Justicia schimperiana – Crotona macrostachyus Community type

This community comprises 21 species and 6 plots (0.24 ha^{-1}) which are distributed between 2375 and 2500 m a.s.l. Compared to the rest of the two communities, it contains the smallest species indicator values. *Justicia schimperiana (Adhataoda schimperiana and Crotona macrostachyus are* the dominant shrub and tree species within this community types respectively. The associated tree and shrubs in this community types includes *Eucalptus globulus, Calpurina aurea, Rumex nervosus, Phytolacca dodacandra, Acacia abyssinica* subsp.*abyssinica, Podocarpus falcatus (P.gracilior), Cordia africana, Buddleia polystachya, Triumfetta rhomboidea, Bersama abyssinica subsp. abyssinica, Capparis tomentosa, Juniperus procera, Hypericum revolutum (H.ianceolatum), Dombeya torrida* *subsp.torrida (D.goetzenii), Grewia ferruginea and Asparagus flagellaris.*

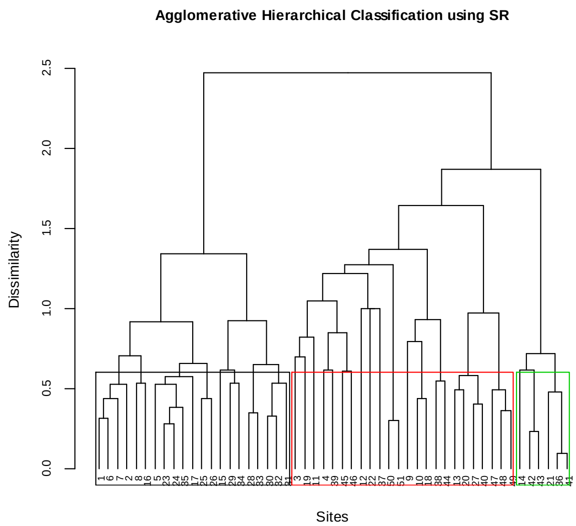

Figure 5: Dendrogram showing plant community types within study area.

Vegetation Structure

DBH Distributions

For the explanation of DBH distribution within Debrelibanos monastery natural forest patch, 57 woody species having 185 individuals whose dbh and height was greater than or equal to 2.5 cm and 2 meter were selected respectively. Accordingly, fifteen dbh classes were established as indicated in figure 6 below. The majority of mature trees (comprising 28 species accounting for 15.1 %) of the individual trees species in the forest are falling in the fifth class (17 - 20 cm) i.e. the majority of woody plant species had DBH between 2.29 – 8.77 cm (5.53 ± 3.24 cm). Followed by the fifth class, the highest percentage of woody species (a total of 124 species) is found in the second (14.1%), fourth (12.4%), seventh (10.3%), eighth (9.2%), third (8.6%), first (7.0%), sixth (7.0%) and tenth classes (5.4%). The remaining 10.9 percent of the woody plant species were fall within ninth, eleventh, fourteen, fifth, twelfth, and thirteenth classes. As depicted on figure 6, the frequency distribution of the DBH class of the woody species formed the gauss type distribution, i.e. there are few number of woody plant species (about 16 %) that had DBH value greater than 32 cm. This means there are relatively fewer species that can be used for different purposes like that of pole, construction, etc. *Olea europaea* subsp.*cuspidata, Prunus africana, Stereospermum kunthianum, Croton macrostachyus, Cordia africana, Dombeya torrida* subsp. *torrida, Juniperus procera, Eucalyptus camaldulensis, Eucalyptus globulus, Ficus sur, Ficus vasta*, *Eulea racemonsa* subsp. *schimperi, Albizia grandibracteata,* and *Hagenia abyssinica* were some of the woody plant species that had DBH greater than 32 cm. These species, as mention above, had great recruitment because of their importance both ecologically and economically for the community.

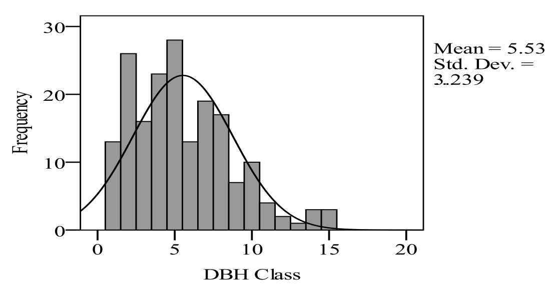

Figure 6: DBH and Percentage of individual tree distribution (Where Class1= < 5, Class 2= 5-8, Class 3= 9-12, Class 4= 13- 16, Class 5= 17 - 20, Class 6= 21-24, Class 7= 25-28, class 8= 29-32, Class 9= 33 -36, Class 10= 37 – 40, Class 11= 41 – 44, Class 12= 45 – 48, Class 13= 49 – 52, Class 14 = 53 – 56, Class 15 = 57 – 60).

Basal Area and Dominance

The basal area of the woody plant species for Debrelibanos monastery remnant dry afromontane natural forest patch was 0.829 m^2 ha^{-1}(annex 2). This result is very low compared to the normal basal area of Virgin tropical forest in Africa which has basal area between 23 – 37 m^2 ha^{-1} (Belachew, 2010). The possible reason could be due to very high degradation of remnant forest patch by different factors particularly anthropogenic factors. The distribution of basal area over DBH class of individual tree indicates that, the highest values of basal area of the forest fall within the highest DBH class (sixteenth class i.e. 6.60+ cm) followed by fifteenth to the first class respectively and form J-shape as shown figure 7a. The highest basal area distribution in the highest dbh class is contributed from *Olea europaea* subsp.*cuspedata, Juniperous procera, Ficus sur, Eucalyptus globules, Croton macrostachyus, Ficus vasta and Acacia abyssinica* subsp.*abayssinica.* Furthermore, these plant species has the highest relative basal area hence they are dominant. The study of Bekele, (1994) stated that basal area (BA) provides a better measure of relative importance of the species than stem count. Thus, those plant species listed above had highest basal area and they are considered as the most important species in the study area.

The comparison of the basal area and densities in the diameter classes showed that there are lower numbers of individuals in the first and gradually increased towards the higher DBH classes (Figure 7a). There are no necessary conditions for increase in mean density of individual plant species as basal area of the individual increases (Bekele, 1994; Denu, 2007) (Figure 7b). There are higher number of individuals in the lower classes and considerably decreasing in the lower classes. However, the basal area of the individual species is lower in the lower classes and exponentially increasing and form J-shape distribution pattern.

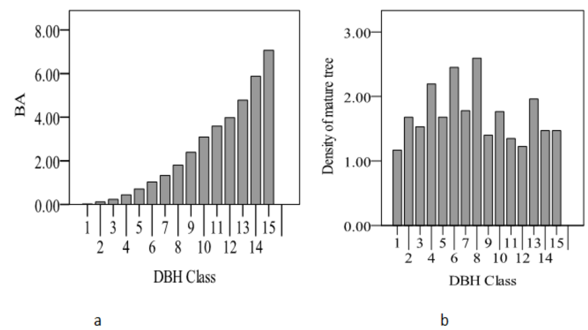

Figure 7: Basal area and density of individual woody plant species distribution over DBH classes in Debrelibanos monastery natural forest patch (Where class1= <5, class2= 5-8, class3= 9-12, class4= 13-16, class5= 17-20, class6= 21-24, class7= 25-28, class8= 29- 32, class9= 33- 36, class10= 37-40, class11= 41-44, class12= 45- 48, class13= 49-52, class14= 53-56, class15= 57-60).

Vertical Stratification

On the bases of International Union Forestry Research Organization (IUFRO) classification scheme (Lamprecht, 1989), three vertical structures of tree/shrubs in Debrelibanos monastery natural forest patch were recognized: upper storey (tee height > 2/3 of the top height), middle storey (tree height between 1/3 and 2/3 of the top height), and lower storey (trees with height < 1/3). The tallest height in the remnant forest patch was *Olea europaea subsp.cuspidata* with height of 35.5 meter. As a result, the upper storey is represented by a height greater than 23.67 which accounts about 48.91% of the density plant species where as the middle storey range from 11.83 – 23.67 meter (47.74%) and lower storey less than 11.83 meter (3.35%) (Table 1).

Table 1: The density, species number, and percentage of individual woody species in the lower, middle and upper strata of Debrelibanos monastery natural forest patch.

Tree story	Frequency	Percent (%)	Number of species
a	102	55.1	48
b	76	41.1	23
c	7	3.8	6

Where: a= lower story (<11.83m); b= middle story (11.83 – 23.67m) and c= upper story (>23.67m)

This table shows that the majority of the individual woody species (about 48 species) of the study area is falling in the lower height class. *Capparis tomentosa, Carissa spinarum, Albizia grandibracteata, Nuxia congesta*, *Acacia abyssinica* subsp. *abyssinica*, *Acokanthera schimperi*, *Acacia etbacia* subsp.*etbaica*, *Grewia ferruginea*, *Dombeya torrida* subsp.*torrida*, *Justicia schimperiana* and *Bersama abyssinica* subsp.*abyssinica* were some of the emergent plant species that contributed to the lower canopy of the forest. The middle storey also contain about 23 species that are emergent in the forest whereas the upper storey contain six plant species such as *Olea europaea* subsp.*cuspidata*, *Calpurina aurea*, *Juniperus procera*, *Acacia abyssinica* subsp.*abyssinica*, *Acokanthera schimperi* and *Crotona macrostachyus*.

The output from analysis of height frequency distribution also showed a decreasing trend in the number of individuals with increasing height, i.e., there are higher number of individuals in the lower height class and a gradual decrease towards the middle and upper class. Similar outcomes were reported in the study of Abiyou Tilahun, (2009) at Menagesha Amba Mariam, Woldemichael *et al.,* (2010) at Hugumbirda-Gratkhassu national forest priority area, and Ayalew (2003) at Denkoro Forest. This could be due to the interference of the forest by the local community (anthropogenic activities) through selective cutting for different purposes (economic and non-economic purposes) such as for fire wood, construction and generating income by selling.

Tree species in seventh class (23.15 – 26.17), eighth (26.18 – 29.20), ninth (29.21 – 32.23) and tenth class (32.24+) dominated the upper canopy of the forest. The plant species in these classes such as *Calpurina aurea*, *Olea europaea* subsp.*cuspidata*, *Juniperus procera*, *Acacia abyssinica* subsp. *abyssinica* and *Acokanthera schimperi* are the emergent tree species that grow above all canopies of trees in the forest. The majority number of individual tree/shrubs (about 31.9 percent) was found in the first height classes i.e. most of woody plant species per hectares had height between 1.00 to 4.76 meters (2.88 $\pm$ 1.877 meter) (figure 8). As indicated on the figure, the distribution formed a reversed J-shape distribution pattern and this could infer that the remnant forest patch is dominated by lower stature individual tree/shrubs (table 1) and this is the characteristics of good regeneration but low recruitment potential (Woldemichael *et al.,* 2010) which might have been caused by anthropogenic activities.

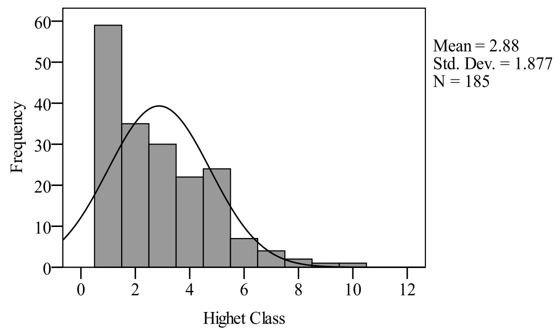

Figure 8: Frequency distribution of height class of woody plant species of the study area (where class '1' = < 8.00 , '2'= 8.01-11.02, '3'= 11.03-14.05, '4'= 14.06-17.08, '5'= 17.09-20.11, '6'= 20.12 - 23.14, '7'= 23.15 - 26.17, '8'= 26.18 - 29.20, '9' = 29.21 – 32.23, an d 32.24+).

Frequency distribution is one of the parameter that helps as the indicator of homogeneity and heterogeneity of given vegetation (Lambrecht, 1989). Accordingly, the result from frequency distribution analysis shows the heterogeneity among individual woody species of the study area. In terms of frequency distribution, some of the most frequent woody species within the study area were: *Olea europaea* subsp.*cuspidata, Eucalyptus globules, Acacia abyssinica* subsp.*abyssinica, Juniperus procera, Crotona macrostachyus, Cordia africana, Carissa spinarum.*

Population structure of forest patch

In the study area, five general patterns of population structures were recognized (Figure 9 A-E). The first type depicted a Gauss-type distribution pattern (bell shaped) with no frequency in the first class and low frequency distribution in the second dbh class and gradually increasing towards a medium classes and then a subsequent decrease in frequency towards the higher dbh classes (Figure 9 A). *Olea europaea* subsp.*cuspidata, Croton macrostachyus and Eucalyptus globulus* are some of the species showing this pattern. According to Teketay (2005), this pattern of population structure shows a poor reproduction (poor regeneration) and recruitment capacity because there are no or relatively few species in the lower and higher dbh classes that contribute for regeneration of the forest and used for different purposes respectively. In order to maintain integrity and health of this population structure, the sustainable use and management are basic measures to be undertaken (Shibru and Balcha, 2004).

The second type (Figure 9B) shows a pattern where individual species are more frequent in the second dbh classes and then gradually decreasing (i.e. form an inverted J-shaped distribution pattern). Species in this pattern had good reproduction and recruitment capacity. This distribution pattern is represented by *Juniperus procera, Acacia abyssinica* Subsp.*abyssinica, Carissa spinarum, Eucalyptus camaldulensis,* and *Cordia africana.*

The third type (Figure 9C) show a U-shaped distribution pattern with a higher number of individual species in the third class and disappears in the next six classes and finally appears. However, there were no species in the first classes. This distribution pattern shows there is an interference of human being for different purposes and they need careful conservation and management action in order to enhance their integrity and health. *Prunus africana, Eulea racemonsa* subsp. *Schimperi, Justicia schimperiana, Ficus vasta, Hypericum revolutum, and Albizia grandibracteata* were the species that included in this distribution pattern.

The fourth pattern (Figure 9D) shows the presence of highest number of an individual species with small dbh values only in a single dbh classes. Some of the species represented within this class include: *Capparis tomentosa, Acacia etbacia* ssp.*etbaica, Asparagus flagellaris, Calpurina aurea, Nuxia congesta, Casuarina cunninghamiana, Dodonaea angustifolia*, *etc*. As in the fourth pattern, the fifth distribution pattern (Figure 9E) also had a single individual woody plant species in the middle and higher dbh classes. This implies that the woody species had poor reproduction and they might disappear in the near future. They also need priory conservation. *Hagenia abyssinica, Stereospermum kunthianum, Dombeya torrida* subsp. *torrida, Vernonia amygdalina, Schefflera abyssinica, Podocarpus falcatus, Myrsine africana, Momordic foetida, Bersama abyssinica* subsp.*abyssinica,* and *Discopodium penninervum* were the species under this distribution pattern.

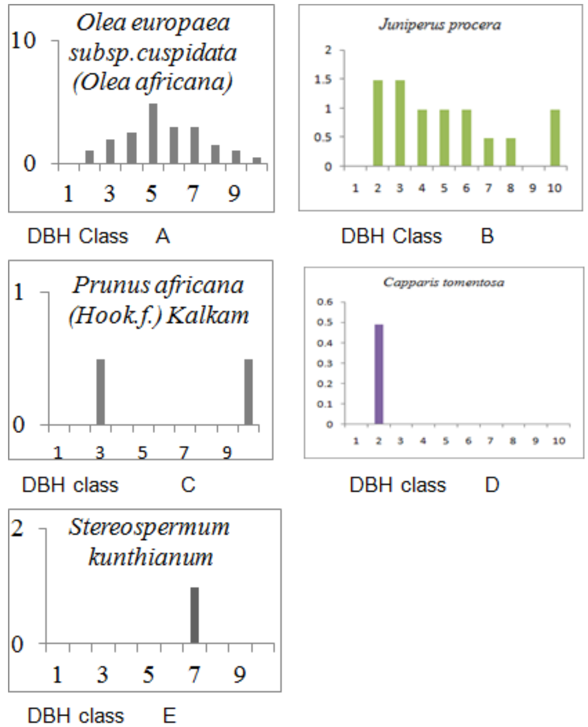

Fig. 9: Population structure of tree species within Debrelibanos monastery natural forest patch (Where '1' = <= 2.50, '2' = 2.51 – 8.89, '3' = 8.90 – 15.28, '4' = 15.29 – 21.67, '5' = 21.68 – 28.06, '6' = 28.07 – 34.45, '7' = 34.46 – 40.83, '8' = 40.84 – 47.22, '9' = 47.23 – 53.61, '10' = >=53.62).

Density and regeneration status

One of the effective criteria for successful conservation and management of the forest resources are determining the regeneration status of the forest on the basis of the composition, distribution and density of seedling and sapling (Teketay, 2005). Accordingly, the sapling density of the Debrelibanos monastery natural forest patch was 4997.86 per hectare (about 52.27 %) while the seedling had density of 4239.60 individuals per hectare (44.34 %). The analysis of woody plant species also reveal that the total density of mature tree, shrubs, tree/shrubs and climbers within Debrelibanos monastery remnant dry afromontane natural forest patch was 9562.43 individual per hectare (table 2).

The study of Chauhan *et al.,(* 2008) show that calculation of the ratio among the mature tree, sapling and seedling can provide information regarding the distribution of mature tree, sapling and seedling and the regeneration status of the forest. In line with Chauhan *et al.,* (2008) the ration of seedling to sapling, seedling to mature tree and sapling to mature tree of Debrelibanos monastery natural forest patch was conducted and the result was 1: 1.2, 13.1: 1 and 15.4: 1 respectively. These reveal that the distribution of sapling density is greater than both seedling and mature tree (i.e. density of sapling > density of seedling > density of mature tree) within study area. According to Dhaulkhadi *et al.,* (2008), a given forest had good regeneration if seedling is greater than sapling and mature tree/adult (seedling density > sapling density > mature tree/adults); fair regeneration if seedling > or ≤ sapling ≤ mature tree; poor regeneration if seedling < sapling ≥ or ≤ mature tree; and no regeneration if species are represented only by adult/mature trees. From the three conditions, the remnant natural forest patch within study area fulfills the third condition and in general, it had poor regeneration status. According to Lemenih and Teketay (2006), adverse conditions such as interventions by human being, poor seed bank, deterioration of seeds, disturbance by browsers, and grazers were the factors contributing for poor regeneration. This implies a need to develop and implement effective forest management system within the study area to promote healthy regeneration and sustainable use of these plant species.

Depending upon the general pattern of frequency distribution, the regeneration of all tree species within the study area were divided in to eight distinct regeneration patterns. The first distribution pattern shows the presence of least density of trees and gradually increases towards the highest density value of seedling and they formed J-shaped distribution pattern. According to the study of Tesfaye *et al.,*(2001) and Bekele (1994), plant species with such distribution pattern had good regeneration and recruitment potential. This pattern was exhibited by *Stereospermum kunthianum, Acokanthera schimperi, Justicia schimperiana, Osyris quadripartita*, *Grewia ferruginea, Asparagus flagellaris, Ficus carica, Ocimum urticifolium, Hypericum revolutum, Brucea antidysenterica, Rumex nervosus, Dodonaea angustifolia*, *Phytolacca dodacandra, Podocarpus falcatus,* and *Salix mucronata* (Figure 10a). The second distribution pattern shows small density value of tree species, higher value of sapling followed by smaller value of seedling density (figure 10b). *Carissa spinarum, Acacia abyssinica* subsp.*abyssinica, Capparis tomentosa, Eucalyptus globulus, Calpurina aurea, Triumfetta rhomboidea*, *Crotona macrostachyus, Dombeya torrida* subsp.*torrida, Rosa abyssinica, Rhus gultinosa, Buddleia polystachya, Premna schimperi, Discopodium penninervum, Albizia grandibracteata,* etc. are some of the plant species that are categorized under this distribution pattern. These plant species exhibited poor regeneration pattern due to poor stocking, adverse conditions in the forest, continuous and selective cutting (Teketay and Granstorm, 1995).

The third distribution pattern also shows smaller density values of the mature trees but higher density value at sapling stage and complete absence of seedling species which implies that this category like that of the second category shows poor regeneration capacity and they requires conservation and management schemes so as to extend the life of those species. Some of the species representing the distribution class includes: *Olea europaea* subsp. *Cuspidata, Eucalyptus camaldulensis, Juniperus procera,* and *Vernonia amygdalina (*Figure 10c). Woody plant species such as: *Myrsine africana*, *Bersama abyssinica* subsp. *abyssinica, and Lippia adoensis* are those species that fall under the fourth regeneration distribution which had smaller density of mature tree and similar/constant amount of sapling and seedling. These species exhibit fair regeneration pattern in the forest (figure 10d). The remaining regeneration distribution pattern of the plant species were observed in single category of woody plant (i.e. either at mature trees, sapling or seedling). For instance, the fifth distribution pattern (figure 10e) shows complete absence of mature tree and seedling. It had only the sapling woody species and it contains species such as *Arundo donax* and *Ricinus communis.* These species shows poor regeneration and conversely these plant species require the application of forest conservation and management techniques through prioritization. The other distribution pattern was depicted in figure 10f which shows the presence of small number of mature tree and relatively higher seedling. This pattern was recognized by *Rhamnus prinoides, Aloe vera, Solanum incanum* and *Cajanus cajan.* These species didn't have any sapling and this might be due to perishing of seedling before reaching sapling stage. The seventh distribution pattern shows the presence of only mature tree. Some of the species showing this pattern are *Ficus sur, Casuarina cunninghamiana, Ficus vasta, Dovyalis abyssinica, Hagenia abyssinica, Prunus africana*, *Dracaena steudneri, Ekebergia capensis, Maesa ianceolata,* and *Momordica foetida*. According to Dhaulkhadi *et al.,* (2008), these plant species don't regenerate because they survive only at the adult or mature tree level. Thus, this situation calls for conservation and management action to sustain their life by giving them time to rejuvenate themselves from seed deposited in the soil.

In general, as depicted on table 3, about 26.67% of woody plant species fall within good regeneration capacity followed by 13.33% species categorized under fair regeneration. However, about 60% of woody plant species of the study area fall under poor and no regeneration category. Some of the woody species falling under these categories includes: *Carissa spinarum, Acacia abyssinica* subsp.*abyssinica, Capparis tomentosa, Eucalyptus globulus, Calpurina aurea, Crotona macrostachyus, Dombeya torrida* subsp. *torrida, Buddleia polystachya, Albizia grandibracteata, Euclea racemosa* subsp. *schimperi, Cordia africana, Schefflera abyssinica, Jasminum abyssinicum,* and *Acacia etbacia* ssp.*etbaica.* The result from questionnaire survey shows that human intervention through selective cutting for construction, firewood and expansion of burial site, intervation by grazers, browser, poor seed dispersal, lack of suitable conditions for growth of seedling to sapling stage and mature tree were the reasons for poor and no regeneration of the these woody plant species within the study area. Therefore, these woody plant species require priority action for conservation/management and sustainable use, unless otherwise after short period of time they could disappear from the forest.

The second priority should be given to those woody species that fall under fair regeneration capacity because unless they are carefully managed and used properly they can face the chance of those plant species under poor and no regeneration. *Olea europaea* subsp.*cuspidata (Olea africana), Myrsine africana*, *Bersama abyssinica* subsp.*abyssinica, Lippia adoensis*, *Rhamnus prinoides, Aloe vera, Solanum incanum,* and *Cajanus cajan* were some of the plant species that are categorized under fair regeneration status. Those plant species that fall under good regeneration category should also be conserved and protected to maintain their sustainability so that can play their own role in maintenance of ecosystem health and integrity.

Table 2: Summary on the number of genera, species, families, Density and percentage density in each category (Tree, sapling and seedling) of woody plant species within study area.

Category	Genera	Spps	Family	Density	percent
Tree	51	46	38	324.97	3.40
Sapling	45	40	33	4997.86	52.27
Seedling	40	36	27	4239.6	44.34

Total	**9562.43**	**100.00**

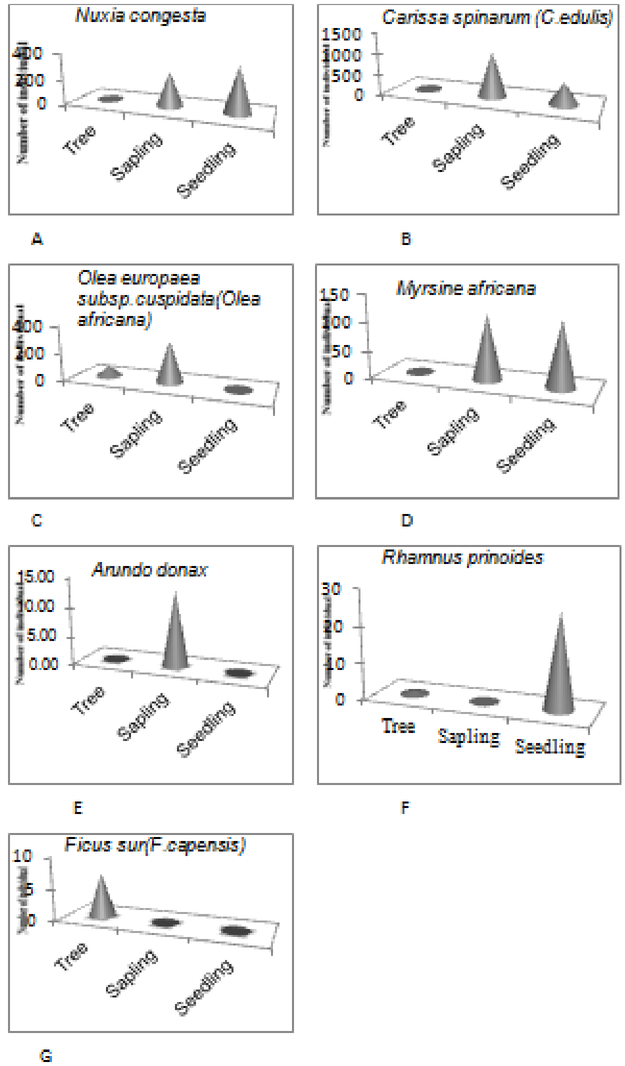

Figure 10 (a-g): Regeneration distribution pattern of plant species within study area.

Table 3: Regeneration status of woody plant species of Debrelibanos monastery natural forest patch

Regeneration type	No. Species	Percent
Good Regeneration	16	26.67
Fair Regeneration	8	13.33
Poor Regeneration	26	43.33
No Regeneration	10	16.67
Total		100.00

Phytogeographic Comparisons

Debrelibanos Monastery remnant natural forest patch is characterized as one of Dry Afromontane forest ecosystem. Dry afromontane forest had altitudinal range above 1500 m and below 3200 m average annual temperature of 14 – 250c. The main vegetation within this forest types include *Juniperus procera, Olea europea* subsp.*cuspidata, Podocarpus falcatus, Prunus africana, Olea capensis, Hagenia abyssinica, Rosa abyssinica, Apodytes dimidiate, Discopodium penninervum, Myrsine africana, Dovyalis abyssinica,* and *Calpurina aurea.* Most of these plant species are found within the study area. Debrelibanos natural forest patch has an altitudinal range of 2400 – 2560 m a.s.l. Even though, the direct comparison of the species diversity of one forest with other forests is not feasible (due to differences in size of the forest, survey methods, and objectives of the study among different forests) (Woldemariam, 2003), the overall species richness of the forest can give a general impression of their diversity and phytogeographical similarity. Accordingly, Debrelibanos monastery natural forest patch is compared with four dry Afromontane forests in the country to see the distribution pattern of woody species in the study area and to know the relative similarity and dissimilarity in its woody species composition (Table 4). These are Menagesha Amba Mariam, Managesha Suba, Munessa and Denkoro dry evergreen Afromontane forests. Menagesha Amba Forest is located at about 28 km west of Addis Ababa between $9^{o}01'$ – $09^{o}00'$ N and 38^{o} 35' – $38^{o}34'$ E. Its altitude ranges from 2400 – 2900 m a.s.l. (Tilahun, 2009). Menagesha – Suba Forest is a relatively well protected forest located about 30 km southwest of Addis Ababa between $08^{o}56'$ – $9^{o}00'$ N and $38^{o}32'$ – $38^{o}34'$ E. Its altitude ranges from 2440 – 3400 m a.s.l. (Demissie, 1980 and 1988; Zawudie, 2007). Munessa Shashemene Forest is located 230 km south of Addis Ababa at $7^{o}31'$N and $38^{o}37'$ E. Its altitude extends from 2100 – 2700 m a.s.l and mean annual temperature and rainfall of 15^{o}c and between 900 and 1500 mm (Tesfaye, 2004). Denkoro Forest is located in south Wello between $10^{o}35'$ – $11^{o}15'$N and $38^{o}35'$ – $38^{o}36'$ E. Its altitudes range from 1500 – 3500 m a.s.l (Ayalew, 2003).

Table 4: Phytogeographical comparison between Debrelibanos monastery natural forest patch and other forests

Name of the Forest	Altitudinal range (m)	a	b	c	SI	Sd
Menagesha Amba Mariam	2400 – 2900	34	26	35	0.53	0.47
Menagesha Suba	2440 – 3400	20	39	40	0.34	0.66
Munessa-Shashemene	2100 – 2700	11	49	16	0.25	0.75
Denkoro	1500 – 3500	26	34	57	0.36	0.64

Key: a = number of species common to both site, b= number of species found only in Debrelibanos monastery natural forest patch, c = number of species found only in the forest in comparison with Debrelibanos monastery natural forest patch, SI = similarity index, Sd = dissimilarity index

The result of Sorensen's similarity index (table 4) indicates that Debrelibanos monastery remnant dry afromontane natural forest patch and Menagesha Amba Mariam forest show the highest similarity (i.e. about 53 %) which is followed by Denkoro and Menagesha Suba forests with similarity value of 36% and 34% respectively. The highest similarity among these forests might be due to their proximity to central Shewa plateau, altitudinal ranges, geological formation and topographic natures. However, Debrelibanos monastery natural forest patch and Munessa-Shashemene forests show the lowest similarity of about 25%. The possible reasons for the highest dissimilarity between them might be due to their altitudinal ranges, amount of rainfall, climatic conditions, level of anthropogenic impact, etc. In addition, Munessa-Shashemene has the proximity and part of Hararge-Bale landmass and far from central Shewa plateau.

Conclusion and Recommendations

The vegetation of Debrelibanos monastery remnant dry afromontane natural forest patch was grouped in to three community types each of which had varying degrees of species diversity, richness and evenness. The variation exhibited among the communities could be due to different factors such as anthropogenic factors (e.g. expansion of burial site, increasing of fuel wood demand, expansion of residence house, grazer, browser, soil moisture and level of seed bank in the soil) and topographic factors like altitude, slope, etc.

The structural and frequency distribution of the remnant dry afromontane forest patch shows that there are variation among DBH, BA and height of the vegetations. For instance, the frequency distribution of individual woody species within DBH class revealed that the number of plant species is smaller in the first class and gradually raised toward the middle class and then decreasing by forming gauss distribution pattern while the frequency distribution of BA of woody species form J-shaped distribution. In contrast the height distribution shows reversed J-shaped distribution. These variations imply that the forest patch is floristically heterogeneous.

Three vertical structures were recognized in the forest patch and these were Upper storey with height greater than 23.67m, middle storey in between 11.83 – 23.67m and lower storey with height less than 11.83m. The result from analysis of population structure indicated that there were five population structures within the study area. The first population structures form a gauss distribution pattern which shows a poor reproduction or regeneration and recruitment capacity. The second distribution pattern formed reversed J-shaped distribution and plant species within this distribution pattern have good reproduction and recruitments. The third population structures shows U-shaped distribution pattern which implies the interference by human being, grazers, browsers and other factors. The fourth and fifth population structures show no or few individuals either at the lower, middle and higher size classes. These plant species exhibited poor reproduction and this implies that they need urgent conservation and management measures that can bring about healthy regeneration and guarantee sustainable use of the species.

The assessment of regeneration status of remnant forest patch was based on sapling and seedling density. The total density of tree, sapling and seedling were 324.97, 4,997.86 and 4,239.60 individual per hectare respectively. The ration of seedling to sapling, seedling to mature tree and sapling to mature trees were 1: 1.2, 13.1: 1 and 15.4: 1 respectively (i.e. density of sapling > density of seedling > density of mature tree) and this implies that the forest patch had poor regeneration status and they are under threat. This was due to expansion of burial site, increasing of firewood demand, expansion of residence house by illegal settlement, clearing of forest patch and replacing with single plant species (*Eucalptus spps*), interference by browsers and grazers. Therefore, it is essential to develop and implement effective conservation measures to curb the anthropogenic interference and to save the floristic composition and biodiversity of area.

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List of Annexes

Annex 1: Synoptic value of each plant species within each cluster/community type

Botanical/Scientific name of species	Cluster 1	Cluster 2	Cluster 3
Acacia abyssinica subsp.abyssinica	0.13	**0.31**	0.11
Acacia etbacia subsp.etbaica	0.05	0.00	0.00
Acokanthera schimperi	0.58	0.00	0.00
Albizia grandibracteata	0.03	0.03	0.00
Aloe vera (A.barbadensis)	0.00	0.17	0.00
Arundo donax	0.00	0.04	0.00
Asparagus flagellaris	0.41	0.02	0.01
Bersama abyssinica subsp.abyssinica	0.01	0.05	0.05
Brucea antidysenterica	0.00	0.15	0.00
Buddleia polystachya	0.01	0.08	0.07
Cajanus cajan	0.10	0.00	0.00
Calpurina aurea	0.27	0.03	0.30

Capparis tomentosa	0.59	0.02	0.03
Carissa spinarum (c. edulis)	**0.81**	0.07	0.01
Casuarina cunninghamiana	0.00	0.17	0.00
Cordia africana	0.00	0.06	0.09
Crotona macrostachyus	0.00	0.19	**0.50**
Discopodium penninervum	0.01	0.09	0.00
Dodonaea angustifolia	0.01	0.09	0.00
Dombeya torrida subsp. torrida (D.goetzenii)	0.08	0.08	0.02
Dovyalis abyssinica	0.00	0.04	0.00
Dracaena steudneri	0.00	0.04	0.00
Ekebergia capensis (E.rueppeliana)	0.00	0.08	0.00
Eucalptus camaldulensis	0.00	**0.28**	0.03
Eucalptus globulus	0.00	0.26	0.42
Euclea racemosa subsp. schimperi	0.10	0.00	0.00
Euphorbia abyssinica	0.03	0.06	0.00
Ficus carica	0.17	0.08	0.09
Ficus sur (F.capensis)	0.00	0.21	0.00
Ficus vasta	0.01	0.06	0.00
Grewia ferruginea	0.18	0.02	0.02
Hagenia abyssinica	0.05	0.00	0.00
Triumfetta rhomboidea	0.10	0.03	0.06
Hypericum revolutum (H.ianceolatum)	0.05	0.09	0.02
Jasminum abyssinicum	0.04	0.01	0.00
Juniperus procera	0.21	0.25	0.02
Justicia schimperiana (Adhataoda schimperiana)	0.00	0.00	**0.95**
Lippia adoensis	0.05	0.02	0.00
Maesa ianceolata	0.00	0.04	0.00
Momordica foetida	0.00	0.04	0.00
Myrsine africana	0.30	0.01	0.00
Nuxia congesta	0.59	0.09	0.00
Ocimum urticifolium	0.09	0.08	0.00
Olea europaea subsp.cuspidata (Olea africana)	**0.64**	0.13	0.00
Osyris quadripartita	0.26	0.15	0.00
Phytolacca dodacandra	0.02	0.04	0.17
Pittosporum viridiflorum	0.00	0.21	0.00
Podocarpus falcatus (P.gracilior)	0.00	0.01	0.11
Premna schimperi	0.12	0.01	0.00

Prunus africana	0.00	0.04	0.00
Rhamnus prinoides	0.10	0.00	0.00
Rhus gultinosa	0.04	0.19	0.00
Ricinus communis	0.05	0.00	0.00
Rosa abyssinica	0.08	0.06	0.00
Rumex nervosus	0.00	0.13	0.17
Salix mucronata (S.subserrata)	0.00	0.08	0.00
Schefflera abyssinica	0.05	0.06	0.00
Solanum incanum	0.01	0.03	0.00
Stereospermum kunthianum	0.00	0.04	0.00
Vernonia amygdalina	0.04	0.01	0.00

annex2: Summary of basal area of all tree species within study area

Scientific/Botanical name	DBH(cm)	BA(in m^2/ha)	Rel.BA
Brucea antidysenterica	3	0.0002	0.03
Capparis tomentosa	3	0.0003	0.04
Ocimum urticifolium	3	0.0003	0.04
Solanum incanum	3	0.0003	0.04
Aloe vera	4	0.0005	0.06
Cajanus cajan	4	0.0006	0.07
Premna schimperi	5	0.0008	0.09
Calpurina aurea	6	0.0014	0.17
Carissa spinarum	8	0.0024	0.29
Justicia schimperiana	8	0.0025	0.3
Acacia etbacia subsp.*etbaica*	8	0.0025	0.3
Lippia adoensis	8	0.0025	0.3
Pittosporum viridiflorum	8	0.0025	0.3
Ficus carica	8	0.0026	0.32
Nuxia congesta	9	0.0028	0.34
Maesa ianceolata	10	0.0039	0.46
Jasminum abyssinicum	10	0.0039	0.46
Dovyalis abyssinica	10	0.0039	0.46

Asparagus flagellaris	10	0.0039	0.46
Rosa abyssinica	12	0.0054	0.65
Rumex nervosus	12	0.0055	0.67
Buddleia polystachya	12	0.0055	0.67
Hypericum revolutum	13	0.006	0.73
Acacia abyssinica subsp.*abyssinica*	13	0.0067	0.81
Salix mucronata	14	0.0075	0.91
Grewia ferruginea	14	0.0075	0.91
Phytolacca dodacandra	15	0.0087	1.04
Casuarina cunninghamiana	15	0.0087	1.04
Osyris quadripartita	15	0.0087	1.04
Euphorbia abyssinica	15	0.0091	1.1
Eucalptus camaldulensis	16	0.01	1.21
Dodonaea angustifolia	18	0.0125	1.5
Schefflera abyssinica	19	0.0137	1.65
Eucalptus globulus	20	0.015	1.81
Podocarpus falcatus	20	0.0154	1.86
Discopodium penninervum	20	0.0154	1.86
Dracaena steudneri	20	0.0154	1.86
Bersama abyssinica subsp.*abyssinica*	20	0.0154	1.86
Euclea racemosa subsp. *schimperi*	20	0.0154	1.86
Ekebergia capensis	20	0.0154	1.86
Rhus gultinosa	20	0.0156	1.88
Albizia grandibracteata	22	0.0189	2.28
Acokanthera schimperi	23	0.0199	2.4
Rhamnus prinoides	23	0.0204	2.46
Myrsine africana	25	0.0241	2.9
Momordica foetida	25	0.0241	2.9
Crotona macrostachyus	26	0.0262	**3.15**
Olea europaea subsp.*cuspidata*	28	0.0299	**3.6**
Vernonia amygdalina	28	0.0302	**3.64**
Juniperus procera	29	0.0318	**3.84**
Cordia africana	30	0.0344	**4.14**
Dombeya torrida subsp.*torrida*	31	0.037	**4.46**
Hagenia abyssinica	33	0.0407	**4.91**
Prunus africana	35	0.0458	**5.53**
Ficus sur(F. capensis)	35	0.0479	**5.78**

Stereospermum kunthianum	39	0.0583	**7.04**
Ficus vasta	41	0.0631	**7.62**
Total Sum		**0.829**	**100**

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