Floristic composition, structure and regeneration status of woody plants in church forests of Dangila, Northwestern Ethiopia

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Abstract: This study was conducted to determine woody species composition, diversity, structure, and regeneration status of sacred groves in Dangila town, Ethiopia. Five church forests were selected for this study among 14 forests in the district. Forty plots of 20 mx20m were laid along 20 transect lines for vegetation data collection. Additionally, 5 mx5m subplots were laid within the main plot to evaluate the regeneration status of woody plants. Woody plants with DBH ≥ 2.5 cm in each plot were identified and recorded. A total of 73 plant species in 64 genera and 42 families were identified. Among these, 43.06, 12.5, 36.11, and 8.33% were trees, tree/shrubs, shrubs, and climbers, respectively. Family Fabaceae were the most dominant contributing 9 (12.5%) species to the total followed by Euphorbaceae, Acantaceae, Rosaceae, and Moraceae with 7 (9.72%) species, 3 (4.17%) species, 3 (4.17%) species and 3 (4.17%) species, respectively. A total density of 548.13 seedlings ha−1, 841.88 saplings ha−1 and 2180.6 mature individuals ha−1 of woody species were counted in the sample plots. The density of height and DBH classes showed inverted J-shape pattern. The Shannon diversity and evenness of woody plant species in Dangila church forests was 3.5 and 0.82, respectively, which is relatively high. The total basal area of the forest was 98.4 m²/ha. These church forests had fair regeneration potential. Species with low important

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PUBLIC INTEREST STATEMENT
This study was conducted to evaluate the potential of church forests in woody species composition, diversity, and regeneration status in a town called Dangila, Ethiopia. The study found that, Sacred groves had a significant role as refugia of woody species which were highly diversified and evenly distributed. However, these forests had only fair regeneration potential though being sacred. The study also revealed the existence of many woody species that have least IVI need to be prioritized for conservation using in-situ and ex-situ conservation approaches. The findings remind the flock of the churches and the community about the status of the forests and the anthropogenic disturbances that imposed the risk for sustainability of these remnant native forests. Based on our findings, we recommend collaboration of local communities, stakeholders, head priest, and diocese of Ethiopian Orthodox Tewahido Churches (EOTC) is mandatory to reduce human encroachment to the church.
value index (IVI) and abundance need to be prioritized for conservation. Silvicultural intervention has to be implemented to strengthen the religious and cultural conservation system of the church forests.

**Subjects:** General Science; Bioinformatics; Biology; Environmental Management; Environment & Philosophy; Environment & Resources; Conservation - Environment Studies; Biodiversity & Conservation; Ecology - Environment Studies

**Keywords:** Phrases: Church forest; Density; Diversity; Regeneration; Vegetation structure

### 1. Introduction

Ethiopia with its vast geographical diversity and due to its high edaphic, climatic, topography, and altitudinal variations has a diversified biota (Yirdaw, 2001). Although there is controversy over the precise figures of the former forest cover in Ethiopia, historical sources indicate that some 35–40% of the land area might have been once covered with forests (EFAP (Ethiopian Forestry Action Program), 1994). As the result of continuous deforestation, most forests have disappeared, and deforestation continues with alarming rate, nearly 141,000 ha (0.93%) of the forest cover was destroyed every year (FAO, 2015). Today, only few forest patches, existed as remnant natural forests usually found surrounding churches and monasteries under traditional conservation effort of the Ethiopian Orthodox Tewahido Churches (EOTC) (Tilahun et al., 2015; Wassie et al., 2010).

The Ethiopian Orthodox Tewahido Church has a long history of forest conservation practice due to religious thought and local people's willingness to protect and conserve them (Bhagwat & Rutte, 2006; Wassie et al., 2010). Ethiopia has a total of around 35,000 churches and monasteries; Most of these churches are located in the Northern and Central Highlands of Ethiopia (Tilahun et al., 2015). Churches have native vegetation rich in biodiversity hosting different plants and animals (Mekonnen et al., 2019). Church forests did not significantly decrease in size rather; these forests have remained remarkably resilient on the landscape despite decades of dramatic change to the world around them (Scull et al., 2017). However, sacred groves have been disturbed and are vulnerable due to land-use change (LUC). Their indigenous trees and shrubs are reducing being substituted by exotic tree plantation like Eucalyptus species because of people's preference for construction, firewood, cash source, and other economic uses (Mekonnen, 2019; Tilahun et al., 2015).

The recent increasing urbanization results in a possible significant change in land use land cover change in the cities due to deforestation and exotic species plantation. The growing population and aggressive demand on the available resources like forest products, has been decreasing the average coverage area of woody plants in the churches yard (Cordelüs et al., 2019; Scull et al., 2017). The main reasons for deforestation and land cover change in Ethiopia are expansion of rudimentary agriculture, fuelwood collection, logging, charcoal production, and the harvest of construction materials (Solomon et al., 2018). This loss is aggravated by the decrease in rainfall and poor forest management practices.

Dangila church forests are the remnant forests in the town. These forests have a number of woody plants that has been naturally regenerated and partly planted by the local communities. The floristic composition, structure and regeneration status of woody plants of these church forests were not yet studied. Out of 14 church forests found in Dangila town, five forests were selected for the present study.

Currently, the loss of woody plants and forest resources that served as shade and means of soil and water conservation is high in church forests of Dangila town. The protected areas like church forests have been disturbed and until realistic alternatives can be found, deforestation will proceed in the very near future. This leads to land degradation in the form of soil erosion and loss of soil fertility, drying up of springs around the church, decline and even loss of biodiversity. Ultimately,
this may affect the welfare of plants, animals and microorganisms and the community living in Dangila town and the country at large.

In addition to the loss of vegetation and risk of degradation, very little is known about woody plants composition and diversity in church forests of Dangila town. Except for a few general botanical studies in the study area, no studies have been made on the diversity, structure and conservation status of woody plants of church forests in the growing Dangila town. Therefore, this study is critically important to evaluate and document the species composition, diversity, structure, and regeneration status of woody plants in the area. In addition, the study provides information and recommendations for the management, sustainable utilization, and conservation of woody plants in the church forests of Dangila town.

2. Materials and methods

2.1. Description of the study area
The study was conducted in Dangila town church forests. Dangila is one of the administration towns in Awi Zone of the Amhara Region in Northwestern Ethiopia which is found about 485 km northwest of Addis Ababa and 78 km southeast of Bahir Dar. This town has an elevation of 2137 m above sea level. Dangila town church forests have a latitude and longitude range between 11°12′38″N 36°49′17″E and 11°16′42″N 36°53′46″E. The total area of the town is about 918.4 km² (CSA, 2010). There are 14 church forests in Dangila town, containing a number of woody plant species among these 5 church forests were selected for this study (Figure 1). The study sites or forests are selected because of the availability of representative plant samples in the churches of the town.

Dangila town is generally characterized by 65% plateaus and 35% rough topography. According to GPS reading during fieldwork, Dangila Church forests is situated in the intermediate of altitudinal range between 2089 and 2172 m a.s.l. The major soil types in the town are Red soil (85%); Sand soil (3%) and Black soil (12%) which are suitable for the agriculture and forest sector. Agricultural cereal crops such as Eragrostis teff, Zea mays and Sorghum are common in the study area (ALZR, 2007).

Figure 1. The study area Map.
The rainfall and temperature condition of the study area was described based on the 10 years data collected from 2008 to 2017 by Western Amhara Meteorology Service Center (2018) in Bahir Dar station. The annual rainfall of Dangila town ranges from 4.7 to 424.8 mm (Figure 2).

2.2. Sampling design
Sampling sites were identified after reconnaissance survey was taken through field visits. Accordingly, 40 main plots having equal size of 20 m x 20 m (400 m²) were laid out to collect woody species data. Systematic sampling method was employed to lay main plots and sub-plots. Within the main plot, five sub-plots with the size of 5 m x 5 m (25 m²), four at the corners and one in the middle were laid for seedling and sapling data collection. The distance between the main plots was 50 m along each of the line transects. A total of 20 line transects were laid a single transect from the church building to every 4 directions of each church forests of the study area at 50 m intervals from each other. Due to difference in forest size, the number of plots was varied between 7 and 10 for each of church forest.

2.3. Vegetation data collection
Vegetation data was collected following Kent and Coker (1992). All woody plant species in each plot with diameter at breast height (DBH) ≥2.5 cm were identified and recorded. Their DBH were measured at breast height or 1.3 m above ground using diameter tape and then recorded. The height of woody plant species were also measured for plants ≥ 2.5 m height by using calibrated bamboo stick (Van Der Maarel, 2005).

The local names of woody plant species and number of individual were carefully recorded. Plant species that were difficult to identify in the field, were collected, pressed, dried and mounted then transported to the National Herbarium at Addis Ababa University for identification by referring Bekele (2007) and flora of Ethiopia and Eritrea (Edwards et al., 1997, 2000; Hedberg et al., 2003). To investigate the regeneration status of forests, the density of seedling (woody plants height < 1 m) and sapling (woody plants height ≥ 1 m and DBH < 2.5 cm) were counted and determined from 200 subplots.

3. Data analysis
3.1. Structural data analysis
Vegetation structure was described based on the analysis of species density, DBH, height, basal area, frequency and important value index (IVI). To analyze the population structure of woody plant species, the DBH and height of tree were classified into 6 DBH classes and 8 height classes based on Kent and Coker (1992). The basal area and density were computed per hectare basis. These data were computed and summarized using Microsoft office Excel 2007 spread sheet using the following formula (Kent & Coker, 1992).
Density: It refers to the number of all individual plant species within the quadrates. According to Kent and Coker (1992), density is computed by converting the count from the sample plot to the hectare basis using the following formula:

\[
\text{Density}(D) = \frac{\text{Number of individuals of a species in the sample}}{\text{Sample area in hectare}}
\]  

(1)

Relative density (RD): It is calculated as the number of plots occupied by a given species per total number of plots laid out, more often as a percentage (Goldsmith et al., 1986).

\[
\text{Relative density (RD)} = \frac{\text{Number of individuals of a species}}{\text{Total number of plots laid out}} \times 100
\]  

(2)

Frequency (F): It was calculated as the number of plots occupied by a given species per total number of plots laid out, more often as a percentage (Goldsmith et al., 1986).

\[
\text{Frequency (F)} = \frac{\text{Number of plots in which a species occur}}{\text{Total number of plots laid out}} \times 100
\]  

(3)

Relative frequency (RF): It is calculated as the number of plots occupied by a given species per total number of plots laid out, more often as a percentage (Goldsmith et al., 1986).

\[
\text{Relative frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Sum of frequencies of all species}} \times 100
\]  

(4)

Basal area (BA): It is the cross-sectional area of tree stems at breast height (1.3 m above ground level). Generally, it is a measure of dominance, which refers to the degree of coverage of species that occupies at ground level (Kent & Coker, 1992).

\[
\text{BA} = \frac{\pi d^2}{4}
\]  

(5)

Where: BA = Basal Area in m²ha⁻¹, d = diameter at breast height (m), and \(\pi = 3.14\).

Dominance (DO) = total cover or basal area of species A/area sampled.

\[
\text{Relative Dominance (RD)} = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100
\]  

(6)

Important Value Index (IVI): is useful to compare the ecological significance of species. It was calculated as the sum of relative dominance (RDO), relative density (RD) and relative frequency (RF) (Kent & Coker, 1992).

\[
\text{IVI} = \text{RD} + \text{RF} + \text{RDO}
\]  

(7)

3.2. Diversity and similarity indices

Diversity Indices: Species diversity and evenness were calculated using Shannon—Weiner (1949) diversity index as follows:

\[
H' = -\sum_{i=1}^{S} \pi_i (\ln \pi_i)
\]  

(8)

Where: \(H'\) is Shannon-Weiner diversity index, \(\sum\) is the sum from species 1 to species \(S\), \(\pi_i\) is the proportion of individual tree species (\(\pi_i = n/N\)), \(S\) is numbers of species encountered, \(\ln\) is the natural logarithm.

Shannon’s Equitability (Evenness): According to Kent and Coker (1992), equitability (evenness) index is calculated using the formula:

\[
\text{Shannon Evenness (J)} = \frac{H'}{H_{\text{max}}} \quad \text{or, } J = \frac{H'}{\ln S}
\]  

(9)

The minimum value of \(H'\) is 0, which is the value for a community with a single species, and increases as species richness and evenness increases (Manuel & Molles, 2007). The species
evenness that measures the equity of species in a given sample area is represented by 0 and 1, where 0 indicates the abundance of a single species and 1 indicates the condition where all species are equally abundant (Whittaker, 1972).

The phytogeographical comparisons of Dangila church forests with other forests in Ethiopia were made using Kent and Coker (1992).

\[ \text{Similarity coefficient} (S_s) = \frac{2a}{2a + b + c} \] (10)

Where \( a \) = the number of species common to both habitats, \( b \) = number of species in the first habitat and absent from the second, \( c \) = number of species in the second habitat and absent from the first.

3.3. Analysis of regeneration status of forests

Regeneration status of woody species of forests was analyzed by comparing the density values of seedlings, saplings and matured woody plants within sacred groves (Dhaulkhandi et al., 2008). According to Dhaulkhandi et al. (2008) and Tiwari et al. (2010), the regeneration status is good, if seedlings > saplings > adults; Fair regeneration, if seedlings > or ≤ saplings ≤ adults; the status is poor regeneration, if the species survives only in sapling stage, and if a species is present only in an adult form it is considered as not regenerating.

4. Result and discussion

4.1. Floristic composition

The total of 73 woody plant species that belong to 63 genera and 42 families were identified and registered from Dangila town church forests (Appendix 1). Of all the families, Fabaceae was the most dominant contributing 9 (12.5%) species to the total and followed by Euphorbiaceae, Acanthaceae, Rosaceae and Moraceae with 7 (9.72%) species, 3 (4.17%) species, 3 (4.17%) species, and 3 (4.17%) species, respectively. The remaining families were represented by two or one species each. That is 10 families with 2 species each and 27 families with one species each. From the total woody plant species, 31 (42.46%) were trees, 9 (12.33%) were tree/shrubs, 27 (36.99%) were shrubs and 6 (8.22%) were climbers (Appendix 1). According to Mekonnen (2019), a total of 174 native and exotic woody plant species were identified in all the 46 sacred groves of northwest Ethiopia.

4.2. Species diversity and evenness

The diversity and evenness of woody species in Dangila church forests was 3.5 and 0.82, respectively. According to Kent and Coker (1992), Shannon-Wiener index value varies between 1.5 and 3.5 and rarely exceeds 4. This indicates the diversity and evenness of woody species in the forest is relatively high. Thus, the results showed that woody species of these sacred groves were highly diversified and evenly distributed. These forests have relatively high value of diversity and evenness when compared with Weiramba forest of North Ethiopia which were 2.3 and 0.66, respectively (Teshaqer et al., 2018), and Tara Gedam church forest with 2.98 and 0.65, respectively (Zegeye et al., 2011).

4.3. Vegetation structure

Density: Across all the study sites 3,489 mature individual woody plants with dbh ≥ 2.5 cm were enumerated. The density of woody species with DBH ≥ 2.5 cm in Dangila church forests was 2180.6 stems ha\(^{-1}\). The most abundant woody species in these forests were *Eucalyptus camaldulensis*,

*Carisa spinarum*, *Syzygium guineense*, *Acacia abyssinica*, *Croton macrostachyus*, *Justicia schimperiana*, and *Albizia schimperiana*. In contrast to these, the least abundant species registered were *Podocarpus falcatus*, *Argemone mexicana*, *Mimusops kummel*, *Myrica salicifolia*, *Acacia seyal*, and
Prunus africana (Appendix). These forests had relatively high density compared with that of Gelawolde community forest in northwestern Ethiopia (Mucheye & Yemata, 2020). The density in our study forests is nearly 3 times higher than the density of Gedo forest at the same DBH class (Kebede et al., 2014).

Densities of tree species forests with DBH < 10 cm, DBH > 10 cm, and DBH > 20 cm were 831.9 (48.58%), 488.8 (28.54%), and 391.9 (22.88%) stems ha⁻¹ respectively. This result confirmed that the density of woody plants in the forests got lesser as the DBH is higher. This may be due to the selection of the trees for firewood, fencing, cattle feed and charcoal production. The ratio of tree densities of DBH > 10 cm (a) to DBH > 20 cm (b) of Dangila church forests was 1.25. This value is small as compared with some other forests in Ethiopia (Table 1). The result of proportion of small-sized to large-sized individuals indicates that the density of lower DBH classes is three times higher than the larger DBH classes of Dangila church forests.

The predominance of small-sized woody species than large-sized DBH class in the church forests might be as the result of selective cutting for church building and charcoal, which took place in these forests a long time ago.

**Frequency:** Based on the percentage frequency values, woody plant species were classified into five frequency classes: A) 0–20, B) 21–40, C) 41–60, D) 61–80, and E) 81–100. The most frequently distributed species in the forests were Croton macrostachyus (100%), Albizia schimperiana (93.8%), Carisa spinarum (93.8%), Vernonia auriculifera (93.8%), Acacia abyssinica (87.5%), Caluasena anisata (87.5%), Maytenus arbutifolia (87.5%), Mytenus ovatus (81.3%), Justicia schimperiana (81.3%), and Eucalyptus camaldulensis (81.3%). Based on the description of Lamprecht (1989) and Simon and Girma (2004), the percentage frequency of the present study revealed medium degree of floristic heterogeneity. The forests have high percentage of number of species in the lower frequency classes (A, B, and C) and higher frequency classes and low percentage of number of species in the middle i.e., C and D (Figure 3).

**Table 1. Tree density comparison of Dangila church forests with other Ethiopian forests**

| Forest                | DBH class | Source                  |
|-----------------------|-----------|-------------------------|
|                       | >10 cm (a) | > 20 cm (b) | Ratio (a/b) |                      |
| Menna-Angetu          | 292       | 139             | 2.10        | Lulekal et al., 2008 |
| Denkora               | 526       | 285             | 1.85        | Abote et al., 2006   |
| Dangila church forests| 488.75    | 391.89         | 1.25        | present study        |
| Achera                | 182.37    | 202.33         | 0.9         | Getaneh & Seid, 2015 |

**Figure 3. Frequency distribution of woody plant species of five frequency classes in Dangila church forests; Where the letters represents the frequency classes: A) 0–20, B) 21–40, C) 41–60, D) 61–80, and E) 81–100.**
**Height distribution:** The individuals of woody plants in the study area were classified into eight height classes: (I) <5 m, (II) 5.1–10 m, (III) 10.1–15 m, (IV) 15.1–20 m, (V) 20.1–25 m, (VI) 25.1–30 m, (VII) 30.1–35 m and (VIII) >35 m. The result revealed that, the highest number of individuals of woody plants found in the height class I (1348.1 ha\(^{-1}\)), which accounts 37.8% of the total height classes. The number of individual species in the height class II decreased to 920.63 ha\(^{-1}\) (25.8%). Woody plants in the height class III, IV, V, and VI together make 35.85% of the total height classes in the forests (**Figure 4a**).

The height class density values of woody plants were higher in the lower class followed by decrease in the higher classes showing an inverted J-shape (**Figure 4a**). This indicated that the forest has been influenced by anthropogenic activities through selective cutting of trees for charcoal production, construction and timber production. Thus, the forest is dominated by small to medium-sized individual species, which is attributed to high rate of regeneration but low recruitment potentials. Similar results were reported in Gelawoldie community forest in northwestern Ethiopia (Mucheye & Yemata, 2020).

**Diameter at Breast Height (DBH):** Among six DBH classes 77.1% of individuals were found in the first two lowered classes (<10 cm and 10.1–20 cm) with 831.8 and 488.7 stems ha\(^{-1}\) respectively (**Figure 4b**). As the DBH class size increases, the number of individuals gradually decreased showing inverted J-shaped pattern similar to the height distribution (**Figure 4a**). Shiferaw (2010) and Getaneh and Seid (2015) reported similar results. This indicates that there is a dominance of small-sized individuals in the forests, which is good for regeneration status if well managed. But it also indicates to have low recruitment potential, which might have been due to selective cutting of large tree individuals.

**Basal area:** The total basal area of all tree species with DBH \(\geq\) 2.5 cm in Dangila church forests was found to be 98.4 m\(^2\)ha\(^{-1}\). According to Lamprecht (1989), the normal basal area of virgin tropical forest in Africa is 23–37m\(^2\)ha\(^{-1}\). Based on this report, the basal area of Dangila church forests is very high indicating that the tree species are thick and very crowded. About 50.2% of the total basal area is distributed in the highest or the last two diameter classes (**Figure 5**) which was due to the presence of large-sized individuals of plant species. These include Eucalyptus camaldulensis, Syzygium guineense, Acacia abyssinica, Albizia schimperiana, and Croton macrostachyus contributed to the total basal area 34.96, 19.61, 13.72, 10.29, and 5.73%, respectively. Though the numbers of individuals in the first three DBH classes of Dangila church forests were high (**Figure 4b**), their contribution to the total basal area was low (**Figure 5**). This indicates that species with the highest basal area do not necessary have the highest density.

Similar results were reported by Mucheye and Yemata (2020) of Gelawoldie community forest in northwestern Ethiopia and found a basal area of 93.8m\(^2\)ha\(^{-1}\). This basal area was higher than Gedo dry afro montane forests in Ethiopia which was 35.5 m\(^2\)ha\(^{-1}\) (Kebede et al., 2014), and lower
than Tara Gedam 115.4m²ha⁻¹ (Zegeye et al., 2011). Trees of higher DBH class in Dangila church forest are fewer but contributed considerably to the total basal area.

4.4. Importance Value Index (IVI)
The important value index (IVI) of each woody plant species in these church forests varied greatly, ranging from 0.20 to 50% (Appendix). More than 79.5% of the woody plant species had lower IVI (lower than 5%) while the remaining 20.5% of the species had higher IVI which is greater than 5%. The 10 most important tree species in Dangila church forests were Eucalyptus camaldulensis, Syzygium guineense, Acacia abyssinica, Albizia schimperiana, Carisa spinarum, Croton macrostachys, Justicia schimperiana, Maytenus arbutifolia, Prunus africana and Caluasena anisata (Appendix). Importance Value Index analysis is used for setting conservation priority. Those species with lower IVI need high conservation efforts while those with higher IVI values need sustainable management.

4.5. Regeneration status of the woody plant Species
The density of seedling, sapling, and mature individuals of woody plants of the church forests in Dangila town was 548.1, 841.9, and 2180.6 stems ha⁻¹ respectively. Based on this result, and according to Dhaulkhandi et al. (2008), the regeneration status of the church forests of Dangila town is fair regeneration since the density of seedlings > or ≤ saplings ≤ adults. The ratio of seedling to mature individuals of woody species in the forest was 0.25:1; the ratio of seedling to saplings was 0.65:1 and sapling to mature individuals was 0.39:1.

Climatic factors and biotic interference influences the regeneration of different woody plant species in the forest. The lower-seedling density values than sapling could be due to biotic disturbances and competition for space, light, and nutrients limitation (Uriarte et al., 2005). The data analysis indicated that the density values for seedling and sapling of the population structure of the forest are low compared to the mature individuals and not agree with the normal patterns of the population. This implies the need to develop and implement forest management regimes in the area to promote healthy regeneration and sustainable use of the species. Compared to seedling individuals, there were more sapling individuals implying the growth of most seedlings to reach sapling stage since church forests are protected areas because of religion of the community.

4.6. Listing woody plant species under regeneration status classes
In order to use the regeneration analysis outcomes for priority setting, species in the study area were identified in to three regeneration status classes (Figure 6a-c). This was done based on the general patterns of distribution of seedling, sapling, and mature plants in the study area following the methods of Simon and Girma (2004).
Figure 6. The regeneration pattern of Dangila Church forest represented by some selected species.

Class I: **Olea europaea ssp. cuspidata** (Figure 6a): In this pattern, there are no seedling and sapling individuals, which substitute the mother plant. Species with such type of pattern are poor in their reproduction and recruitment potential because there are no juveniles, which tend to become a mother plant. This might be due to anthropogenic disturbances such as selective cutting of trees or the conditions of their microhabitats, which might not be conducive for their reproduction. *Olea europaea* ssp. *cuspidata*, *Argemone Mexicana*, *Acacia seyal*, *Citrus aurantifolia*, *Cupressus lusitanica*, *Debregeasia saeneb*, *Ficus thonningii*, *Ficus vasta*, *Juniperus procera*, *Myrica salicifolia*, *Osyris quadripartite*, *Prunus africana*, *Phytolaca dodecandra*, *Podocarpus falcatus*, *Rhoicissus tridentate*, *Stereospermum kunthianum*, and *Urera hypselondendron* are species in this pattern. The result implies that these species need first conservation priority.

Class II: **Grewia ferruginea** (Figure 6b): The pattern of distribution in this category shows low number of seedlings and saplings plants than mature mother plants. It exhibits a higher recruitment than regeneration. The species exhibiting this type of regeneration curve are *Grewia ferruginea*, *Syzygium guineense*, *Croton macrostachyus*, *Carisa spinarum*, *Rosa abyssinica*, *Mytenus ovatus*, *Millettia ferruginea* and others. The pattern indicates that the juvenile performances of these species are under strong factors of influence. These might be due to anthropogenic disturbances or environmental factors that change the seedling survival of plants.

Class III: **Acacia decurrens** (Figure 6c): This pattern of distribution shows higher number of seedling and saplings than the mother plants. The number of sapling is greater than the mature individuals of trees or shrubs. The distribution of seedling, sapling and mature plants is exhibited by inverted J-shape curves. The plant species included in this regeneration category are *Acacia decurrens*, *Mimusops kummel*, *Sida ovate*, and *Ocimum lamiiolium*. This pattern signifies that these species have good regeneration potential. Even though the regeneration potential is good, in the study area, selective clearance of *Acacia decurrens* was observed and nature of reproduction of *Mimusops kummel* and *Sida ovate* were low.

4.7. Phytogeographical comparison

The species diversity comparison of one forest with other forests is not feasible due to variations in size, method of survey used, and objective of the study among forests. However, the overall species richness of the forest can give more or less a general impression of their diversity and phytogeographical similarity. Regarding to this, Dangila Church forest was compared with three forests in the country to see the distribution pattern of woody species in the study area and to know the relative similarity of woody species composition (Table 2). These are D lifaqar Regional Park, Adey Amba enclosure forest and Yangudi-Rassa National park. D lifaqar Regional Park is located in Dodotta-Sire district in the Northeastern part of Arsi zone, Oromia Regional state, 125 km south of Addis Abeba. Its altitude ranges from 1400 to 2500 m.a.s.l. (Dereje, 2006), in which the present study area is included. Adey Amba enclosure forests located about 85 km East of Gonder between 12°31’–12°33’ North and 37°49’–37°44’ East. Its altitude ranges from 2090 to 2603 m.a.s.l. (Wondie et al., 2014). Yangudi-Rassa National park is found in the northeastern Ethiopia, Afar regional state 500 km from Addis Abeba with central coordinates 10°52’ North and 41°15’ East. Its elevation ranges from 400 to 1460 m.a.s.l. (Semere, 2010).
Table 2. Phytogeographical Comparison of Dangila church forests with other three forests in Ethiopia

| Forest                  | a    | b    | c    | Ss  | Reference         |
|-------------------------|------|------|------|-----|-------------------|
| Dilfaqar regional park  | 18   | 16   | 30   | 0.44| Dereje (2006)     |
| Adey Amba enclosure forest | 18   | 32   | 30   | 0.36| Wandie et al. (2014) |
| Yangudi-Rassa National park | 4    | 18   | 44   | 0.11| Semere (2010)    |
| Dangila Church forest    | _    | _    | _    | 1   | Present study     |

The overall similarity indices between Dangila Church forest and the other three forests in Ethiopia (Table 2) ranged between 0.11 and 0.44. The highest floristic similarity (0.44) was shared with Dilfaqar Regional Park. Range of altitude and climatic conditions of the park is very similar to Dangila Church forest. These common characteristics of the two forests contributed to their similarity in their vegetation. Even though Adey Amba forest is geographically closely related to Dangila Church forest, their similarity with their vegetation (0.36) is less compared to Dilfaqar Regional Park (0.44). This may be due to their difference in soil types and moisture variations.

The distribution range of a species is controlled by environmental factors for which the organism has the narrowest range of adaptability or control. Other important factors controlling species distribution apart from changes in the environmental conditions include evolutionary changes that greatly influence the potential range of species (Mwasumbi et al., 2000). This explains high dissimilarity between species confined to Dangila Church forest and Yangudi-Rassa forest and the two forests differ in their woody species probably due to different levels environmental conditions, soil type and other factors.

5. Conclusion and recommendation

5.1. Conclusion
Dangila Church forests are the remnant forests in the study area with relatively high species diversity and evenly distributed. The forests harbor 73 woody plant species belonging to 64 genera and 42 families. Trees had the largest proportion of life forms. The overall distribution of DBH classes of woody plants had inverted J-shape pattern that indicates the potential source of recruitment and ensures sustained regeneration of the forest if properly managed. However, the number of individuals in the higher diameter class decline considerably suggesting that there is human interference that can attribute to the unplanned and unsustainable exploitation of woody species in the forest by the community not only for Church building materials but also for generating income through plantations of some exotic plants such as Eucalyptus camaldulensis. Therefore, species with high diameter but in the lower density needs more attention to conservation. The forest is being heavily exploited for monoculture, charcoal production and house building. Nearly 80% of the total woody plant species of these church forests had lower IVI (lower than 5%) that needs priority for conservation. Dangila Church forests are rich in diversity because of its sacredness and religious thought of Ethiopian Orthodox Tewahido Church in Forest Management. The density of seeding, sapling and matured woody plants of these forests showed the need for conservation priority for most woody plant species of poor regeneration status.

5.2. Recommendation
Based on the results of the study, the following recommendations are made; (i) Species that have least IVI values like Mimusops kummel, Argemone Mexicana, Myrica salicifolia, Podocarpus falcatus, Acacia seyal, Prunus africana, and Ocimum lamiifolium need to be prioritized for conservation using in-situ and ex-situ conservation approaches. (ii) These remnant forests should be conserved
through in-situ conservation using communities and stakeholders for their relatively high composition and diversity of woody plant species. (iii) Collaboration of local communities, stakeholders, head priest, and diocese of Ethiopian Orthodox Tewahedo Churches (EOTC) is mandatory to reduce human encroachment to the church. (iv) Participatory Forest Management (PFM), rehabilitation and restoration activities have to be implemented for the integrity of sacred groves in addition to religious conservation mechanisms of the church. (v) To minimize human impacts on Dangila Church forest, awareness creation, and training on the value of forest resources and ecological consequences of deforestation is required for the community. (vi) Detailed ethnobotanical studies are also required to explore the source of medicinal plants and wealth of indigenous knowledge on the diverse group of plants and their implication in conservation. (vii) Finally, further studies on soil seed bank, seed physiology, soil fertility, and land use management system in the area are recommended.

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The authors declare that they have no competing interests.

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### Table A1: List of Plant Species Collected in Dangila Church Forest

| Family Name | Scientific Name | Habit | RD | RF | RDOM | IVI | Rank |
|-------------|----------------|-------|----|----|------|-----|------|
| Fabaceae    | Acacia abyssinica Hochst. | Wild | 2.1 | 0.0 | 13.7 | 21.4 | 3.2 |
| Fabaceae    | Acacia decurrens Willd. | Wild | 0.0 | 0.0 | 0.00 | 1.9 | 38 |
| Fabaceae    | Acacia inahai Steud. & Hochst. ex Benth. | Wild | 0.0 | 0.0 | 0.00 | 0.2 | 1.3 |
| Fabaceae    | Acacia seyal Del. | Wild | 0.0 | 0.0 | 0.00 | 0.2 | 72 |
| Euphorbiaceae | Acalypha psilostachya Hochst. ex A.Rich. | Wild | 0.0 | 0.0 | 0.00 | 0.2 | 72 |
| Acanthaceae | Acanthus pubescens Oliv. | Wild | 0.0 | 0.0 | 0.00 | 0.2 | 72 |
| Icacinaceae | Apodytes dimidiato E. Mey. | Wild | 0.0 | 0.0 | 0.00 | 0.2 | 72 |
| Fabricaceae | Arundo donax L. | Wild | 0.0 | 0.0 | 0.00 | 0.2 | 72 |
| Meliaceae   | Azadirachta indica A. Juss. | Wild | 0.0 | 0.0 | 0.00 | 0.2 | 72 |

(Continued)
| Scientific Name | Family Name | RD  | RF  | RDOM | IVI   | Rank |
|-----------------|-------------|-----|-----|------|-------|------|
| Acacia abyssinica Hochst. | Fabaceae | 4.5 | 3.2 | 13.72 | 21.4  |
| Bridelia micrantha Hochst. | Euphorbiaceae | 0.5 | 1.1 | 0.03  | 1.63  |
| Bridelia antidysenterica Mill. | Simaroubaceae | 1.9 | 2.9 | 0.06  | 4.86  |
| Calyptrina aurea (Aiton) Benth. | Fabaceae | 1.5 | 0.9 | 0.08  | 2.48  |
| Caluasena anisata (Wild.) Hook.f. ex Benth. | Rutaceae | 3.7 | 3.2 | 0.15  | 7.05  |
| Capparis tomentosa Lam | Capparidaceae | 2  | 2.7 | 0.12  | 4.82  |
| Carex steudneri Bock | Cyperaceae | 0.7 | 1.7 | 0.19  | 2.59  |
| Carisa spinarium L | Apocynaceae | 7.9 | 3.4 | 2.70  | 14.0  |
| Citrus aurantifolia Christm. | Rutaceae | 0.04 | 0.2 | 0.00  | 0.27  |
| Clerodendrum myricoides (Hochst.) R. Br. ex Vatke. | Lamiaceae | 0.7 | 1.6 | 0.03  | 2.33  |
| Clutia lanceolata Forssk. | Euphorbiaceae | 0.1 | 0.5 | 0.00  | 0.60  |

(Continued)
| Scientific Name | Family Name | RD  | RF  | RDOM | IVI    | Rank |
|-----------------|-------------|-----|-----|------|--------|------|
| Habit           | Acaia abyssinica Hochst. |     |     |      |        |      |
| S               | Coffea arabica L. |     |     |      |        |      |
| 43              | S            |     |     |      |        |      |
| Combretum malle R.Br. ex G.Don | Combretaceae | 0.2 | 0.5 | 0.02 | 0.72   | 55   |
| S               | Cordia africana Lam. |     |     |      |        |      |
| 64              | T            |     |     |      |        |      |
| Croton macrostachyus Del. | Euphorbiaceae | 3.6 | 3.6 | 5.64 | 12.8   | 6    |
| T               | Cupressus lusitanica Mill. |     |     |      |        |      |
| 21              | T            |     |     |      |        |      |
| Debregeasia saeneb (Forsk.) Hepper & J.R.I. Wood | Urticaceae | 0.4 | 0.7 | 0.04 | 1.14   | 45   |
| 35              | S            |     |     |      |        |      |
| Dombeya torrid subsp. Torrid | Sterculiaceae | 0.4 | 0.9 | 0.03 | 1.33   | 41   |
| T               | Davyalis abyssinica A. Rich. |     |     |      |        |      |
| 44              | S            |     |     |      |        |      |
| Dracaena steudneri Engl. | Dracaenaceae | 0.6 | 1.6 | 0.09 | 2.29   | 33   |
| T               | Ekebergia capensis Sparrm |     |     |      |        |      |
| Scientific Name | Family Name | RD | RF | RDOM | IVI | Rank |
|-----------------|-------------|----|----|------|-----|------|
| *Acacia abyssinica* Hochst. | Fabaceae | 4.5 | 3.2 | 13.7 | 21.4 | 21.4 |
| *Eucalyptus camaldulensis* Dehnh. | Myrtaceae | 2.9 | 3.49 | 4.9 | 1.6 | 3.94 |
| *Euphorbia abyssinica* J. F.Gmel. | Euphorbiaceae | 0.9 | 1.16 | 1.44 | 1.44 | 1.44 |
| *Ferula communis* L. | Apiaceae | 1.3 | 2.4 | 3.7 | 2.4 | 2.4 |
| *Ficus sur* Forssk. | Moraceae | 0.5 | 1.49 | 1.49 | 1.49 | 1.49 |
| *Ficus thornii* Bäume. | Moraceae | 0.1 | 0.19 | 0.19 | 0.19 | 0.19 |
| *Grewia ferruginea* H. | Tiliaceae | 1 | 0.5 | 0.5 | 0.5 | 0.5 |
| *Jasminum abyssinicum* Hochst. | Oleaceae | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |
| *Juniperus procera* Hochst. ex Endl. | Cupressaceae | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| *Justicia schimperiana* Hochst. | Acanthaceae | 7.1 | 5.4 | 5.4 | 5.4 | 5.4 |
| *Maytenus arbutifolia* (Hochst.exA.Rich.) R. Wilczek | Calabaraceae | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |

(Continued)
| Scientific Name | Family Name | RD | RF | RDOM | IVI | Rank |
|-----------------|-------------|----|----|------|-----|------|
| Acacia abyssinica Hochst. | Fabaceae | 4.5 | 3.2 | 13.72 | 21.4 |
| Maytenus obscura A. Rich. | Celastraceae | 1 | 2.5 | 0.23 | 3.73 |
| Millettia ferruginea Hochst. | Fabaceae | 2.3 | 2.9 | 1.55 | 6.75 | 11 |
| Mimusops kummel B. DC. | Sapotaceae | 0 | 0.2 | 0.47 | 0.67 |
| Myrica salicifolia A. R | Acanthaceae | 0 | 0.2 | 0.00 | 0.20 | 71 |
| Myrtenus ovatus | Celastraceae | 2 | 2.9 | 0.47 | 5.37 |
| Ocimum lamifolium Hochst. ex. Benth. | Lamiaceae | 0.1 | 0.2 | 0.28 | 0.58 | 62 |
| Olea europaea ssp. cuspidata L | Oleaceae | 0.1 | 0.5 | 0.04 | 0.64 |
| Osyris quadripartita Decn. | Santalaceae | 0.4 | 0.7 | 0.03 | 1.13 | 46 |
| Pavetta abyssinica Fresen. | Rubiaceae | 0.8 | 1.8 | 0.02 | 2.62 |
| Phytolaca dodecandra L. Her | Phytolacaceae | 0.8 | 1.1 | 0.01 | 1.91 | 36 |
| Podocarpus falcatus Thumb. | Podocarpaceae | 0 | 0.2 | 0.00 | 0.20 |

(Continued)
| Scientific Name        | Family Name       | RD    | RF  | RDOM | IVI   | Rank |
|-----------------------|-------------------|-------|-----|------|-------|------|
| Acaia abyssinca Hochst. | Fabaceae          | 4.5   | 3.2 | 13.72| 21.4  | 70   |
| Premna schimperi Engl. | Verbenaceae       | 0.1   | 0.5 | 0.02 | 0.62  | 59   |
| Prunus persica L.     | Rosaceae          | 1.8   | 2.9 | 2.38 | 7.08  | 9    |
| Prunus africana (Hook. f.) | Rosaceae     | 0     | 0.2 | 0.01 | 0.21  | 69   |
| Pterobium stellatum L. | Fabaceae          | 0.3   | 0.2 | 0.28 | 0.78  | 53   |
| Qmnrhus glutinosa M.   | Anacardiaceae     | 1.9   | 2.7 | 0.39 | 4.99  | 15   |
| Rhamnus prinoides L. Herl. | Rhamnaceae | 0.2   | 0.5 | 0.00 | 0.70  | 56   |
| Rhoicissus tridentate (L.f.) Wild & R.B. Drumm | Vitaceae | 0.1   | 0.2 | 0.28 | 0.58  | 63   |
| Ricinus communis L.    | Euphorbiaceae     | 0.1   | 0.2 | 0.00 | 0.30  | 67   |
| Rosa abyssinica Lindley | Rosaceae         | 2     | 2.0 | 0.61 | 4.61  | 18   |
| Rubus apetalus Poir.   | Rosaceae          | 1.1   | 1.4 | 0.00 | 2.50  | 30   |
| Rumex nervusus Vahl    | Polygonaceae      | 0.4   | 0.5 | 0.00 | 0.90  | 50   |

(Continued)
| Scientific Name | Family Name | RD  | RF  | RDOM | IVI  | Rank |
|-----------------|-------------|-----|-----|------|------|------|
| Acacia abyssinica Hochst. | Fabaceae | 4.5 | 3.2 | 13.72 | 21.4 |
| Sesbania sesban L. Merr. | Fabaceae | 0.2 | 0.7 | 0.03 | 0.93 |
| Sida ovate Forsk. | Malvaceae | 0.2 | 0.7 | 0.00 | 0.90 | 51 |
| Stereospermum kunthianum Cham | Euphorbiaceae | 0.4 | 1.4 | 0.11 | 1.91 |
| Syzygium guineense Wild.DC. | Myrtaceae | 5.1 | 2.3 | 19.14 | 26.5 | 2 |
| Urena hypselondendron A. Rich. | Urticaceae | 1.1 | 2.0 | 0.01 | 3.11 |
| Vernonia amygdalina Del. | Asteraceae | 2.3 | 2.7 | 0.39 | 5.39 | 13 |
| Vernonia auriculifera Hiern. | Asteraceae | 2.3 | 3.4 | 0.10 | 5.80 |

Where: T = Tree, T/S = Tree/Shrub, S = Shrub, C = Climber, RD = Relative density, RF = Relative frequency, RDOM = Relative dominance, and IVI = Important value index.
