Species composition, structure and regeneration status of woody plant species in a dry Afromontane forest, Northwestern Ethiopia

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Abstract: Dry evergreen Afromontane forests are the most threatened in Ethiopia due to agricultural land expansion as they are exposed to high population pressure and thus, conservation measures should be based on scientific evidence since resources for nature conservation are limited. We evaluated the species composition, structure and regeneration status of woody plant species at Gelawoldie community forest. This was analyzed from 32 quadrats laid down in belt transect, each with 400 m² and 25 m² for trees and shrubs, and seedlings and saplings, respectively using systematic sampling method. Diversity was analysed using Shannon-Wiener diversity index. A total of 59 woody plant species in 49 genera and 38 families were identified. Of these, 35.5%, 50.8% and 13.5% were trees, shrubs and climbers, respectively. The diversity and evenness of the forest were 3.8 and 0.9, respectively. Moreover, the forest had total mean stand density of 2016 stems ha⁻¹ and basal area of 93.8 m²ha⁻¹. More than 61% of the woody plant species had lower than 5% importance value index (IVI), while the remaining 39% had ≥ 5%. The overall results of the present study revealed higher number of individuals at the lowest diameter (2.5–10 cm) and height classes and progressively declined numbers in higher classes yielding reverse J-shaped distribution pattern. This shows that the forest had healthy regeneration. However, analysis from individual woody plant structure, and count of seedlings and saplings showed that about 17.7% and 5.3% of the species including the endemic have fair and poor regeneration, respectively.

ABOUT THE AUTHOR

Getie Mucheye is a botanist by specialization currently working as a Wildlife Development and Protection expert in Amhara National Regional State Environment, Forest and Wildlife Protection and Development Authority. The author has long years of experience in Meteorology, Culture, Tourism and Parks Development. He is more enthusiastic to conduct research and pursue his further study in the fields of plant diversity analysis, effect of climate change on diversity, conservation and ecosystem services.

PUBLIC INTEREST STATEMENT

The present study was conducted to evaluate the woody plant diversity and regeneration status of Gelawoldie community forest attributed to the high risk of destruction pressure from agricultural land expansion, overgrazing and selective cutting. The study has found out that the forest had relatively higher diversity, however with different regeneration status. The findings of this study will serve as a baseline data to design and implement data-based and better forest management plans to responsible bodies. Moreover, the findings remind the surrounding community about the status of the forest and the human factors affecting the future and the risk posed on the services derived from the forest. Timely actions from all the stakeholders will contribute a lot for the continuity of the forest.
Thus, there is a strong need for conservation measures that have to start by identifying the major drivers of low regeneration and the subsequent loss.

Subjects: Agriculture and Food; Botany; Plant Biology; Plant Ecology; Biodiversity & Conservation

Keywords: diversity index; height class; importance value index; regeneration; saplings; seedlings

1. Introduction
Ethiopia belongs to the 25 biodiversity-rich countries in the world. There are 34 biodiversity hotspots worldwide, of which two; Eastern Afromontane and Horn of Africa are found in Ethiopia. This utmost is ascribed to the great geographical diversity particularly altitude that consequently determines macro and micro climatic variability and creates environments that support a wide variety of flora and fauna (Ethiopia Biodiversity Institute [EBI], 2014). Furthermore, Ethiopia harbours a high degree of endemism with 544 endemic plant taxa, representing 10% of the overall flora (Kelbessa & Demissew, 2014). Approximately 16.7% of the flora represents woody plants, of which 30% are trees mainly indigenous (Tona, 2016). Similar to other biological systems, indigenous plant species have adapted through several years of evolution and serve as womb for the development of biodiversity and keystone natural resources such as soils and water (Negash, 2010).

Historical records indicate that an equivalent of 35–40% of Ethiopia’s land area had once been covered by natural high forests. However, data from airborne and satellite remote sensing have revealed a natural high forest cover of 4.75% and 0.20% in the 1970s and 1980s, respectively (Reusing, 2000). According to Food and Agriculture Organization of the United Nations (2010), approximately 11% of the total area of Ethiopia has been covered by forests of all types; high forest, open forest, plantations etc. The forest cover has shown a tremendous decrease from 1990 to 2000 and declined to 4% of the total land area of Ethiopia (EarthTrends, 2003). This indicates the sharp and radical decline in the forest cover of the country through years. Consistently, the results of comparative studies have found small closed/high forest cover percentage of the total land area in Amhara, Oromia, Tigray and southern regions (Homeier, 2011). The closed/high forest cover showed a 44,000 ha decrease per year from 2005 to 2009, resulting in a 14.6% change (Homeier, 2011). However, the reduction is more severe in Amhara and Tigray region while open and mosaic forest covers increased as per forest definition of Mayaux et al. (2003) and Homeier (2011). Among the forest types in Ethiopia, dry evergreen Afromontane forest and grassland complex that occur above 1800 m and below 3000 m cover most of the total land area. This forest is found in areas where Ethiopian highland agriculture developed thousands of years ago and is inhabited by the majority of the population in the country (Friis et al., 2010; Gurmessa, 2011). The distribution of dry evergreen Afromontane forests and grassland coincides with areas that people have dominantly been practicing cereal-based agriculture. This has resulted in a significant destruction pressure on the forests because of the exponential population growth and the accompanied demand for fuelwood and land for agriculture (Friis et al., 2010; Gurmessa, 2011).

Similarly, the Amhara National Regional State (ANRS) in Northwestern Ethiopia shares these phenomena. The region has a total area of approximately 170,052 km2, of which 2%, 27% and 6% is covered by high forest, shrubland and woodland, respectively (Sisay et al., 2017). More than 60% of the total land area in ANRS is covered by Afromontane vegetation, of which dry Afromontane forests occupy the largest proportion (Wassie, 2017) approximately 18% (Homeier, 2011). The dry Afromontane forests in the region are found as remnant forests in the landscape either as protected state or Ethiopian Orthodox church forests (Wassie, 2017). These forests are under increasing pressure by human population through farmland expansion, tree harvesting, urbanization and others.
These anthropogenic activities have caused a significant forest cover change over the years. There has been a dramatic decline in forest cover between 1987 and 1999 in ANRS due to the extended transition period soon after the fall of the Derge regime (Alemneh et al., 2019). This period was characterized by land grabbing for farm expansion and grazing, encroachment of agriculture in higher elevation and weakening of communal land management practices (Alemneh et al., 2019). From 1999 to 2014, the tree cover change was static. The tree cover change has been intense and an overall increase of 3% was reported from 2014 to 2017. However, the increment has been attributed entirely to a shift from mixed crop and livestock agriculture to plantation forestry dominated by eucalyptus (Alemneh et al., 2019). Studies have shown that there are about 209, 799 ha of plantations, most of which are covered by eucalyptus (Wassie, 2017). The development of eucalyptus plantation has increased rapidly and suppresses the regeneration and growth of indigenous species, causes loss of biodiversity, soil quality and moisture content in natural and sacred church forests in the region (Chanie et al., 2013; Mekonnen, 2019).

Evidence strongly suggests the need for conservation actions so as to protect and save threatened endemic and indigenous plant species in dry evergreen Afromontane forests of ANRS. The successful conservation and better management of forests require up-to-date information on the forests such as vegetation composition, structure, abundance, diversity and status. This is due to the fact that the efforts invested to protect plant diversity must be prioritized. Moreover, vegetation data are lacking in the study area. The objective of this study was to evaluate woody plant species diversity, structure and regeneration status of Gelawoldie community forest and compare with other forests in ANRS, Northwestern Ethiopia.

2. Materials and methods

2.1. Description of the study area

The study was undertaken at Gelawoldie community forest (Figure 1), which is found in Yilmana Densa district of West Gojjam zone of the ANRS, Northwestern Ethiopia. Geographically, the district is situated at 11°29'59.99" N latitude and 37°19' 60.00" E longitude. The district covers a total area of 99 180, of which 56% undulating, 20% mountainous, 8% gorge and 16% plateau with the highest plateau of Mount Adama (Taddege, 2019).

Gelawoldie community forest is 45 km from Bahir Dar, the capital city of ANRS. It is found in Konch Gosheye kebele of Yilmana Densa district and bordered by Kotet river in the north (Figure 1). The coordinates of the forest are between 12°41’14.4”–12°41’27.32” N latitude and 32°94’80.0”–
32° 95'52.76" E longitude. It covers over 36.9 ha. The forest has an average altitude of 2343 metre above sea level (m.a.s.l.)

Rainfall and temperature data for Yilmana Densa district for the past almost two decades (2000–2018) were obtained from Western Amhara Meteorology Service Center (2018) in Bahir Dar. According to the data, the mean annual maximum temperature is 25.6°C and the mean minimum temperature is 10.4°C (Figure 2). The hottest month is May with maximum temperature of 28.4°C and the coldest month is January with minimum temperature of 6.1°C. The district has unimodal rainy season from June to September and has an average annual rainfall of about 1171.9 mm (Figure 2)

2.2. Sampling design
Reconnaissance survey was conducted through field visits and physical observation in order to get the general view of site conditions and identify sampling sites. Systematic sampling method was employed to lay the quadrats for inventory of woody species in the study area. A total of six belt transects each with 100 m spacing were laid down along an altitudinal gradient from the bottom to the top of the forest. The first belt transect was laid out randomly at one side of the forest along the gradient. A total of 32 quadrats of 20 m × 20 m (400 m2), 4–6 per belt transect were established. Quadrats were 50 m far apart. Each belt transect consisted of different numbers of quadrats depending on their length ranging from 230 to 420 m. Physiographic variables such as altitude, aspect and slope were recorded for each quadrat. However, variations in species composition were not recorded which might be due to narrow altitudinal range (Data not shown). Data on diversity of trees, shrubs and woody climbers were collected following Kent and Coker (1992). Diversity was determined using Shannon-Wiener diversity index which measures both species richness and evenness/abundance. This technique was selected as it is not sensitive to sample size. Sub-quadrats of 5 m× 5 m were laid down at corners and centre of each 20 m × 20 m quadrat to collect data on seedlings and sapling.

2.3. Vegetation data collection
All the woody plant species in each quadrat were recorded and documented in vernacular names. For plant species that were difficult to identify in the field, plant samples with all parts were collected, pressed, dried and mounted. The voucher specimens were identified at a species level using authenticated specimens, published flora volumes of Ethiopia and Eritrea, and experts available in the National Herbarium, Addis Ababa University, Ethiopia. The structural attributes of woody species in the forest were evaluated in terms of DBH, height, density and basal area. Diameter was measured for every individual tree and shrub with DBH greater than 2.5 cm at breast height or 1.3 m above ground using a diameter tape. Where the tree was branched at breast height or below, the diameter was measured separately for the branches and averaged. In cases where tree trunk buttressed, diameter measurements were taken just above the buttresses. Height was measured for every individual tree
and shrub with DBH > 2.5 cm and height > 3 m using Suunto clinometer. Where measuring tree and shrub height with clinometer was a challenge, these parameters were estimated visually. Seedlings (height = 1.0 m) and saplings (height greater than 1.0 m and less than 3 m) were also counted and recorded as described by Senbeta and Teketay (2001). DBH values were converted into diameter to calculate the basal area of the species. In each quadrat, the species list and number of trees, seedlings and saplings were recorded to determine the regeneration status.

2.4. Data analysis

2.4.1. Diversity analysis
Floristic data were analyzed using the Shannon–Wiener's diversity index ($H'$) as follows:

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

Where; $p_i$ is the proportion ($n/N$) of individuals of one particular species found ($n$) divided by the total number of individuals found ($N$), $\ln$ is the natural log, $\Sigma$ is the sum of the calculations, and $s$ is the number of species (Shannon & Wiener, 1949).

Shannon’s Equitability (EH) or Evenness was determined by:

$$EH = \frac{H}{H_{max}} = \frac{H}{\ln s}$$

Where; $S$ is the number of species recorded (Shannon & Wiener, 1949).

2.4.2. Analysis of vegetation structure
The structure of the vegetation was analyzed by computing species density, DBH, height, basal area, frequency and important value index (IVI). The DBH and tree height were classified into DBH and height classes as described in Kent and Coker (1992) and, Kuma and Shibru (2015).

DBH = ($C/m$) where, $C$ is circumference and $\pi$ is $\approx 3.14$

Frequency($F$) = \(\frac{\text{number of quadrats in which species A occurs}}{\text{total number of quadrats sampled}}\)

Relative Frequency($RF$) = \(\frac{\text{frequency value for species A}}{\text{total of all frequency values for all species}} \times 100\)

Density($D$) = \(\frac{\text{number of individuals of species A counted}}{\text{area sampled in meter square}}\)

Relative density($RD$) = \(\frac{\text{number of individuals of species A counted}}{\text{total number of individuals in the area}} \times 100\)

Basal area (BA) = $\pi D^2/4$ = (DBH/2)$^2\pi$ = $C^2/4\pi$ $C$ = Circumference, $D$ = diameter, DBH is diameter at breast height, $\pi$ $\approx 3.14$

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

Relative dominance(RDO) = \(\frac{\text{dominance for species A}}{\text{total dominance for all species}} \times 100\)

Importance values index (IVI) is a unitless score calculated by adding the relative dominance (RDO), relative density (RD) and relative frequency (RF) of a species (Kent & Coker, 1992; Mueller-Dombois & Ellenberge, 1974). It is useful to compare the ecological significance of a species (Lamprecht, 1989), and a good index for summarizing vegetation characteristics and ranking species for management and conservation practices.
2.4.3. Regeneration status analysis

The regeneration status of the trees, shrubs and woody climbers was determined by computing density ratios between seedlings and mature individuals, seedlings and saplings, and sapling and mature individuals (Dhaulkhandi et al., 2008).

2.4.4. Similarity and dissimilarity analysis

Sørensen is the most common binary similarity coefficient used to analyze similarity between different forests. Sørensen’s coefficient was calculated as:

\[ Ss = \frac{2a}{(a+b+c)} \] (Sørensen, 1948)

\[ Ss = \text{Sørensen’s similarity coefficient}; \ a = \text{number of species common to both forests}; \ b \text{ and } c = \text{number of species in forests } b \text{ and } c \]

3. Results and discussion

3.1. Diversity of woody plant species

A total of 59 woody plant species belonging to 49 genera and 38 families were recorded and identified in the Gelawoldie community forest. The life form distribution of these species was 21 (35.6%) trees, 3(50.8%) shrubs and 8(13.5%) woody climbers (Table 1). Nearly similar numbers of woody plant species were reported by Fisaha et al. (2013) in Wof Washa natural forest, Tadele et al. (2014) in Zêngenê forest, Birhanu et al. (2018) in Amoro forest and Ayanaw and Dalie (2018) in Yemrehane Kirstos forest. The study forest has greater number of species than Shello Giorgis (Ayalew et al. 2020), Awi zone (Gebeyehu et al., 2019), Weiramba (Teshager et al., 2018) and Wanzaye (Getnet 2018) dry Afromontane forests of Amhara Region. However, Gelawoldie forest has considerably lower species richness than Tara Gedam and Abebaye (Zegeye et al., 2011) and Mahbere Sillassie Monastery forests (Habtamu, 2017). Fabaceae and Asteraceae were the most species-rich families comprising of 5(8.78%) species each followed by Capparidaceae and Euphorbiaceae with 3(5.26%) species each (Table 1). On the other hand, the genus Vernonia had the richest species in the study area followed by Acacia, Acanthus, Jasminum and Maytenus. Mekonen et al. (2015) and Habtamu (2017) have found Fabaceae as the dominant family in Waynuwuha natural forest and Mahbere Sillassie Monastery forest, respectively. The variations in species composition are probably due to differences in extent of protection, geographical location and different level of awareness in the communities. This could be inferred from the higher species richness in Tara Gedam and Mahbere Sillassie Monastery which received a relatively better protection. In Gelawoldie community forest, Juniperus procera and Eucalyptus camaldulensis were found outside the sampling quadrats, which might be an indication for potential expansion of exotic species to the forest. This calls for swift conservation intervention actions. From the total woody species, Acanthus sennii, Clemanthus longicauda, Laggea tomentosa categorized under near threatened (NT) and Vernonia leopoldii classified under least concern (LC) category were endemic to Ethiopia (Vivero et al., 2005). The results are in agreement with those of Zewdie (2013) and lower than those reported in Sesa Mariam Monastery (Mesheha et al., 2015). The relatively high endemics in Gelawoldie community forest may be due to the fact that the forest shares some characteristics of both moist Afromontane and dry Afromontane forests (Friis et al., 2010).

3.2. Species diversity and evenness

Although the study forest is managed mainly by the community and had higher exposure to anthropogenic activities such as selective tree cutting, grazing and agricultural expansion, the overall Shannon–Wiener diversity and evenness indices were high; 3.8 and 0.9, respectively (Table 2). The diversity and abundance results of the present study are relatively larger than other similar forests such as Sinko community forest (Zewdie, 2013), Yemrehane Kirstos church forest (Ayanaw & Dalie, 2018) and Amoro forest (Birhanu et al., 2018). This high diversity and evenness reflect improved forest management in the community. Comparison of the species composition of Gelawoldie community forest to other dry evergreen Afromontane forests showed a range of
Table 1. List of woody plant species in Gelawoldie community forest with their family name, mean densities, relative densities (%), frequency, relative frequency (%), dominance (Do), relative dominance (%), IVI (%) and habit

| Scientific Name            | Family      | Density | RD  | F   | RF  | Do  | RDO | IVI  | Habit | Collection No |
|----------------------------|-------------|---------|-----|-----|-----|-----|-----|------|-------|---------------|
| Acacia abyssinica Hochst. ex.Benth. | Fabaceae    | 78      | 3.7 | 0.7 | 4.0 | 6.0 | 4.3 | 12.0 | Tree  | GM001         |
| Acacia lahai Steud. &Hochst. ex Benth | Fabaceae    | 78      | 3.7 | 0.6 | 3.4 | 7.0 | 5.0 | 12.1 | Tree  | GM005         |
| Acanthus eminens C.B Clarke | Acanthaceae | 20      | 0.9 | 0.1 | 0.8 | 0.0 | 0.0 | 1.7  | Shrub | GM054         |
| Acanthus sennii Chiave     | Acanthaceae | 19      | 0.9 | 0.2 | 1.0 | 0.0 | 0.0 | 1.9  | Shrub | GM026         |
| Albizia schimperiana Oliv. | Fabaceae    | 76      | 3.6 | 0.8 | 4.6 | 5.0 | 3.6 | 11.8 | Tree  | GM008         |
| Berkheya spekeana Oliv.   | Asteraceae  | 9       | 0.4 | 0.1 | 0.8 | 0.0 | 0.0 | 1.2  | Shrub | GM015         |
| Bersama abyssinica Fresen. | Meliaceae   | 132     | 6.2 | 0.9 | 5.4 | 7.0 | 5.0 | 16.6 | Tree  | GM011         |
| Bridelia micrantha (Hochst.)Baill | Euphorbiaceae | 68  | 3.2 | 0.5 | 3.0 | 7.0 | 5.0 | 11.2 | Tree  | GM019         |
| Brucea antidy senteric J.F. Miller | Simaroubaceae | 22 | 1.0 | 0.3 | 1.7 | 0.0 | 0.0 | 2.7  | Shrub | GM047         |
| Buddleja polyspachya Fresen. | Buddlejaceae | 19  | 0.9 | 0.3 | 1.5 | 3.0 | 2.1 | 4.5  | Tree  | GM033         |
| Calpurnia aurea (Alt.) Benth. | Fabaceae    | 105     | 4.9 | 0.7 | 4.2 | 0.0 | 0.0 | 9.1  | Shrub | GM024         |
| Capparis tormentosa Lam.  | Capparidaceae | 26 | 1.2 | 0.3 | 1.9 | 0.0 | 0.0 | 3.1  | Climber | GM009       |
| Carissa edulis (Forssk.) Vahl. | Apocynaceae | 101     | 4.7 | 0.6 | 3.6 | 8.0 | 5.7 | 14   | Shrub | GM006         |
| Clausena anisata (Wild.) Benth. | Rutaceae    | 27      | 1.3 | 0.2 | 1.0 | 0.0 | 0.0 | 2.3  | Shrub | GM020         |
| Clematis longicauado Steude.ex.A.Rich | Ranunculaceae | 20 | 0.9 | 0.3 | 1.5 | 0.0 | 0.0 | 2.4  | Climber | GM034       |
| Clerodendron myricoides (Hochst.) R.Bre exVatke. | Verbenaceae | 12      | 0.6 | 0.1 | 0.8 | 0.0 | 0.0 | 1.4  | Shrub | GM048         |

(Continued)
| Scientific Name                  | Family                        | Density | RD | RF | Do | RDO | IVI | Habit | Collection No |
|----------------------------------|-------------------------------|---------|----|----|----|-----|-----|--------|---------------|
| **Table 1. (Continued)**         |                               |         |    |    |    |     |     |        |               |
| Clutia abyssinica                | Euphorbiaceae                 | 44      | 2.1| 0.3| 2.1| 4.2 | 0.0 | Shrub  | GM0036        |
| Croton delavayi                   | Euphorbiaceae                 | 76      | 3.6| 0.9| 5.5| 2.9 | 12   | Tree   | GM002         |
| Cyanodes adwarii                 | Euphorbiaceae                 | 26      | 1.2| 1.3| 5.0| 3.6 | 6.1  | Shrub  | GM0018        |
| Convolvulus abyssinica           | Euphorbiaceae                 | 18      | 1.8| 0.2| 0.9| 8.1 | 5.8  | Tree   | GM0043        |
| Dovyalis abyssinica              | Euphorbiaceae                 | 39      | 1.8| 0.2| 1.3| 8.0 | 5.7  | Tree   | GM031         |
| Dovyalis abyssinica              | Euphorbiaceae                 | 18      | 0.8| 0.1| 0.8| 8.0 | 5.7  | Tree   | GM029         |
| Ekebergia capensis               | Meliaceae                     | 58      | 2.7| 0.3| 1.7| 10.0| 7.1  | Tree   | GM029         |
| Eucalyptus camaldulensis         | Myrtaceae                     | 24      | 1.1| 0.0| 0.0| 1.1 | 1.1  | Tree   | GM049         |
| Feuer canta L.                   | Moraceae                      | 11      | 0.5| 0.1| 0.4| 0.0 | 0.0  | Shrub  | GM056         |
| Feuer canta L.                   | Moraceae                      | 15      | 0.7| 0.2| 1.0| 0.0 | 0.0  | Shrub  | GM007         |
| Feuer canta L.                   | Moraceae                      | 14      | 0.7| 0.1| 0.5| 0.0 | 0.0  | Shrub  | GM032         |
| Feuer canta L.                   | Moraceae                      | 12      | 0.6| 0.1| 0.6| 0.0 | 0.0  | Shrub  | GM046         |
| Feuer canta L.                   | Moraceae                      | 13      | 0.6| 0.2| 1.0| 0.0 | 0.0  | Shrub  | GM016         |
| Feuer canta L.                   | Moraceae                      | 18      | 0.8| 0.1| 0.6| 0.0 | 0.0  | Shrub  | GM009         |
| Feuer canta L.                   | Moraceae                      | 13      | 0.6| 0.2| 1.0| 0.0 | 0.0  | Shrub  | GM016         |
| Feuer canta L.                   | Moraceae                      | 18      | 0.8| 0.1| 0.6| 0.0 | 0.0  | Shrub  | GM009         |
| Feuer canta L.                   | Moraceae                      | 14      | 0.7| 0.1| 0.4| 0.0 | 0.0  | Shrub  | GM028         |
| Feuer canta L.                   | Moraceae                      | 24      | 1.1| 0.1| 1.1| 1.1 | 1.1  | Shrub  | GM010         |
| Scientific Name                      | Family           | Density | RD  | F   | RF  | Do  | RDO | IVI  | Habit | Collection No |
|--------------------------------------|------------------|---------|-----|-----|-----|-----|-----|------|-------|---------------|
| *Maytenus arbutifolia* (Hochst.ex.A.Rich.) Wilczek. | Celastraceae    | 69      | 3.2 | 0.5 | 2.9 | 0.0 | 0.0 | 6.1  | Shrub | GM013         |
| *Maytenus obscura* (A. Rich.) Cuf   | Celastraceae    | 29      | 1.4 | 0.2 | 1.2 | 7.0 | 5.0 | 7.6  | Tree  | GM004         |
| *Myrsine Africana* L.               | Myrsinaceae     | 25      | 1.2 | 0.2 | 1.3 | 0.0 | 0.0 | 2.5  | Shrub | GM041         |
| *Ocimum lammifolium* Hochst.ex.Benth. | Lamiaceae       | 18      | 0.8 | 0.1 | 0.8 | 0.0 | 0.0 | 1.6  | Shrub | GM058         |
| *Olinia rochetiana* A.Juss.         | Oliniaceae      | 18      | 0.8 | 0.1 | 0.8 | 6.0 | 4.3 | 5.9  | Tree  | GM049         |
| *Osyris quadripartita* Decn.        | Santalaceae     | 95      | 4.5 | 0.7 | 4.2 | 6.0 | 4.3 | 13   | Tree  | GM025         |
| *Otostegia tomentosa* (Chiov.)      | Lamiaceae       | 8       | 0.4 | 0.1 | 0.4 | 0.0 | 0.0 | 0.8  | Shrub | GM014         |
| *Phytolacca dodecandra* L. Her      | Phytolaccae     | 9       | 0.4 | 0.1 | 0.5 | 0.0 | 0.0 | 0.9  | Climber | GM057       |
| *Pittosporum viridiflorum* Sims     | Pittosporaceae  | 74      | 3.5 | 0.5 | 2.9 | 7.0 | 5.0 | 11.4 | Tree  | GM053         |
| *Premna schimperi* Engl.             | Verbenaceae     | 6       | 0.3 | 0.1 | 0.4 | 0.0 | 0.0 | 0.7  | Shrub | GM044         |
| *Protea gaguedi* Gmel.               | Proteaceae      | 21      | 1.0 | 0.2 | 1.3 | 0.0 | 0.0 | 2.3  | Shrub | GM027         |
| *Petrorhagia stellatautum* (Forsk.) Brenan. | Fabaceae      | 44      | 2.1 | 0.5 | 2.9 | 0.0 | 0.0 | 5.0  | Climber | GM035       |
| *Ritchiea albersii* Gilg.            | Capparidaceae   | 8       | 0.4 | 0.1 | 0.8 | 0.0 | 0.0 | 1.2  | Shrub | GM052         |
| *Ritchiea steudnerii* Gilg.          | Capparidaceae   | 29      | 1.4 | 0.3 | 1.5 | 6.0 | 4.3 | 7.2  | Tree  | GM030         |
| *Rhus vulgaris* Meikle               | Anacardiaceae   | 26      | 1.2 | 0.3 | 1.9 | 4.0 | 2.9 | 6.0  | Tree  | GM022         |
| *Rosa abyssinica* Lindley            | Rosaceae        | 98      | 4.6 | 0.8 | 4.9 | 6.0 | 4.3 | 13.8 | Shrub | GM003         |
| *Rubus opetalus* Poir.               | Rosaceae        | 17      | 0.8 | 0.2 | 1.0 | 0.0 | 0.0 | 1.8  | Climber | GM050        |
| *Rumex nervosus* (Vaht)              | Polygonaceae    | 23      | 1.1 | 0.2 | 1.2 | 0.0 | 0.0 | 2.3  | Shrub | GM021         |
| *Sida ovata* Forsk.                  | Malvaceae       | 37      | 1.7 | 0.2 | 1.2 | 0.0 | 0.0 | 2.9  | Shrub | GM007         |

(Continued)
| Scientific Name                        | Family                | Density | RD | RF | Do  | RDO | IVI  | Habit | Collection No |
|---------------------------------------|-----------------------|---------|----|----|-----|-----|------|-------|---------------|
| Solanum indicum L.                    | Solanaceae            | 9       | 0.4| 0.1| 0.5 | 0.0 | 0.0  | 0.9   | GM055         |
| Stereospermum kunthianum Cham         | Bignoniaceae          | 8       | 0.4| 0.1| 0.4 | 0.0 | 0.0  | 0.0   | GM042         |
| Stephania abyssinica (Qu.- Dill&A.Rich) Walp. | Menispermaceae        | 15      | 0.7| 0.1| 0.5 | 0.0 | 0.0  | 1.2   | GM039         |
| Vernonia amygdalina Del.              | Asteraceae            | 26      | 1.2| 0.2| 1.2 | 0.0 | 0.0  | 1.8   | GM051         |
| Vernonia myriantha Hoekf.             | Asteraceae            | 52      | 2.4| 0.2| 2.2 | 3.0 | 4.1  | 1.7   | GM038         |
| Vernonia quartiniana A. Rich.         | Asteraceae            | 46      | 2.2| 0.3| 1.9 | 1.5 | 4.1  | 1.7   | GM046         |

NB—The zero values included in the table are not actually zero, but very small numbers close to zero.
Table 2. Comparison of species diversity, evenness indices and Sorensen similarity index among different dry evergreen Afromontane forests in Ethiopia

| Forest                  | $H'$ | $EH$ | a   | b   | c   | $Ss$ | Sources                      |
|-------------------------|------|------|-----|-----|-----|------|------------------------------|
| Sinko community         | 2.8  | 0.6  | -   | -   | -   | -    | Zewdie (2013)                |
| Amaro                   | 3.3  | 0.9  | 25  | 32  | 34  | 0.43 | Birhanu et al. (2018)        |
| Yemrehane Kirstos church| 2.9  | 0.8  | 14  | 25  | 45  | 0.23 | Ayanaw and Dalle (2018)      |
| Angada                  | 3.4  | 0.4  | 27  | 32  | 60  | 0.37 | Alemu (2011)                 |
| Gelawoldie community    | 3.8  | 0.9  | -   | -   | -   | -    | Present study                |
| Sesa Mariam Monastery   | 3.8  | 0.9  | -   | -   | -   | -    | Meshesha et al. (2015)       |
| Wof Washa               | 4.0  | 0.9  | 26  | 82  | 33  | 0.31 | Yirga et al. (2019)          |
| Yegof                   | 2.3  | 0.6  | 18  | 38  | 41  | 0.31 | Woldearegay et al. (2018)    |
| Zengena                 | 2.7  | 0.7  | 18  | 32  | 41  | 0.33 | Tadele et al. (2014)         |

$Ss = $ Sorensen coefficient
similarity indices (Table 2). The resemblance was found generally moderate. The strongest similarity was recorded with Amoro forest (Birhanu et al., 2018) followed by Angada (Alemu, 2011) and Zengena forests (Tadele et al., 2014). The weakest similarity was found with Yemrehane Kirstos church forest (Table 2). The strongest similarity with Amoro forest might be attributed to geographical proximity and resemblance in climatic factors (Friis et al., 2010). The two forests are found in adjacent districts and seed dispersal by animals can occur.

Table 3. Stand densities of Gelawoldie community forest and other Afrotropical forests at two DBH classes

| Forest                  | DBH ≥10 and ≤ 20 cm(a) | DBH>20 cm(b) | a/b | Sources            |
|-------------------------|------------------------|--------------|-----|--------------------|
| Sinko Community         | 206.0                  | 104.0        | 2.0 | Zewdie (2013)      |
| Chilma                  | 638.0                  | 250.0        | 2.6 | Beche (2011)       |
| Denkoro Chaka           | 526.0                  | 285.0        | 1.9 | A. Ayalew et al. (2006) |
| Angada                  | 372.8                  | 252.0        | 1.5 | Alemu (2011)       |
| Gelawoldie community    | 170.0                  | 73.0         | 2.3 | Present study      |

3.3. Analysis of structural characteristics

The total mean stand density of woody species was 2016 individuals ha⁻¹, of which 631 were trees with DBH > 2.5 cm. *B. abyssinica* was the most abundant species followed by *C. aurea, C. edulis* and *R. abyssinica* (Table 1). Individuals with DBH class ≥10 and ≤ 20 cm (a) were 170 ha⁻¹ and DBH >20 cm (b) were 73 ha⁻¹. The ratio described as a/b is taken as the measure of size class distribution (Breitenbach, 1963). Accordingly, the ratio of the study forest was 2.3 (Table 3). This showed that the proportion of medium-sized individuals (DBH ≥10 and ≤ 20 cm) is greater than the large-sized individuals (DBH>20 cm). Gelawoldie community forest has more trees in the lower DBH classes than in the higher classes when compared to Sinko community (Zewdie, 2013), Angada (Alemu, 2011) and Denkoro Chaka (A. Ayalew et al., 2006) forest. However, the ratio is relatively smaller than the results obtained from Chilma forest (Beche, 2011). The proportion of small-sized individuals (DBH<10 cm) was much larger (46.8%). This indicates that there was selective cutting in the community forest.

According to this study, *D. angustifolia, D. abyssinica* and *V. amygdalina* were the dominant species after *E. capensis* (Table 1). Likewise, individuals of *C. macrostachyus* and *B. abyssinica* were more frequently available in the study forest followed by *R. abyssinica, A. schimperiana, O. quadripartita, C. aurea* and *A. abyssinica* (Table 1). The least frequent species in the study area were *F. carica, L. tomentosa, O. tomentosa, P. schimperi, J. schimperiana* and *S. kunthianum*, which cover approximately 6.3% of the area. The woody species in this study were classified into six frequency classes as A = 1–5; B = 6–10; C = 11–15; D = 16–20; E = 21–25 and F = 26–30 according to
Lamprecht (1989). Most species approximately 43.9% occurred in 1–5 of the study quadrats followed by 6–10. The remaining species were evenly distributed to other frequency classes (Figure 3). The Gelawoldie community forest showed high values in the lower frequency classes and low values in the higher frequency classes which indicates high degree of plant species heterogeneity (Figure 3). This agrees with the findings of Bantiwali (2010), Alemu (2011), and Achiso (2014) on Angada, Sanka-Meda and Choke mountain forests, respectively.

3.4. Vegetation structure

3.4.1. Diameter at breast height (DBH)
The distribution of woody plant species in different DBH classes is shown in Figure 4. A total of 457 individuals with height >2 m and DBH >2.5 cm was recorded in the study forest. Matured/trees woody plants of the study area were classified into five DBH classes as: I = 2.5–10 cm; II = 10.01–20 cm; III = 20.01–30 cm; IV = 30.01–40 cm and V = 40.01–50 cm. The first DBH class had the highest species density ha-1. About 83% of the tree density ha-1 was in the I and II DBH classes but only 1.57% to DBH classes IV and V (Figure 4). This shows that the total number of trees decreased with an increasing tree diameter (Figure 4). A. abyssinica and A. schimperiana were the only species found in the higher two DBH classes (IV and V) and C. macrostachyus, P. viridiflorum and B. micrantha were dominant in the middle DBH classes. The DBH distribution pattern of woody plant species indicates the general trend of population dynamics and recruitment status of the species (Zegeye et al., 2011). Thus, the DBH distribution of woody plant species of the study area indicates almost a reverse J-shape which is usually an indicator of healthy population status of a species. The result concurs with DBH frequency distribution of Sesa Mariam Monastery forest (Meshesha et al., 2015), Wanzaye natural forest (Asfaw, 2018) and Amoro forest (Birhanu et al., 2018) of the Amhara Region. Contrary to the present study, Teshager et al. (2018) and Gebeyehu et al. (2019) have found bell-shaped and irregular J-shaped woody plant population frequency distribution patterns. The similarities and variations among these forests might be attributed to the different management practices and anthropogenic activities in and around the forests.

3.5. Height distribution

The height class frequency distribution of trees and shrubs showed similar pattern to DBH distribution (Figure 5). The frequency distribution of height classes of trees and shrubs in the study forest was described using 25 woody species with 837 individuals and classified into five height classes according to Ayanow and Dalle (2018) with little modification as I = 2.0–5.0 m; II = 5.01–10.0 m; III = 10.01–15.0 m; IV = 15.01–20.0 m and V = 20.01–25 m. Slightly more than 75.6% of the individual woody plants were in height classes I and II (Figure 5). The results agree with those of Alemu (2011), Zewdie (2013), and Birhanu et al. (2018) in Angada, Sinko community and Amoro forests, respectively. The lower number of large-sized individuals in the upper classes of Gelawoldie community forest implies the presence of small number of adult trees for reproduction (Lamprecht, 1989). On the other hand, the dominance of small-sized individuals is
3.6. Basal area
The total basal area of woody species in Gelawoldie community forest with DBH > 2.5 cm was 93.8 m²/ha (Table 4). The study forest had relatively larger total basal area than Chilimo (Bekele, 1994), Denkoro (A. Ayalew et al., 2006), Sanka Meda (Bantiwalu, 2010), Angada (Alemu, 2011) and Sinko community forests but lower than Wof Washa forest (Bekele, 1994). Most of the basal area was contributed by A. abyssinica (306.0 m²/ha), A. shimperiana (287.9 m²/ha), A. lahai (154.3 m²/ha), C. macrostachyus (135.9 m²/ha), S. kunthianum (131.7 m²/ha), V. amygdalina (126.5 m²/ha) and P. viridiflorum (122.6 m²/ha). Basal area provides the measure of the relative importance of the species rather than simple stem count (Lamprecht, 1989). Species with higher basal area could be considered as the most important species in the study forest. In this study, basal area analysis across individual species revealed that there was high domination by very few or small woody species. Accordingly, A. abyssinica, A. schimperiana, A. lahai, C. macrostachyus, S. kunthianum, V. amygdalina and P. viridiflorum, were the most dominant in descending order and important species in terms of their basal area. They accounted for 57.5% of the total basal area. The contribution of small-sized individuals to the basal area was relatively small. Gelawoldie community forest had basal area higher than most forests in Ethiopia. This suggests that the study forest has better growth and potential to retain higher biomass.

3.7. Importance value index (IVI)
The important value index (IVI) of woody plant species varied greatly, ranging from nil to 16.6% (Table 1). More than 61% of the woody plant species had lower IVI; lower than 5% while the remaining 39% of the species had IVI ≥ 5%. The ecologically most important plant species with higher IVI values in descending order were B. abyssinica, C. edulis, R. abyssinica, O. quadrifolia, A. lahai, A. abyssinica, C. macrostachyus, A. schimperiana, E. capensis, P. viridiflorum and B. polystachya. These species represent more than 48% of all species in the study area. Almost similar IVI values are found in

| Forest                | Basal area (m²/ha) | Source                     |
|-----------------------|--------------------|----------------------------|
| Wof Washa             | 101.8              | Bekele (1994)              |
| Gelawoldie community  | 93.8               | Present study              |
| Angada                | 79.8               | Alemu (2011)               |
| Denkoro               | 45.0               | A. Ayalew et al. (2006)    |
| Sanka Meda            | 34.7               | Bantiwalu (2010)           |
| Sinko community       | 22.1               | Zewdie (2013)              |
Denkoro forest for M. arbutifolia, M. africana and J. abyssinicum (Mekonen et al., 2015). C. edulis, P. viridiflorum, C. aurea, B. abyssinica and C. macrostachyus have lower IVI values in Denkoro forest than Gelawolodie community forest (Mekonen et al., 2015). According to Shibru and Balcha (2004), the greatest IVI value reflects the presence and extent of dominant species in relation to other species in the structure of a forest stand. Moreover, IVI is used as a criterion to prioritize a species for conservation actions (Kacholi, 2013). In this regard, most of the species including the endemic ones in the present study require high priority for conservation efforts.

3.8. Regeneration of woody species
A total of 758 seedlings, 627 saplings and 632 matured individuals were recorded in the study area (Appendix 1). The ratio of seedlings and saplings to the matured woody plants was 1.2 and 1, respectively. Approximately 77%, 17.7% and 5.3% of the species had good, fair and poor regeneration status, respectively (Appendix 1). A. lahai, B. abyssinica, C. aurea, C. edulis, C. macrostachyus, E. capensis, O. quadripartita, M. arbutifolia, P. viridiflorum, R. abyssinica and other species had higher number of seedlings and saplings compared to matured plants (Appendix 1). The densities of seedlings were higher than those of saplings and matured woody plants which resulted in an overall good regeneration. Ayalew et al. (2006), Birhanu et al. (2018) and Getnet (2018) have found good regeneration status of B. abyssinica in Denkoro, Amoro and Wanzaye forests, respectively. Likewise, M. arbutifolia in Wanzaye (Getnet et al. 2018), Yemrehene (Ayanaw et al. 2018) and Yegof Washa (Woldearegay et al. 2018) forests found to have good regeneration. The good regeneration in some species might be due to un-palatability by herbivores.

This also agrees with the findings of Gebeeyehu et al. (2019) who have assessed regeneration status of five forests in Awi zone. Contrary to the present study, A. Ayalew et al. (2006) have reported poor regeneration status of M. arbutifolia, D. abyssinica and E. capensis in Denkoro forest. On the other hand, A. abyssinica, A. sennii, B. spekeana, C. anisata, C. longicauda, D. angustifolia, D. abyssinica, F. carica, O. rochetiana and some others showed fair regeneration. In the present study, poor regenerations were recorded for 5.3% of the species. This is due to the fact that the study area is under high overgrazing and browsing pressure by domestic animals.

4. Conclusion
The present study provides valuable information about the present conditions of woody plant species diversity, structure and regeneration status of Gelawolodie community forest. The results revealed that the diversity in the forest is high, evenly distributed and also harbours reasonable number of endemic plants. The overall stand densities expressed as DBH and height classes and number of seedlings, saplings and matured plants showed inverse J-shaped distribution pattern which suggests a stable population structure of the forest. However, a small number of species were poorly represented or missed either in the lower or higher DBH and height classes and this included the endemic plant species. Therefore, evidence-based and well-planned long-term conservation measures are commendable.

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Appendix
Density of seedling, sapling and matured tree species/ha in Gelawoldie community forest

| No. | Species Name               | Seedlings | Saplings | Trees |
|-----|----------------------------|-----------|----------|-------|
| 1   | *Acacia abyssinica*        | 4         | 16       | 58    |
| 2   | *Acacia lahai*             | 34        | 28       | 16    |
| 3   | *Achanthus eminens*        | 8         | 7        | 5     |
| 4   | *Achanthus sennii*         | 9         | 6        | 4     |
| 5   | *Albizia schimperiana*     | 24        | 23       | 29    |
| 6   | *Berkheya spekeana*        | 3         | 2        | 4     |
| 7   | *Bersama abyssinica*       | 61        | 43       | 28    |
| 8   | *Bridelia micrantha*       | 24        | 18       | 26    |
| 9   | *Brucea antidysenterica*   | 9         | 6        | 7     |
| 10  | *Buddleja polystachya*     | 7         | 3        | 9     |
| 11  | *Calpurnia aurea*          | 46        | 28       | 31    |
| 12  | *Capparis tomentosa*       | 13        | 7        | 6     |
| 13  | *Carissa edulis*           | 39        | 35       | 27    |
| 14  | *Clausena anisata*         | 8         | 10       | 9     |
| 15  | *Clemans his longicauda*   | 7         | 5        | 8     |
| 16  | *Clerodendron myricoides*  | 5         | 4        | 3     |
| 17  | *Clutia abyssinica*        | 18        | 15       | 11    |
| 18  | *Croton macrostachyus*     | 18        | 20       | 38    |
| 19  | *Cynotis hirsute*          | 9         | 8        | 9     |
| 20  | *Dodonaea angustifolia*    | 11        | 15       | 13    |
| 21  | *Dovyalis abyssinica*      | 5         | 6        | 7     |
| 22  | *Ekebergia capensis*       | 24        | 19       | 15    |
| 23  | *Eucalyptus comadulensis*  | 0         | 0        | 0     |
| 24  | *Ficus carica*             | 4         | 4        | 3     |
| 25  | *Grewia ferruginea*        | 6         | 5        | 4     |
| 26  | *Hibiscus ludwigii*        | 5         | 4        | 3     |
| 27  | *Hypericum quartinianum*   | 5         | 4        | 5     |
| 28  | *Jasminum abyssinicum*     | 5         | 4        | 4     |
| 29  | *Jasminum grandiflorum*    | 7         | 6        | 5     |
| 30  | *Juniperus procera*        | 0         | 0        | 0     |

(Continued)
(Continued)

| No. | Species Name                      | Seedlings | Saplings | Trees  |
|-----|-----------------------------------|-----------|----------|--------|
| 31  | Justicia schimperiana             | 0         | 1        | 3      |
| 32  | Laggara tomentosa                 | 3         | 6        | 5      |
| 33  | Maesa lanceolata                  | 8         | 9        | 7      |
| 34  | Maytenus arbutifolia              | 34        | 21       | 14     |
| 35  | Maytenus sennegogolensis          | 12        | 9        | 8      |
| 36  | Myrsine africana                  | 9         | 10       | 6      |
| 37  | Ocimum lammiifolium               | 7         | 5        | 6      |
| 38  | Olinia rochetiana                 | 5         | 7        | 6      |
| 39  | Osyris quadripartita              | 38        | 30       | 27     |
| 40  | Otostegia tomentosa               | 1         | 4        | 3      |
| 41  | Phytolacca dodecandra             | 4         | 3        | 2      |
| 42  | Pittosporum viridiflorum          | 31        | 21       | 22     |
| 43  | Premna schimperi                  | 2         | 3        | 1      |
| 44  | Protea goguedi                    | 7         | 8        | 6      |
| 45  | Pterolobium stellatum             | 21        | 13       | 10     |
| 46  | Rhus vulgaris                     | 0         | 3        | 5      |
| 47  | Ritchiea albersii                 | 11        | 8        | 10     |
| 48  | Ritchiea steudneri                | 9         | 8        | 9      |
| 49  | Rosa abyssinica                   | 43        | 29       | 26     |
| 50  | Rubus apetalus                    | 8         | 5        | 4      |
| 51  | Rumex nervosus                    | 8         | 7        | 8      |
| 52  | Sida ovate                        | 15        | 10       | 12     |
| 53  | Solanum indicum                   | 3         | 2        | 4      |
| 54  | Stereospermum kunthianum          | 1         | 2        | 5      |
| 55  | Stephania abyssinica              | 7         | 5        | 3      |
| 56  | Vernonia amygdalina               | 9         | 9        | 8      |
| 57  | Vernonia myriantha                | 19        | 17       | 16     |
| 58  | Vernonia leopoldii                | 18        | 15       | 13     |
| 59  | Vernonia quartiniana              | 8         | 6        | 5      |

0 indicates that the species was found outside the quadrat and data of seedlings, saplings and trees were not collected.
