



# Woody Species Diversity and Composition of Dry Woodland Vegetation in West Shewa, Central Ethiopia: Implications for Their Sustainable Management

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**Abstract:** The dry land forest of Ethiopia possesses diverse tree species that are known for their ecological and economic values. Despite growing recognition of environmental and economic benefits of these species, the woodland harbouring these species is degrading. Adequate knowledge on the resource base including the current status of its population is crucial for sustainable management of the forest resource. Therefore, this study was carried out to investigate the diversity and composition of woody species in Kara dry lands forest. A total of 90 quadrants were established along transect lines. A 400 m<sup>2</sup> quadrants was used, distance between quadrants and transecting lines were 200 m and 500 m respectively. Species diversity and evenness, density, frequency, important value and regeneration status were assessed. This study reveals total of 48 woody species representing 23 families and 31 genera's were found. Out of that, 13 woody species were identified as gum and resin bearing species. The genus of *Commiphora* and *Acacia* species were found to be the dominant gum and resin bearing species at the study area. Diversity of the entire woody species assemblage and of the gum- and resin-bearing species was  $H= 3.47$  and  $H= 2.3$  respectively. The evenness values of entire and gum and resin producing woody species were 0.67 and 0.77 respectively. The gum and resin producing woody species accounted for 44.56% of the density, 49.87% of the basal area and 45.49% of the Importance Value Index. However, we recorded the declining natural regeneration of most gum- and resin-bearing woody species except for a small number of species, which exhibited signs of healthy populations. Generally, the results of the present study highlighted the absence of conservation actions that will probably be subject to a progressive decline of gum and resin bearing species because of uncontrolled grazing, charcoal production and shifting cultivation. Therefore, proper management plan and domestication of the species through artificial regeneration and area closure are urgently needed.

**Keywords:** Composition, Diversity, Importance Value Index, Woody Species, Woodland

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## 1. Introduction

Ethiopia is endowed with extensive vegetation cover in dry land areas. *Acacia-Commiphora* and *Combretum-Terminalia* woodlands are the most dominant vegetation types that cover large parts of the dry land areas in Ethiopia [1]. The dry woodlands of Ethiopia cover about 3.5 million hectares of land. These forest resources harbor diverse woody species which produce commercial gums and resins [1, 2]. In dry woodlands of Ethiopia, 21 *Commiphora*, 6 *Boswellia*, 12 *Acacia* and 3 *Sterculia* species have been identified so far as

major sources of gums and resins [1, 3-5]. Produce, use and commercialization of thus by products has long history and Ethiopia is considered as one of the world major producers and exporters of these products [5, 6]. It is estimated that about, 270,000 tons of gums and resins produced annually in Ethiopia [2]. Kara forest also has very high potential of gum and resin bearing vegetations which provide subsistence and income generation for local community. However, exploitation of these forest resources has not yet generated useful income due to poor tapping and collection techniques. Despite the growing recognition of the ecological and

socioeconomic significance of the dry land forest in Ethiopia, few policies and practices try to address issues related to these versatile resources when planning development of dry lands [4, 5, 7]. As a result, these dry forests are under increasing anthropogenic and natural pressures [8-11], also argued that there is a massive transformation of forestland into farmlands in the *Combretum-Terminalia* woodland belt, ignoring the various socio-economic and ecological benefits that can be obtained through sustainable management and conservation of the forest vegetation. Moreover, different studies made in Ethiopia have indicated that these vegetations are declining from time to time [2, 6, 12, 13]. The major factors which affected the natural vegetation of the country were agricultural expansion, settlement, deforestation, land degradation, and invasive species [14, 15]. The growing pressure on dry forest resources is partly due to inadequate information on the regeneration status of high value tree species, especially those produce commercial gum and resins at national scale is among problems hindering strategic consideration of dry forests [1]. On the top this; the diversity and composition of woody species is not well studied due to the absence of a systematic and rigorous data collection system at national level in several developing countries. Nowadays, the professional efforts to evaluate the population status of woody species are systematically attempted since globally gum and resin production considered as an essential medium of economy and sustainable development. Therefore, the objective of this

study was to provide empirical information on the diversity and composition of woody species in Kara forest and thereby to contribute to the ongoing efforts to better integrate these resources in livelihood development and ecosystem management in these dry woodlands.

## 2. Materials and Methods

### 2.1. Description of the Study Site

The studied forest located in Ambo district, West Shewa Zone of Oromia Regional State, Western lowlands of Ethiopia (Figure 1). Ambo district (longitude 37° 32' to 38° 3' E and latitude 8° 47' to 9° 20' N) is located in Western Shewa zone of the Oromia Regional State. The altitude within the district ranges from 1400 to 3045 masl. The annual rainfall and temperature range from 800 – 1000 mm and 15°C – 29°C, respectively. The mean temperature is 18.6°C. Kara is covered with desert and semi-desert vegetations including *Acacia-Commiphora* and *Combretum-Terminalia* woodland. It is a mixture of *Acacia*, *Boswellia*, *Commiphora*, *Balanites* and various other woody species and short grasses at varying density. It also hosts various species of wild animals including mammals, birds, and reptiles. According to the elderly people, 30 years ago, land was almost all owned common. Currently, however, pastoralists own small plots of rangeland within enclosures near their croplands and around their homesteads.

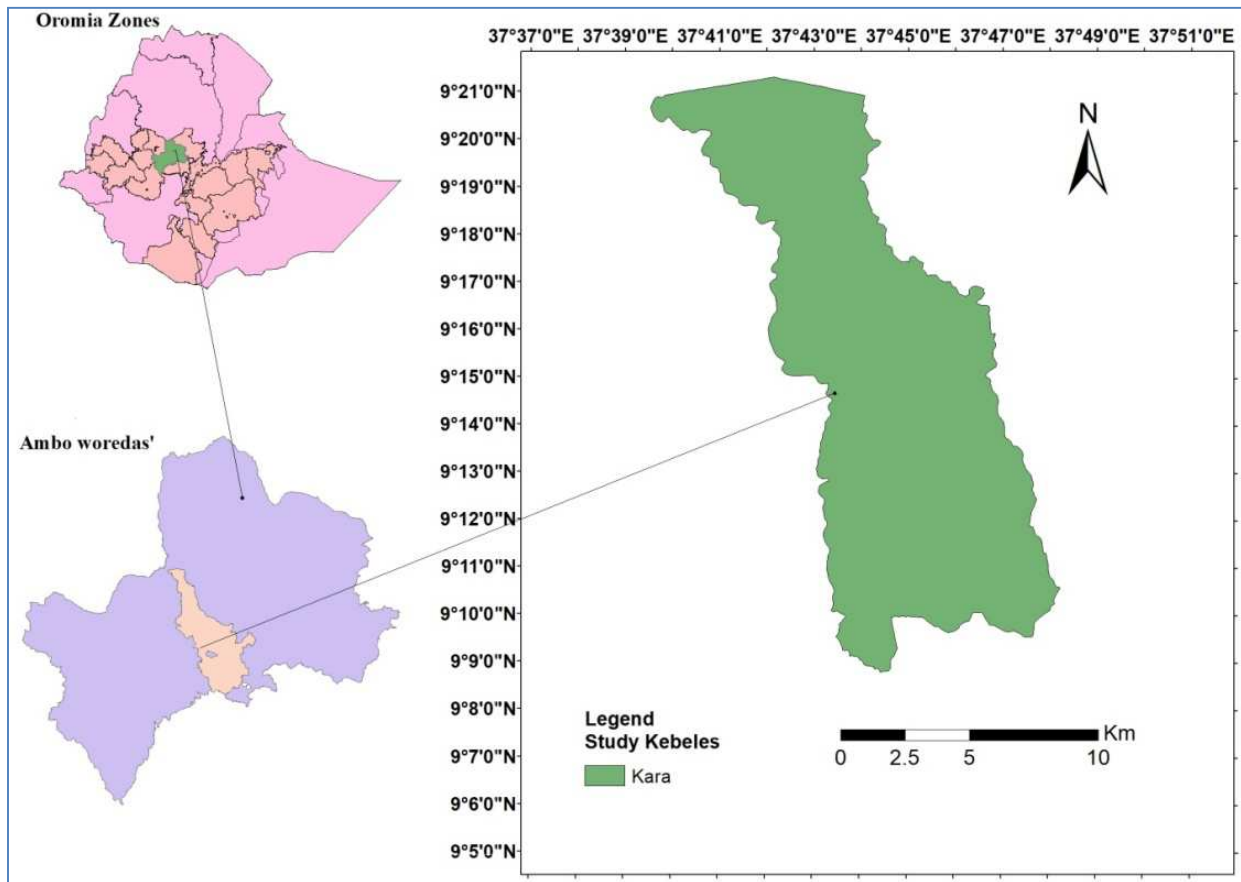


Figure 1. Map of study area.

## 2.2. Sample Size and Sampling Techniques

A reconnaissance survey was conducted in order to examine the status of the forest resource in the study area. The information from reconnaissance survey indicated that the distribution and structure of vegetation were uniform. Kara forest is covered with *Combretum-Terminalia* woodland including *Boswellia* species. Further, the topography of most parts of the forest areas is uniform. Based on this observations, transects with different lengths were laid along altitudinal gradient. The first transect line was randomly laid and the rest were set at an interval of 500m from each other. The variations in the length of transect lines resulted from inaccessibility of some parts of the forest and encountering other land uses. A total of 90 (20m x 20 m) sample plots with 200 m interval were laid along the transect lines. Moreover, four smaller sample plots of size 5 X 5 m were established in the corner of each main plot to assess regeneration of all woody species. The first sample plot was laid randomly and the others systematically at pre-specified intervals to be distributed in the surveyed forests. In each quadrant, the identities of all woody species, as well as the numbers of all individuals, including seedlings, were recorded. In addition, the diameter at breast height (DBH) for individuals >5 cm diameter was measured using caliper. Individuals with heights of < 1.5m were considered as seedlings, counted and recorded [1]. Plant identification was mostly made in the field and, for those species which could not be identified in the field, herbarium voucher specimens were collected and identification was made at Ethiopian Biodiversity Institute.

## 2.3. Data Analyses

The collected data were used to compute species richness, diversity, evenness, density, frequency, basal area, Importance Value Index (IVI), and regeneration status of woody species of study area. The species richness of woody plants was determined from the total number of woody species recorded. The diversity of woody species was determined using the Shannon-Wiener Diversity Index (H) and Evenness or Equitability Index (E) [16]. Density of woody species was determined by converting the total number of individuals of each woody species encountered in all the quadrants to the equivalent number per hectare. Relative density was calculated as the percentage of the density of each species divided by the total stem number of all species ha. Frequency, which refers to the degree of dispersion of individual species in an area, was expressed as the ratio of the number of quadrants in which a species occurred to the total number of quadrants, whereas relative frequency was computed as the ratio of the frequency of the species to the sum total of the frequency of all species [17]. The dominance of the woody species was determined from basal area (BA) for all woody species with DBH 2.5 cm. Relative dominance was calculated as the percentage of the total basal area of a species out of the total basal areas of all

species. The IVI is used to give an overall indication of the importance of a plant species in a plant community [17]. It is the sum of the values of relative frequency, relative density, and relative dominance of the species. The population structures and status of natural regeneration of most threatened gum- and resin- bearing woody species was assessed from the frequency distribution of diameters based graph histograms constructed by grouping all individuals of each woody species into the following successive diameter classes: Seedling, Sapling, 5-10cm, 11-15cm, 16-20cm, 21-25cm, 26-30cm, 31-35cm and >36cm.

## 3. Results and Discussion

### 3.1. Floristic Composition

A total of 48 woody species representing 23 families and 31 genera were recorded in the study area (Figure 2). Present study revealed that Kara forest is floristically poor compared with other forest lands like Gra-Kahsu [18]. However, it is more or less comparable with Borana woodland [8] and better than Gambella low land [19], South Omo zone [3] and Benishangul-Gumuz [20] forests. Vegetation with a high extent of human disturbance due to encroachment shows relatively fewer species number than others [21]. According to [22], the difference in species composition over various forest lands could be due to topographic differences among the forests compared and the amount of available suitable environmental conditions in the respective forests. Such difference may also due to the various physical and edaphic characteristics of the areas.

*Burseraceae* and *Fabaceae* were the most diverse families, each represented by 10 and 8 species respectively (Figure 2). The highest representation of species from the family *Burseraceae* in Kara forest could be related to the fact that it is the largest family in the flora of Ethiopia. This could also be attributed to its higher regeneration potential and seed dispersal capability of their species as well as better adaptation to a wide range of ecological conditions. *Burseraceae* was also found to be dominant in other woodland forests in Ethiopia like Borana [8].

In total, 13 species were identified as sources of gums and resins (Table 1). *Commiphora* and *Acacia*, two of the genera's with gum and resin producing species, were the first and second most diverse genera's, represented by 8 and 3 species, respectively (Figure 2). The study area supported equivalent diversity of gum and resin bearing woody species compared to other areas in Ethiopia with similar agro-ecology. [19], for example, reported 11 gum and resin-bearing species from lowland of South West Ethiopia. But higher numbers (15 species) of gum- and resin-bearing species were reported from southern Ethiopia as compared to in this study area [3]. In this part of the country, *Commiphora africana* and *Acacia Senegal* were the main sources of gum and resins [3, 19].

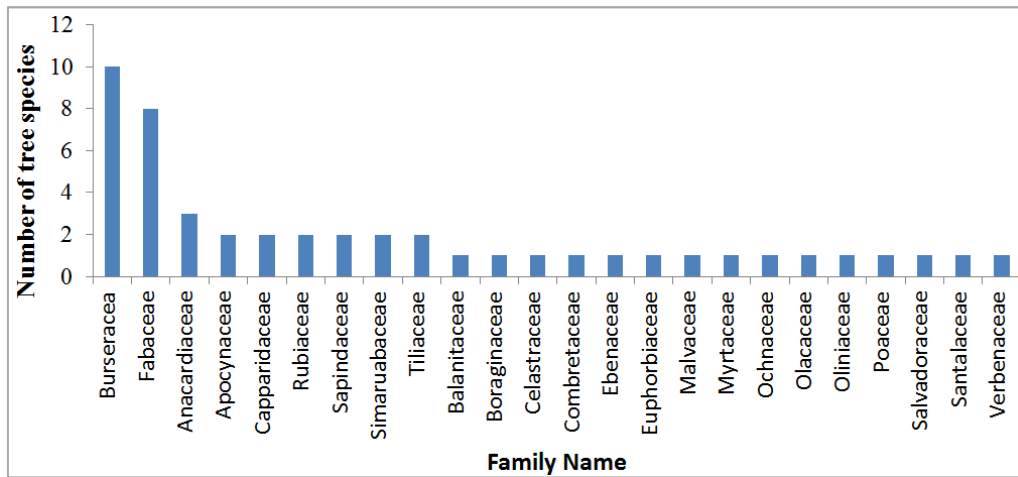


Figure 2. Plant Families with their number of woody plant species occurred in Dry woodland Vegetation of West Shewa, Central Ethiopia.

### 3.2. Diversity and Evenness

A measure of species diversity is an important character of a plant community that plays a crucial role in ecosystem and conservation of threatened species. The diversity of all woody species was 3.47, while the corresponding value of evenness was 0.67 (Table 1). Similarly, the diversity of gum and resin bearing woody species in Kara forest was 2.30 while the corresponding value of evenness was 0.77. The species diversity of Kara forest ( $H' = 3.47$ ) was lower than those reported from other woodland forests in the country [23]. However, the overall diversity of the forest falls within the normal range of Shannon-Wiener diversity index, which lies between 1.5 and 3.5 [17].

The evenness value ( $J = 0.67$ ) was lower than those reported from other woodland forests like Sire Beggo [23], indicating a relatively inequitable distribution of individuals among various species in the forest. The low evenness in areas can be attributed to excessive disturbance, variable conditions for regeneration and exploitation of some species. Moreover, illegal felling, over-exploitation of forest resources, encroachment and domestic grazing are man-induced disturbances that can affect the natural regeneration of woody species.

Woody species, which are commonly known as bush encroachers, invaders, and indicators of land degradation like *Acacia drepanolobium*, *Carissa spinarum*, *Euclea divinorum*, *Grewia avelutina* and *Balanitesaegyptiaca* were also found increasing in Gnemer forest.

Table 1. Diversity indices of woody plant species in recorded in Dry woodland Vegetation of West Shewa, Central Ethiopia.

Diversity indices	All woody species	Gum and resin bearing woody species
Shannon ( $H'$ )	3.47	2.3
Evenness ( $J$ )	0.67	0.77
Species richness ( $S$ )	48	13

### 3.3. Density, Frequency and Dominance

The densities of all woody species, including seedlings were 538 stems per ha. Of these, the densities of gum- and resin-bearing woody species accounted for 239.7 stems per

ha (about 44.56% of total) in the study area. In the study area, density was lower than those reported from other woodland like Hamer (1804  $ha^{-1}$ ) individuals [3], Tara Gedam (3,001 individuals  $ha^{-1}$ ) and Abebaye (2,850 individuals  $ha^{-1}$ ) [24]. But, its density was found to be higher than Sherkole and Guba, 488 and 256 stems per ha respectively [20] and woodlands (376.86 individuals  $ha^{-1}$ ) [25] in Ethiopia. The difference in the density of woody species can be due to altitudinal gradients and habitat suitability of different woody species forming the forest as well as the extent of anthropogenic influences [26].

In the study area, a total basal area for all woody species was 17.51  $m^2$  per ha whereas, the basal areas of gum- and resin-bearing species were 8.73 (49.87%)  $m^2$  per ha. The least and greatest frequencies were one and 87. The most frequent gum- and resin-bearing species was *Acacia mellifera* (Vahl) Benth. It was encountered in 87 quadrants, whereas, *Acacia senegal* (L.) Willd, *Acacia seyal* Del and *Commiphora Africana* (A. Rich) Engl were recorded in 81, 63 and 42 of 90 sampled quadrants. A high dominance of *Acacia* species in our survey is also likely associated to the ability of those to withstand long dry seasons, thus resulting in their abundance and year round availability in semi-arid areas. Moreover, this might be attributed to its higher density and occurrence in a wide altitudinal range. Comparable results reported from other gum and resin producing localities in Ethiopia. For instance, [8] and [3] reported total density per ha of 1017 and 882 (49% and 68% of the total woody stems density) at Arero and Yabello districts in Borana zone, Oromia region in Ethiopia and 919 and 1085  $ha^{-1}$  (48% and 50% of all species density) at Hamer and Bena-Tsemay south Omo zone, southern region in Ethiopia. The variation in density and frequency between species may be attributed to habitat differences, habitat preferences among the species, species characteristics for adaptation, degree of exploitation and conditions for regeneration [6].

### 3.4. Importance Value Index (IVI)

The Importance Value Index has been helped to recognize the ecological role of the woody species in forest structure

[27]. Accordingly, IVI of gum and resin bearing species accounted about 45.49%. The gum and resin bearing woody species with the highest IVI were *Acacia mellifera*, *Acacia senegal* and *Acacia seyal* (Table 2). The higher Importance Value Index of *Acacia mellifera* could be attributed to its higher density and frequency than the other species. IVI is an important parameter that reveals the ecological significance of species in a given ecosystem, since it reflects the combined effect of species density, frequency and dominance [12, 17, 28, 29]. It enables prioritizing species for conservation interventions such that species with lowest IVIs might benefit from conservation and management

interventions [30, 31]. Thus, *Acacia mellifera* can be designated as the most ecologically significant species in Kara forest. Moreover, gum- and resin-bearing species were the principal components of the studied vegetations, as demonstrated in the above result. More or less comparable results were reported by [3] at South Omo. *Commiphora erythraea* showed lower IVI (3.20) at study sites, this may be due to intensive human interference of the area. The results suggest that the species having low IVI value should be prioritized for conservation. According to [32] and [33] the lower IVI indicate that these woody species are threatened and need immediate conservation measure.

**Table 2.** Overall Mean IVI of trees and shrub (>5cm DBH) species in Dry woodland Vegetation of West Shewa, Central Ethiopia.

Botanical name	RD	RF	RDo	IVI
<i>Acacia albida</i> Del.	8.31	6.28	4.73	19.32
<i>Acacia brevispica</i> Harms	2.32	3.52	3.97	9.81
<i>Acacia drepanolobium</i> Harms ex Sjoest.	0.57	0.57	0.71	1.85
* <i>Acacia mellifera</i> (Vahl) Benth.	9.81	8.28	8.09	26.18
<i>Acacia robusta</i> Bruch.	0.26	0.29	0.14	0.69
* <i>Acacia senegal</i> (L.) Willd.	8.11	7.71	6.66	22.48
* <i>Acacia seyal</i> Del.	4.85	5.99	5.55	16.40
<i>Acacia tortilis</i> (Forssk.) Hayne	4.60	5.23	3.36	13.19
<i>Acokantheraschimperi</i> (A.Dc.) Schweinf	0.62	0.86	0.63	2.11
<i>Balanitesaegyptiaca</i> (L.) Del.	1.70	2.09	3.39	7.19
<i>Bosciaangustifolia</i> A. Rich	0.83	1.14	0.95	2.92
* <i>Boswellianeglecta</i> S. Moore	2.89	3.04	4.60	10.54
* <i>Boswelliapapyrifera</i> (Del.) Hochst	3.98	2.76	4.73	11.46
<i>Canthiumpseudosetiflorum</i> Bridson	0.31	0.29	0.05	0.64
<i>Carissa spinarum</i> L.	0.93	0.86	0.63	2.42
<i>Combretummolle</i> R. Br. ex G. Don	0.26	0.38	0.11	0.75
* <i>Commiphoraafricana</i> (A. Rich) Engl.	4.29	4.00	4.92	13.20
* <i>Commiphoraconfusa</i> Vollesen	2.32	2.95	3.54	8.81
* <i>Commiphoraerythraea</i> (Ehrenb.) Engl.	0.98	0.67	1.55	3.20
* <i>Commiphorahabessinica</i> (Berg) Engl.	1.50	1.14	1.75	4.38
* <i>Commiphorakua</i> (R. Br. ex Royle) Vollesen	1.03	1.05	2.06	4.14
* <i>Commiphoramyrtha</i> (Nees) Engl. Syn. C. molmol	1.24	0.86	1.98	4.08
* <i>Commiphoraschimperi</i> (Berg.) Egnl.	2.58	2.28	3.33	8.20
* <i>Commiphoraterebinthina</i>	0.98	1.33	1.11	3.42
<i>Cordia siriensis</i> Lam.	0.46	0.19	0.32	0.97
<i>Croton dichogamus</i> Pax	0.36	0.19	0.51	1.06
<i>Doberaglabra</i> (Forssk.) Poir.	0.62	0.38	0.71	1.71
<i>Dodonaeaangustifolia</i> L. f.	1.81	2.00	2.06	5.87
<i>Eucleadivinorum</i> Hiern.	1.03	1.05	0.24	2.32
<i>Gardenia ternifolia</i> Schumach. & Thonn	4.18	3.24	3.65	11.07
<i>Grewia ferruginea</i> Hochst. ex A. Rich	3.61	4.19	2.46	10.26
<i>Grewia velutina</i> (Forssk.) Vahl	3.10	4.47	3.97	11.54
<i>Harrisonia abyssinica</i> Oliv.	3.98	4.85	3.49	12.32
<i>Hibiscus crassinervius</i> Hochst. Ex A. Rich.	0.05	0.10	0.03	0.18
<i>Kirkiaburgeristannard</i> subsp. <i>Burgeri</i>	0.41	0.29	0.30	1.00
<i>Lanniatrithala</i> (A. Rich.) Engl.	1.65	1.62	1.60	4.87
<i>Maeruatrithalla</i> A. Rich.	2.27	2.76	3.33	8.36
<i>Maytenus senegalensis</i> (Lam.)	0.57	0.29	0.14	1.00
<i>Ochnainermis</i> (Forssk.) Schweinf ex Penzig	0.57	0.48	1.43	2.47
<i>Oliniarochetiana</i> A. Juss.	0.62	0.38	0.86	1.86
<i>Osyrisquadripalita</i>	0.21	0.19	0.14	0.54
<i>Oxytenanthera abyssinica</i> (A. Rich.)	1.60	1.24	1.27	4.11
<i>Ozoroa insignis</i> Del. subsp. <i>Insignis</i>	1.19	1.71	1.62	4.52
<i>Pappeacapensis</i> Eckl. & Zeyh.	1.14	0.95	1.24	3.32
<i>Premnaschimperi</i> Engl.	1.24	1.14	1.43	3.81
<i>Rhus vulgaris</i> Meikle	1.91	2.09	0.29	4.29
<i>Syzygium guineense</i> (Wild.) DC.	1.76	2.28	0.30	4.34
<i>Ximenea americana</i> L.	0.41	0.38	0.08	0.87

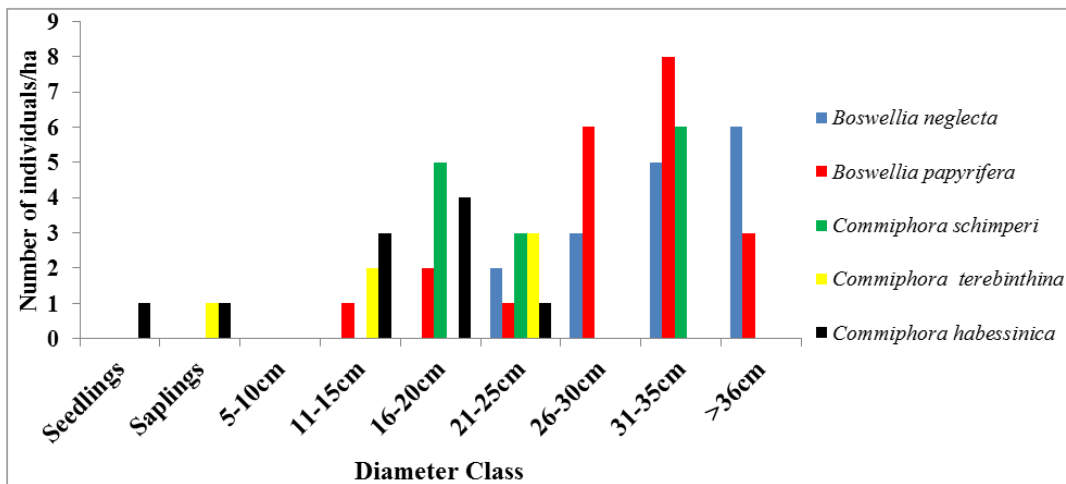
[RD (%) = relative density, RD (%) = relative frequency, RF (%) = relative dominance RDo (%), IVI = Importance Value Index (%). \*Gum- and resin-producing species, as identified by local communities at Dry woodland Vegetation of West Shewa, Central Ethiopia].

**3.5. Regeneration Status**

Information on population structure of woody species indicates the history of the past disturbance on the species and hence, used to forecast the future trend of the population of that particular species. In study area, a total of 2301 individuals and 364 seedlings and saplings were counted from all quadrants. In general the distribution of seedlings and sapling of all woody species is less than mature trees. According to [34], the regeneration status of a forest is poor if number of seedlings and saplings are much less than mature individuals. The regeneration status of current study is an agreement with the findings of [35] where they found most of the plants were belonged to the Least Concerned category in Rangamati.

The regeneration status of gum and resin bearing woody species also showed that the population is dominated by mature individuals with small number of seedlings and saplings. *Boswellia papyrifera* (Del.) Hochst, *Boswellia neglecta* S. Moore, *Commiphora schimperi* (Berg.) Egnl, *Commiphora terebinthina* and *Commiphora habessinica* (Berg) Engl need special attention since they were represented with only a few individuals of seedlings (Figure 3). According to the informants, people in the study area are more concerned about the wood production from *Boswellia* rather than gum production means more cutting than conservation. Except few people aware about methods of establishment, conservation and management of *Boswellia* trees. This implies that the chance for conservation and protection of the species is very limited and people

knowledge about tree tapping and gum production is poor. Study in Sudan Jebel Marra, West Sudan by [36] has also reported unstable populations of *B. papyrifera* in different sites. The lowest density (56 trees per ha) of the *Boswellia papyrifera* tree species was also reported from Shimelegir Forest, Jawi District, Ethiopia by [37]. Moreover, several studies in Ethiopia [6, 7] have also reported that *B. papyrifera* is facing rapid population decline and it is among those important woody species that are highly endangered [11]. This is an indication that the species is under threat not only in the study area but also in several geographical locations in the region of its distribution due to continuous tapping for incense production, human induced fire, overgrazing and climatic anomalies. The major threatening factors of the *Commiphora* dominated woodlands are assumed to be the continuous influx of immigrants from the highland of the West Shewa. Such influxes are motivated by the existence of vast woodland with its fertile soil and favourable climate for the cultivation of sesame and maize. This has attracted thousands of immigrants from various parts of the country especially from the nearby highland area. On the top this, seedlings of *Commiphora* species are highly preferred by goats and other livestock which might have contributed to their poor regeneration compared to the high seedlings densities of *Acacia* species. Moreover, most of the people in the study area are charcoal producers which might threat regeneration status of gum and resin bearing woody species in the study area.



**Figure 3.** Diameter class frequency distribution of most threatened gum and resin bearing woody species in Dry woodland Vegetation of West Shewa, Central Ethiopia.

**4. Conclusion and Recommendation**

The results of this study indicated that Kara forest had high woody species diversity. *Burseraceae* and *Fabaceae* were the most diverse families in the study area. However, the population structure of *Boswellia* and *Commiphora* species illustrates that natural regeneration and recruitment is lacking in the study area. This indicates the population of these

species is unstable and under threat due to lack of recruitments through regeneration. The current status of gum and resin bearing species not only in the study area but also across all regions where the species are naturally distributed calls urgent implementation of conservation strategies to save the species from extinction. It is therefore imperative to develop and implement effective conservation measures to save the plant biodiversity of this area.

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## Authors' Contributions

Gadisa Demie is a lecturer at Department of Forestry, College of Agriculture and Veterinary Science Ambo University. He planned the study, collected data, identified the species, analyzed the data and wrote the manuscript.

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