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Gum and resin bearing dryland forests of Somali region, Southeastern Ethiopia: Diversity, structure and spatial distribution

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A B S T R A C T

Despite its ecological and socio-economic contributions, the lowland dry forests of Ethiopia have been experiencing severe deforestation and degradation challenges. It is, therefore, crucial to assess the status of the dry forest resources to formulate an appropriate management strategy and its sustainable utilization. This study was formulated to determine spatial distribution, species composition, structure, and regeneration of the gum and resin species bearing dry forests in the Somali regional state of Ethiopia. The recent Sentinel-2A image was procured and used to classify the area, using a supervised Random Forest Algorithm, into different land covers and vegetation types. Inside the two key vegetation types (Acacia dominated woodland and Mixed woodland), forest inventory was conducted by establishing 30 m x 30 m size quadratic sample plots. The results revealed that the study area was divided into settlement (0.2%), bare land (6.0%), undifferentiated forest (0.5%), acacia woodland (36.3%), mixed woodland (54.1%) and scrubland (2.9%). Thirty-four woody species were identified and recorded with a Shannon diversity of 3.03. The population structure showed a lack of sufficient natural regeneration. It is, therefore, imperative to say that the forest containing the gum and resin-bearing species is not replacing itself. On the other hand, the forest has the potential to produce Oleo-gum resin in various kinds and amounts. Thus, implementing appropriate restoration measures is urgent to enhance natural regeneration. Moreover, formulating sustainable utilization while creating product market of gum and resins are important considerations for the future development of the sector.

Keywords: Somali, Horn of Africa, Gum and Resin

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Introduction

Dry forests in the tropics are important forest biomes that support the livelihood of millions of people around the globe (Djoudi *et al.*, 2015). In addition, it provides multiple ecosystem services (Cortés-Calderón *et al.*, 2021). The dry forest covers about 42% of tropical and subtropical forests (Hasnat and Hossain, 2019). Compared with other biomes, it is much more prone to loss of biodiversity and habitat fragmentation due to the alarming rate of deforestation and forest degradation (Maass, 2010; Rivas *et al.*, 2020). While it comprises extensive distribution, it receives less research attention as compared to the moist tropical forest (Sunderland *et al.*, 2015) The *Combreterm – Terminalia* and the *Acacia - Commiphora* are the two widely distributed forest ecosystems in the dry lowlands of Ethiopia. The resources are significant in biodiversity endowed with numerous endemic plants and animals (Bareke, 2018). The woodland is also a source of various gum and resin products such as frankincense, myrrh, opopanax, and gum. It plays an important role economically, from enhancing household income (Berhanu *et al.*, 2021; Walle and Nayak, 2021; Worku *et al.*, 2014) to improving the GDP of the country (Mekonnen *et al.*, 2013).

The dry forest resource of El – Weyni district, Somali, region, Ethiopia is huge comprising a large number of gum and resin-bearing species. However, this economically important resource has been underutilized in terms of production and utilization. The forest resource lacks natural regeneration may lead to forest degradation and requires urgent action. The contribution of the forest landscape to biodiversity is unknown. Hence, evidence-based planning and implementation of sustainable utilization is crucial. Forest inventory, which can reveal the existing diversity and structure of the forest, is an important phase in forest management. Understanding the regeneration status of woody species in general, and gum and resin-bearing species in particular, is fundamental in formulating appropriate policy and strategy both at a national and regional level. In addition, knowledge and information in these areas are crucial for the sustainable utilization of the resources.

Previous studies on gum and resin-bearing dry forests in Ethiopia have emphasized the western and northwestern dry lowlands, providing critical information on their proper utilization and ecological sustainability (Addisalem *et al.*, 2016; Bekele, 2016; Mokria *et al.*, 2017; Yilma *et al.*, 2016), and socioeconomic aspects (Eshete *et al.*, 2005; Tilahun *et al.*, 2015). On the other hand, there is scarce information on the forest resources of the Somali region of the southeastern lowlands. Limited work has been conducted with emphasis on the current forest composition structure, and the spatial distribution of the dry woodlands in general and Gum and resin-bearing species in particular. The objective of this study was, therefore, to fill in the gap of information and determine the species composition, structure, and regeneration of gum and resin species. At the same time, it quantifies the spatial distribution of gum and resin-bearing species in the El-Weyni district of the Somali regional state of Ethiopia.

Materials and Methods

The study area

The study was conducted in the El-Weyni district in the Somali Regional State of Ethiopia. It is located between 42° 45' to 43° 25' East and 6° 20' to 6° 45' north. El–Weyni was selected for the study because it is one of the potential sites for the gum and resin species from the Eastern lowland dry forest regions of Ethiopia. The total area of the study area is estimated at 242,030 hectares. The altitude of the study area extends from 331 to 1035 through an average value of 482 m.a.sl. The landform of the study area is mainly characterized by a smooth plain with some rugged topography in the Northeastern section of the district. The climatic condition of the study area is described as dryland affected by recurrent drought. The site has an annual average precipitation of 200 mm, and the mean maximum and minimum temperature is 28°C and 40°C, respectively (Hussein *et al.*, 2021).

The vegetation types of the study area are the dry woodland ecosystem types of *Acacia-Commiphora* woodland and scrubland (Friis *et al.*, 2010). In this ecosystem, gum and resin-bearing tree species are widely distributed. The woodland usually coexists with grasslands and pastureland. The pastoral system is the common livelihood means of the community in the area.

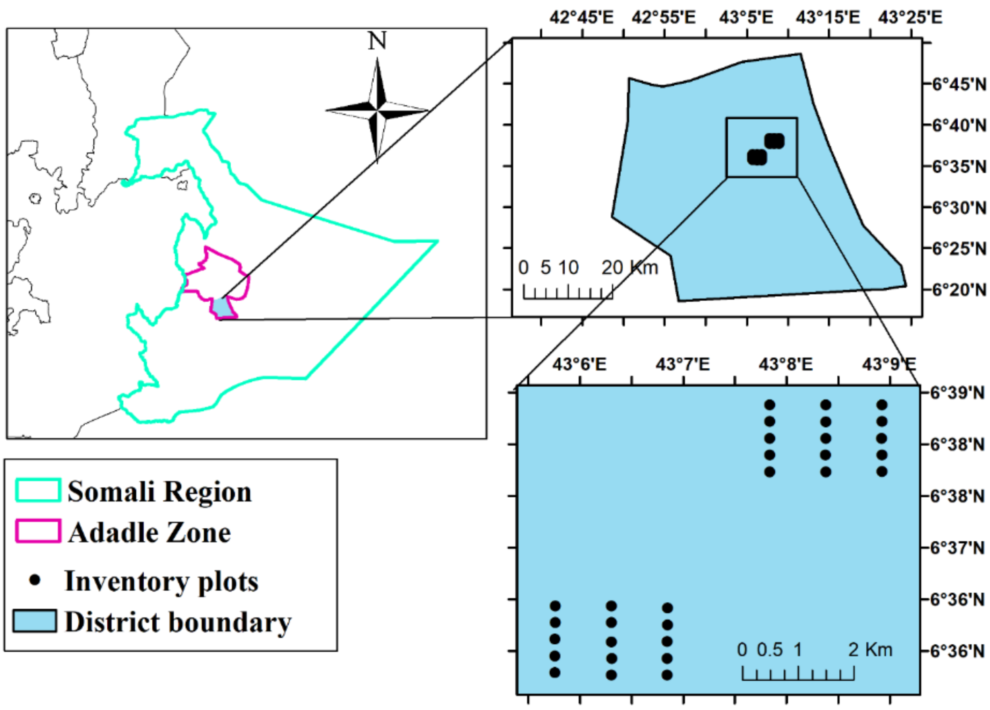

Figure 1. Location map of the study area and forest inventory plots.

Vegetation data collection and analysis

A reconnaissance survey was conducted before undertaking the forest inventory. A systematic random sampling technique was employed to lay sampling plots. Thirty quadratic plots of 30 x 30 meters were established to record the seedlings, saplings, and adults of all woody species. For the adult, the diameter at breast height (DBH) and height were measured using standard diameter tape and a True-pulse height meter, respectively. The total number of seedlings and saplings was counted and recorded within each plot. Environmental data such as location (latitude and longitude), altitude, slope and aspect were recorded from the center of each sample plot. For the present study, different growth stages were pre-defined as adult (height greater than 1 meter), sapling (height between 0.5 and 1 meter), and seedling (height less than 0.5 meters).

In order to describe the woody species diversity, the Shannon-Wiener Diversity Index (H) and Evenness (E) were employed using the following equations:

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

Where: H = Shannon–Wiener diversity index and Pi = the proportion of individuals found in the i^{th} species.

$$E = \frac{H}{H_{max}} = \frac{H}{\ln S'}$$

Where: E = Evenness, H_{max}= the maximum level of diversity possible within a given population, which equals ln (number of species).

The absolute density (number of stems per hectare), frequency (number of plots with a species presence) and dominance (basal area of a species in m^2 per hectare) were calculated for all woody species in the study area using the standard methods. Then, relative density, relative frequency, and relative dominance were calculated using the following equations:

$$Relative\ density\ (RD) = \frac{Number\ of\ individuals\ of\ species}{Total\ number\ of\ individuals} x\ 100$$

$$Relative\ frequancy\ (RF) = \frac{Frequancy\ of\ a\ species}{Frequancy\ of\ all\ species}\ x\ 100$$

$$Relative\ dominance\ (RDO) = \frac{Dominance\ of\ a\ species}{Dominance\ of\ all\ species}\ x\ 100$$

$$\boldsymbol{Important\ value\ index = RD + RF + RDO}$$

With the purpose of understanding the community and population structure, a population frequency diagram was generated based on different diameter sizes. The vegetation analysis was conducted on the R software program using the "vegan" and the "BiodiversityR" packages (Dixon, 2003; Kindt, 2018; Team, 2021).

Spatial data collection and analysis

Several spatial databases were collected to quantify the current distribution of different forest communities in the study area. The freely available Sentinel 2A satellite images with 10 - meter spatial resolution were downloaded. A better cloud-free image was selected from the available list of images. Two tiles (T38 NKN and T38 NLN) encompassed the entire study area. The selected satellite image was acquired in the late dry season (January – February/2022) to allow for clear separation of the different vegetation types. Only the spectral bands of the satellite images (Sentinel L2A) covering the Blue (Band - 2), Green (Band - 3), Red (Band - 4) and Near Infrared (Band - 8) were selected for the study.

Table 1. Description of different types of land cover classes.

No.	land cover classes	Description
1	Bare land	Areas with no vegetation cover consisting of exposed soil and/or bedrock
2	Settlement	Land covered by residences, road networks, buildings and small industrial areas in both rural and urban areas.
3	*Acacia* dominated woodland	Land covered by *Acacia-Commiphora* woodland but *Acacia* is a dominant species than *Boswellia* and *Commiphora*
4	*Commiphora* dominated woodland	Land covered by *Acacia-Commiphora woodland* but *Boswellia* and *Commiphora species* are dominant than *Acacia species*
5	Scrubland	Land covered by small trees, shrubs and herbs, which may be succulent, geophytic, or annual.
6	Undifferentiated forest	The undifferentiated forest is inaccessible to differentiating physically

The images were geometrically and radiometrically (i.e., top of the atmosphere) corrected. Image pre-processing techniques such as sub-setting, layer stacking and image enhancement were conducted for the downloaded images. The Random Forest algorithm of the supervised classification technique was implemented to classify the image into the aforementioned classes (Table 1). The spatial analysis was conducted on R software and ArcGIS software programs.

Results and Discussion

Woody species distribution, diversity and composition

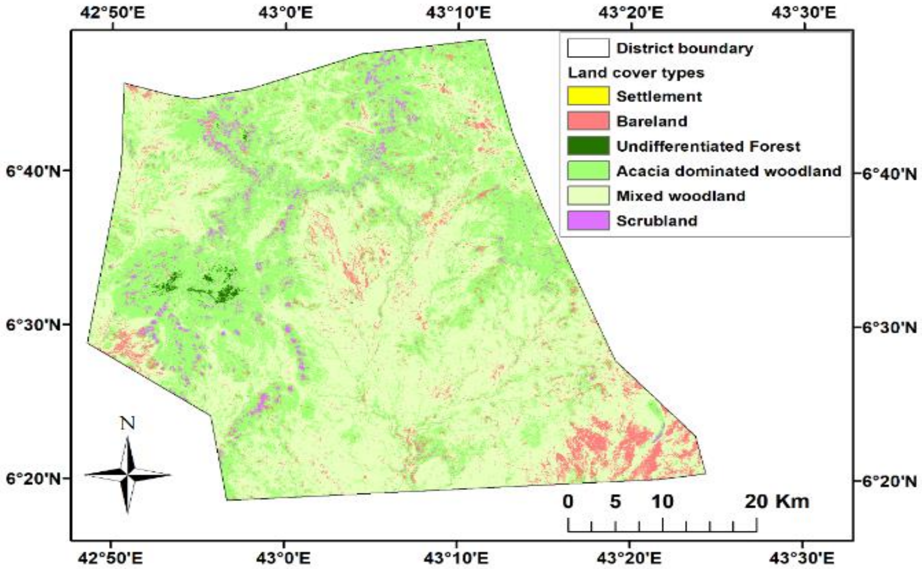

Figure 2. Spatial distribution map of vegetation types of the study area.

The distribution map of the study area implies that the district has a total area of 242,030.35 hectares (Figure 2). The Acacia woodland (36.3%) and mixed woodland (54.1%) vegetation types dominated the landscape. The proportion of the other land cover categories was 14416.9 ha (5.9%) bare land, 7193.7 ha (2.9%) scrubland, 1165.1 ha (0.5%) undifferentiated forest and 510.2 ha (0.2%) settlement. The undifferentiated forest was found in remote and inaccessible areas where the altitude is relatively higher.

Table 2. The area coverage and density of predominant woody species in the study area.

No.	Land cover types	Area (ha)	Proportion (%)	Botanical name	Density of dominant tree species (stem/ha)
1	Settlement	510.24	0.21		-
2	Undifferentiated forest	1165.11	0.48		-
3	Scrubland	7193.71	2.97		-
4	Bare land	14416.89	5.96		-
5	Acacia dominated woodland (n = 15)	87864.94	36.30	*Acacia senegal*	49.6
				Commlphoragowlello	13.3
				Commiphora myrrha	12.6
				Commiphora truncata	6.7
				Commiphora erythraea	5.9
				Boswellia neglecta	5.2
				Boswellia rivae	5.2
6	Mixed woodland (n = 15)	130879.46	54.08	*Boswellia neglecta*	18.5
				Commlphora gowlello	14.8
				Acacia senegal	13.3
				Commiphora truncata	13.3
				Commipbora hodai	11.9
				Commiphora erythraea	11.1
				Commipbora samharensis	10.4
	Total	242,030.35	100.00		

A total of 34 woody species were recorded from the study area of which *Acacia, Boswellia,* and *Commiphora* are the three genera producing gum and resin. The mean pooled diversity of the study area is 3.03 and 0.93 for the Shannon and Simpson diversity indices, respectively (Table 3). *Acacia senegal, Commiphora erythraea, Commlphora gowlello, Acacia asak* and *Commiphora myrrha*, are the five most frequently found species in the study area. While the most dominant gum and resin bearing species in the study area include *Commiphora guidotii, Commiphora erythraea, Commiphora myrrha, Boswellia rivae* and *Acacia senegal.*

Table 3. Woody species diversity of the study.

Diversity indices	Pooled values
Richness	34.00
Shannon diversity	3.03
Simpson diversity	0.93
Evenness	0.61

The spatial distribution, together with composition and density of the gum and resin species (Table 3) indicate that there is a huge potential in the study area to produce several types of Oleo-gum resins such as gum arabic from *A. senegal*, frankincense from *B. neglecta* and *B. rivae*, myrrh from *C. myrrha* and *C. truncate*, opopanax from *C. guidotii*, Hager from *C. africana*.

Table 4. Estimated production potential of different gum and resin products in the study area.

Product name	Density (stems/ha)		Mean production kg/tree/yr	Estimated production gum/resins in kg/ha/yr	
	Acacia woodland	Mixed woodland		Acacia woodland	Mixed woodland
Gum arabic	49.6	13.3	3.4	168.6	45.2
Myrrh	34.1	48.9	3.9	132.9	190.7
Frankincense	10.4	24.4	3.9	40.6	95.2
Hager	5.9	11.8	5.3	31.3	62.5
Opopanax	5.2	6.7	NA	-	-
Damacho	2.9	2.2	NA	-	-
Unidentified	7.4	15.6	NA	-	-

The estimated production (Table 4) shows variation between the two types of vegetation. In the *Acacia* woodland, there is a better production potential of gum arabic compared to the mixed woodland. While myrrh, frankincense and Hager are produced in greater quantity from the Mixed woodland vegetation type. Thus, the resource potential of the study area is huge and is an indication of the need for a better utilization of the resource. The results are also consistent with a study that claims the underutilization of gum and resin resources in Ethiopia (Tadesse *et al.*, 2007). It should be noted that these products are internationally demanded commodities for various applications such as food, beverages, pharmacology, adhesives and cosmetics industries and can be sources needed hard currencies (Başer *et al.*, 2003; Lemenih and Teketay, 2005; Sambawa *et al.*, 2016; Hamad *et al.*, 2017; Efferth and Oesch, 2022).

Structure and regeneration status

The diameter class distribution of the entire community showed "reverse J-shaped" which is regarded as a higher density of individuals found at the lower diameter classes and gradually decreasing their density with increasing diameter class (Figure 3). The first diameter class (< 5 cm DBH) shows a slight decrease that indicates insufficient regeneration of woody species at the community level. The regeneration status also indicates a "J-shape" which shows the unhealthy status of the regeneration of woody species (Figure 3).

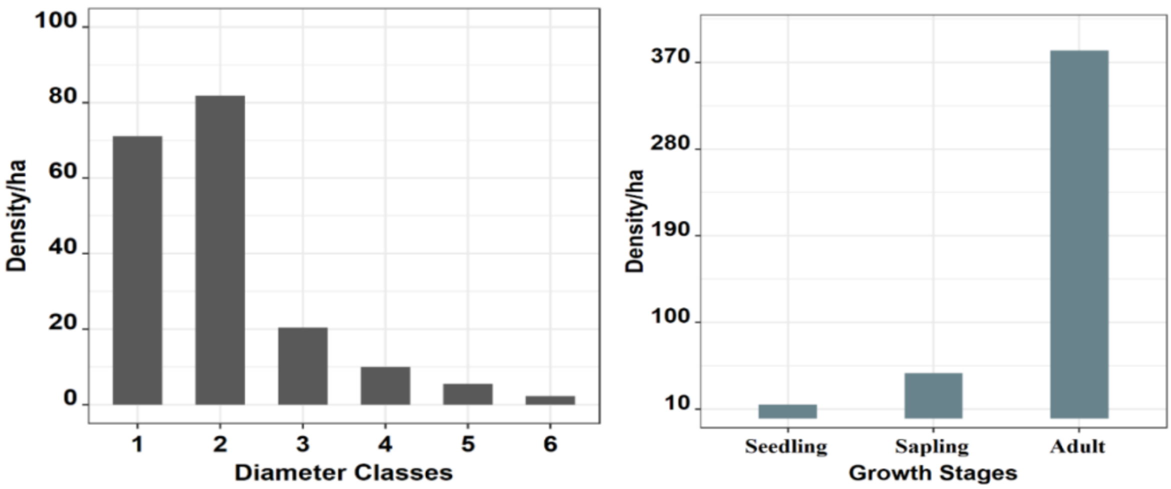

Figure 3. Diameter class distribution (diameter class in cm: class 1 < 5 cm, 2 =5 – 10 cm, 3 = 10 – 15 cm, 4 = 15 – 20 cm, 5 = 20 – 25 cm, 6 ≥ 25 cm) of the community (Left) and regeneration status of woody species (Right).

The population structure of some of the species (most of them are gum and resin-bearing species) shows an irregular pattern and is bell-shaped (Figure 4). The bell-shaped pattern is described by the larger density of individuals in the middle diameter class (DBH = 5-20 cm). Except for *Acacia asak*, the population structure of the dominant woody species lacks the density of individuals at the lower diameter class (particularly in the first and second classes), which indicates poor regeneration and recruitment. This pattern is consistent with previous studies in the lowland dry forest of Ethiopia (Adem *et al.*, 2014; Hido *et al.*, 2020).

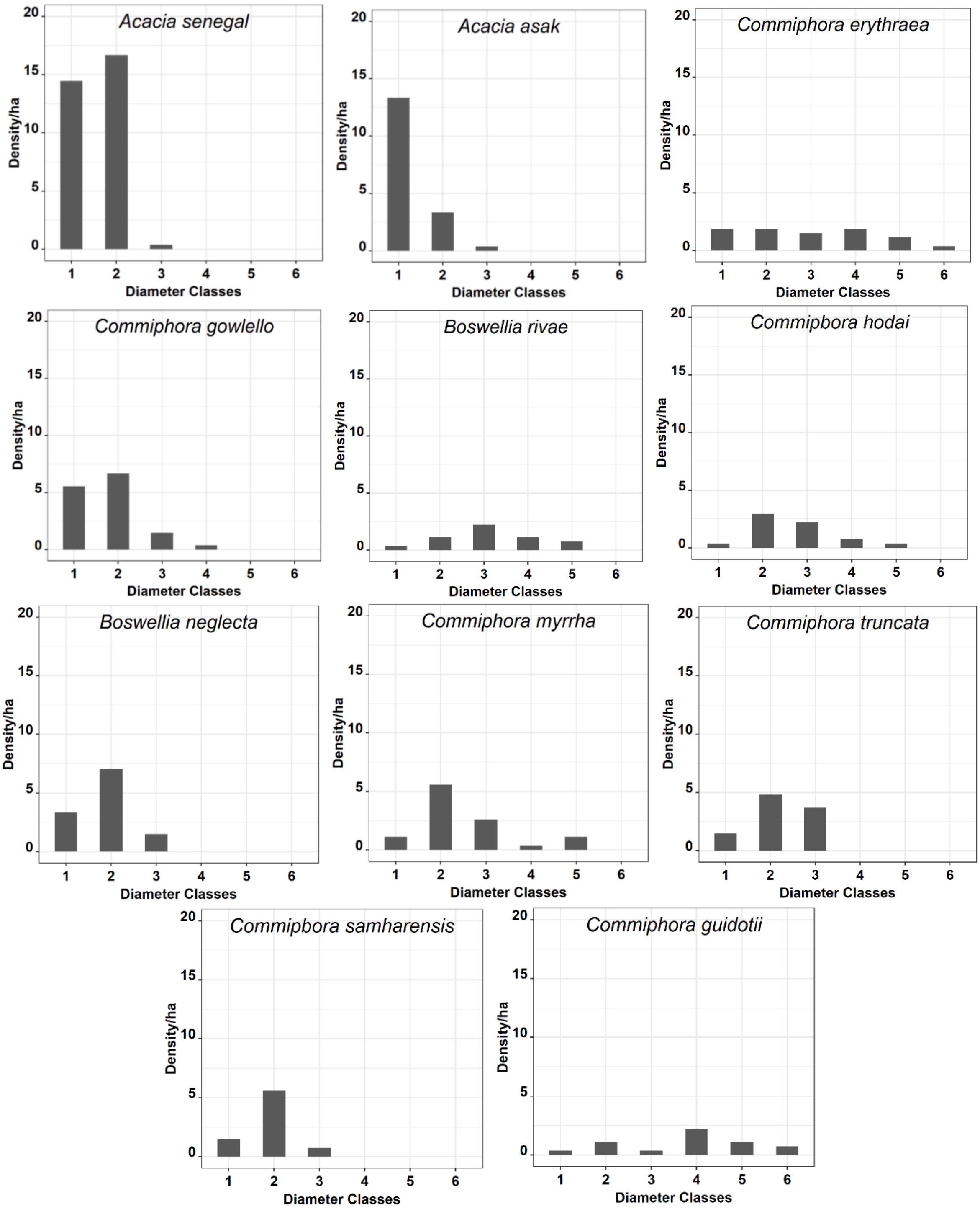

Figure 4. Diameter class distribution (diameter class in cm: class 1 < 5 cm, 2 =5 – 10 cm, 3 = 10 – 15 cm, 4 = 15 – 20 cm, 5 = 20 – 25 cm, 6 ≥ 25 cm) of dominant and abundant species.

The results also showed that the vegetation resources of the study area are relatively less affected by urbanization and agricultural expansion, unlike the western and Northwestern lowland forests of Ethiopia. Moreover, it was observed that there was relatively less charcoal production and marketing in the study area. However, the vegetation might be affected by over-grazing activities since the livelihood of the community depends primarily on livestock production. The free grazing practice of the lowland forests in the Horn of Africa has been reported as a major factor that hampers the natural regeneration of gum and resin species (Lemeneh and Kassa, 2011). Climate variability and frequent drought could also be another factor for the loss of regeneration of the woody plants in general and gum and resin-bearing species in particular.

The findings of the study highlight the contribution of dry forests in the Horn of Africa to enhance livelihood as well as halt the decline of biodiversity. These are the two most challenging global sustainability issues (Wei *et al.*, 2018). However, little attention is usually given, in terms of research and development to the lowland dry forests of Ethiopia as compared to the montane forest. For instance, the absence of nurseries that propagate and raise lowland tree species is one of the most compelling explanations for the claim that there is a lack of attention to the lowland dry forests. Moreover, the soil, in Arid and Semi-arid circumstances, is highly vulnerable for degradation so forest restoration is crucial and cost-effective (Crouzeilles *et al.*, 2020). With a slight reduction in human pressures, the restoration of such areas may require little effort to achieve results that are more significant before the degradation reaches the stage of no return.

Finally, it is suggested that research and development in these ecologically and economically useful lowland dry forests would be very helpful to effectively restore the landscapes by selecting appropriate restoration techniques and available propagation mechanisms. Implementing appropriate restoration is urgent to enhance and aid natural regeneration while, at the same time, formulating sustainable utilization and marketing of gum and resin species would be crucial to the well-being of the surrounding community and the country at large.

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