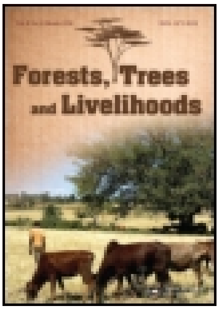

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Diversity, regeneration status, and population structures of gum and resin producing woody species in Borana, Southern Ethiopia

Adefires Worku [a], Demel Teketay [b], Mulugeta Lemenih [c] & Masresha Fetene [d]

[a] Ethiopian Institute of Agricultural Research, Forestry Research Center, P.O. Box 30708, Addis Ababa, Ethiopia

[b] Eco Mark Africa, African Eco-Labelling Mechanism Secretariat, 4th Floor, International House, P.O. Box 41607-00100, Nairobi, Kenya

[c] Wondo Genet College of Forestry and Natural Resources, P.O. Box 128, Shashemene, Ethiopia

[d] Addis Ababa University, Science Faculty, Biology Department, P.O. Box 31819, Addis Ababa, Ethiopia

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Diversity, regeneration status, and population structures of gum and resin producing woody species in Borana, Southern Ethiopia

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[a]*Ethiopian Institute of Agricultural Research, Forestry Research Center, P.O. Box 30708, Addis Ababa, Ethiopia;* [b]*Eco Mark Africa, African Eco-Labelling Mechanism Secretariat, 4th Floor, International House, P.O. Box 41607-00100, Nairobi, Kenya;* [c]*Wondo Genet College of Forestry and Natural Resources, P.O. Box 128, Shashemene, Ethiopia;* [d]*Addis Ababa University, Science Faculty, Biology Department, P.O. Box 31819, Addis Ababa, Ethiopia*

Severe drought and large-scale ecosystem degradation are the two major threats exacerbating livelihood vulnerability of the pastoral and agropastoral communities in Borana Zone, southern Ethiopia. Strategic integration and sustainable management of the vast gum and resin bearing dry forests offer significant socioeconomic and ecological opportunities to enhance adaptation of these communities to adverse climatic variability, while enhancing ecosystem resilience. This study was carried out to investigate the diversity, abundance, distribution, and population structure of gum and resin bearing species in Borana drylands. Surveys were carried out in two districts: Arero and Yabello. Seventy-five (20×20 m) quadrats were established at 500 m intervals along transects in seven localities. Forty-six woody species distributed in 16 families and 25 genera were encountered. Gum and resin producing species comprised about 42 and 61% of the total number of species, 49 and 68% of the density ha^{-1}, and 73 and 84% of the total basal area at Arero and Yabello, respectively. Regeneration and diameter class distribution showed clear signs of healthy populations, except for a small number of species, which exhibited bell-shaped diameter class distribution patterns. The results revealed that Borana Zone hosts more diverse commercial gum and resin bearing species compared to the northern part of the country, where organized production and marketing of gum and resin are well developed, and other relatively similar places, such as Middle Rift Valley and the neighbouring Somali region in Ethiopia. Such diversity, abundance, and the overall positive regeneration status of most of the gum and resin bearing species in Borana make up a solid and healthy basis for promoting the sustainable management of woodland resources through organized production and commercialization of high value oleo-gum resins.

Keywords: dry woodland; density; frequency; dominance; Importance Value Index; climate change adaptation

Introduction

Among the different agro-ecological zones existing in Ethiopia, drylands (super arid, arid, semi-arid and dry, subhumid areas) cover the largest landmass proportion of the country, estimated at over 70% (Georgis et al. 2010). Drylands in Ethiopia spread from 124 m below sea level to 1,500 m above sea level, with rainfall ranging from 100 to 700 mm annually (Georgis et al. 2010). These ecosystems host vast dry forest resources and are home for a diverse flora and fauna and for unique endemic species (FAO 2010; Eshete et al. 2011).

*Corresponding author. Email: dteketay@yahoo.com

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Dry forest resources are adapted to the pastoralist and agropastoralist land use systems and to the harsh environment (Dalle et al. 2005). However, overgrazing, increasing population pressure, and climate change have resulted in a severe degradation of these forests, making them vulnerable to desertification (Teketay 2004–2005; Kassahun et al. 2008).

Dry forest and woodland resources in Ethiopia, as elsewhere in Africa, are important components of the livelihoods of pastoralists and agropastoralists (Lemenih et al. 2003; Woldeamanuel 2011; Worku et al. 2011). The complex socioeconomic and ecological conditions of these communities and their ecosystems call for studies that facilitate mainstreaming dry forest resources in development and conservation efforts (Lemenih and Teketay 2004; Teketay 2004–2005; Worku et al. 2011).

Borana Zone, where this study was conducted, is located in southeastern Ethiopia. In this zone, most of the landmass (69.1%) is characterized as arid and semi-arid (Solomon et al. 2007). As described in Worku et al. (2011), Borana Zone houses several valuable species in the genera *Acacia, Commiphor,a* and *Boswellia*, principal sources of commercial gums and resins. These species are also often used for fodder and provide herbal medicine (Dalle et al. 2005; Worku et al. 2011).

Despite the growing ecological and socioeconomic recognition of the dry woodland resources in general, very little research has been done to understand the ecological and population status of the dry woodland vegetation in Ethiopia (e.g., Eshete et al. 2005; Lemenih et al. 2007; Abiyu et al. 2010; Eshete et al. 2011). In particular, detailed information on the diversity and population status of gum and resin producing species is scanty in the southern and southeastern parts of the country, although it is of crucial importance for an integrated and sustainable management of these versatile resources.

The objectives of this study were to provide quantitative information on the species diversity, abundance, regeneration status, and distribution of gum and resin bearing woody species in Borana drylands, southern Ethiopia, and thereby to contribute to the ongoing efforts to better integrate these resources in livelihood development and ecosystem management in these dry woodlands.

Materials and methods

Study areas

Borana Zone (hereafter referred to as Borana) lies at the most southern and southeastern edges of the Oromia National Regional State, southern Ethiopia, between 36^0 42' 38''' to 39^0 45' 15''' E and 3^0 31' 31''' to 6^0 35' 37''' N (Figure 1). Most of the area falls under the dry climatic regime with marginal or no agricultural potential. The mean annual rainfall ranges between 400 and 600 mm (Dalle et al. 2005). The rainfall distribution is bimodal with a short rainy season occurring between April and May and a major dry season occurring between December and February (Dalle et al. 2005). The small monthly rainfall is associated with a high evapo-transpiration rate, which makes the rainfall unable to sustain good livestock and agricultural production (Sabine 2004). The human population of Borana is estimated at about 400,000 (Dalle et al. 2005). The people of the study area are called Borana, the eldest branch of the Oromo ethnic group in Ethiopia, and derive their subsistence from livestock husbandry and small-scale traditional farming practices. Most communities are dependent on the collection of various non-timber forest products to generate income (Dalle et al. 2005; Worku et al. 2011).

The two districts (Arero and Yabello) where this study was conducted are covered with woodlands dominated by an *Acacia-Commiphora* formation.

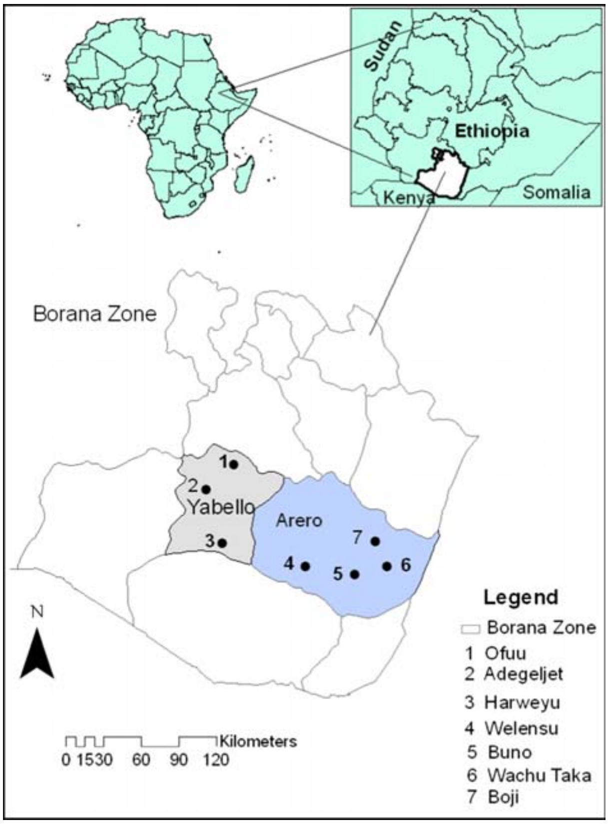

Figure 1. Map of Ethiopia showing location of the study areas.

Data collection

In the Arero district, seven key informants were asked to list potential sites based on the availability of gum and resin bearing species and the gum and resin collection history. The informants were two elderly men representing local communities, two middlemen, and three experts, one from the natural resources management department, one from a local nongovernmental organization, and one from a gum and resin marketing company. Seven potential sites were identified and four localities (Buno, Wachu Taka, Boji, and Welensu) were randomly selected for vegetation assessment. A similar procedure was applied in the Yabello district, where three localities (Harweyu, Adegeljet, and Ofuu) were finally selected from the listed five localities.

To assess the diversity and population status of woody species, 75 (20 × 20 m) quadrats (43 at Arero and 32 at Yabello) were laid down at intervals of 500 m along north-south transects. Transects were 500 m apart from each other. We used a similar number of quadrats in each locality. In each quadrat, 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 ≥ 2.5 cm diameter was measured.

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 the National Herbarium at Addis Ababa University.

Data analyses

The collected data were used to compute species richness, diversity, evenness, similarity, density, frequency, basal area, Importance Value Index (IVI), and population structure of woody species in each study district. 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) (Magurran 1988). The similarity in woody species composition of the two districts was computed using Jaccard's Similarity Coefficient (S_j) (Magurran 1988).

Density of woody species was determined by converting the total number of individuals of each woody species encountered in all the quadrats 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^{-1}.

Frequency, which refers to the degree of dispersion of individual species in an area, was expressed as the ratio of the number of quadrats in which a species occurred to the total number of quadrats, whereas relative frequency was computed as the ratio of the frequency of the species to the sum total of the frequency of all species (Kent and Coker 1992).

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 (Kent and Coker 1992) is used to give an overall indication of the importance of a plant species in a plant community. It is the sum of the values of relative frequency, relative density, and relative dominance of the species.

Biodiversity Professional Version 2 Software Program (Niel 1997) was used to run the analyses of the vegetation data.

Results

Species richness

Forty-six woody species (41 at Arero and 23 at Yabello) representing 16 families and 25 genera were recorded (Table 1). Burseraceae and Fabaceae were the most diverse families, each represented by 12 (26%) and 11 (24%) species, respectively. *Commiphora* and *Acacia*, two of the genera with gum and resin producing species, were the first and second most diverse genera, represented by 10 and 6 species, respectively. In total, 18 (39%) species (17 at Arero and 14 at Yabello) were identified as sources of gums and resins. However, according to respondents, three of these species, namely *Acacia oerfota, Lannea rivae*, and *Sterculia stenocarpa*, were only occasionally visited and their gums collected and mixed with other types of commercial gum.

Diversity, evenness, and similarity

The diversity of all woody species in Arero and Yabello were 3.22 and 2.77, respectively, while the corresponding values of evenness were 0.87 and 0.78, respectively. Similarly, the diversity of gum and resin bearing woody species in Arero and Yabello were 2.6 and 2.23, respectively, while the corresponding values of evenness were 0.88 and 0.82.

The two sites shared 18 woody species in common, of which 13 were gum and resin bearing species (Table 1). The similarity of all woody species ($S_j = 0.39$) was low, while that of gum and resin bearing species ($S_j = 0.72$) was relatively very high.

Table 1. List of species encountered in the study quadrats at Arero and Yabello.

		Arero				Yabello			
Scientific name	Family	**RDE**	**RFR**	**RBA**	**IVI**	**RDE**	**RFR**	**RBA**	**IVI**
Grewia tembensis Fresen.[S]	Tiliaceae	12.35	4.1	1.25	17.70	–	–	–	–
Grewia villosa Willd.[S]	Tiliaceae	8.72	3	0.50	12.22	7.65	4.82	0.77	13.24
Boswellia neglecta S. Moore*[T/S]	Burseraceae	7.72 (15.0)	6.9	16.25	30.87	4.97 (4.3)	5.70	7.50	18.18
Acacia senegal (L.) Willd.* [T/S]	Fabaceae	7.58 (23.0)	6.5	2.50	16.58	9.18 (12.7)	7.89	4.75	21.82
Commiphora africana (A. Rich.) Engl.* [T/S]	Burseraceae	7.10 (23.3)	6.9	5.00	19.00	6.50 (10.5)	6.15	5.97	18.63
Grewia bicolor Juss.[S]	Tiliaceae	4.48	1.9	0.38	6.76	13.47	4.82	0.15	18.44
Blepharispermum sp.[S]	Asteraceae	3.72	1.6	0.50	5.82	–	–	–	–
Harmsia sidoides K. Schum.[S]	Sterculiaceae	3.72	1.9	0.25	5.87	2.60	0.88	0.46	3.94
Ipomoea donaldsonii Rendle[S]	Convolvulaceae	3.72	1.8	0.50	6.02	–	–	–	–
Commiphora erythraea (Ehrenb.) Engl.*[T]	Burseraceae	3.38 (4.0)	5.7	12.50	21.58	3.37 (1.1)	4.39	4.75	12.50
Commiphora confusa Vollesen* [T]	Burseraceae	2.86 (1.1)	5	7.50	15.36	10.71 (5.8)	10.96	21.44	43.11
Commiphora myrrha (Nees) Engl.* [T]	Burseracea	2.81 (7.8)	3.7	2.50	9.01	–	–	–	–
Boswellia microphylla Chiov.* [T/S]	Burseraceae	2.67 (2.6)	3	3.75	9.42	–	–	–	–
Commiphora habessinica (Berg) Engl.*[T/S]	Burseraceae	2.48 (1.5)	4.1	5.00	11.58	5.05 (4.9)	6.14	7.81	19.0
Acacia bussei Harms ex Sjöstedt[T]	Fabaceae	2.34	4.2	7.50	14.04	2.60	4.82	6.13	13.55
Commiphora kua (R. Br. ex Royle) Vollesen* [T/S]	Burseraceae	2.24 (1.1)	3.7	3.75	9.69	3.60 (3.8)	4.82	4.90	13.32
Acacia mellifera (Vahl) Benth.* [T/S]	Fabaceae	2.10 (6.5)	3.5	1.25	6.85	5.66 (12.9)	7.02	2.60	15.29
Dodonea angustifloia L. *f.*[T/S]	Sapindaceae	2.00	0.7	0.25	2.95	–	–	–	–
Commiphora terebinthina Vollesen*[T/S]	Burseraceae	1.72 (3.1)	3.2	2.50	7.42	–	–	–	–
Commiphora boranensis Vollesen*[T/S]	Burseraceae	1.67 (2.9)	2.8	1.25	5.72	0.99 (0.9)	1.75	0.92	3.66

Table 1 – *continued*

		Arero				Yabello			
Scientific name	Family	**RDE**	**RFR**	**RBA**	**IVI**	**RDE**	**RFR**	**RBA**	**IVI**
Commiphora schimperi (Berg) Engl.* [T/S]	Burseraceae	1.43 (3.4)	2.7	1.25	5.38	1.84 (3.2)	3.07	1.99	6.90
Vernonia cinerascens Sch. Bip.[S]	Asteraceae	1.29	0.5	0.38	2.16	–	–	–	–
Indigofora volkensii Taub.[S]	Fabaceae	1.24	0.5	0.25	1.99	–	–	–	–
Lanea rivae (Chiov.) Sacl.*[T]	Anacardiaceae	1.19 (1.7)	3.5	5.00	9.69	1.22 (2.0)	3.51	2.91	7.64
Kirkia burgeri Stannard[S]	Simaroubaceae	1.14	1.8	2.50	5.44	–	–	–	–
Premna schimperi Engl.[S]	Verbenaceae	1.05	1.1	0.25	2.40	–	–	–	–
Acacia tortilis (Forssk.) Hayne[T]	Fabaceae	1.05	1.8	2.50	5.35	3.14	5.7	6.89	15.73
Lanea triphylla (A. Rich.) Engl.[T]	Anacardiaceae	0.95	0.5	0.50	1.95	–	–	–	–
Delonix ellata (L.) Gamble[T]	Fabaceae	0.91	2.8	5.00	8.71	–	–	–	–
Plectranthus igniarius (Schweinf.) Agnew[S]	Lamiaceae	0.86	0.5	0.13	1.48	–	–	–	–
Commiphora corrugata Gillett & Vollesen* [T/S]	Burseraceae	0.57 (0.7)	1.8	0.50	2.87	–	–	–	–
Sterculia stenocarpa H. Winkler*[T]	Sterculiacea	0.48 (0.7)	2.3	2.50	5.28	0.54 (1.3)	1.32	1.07	2.93
Acacia oerfota (Forssk.) Schweinf.*[S]	Fabaceae	0.48 (1.4)	0.7	0.38	1.55	2.30 (12.9)	3.91	0.31	5.67
Erythria melanacantha Taub. ex Harms [T]	Fabaceae	0.48	1.2	1.25	2.93	–	–	–	–
Maerua triphylla A. Rich.[T/S]	Capparindaceae	0.43	0.5	0.38	1.30	–	–	–	–
Terminalia prunioides Laws.[T/S]	Combretaceae	0.38	1.1	0.38	1.86	–	–	–	–
Delonix baccal (Chiov.) Bak. *f*.[T]	Fabaceae	0.19	0.7	1.25	2.14	–	–	–	–
Sesamothamus rivae [T]	Pedaliaceae	0.19	0.9	0.25	1.34	–	–	–	–
Terminalia brownii Fresen.[S]	Combretaceae	0.14	0.2	0.25	0.59	–	–	–	–
Ormocarpum trichocarpum (Taub.) Engl.[S]	Fabaceae	0.14	0.4	0.13	0.67	–	–	–	–
Hibiscus crassinervius Hochst. ex A. Rich.[S]	Tiliaceae	0.05	0.4	0.13	0.57	–	–	–	–
Acacia seyal Del.*[T]	Fabaceae	–	–	–	–	10.71 (23.7)	8.34	17.0	36.05

Table 1 – *continued*

		Arero				Yabello			
Scientific name	Family	RDE	RFR	RBA	IVI	RDE	RFR	RBA	IVI
Dicrostachys cinerea (L.) Wight & Arn.$^{T/S}$	Fabaceae	–	–	–	–	1.30	0.88	0.15	2.33
Grewia tenax (Forssk.) Fiori^{S}	Tiliaceae	–	–	–	–	0.99	1.32	0.15	2.47
Balanites aegyptiaca (L.) Del.$^{T/S}$	Balanitaceae	–	–	–	–	0.54	1.75	0.92	3.20
Boscia mossambicensis Klotzsch^{T}	Capparidaceae	–	–	–	–	0.23	0.88	0.46	1.57
Total		100	100	100	300	100	100	100	300
Total density ha^{-1}		2,098 (805)				1,307 (331)			
Total frequency		566				230			
Total basal area		8				6.53			

Note: RDE (%) = relative density (figures in parentheses are seedlings); RFR (%) = relative frequency; RBA (%) = relative basal area; IVI = Importance Value Index; S = shrub; S/T = shrub/tree; T = tree.
*Gum and resin producing species.

Density, frequency, and dominance

The densities of all woody species, including seedlings, were 2,098 and 1,307 stems ha^{-1} at Arero and Yabello, respectively (Table 1). Of these, the gum and resin bearing species accounted for 1,017 (about 49% of total) and 882 (about 68% of total) stems ha^{-1} at Arero and Yabello, respectively (Figure 2). A few species dominated the woody vegetation at the two districts. For instance, five species, namely *Boswellia neglecta, Acacia senegal, Commiphora africana, Grewia tembensis*, and *G. villosa*, contributed to 44% of the total density at Arero, while *Grewia bicolor, Commiphora confusa, Acacia seyal, A. senegal*, and *G. villosa* contributed to 53% of the total density at Yabello. *Acacia senegal* was the only species with relatively high densities in the two study districts.

The three most abundant gum and resin producing species were *B. neglecta*, *A. senegal*, and *C. africana* at Arero, with 162, 159, and 149 individuals ha^{-1}, respectively, and *C. confuse*, *A. seyal*, and *A. senegal*, with 151, 140, and 120 individuals ha^{-1}, respectively, at Yabello. At Arero, the highest frequency (91%) was recorded for *B. neglecta* and *C. africana*, each recorded in 39 out of the 43 quadrats, followed by *A. senegal* (86%), recorded in 37 quadrats. *Commiphora confusa* and *A. seyal* were the most frequently recorded gum and resin bearing species at Yabello, with frequencies of 78% and 59%, respectively, followed by *A. senegal* and *A. mellifera*, each with 56 and 50% (Table 1). At Arero, the minimum frequency was observed for *A. oerfota* (16%), while at Yabello it was *S. stenocarpa* (9%). The total basal areas of woody species were 8.0 and 6.5 m^2 ha^{-1}, in Arero and Yabello, respectively, including 5.9 (73%) and 5.5 (84%) m^2 ha^{-1} for gum and resin bearing species (Table 1).

Importance Value Index

Gum and resin bearing species accounted for about 63 and 75% of the IVI at Arero and Yabello, respectively. The species with the highest IVI were *B. neglecta, C. erythraea, C. Africana*, and *A. senegal* at Arero, and C. *confusa, A. seyal*, and *A. senegal* at Yabello (Table 1).

Regeneration status and population structure

The total seedling density of gum and resin producing species were 344 and 152 individuals ha^{-1} at Arero and Yabello, respectively. Species with the highest seedling density were *C. africana, A. senegal*, and *B. neglecta* at Arero, and *Acacia seyal*, *A. mellifera*, *A. senegal*, and *C. africana* at Yabello (Table 1).

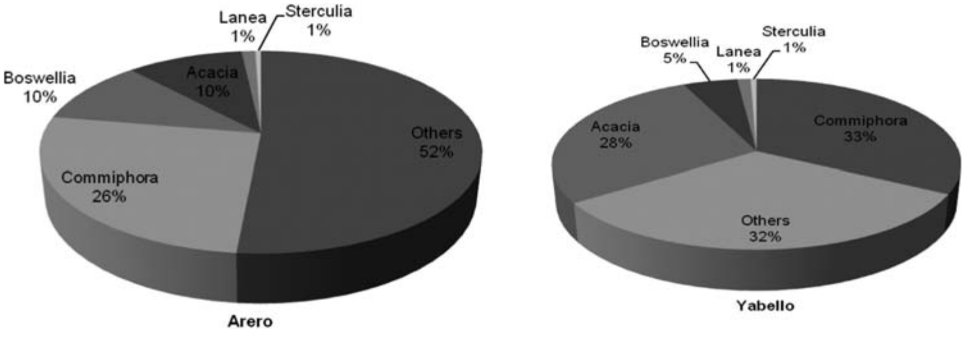

Figure 2. Proportion of the density (stem number) ha^1 of gum and resin bearing and associated species at Arero and Yabello districts, respectively, Borana drylands, southern Ethiopia.

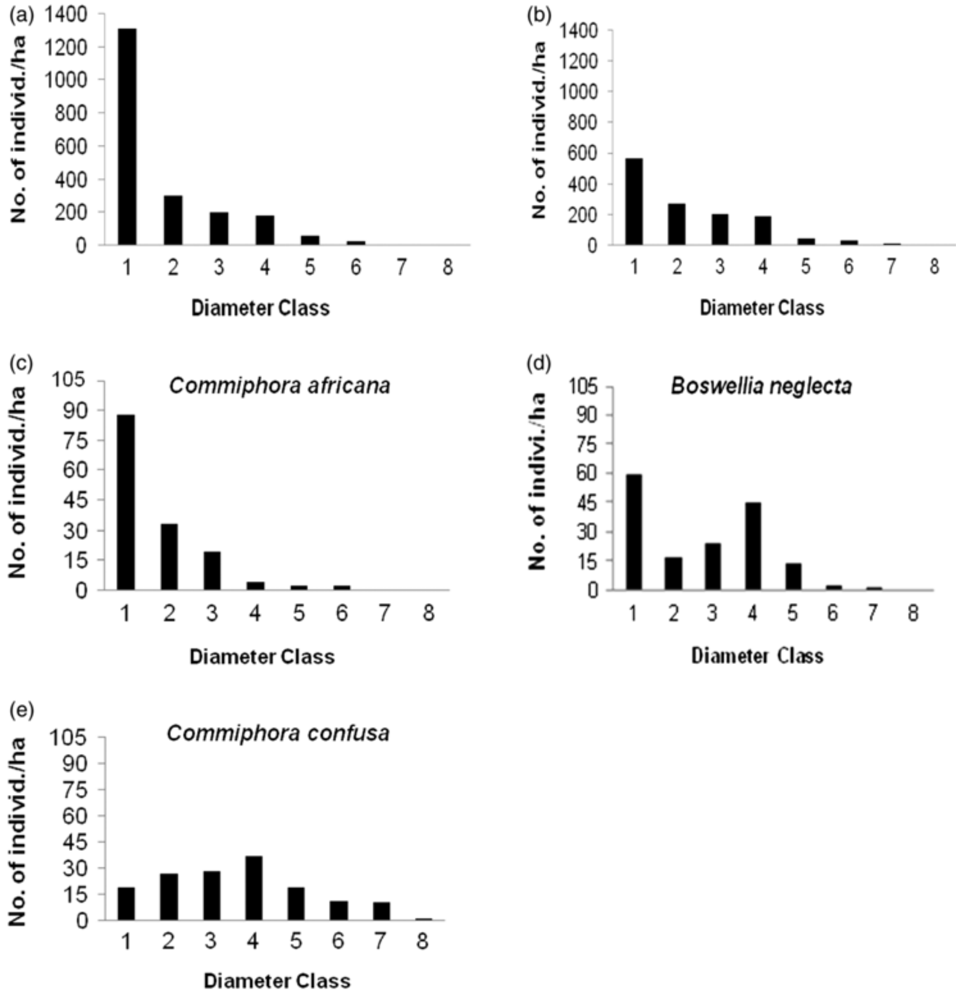

Figure 3. Diameter size class distribution of the entire vegetation at Arero (a) and Yabello (b) districts and three selected species (c–e) in the Borana drylands and southern Ethiopia (diameter class in cm: class 1 = 0–4 cm, 2 = 4–8, 3 = 8–12, 4 = 12–16, 5 = 16–20, 6 = 20–24, 7 = 24–28 and 8 = $>$ 28).

The population structure of the entire woody species showed higher stem densities in the lower diameter classes and progressively declining stem densities with increasing diameter classes at both districts (Figures 3a & 3b).

Based on their population structures, the gum and resin producing species can be categorized into two diameter class distribution patterns. Group I contained species with a progressively declining numbers of trees with increasing diameter (e.g., *C. africana*) (Figure 3c). This group was comprised of *A. mellifera*, *A. senegal, A. oerfota, C. africana, C. myrrha*, and *C. schimperi* at Arero and *A. mellifera, A. senegal, A. oerfota*, and *C. africana* at Yabello. Group II was comprised of all other species from both districts with a bell-shaped or irregular distribution (e.g., *B. neglecta* and *C. confusa*) (Figures 3d & 3e).

Discussion and conclusions

The woodlands of Borana support diverse woody species, many of which produce gums and resins of high socioeconomic importance, with good stocking density and considerable horizontal distribution (frequency). The Borana rangelands have also been reported to house high floristic diversity with over 327 plant species (Dalle et al. 2005). The richness in gum and resin bearing species in Borana is much higher than in other woodlands in the country. For instance, only nine (Gebrehiwot 2003; Eshete et al. 2011), two (Argaw et al. 1999), and seven (Lemenih et al. 2003) gum and resin bearing species have been reported from northern, central, and southeastern Ethiopia, respectively, compared with the 18 species reported here from Borana. In addition, the genus *Commiphora* is represented by only one resin producing species, namely *C. africana*, in northern Ethiopia (Gebrehiwot 2003; Eshete et al. 2011), compared with the ten species reported here. Similarly, fewer gum and resin bearing species were reported from Eritrea (Ogbazghi et al. 2006) than those reported here.

The relatively high species richness, diversity, and abundance of gum and resin bearing species in Borana indicate the existence of yet untapped resources that could be used as viable options either for organized production and marketing by the local pastoral and agropastoral communities to diversify their livelihoods and/or local, national, and/or international private investments to develop the gum-resin subsector value chain.

Many authors use one form or another of the IVI to rank species in terms of their ecological importance in the functioning of a plant community (e.g., Lévesque et al. 2011; Sunil et al. 2011). The fact that several of the gum and resin bearing species are among those with the highest IVIs suggests that they are also among the most ecologically important species. Most of the gum and resin bearing species are also multipurpose in nature (Worku et al. 2011), for instance for improving soil conditions or as sources of fodder. This supports their integration into current initiatives to ensure food security, combating desertification and mitigating climate change in the study areas (Lemenih and Teketay 2004).

The population structure of woody species can help understand the regeneration status of species and forest stands (Tesfaye et al. 2010; Zegeye et al. 2011). Reverse J-shaped distributions such as those shared by Group I species in this study indicate a healthy and stable regeneration (Harper 1977; Silvertown 1982). In contrast, bell-shaped distributions (Group II species in this study) suggest hampered regeneration. This may be inherent to the biology of the species or due to external factors, which require further investigation. Despite indications of hampered regeneration, most of the species in Group II had a considerable number of individuals in the middle diameter classes that could be managed sustainably to improve their regeneration and produce gums and resins.

Generally, regeneration of the woody species was better at Arero compared with Yabello, which might be attributed to more permanent settlements of people and farming activities at Yabello, which are exerting continuous pressure on the woody vegetation resources. As indicated by Dalle et al. (2005) and Worku et al. (2011), gum and resin bearing species are among the main fodder species in Borana. Seedlings of some of the *Commiphora*, *Boswellia*, and *Sterculia* species are browsed by small calves, goats, sheep, and wild animals, which might have contributed to their poor regeneration compared to the high seedling densities of *Acacia* species. Grazing was also mentioned as a major detrimental factor for tree regeneration elsewhere in dry forests of the tropics (Miles et al. 2006; Staver et al. 2009). *Commiphora corrugata*, *C. confuse, C. kua*, and *S. stenocarpa* at Arero and *S. stenocarpa*, *C. erythraea, C. boranensis*, and *L. rivae* at Yabello need special attention since they were represented with only a few individuals of seedlings. *Commiphora corrugata* showed the least IVI among the gum and resin bearing species. The fact that it has the lowest density and frequency values suggests a patchy distribution, and, thus, the need for measures to facilitate its regeneration.

Recurrent drought and severe degradation of rangelands in Borana drylands have made subsistent livestock production and crop farming unpredictable and unable to support livelihoods (Dalle et al. 2005; Worku et al. 2011). Food shortage is a common event, even in normal seasons (Sabine 2004). Hence, income generated from the sale of gums and resins has been identified as an important safety net during recurrent drought periods (Worku et al. 2011). In Borana, the need for environmentally friendly alternative strategies that help diversify the livelihoods of pastoralists and agropastoralists is more important than ever. In this regard, our findings revealed that there is a huge potential for the sustainable management and strategic integration of the gum and resin resources with other initiatives targeting socioeconomic development and environmental conservation in Borana.

Further in-depth research is required to understand the biology and ecology of gum and resin bearing species, mainly in view of their response to alarming climate and land-use changes and to encourage their inclusion in plantation and domestication schemes. It would also be beneficial to develop suitable tapping, processing, and handling technologies that could add value to the products. Particular attention is required to address the hampered regeneration of some of the species. With successful management and development, promoting the integration of the gum and resin resources in Borana with the other ongoing initiatives, through the active involvement of local communities, could be an appropriate pathway to socioeconomic development and environmental conservation, as well as climate change adaptation and mitigation.

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