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Research Article

Distribution, Association and Population Structure of Osyris Quadripartita (African Sandalwood) in a Dry Woodland Forest, Southern Ethiopia

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ABSTRACT

The population status of Osyris quadripartita (Africa sandalwood) is endangered in some places due to overexploitation for commercial values. The study aim was to assess distribution, association and structure at Arba Minch Zuria and Banna-Tsemay Districts, Southern Ethiopia. An inventory of species was carried out for determining the relative proportion of the selected woody species in communities. Systematic sampling was used to collect data from 62 quadrats (20 m x 20 m) established along transects. Woody species DBH of >2.5 cm and Height of >1.5 m were measured at each sampled plots. The result showed that 75 woody species from 29 families were recorded from both sites; Fabaceae (17%) and Combretaceae (12%) had the highest number of species. From five major plant community identified, Community type IV was highest in species richness while diversity and evenness were highest in community type III. Likewise, Osyris species highest richness was recorded in community IV. The stem density and DBH classes of the species showed the reversed J-shaped plots. But, basal area and regeneration status of the species showed Gaussian curve (Mayile site) and inverted J-shape (Shara site). The analysis results showed fair regeneration status, but high disturbance on matured trees. We conclude that current over harvesting of mature trees from parent-tree influenced the regeneration status of species. If this unsustainable harvesting by local people continues, the capacity of the species to maintain its wild population is significantly reduced. Therefore, management and conservation strategies that incorporates to supporting the livelihood peoples under such environment.

Keywords: African sandalwood; Community type; Regeneration status; Species richness

INTRODUCTION

Osyris quadripartita (African sandalwood), synonymous with *Osyris abyssinica* Hochst Ex A. Rich and *Osyris lanceolata* Hochst and Steudel [1], is an evergreen, root hemi-parasite plant. It is a culturally and commercially important species that has been used for herbal medicine, religious activities and by the perfumery oil industry [2]. In recent time, trade in African Sandalwood oil has also increased, because of ready markets in Asia and Europe [3]. However, Sandalwood trade in African is unsustainable because the wood is smuggled from natural stands and there is no clear domestication program for the species [4]. Moreover, the exploitation of this species for herbal medicine has increased [5] leading to its decline in natural stands [6]. Recently, while the resource has been declining, the markets of sandalwood and its products have been rising [7-9]. 40 years ago, the price of sandalwood oil was under US \$100 kg^{1}; now it is over US \$2,000 kg^{1} reflecting the constraint to supply. The increase in demand and attractive prices offered for the wood, oil and its products have increased the pressure on the present sandalwood resource base [7].

African sandalwood is an important plant species for trade. It became famous in the perfumery and fragrance industry in the early 1900s, following a decline in the resource base of Indian and Australian sandalwood that are considered to be the major sources [10]. Since then, harvesting of the species has been intensive and uncontrolled, which has resulted in some populations remaining only as patches in forests. Currently, the best sandalwoods are believed to have been deteriorated; and the species is considered as endangered due to over harvesting [10]. The harvesting mode, that involves removal of the roots, has further intensified the threat [11]. Arising from this concern, African Sandalwood is categorized as a Least Concern Species in the IUCN List of Threatened Species 2018 report [12].

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In Ethiopia, *Osyris quadripartita* resources have been used for traditional purposes [13], but the economic contribution to the livelihood of rural communities has not been established elsewhere [14]. Since 2012, demands for *Osyris quadripartita* as raw materials for industrial purposes have increased in Southern Ethiopia [15]. There has been limited inventory data and lack of documentation on the species reported previously in the areas of Southern Ethiopia [14]. This research was deemed to be crucial before extensive *Osyris quadripartita* populations are exploited and, moreover, to establish the current population structure of the species; particularly in dry woodland forests of Southern Ethiopia. The distribution and population structure of particular plant species is not well documented previously in this region; so, knowing the resource inventory of such key plants in the wild is essential. Mainly, generation of scientific knowledge through the studies on abundance, population structure and habitat of *Osyris quadripartita* species could be one of the intervention mechanisms to contribute towards the conservation of plant resources and their associated biodiversity. This study provides platform information for the conservation and sustainable utilization of the African sandalwood species and their host trees and shrubs in their natural habitats. The study shows the current status and population structure across habitats, and provides evidence for more conservation efforts in the future.

MATERIALS AND METHODS

Description of the study area

The study was carried out in Banna-Tsemay and Arba Minch Zuria districts within the Southern Nations, Nationalities and Peoples Regional state (SNNPRs), Southern Ethiopia. Geographically, Banna-Tsemay is located between latitude of 5° 31’ to 5° 34' N and longitude 36° 41' to 36° 46' E. Arba Minch Zuria is located at latitude 6° 04’ to 6° 08' N and longitude 37° 32' to 37° 34' E (Figure 1). The elevation of the study area ranges from 1100 m to 2100 m above sea level [16]. The rainfall patterns of the study areas are characterized by a bimodal rainfall pattern. The mean annual rainfall for Arba Minch and Key Afer station ranges between 898 mm and 1315 mm, respectively. The average minimum and maximum annual temperature for the two districts ranges between 17.44-30.51°C and 16.30-27.54°C, respectively. Moreover, the mean annual relative humidity for both sites ranges between 56.09% and 67.38%, respectively [17].

The dominant vegetation types in the districts are *Combretum-Terminalia* woodlands and *Acacia-Commiphora* woodlands [18]. Soil types were grouped in the textural class of sandy loam, neutral pH and they exhibited excessive drainage. The livelihoods of the local people in the districts are based on mixed farming, but pastoral animal husbandry predominates over crop production. In addition, bee keeping and collection of wood and non-wood products (e.g., wild edible and medicinal plants, incense, gum, etc.) are practiced in the areas [19].

Selection of the study sites and sample design

The study sites were purposively selected based on the occurrence of relatively intact *Osyris* sites, type of agro-ecological zone, accessibility and whether or not Osyris exploitation in the stands for investment was allowed. The selected forest sites are Mayile forest site (Bana Tsemay district), and Sharra forest site (Arba Minch Zuria district). The total areas stratified for study were Mayile (1506 ha) and Sharra (1074 ha). At each selected site, transect lines were systematically placed along the altitudinal gradient of the whole study areas and the upper and lower altitude limits were also determined. Within the defined altitude intervals, sampling plots having 20 m x 20 m (400 m^2) were systematically placed along the transect lines. In both sites, a total of 62 quadrats (31 in each site) were laid for collection of vegetation inventories. A nested plots design was used [20]. The largest plots (20 m x 20 m) were used for collecting tree/ shrubs species data; and five small plots (2 m x 2 m) were used for counting sapling and seedlings (Figure 2). The transect lines were respectively 1 km and 0.7 km apart from each other (Figure 3). The distance between plots 200-300 m varies based on the altitudinal.

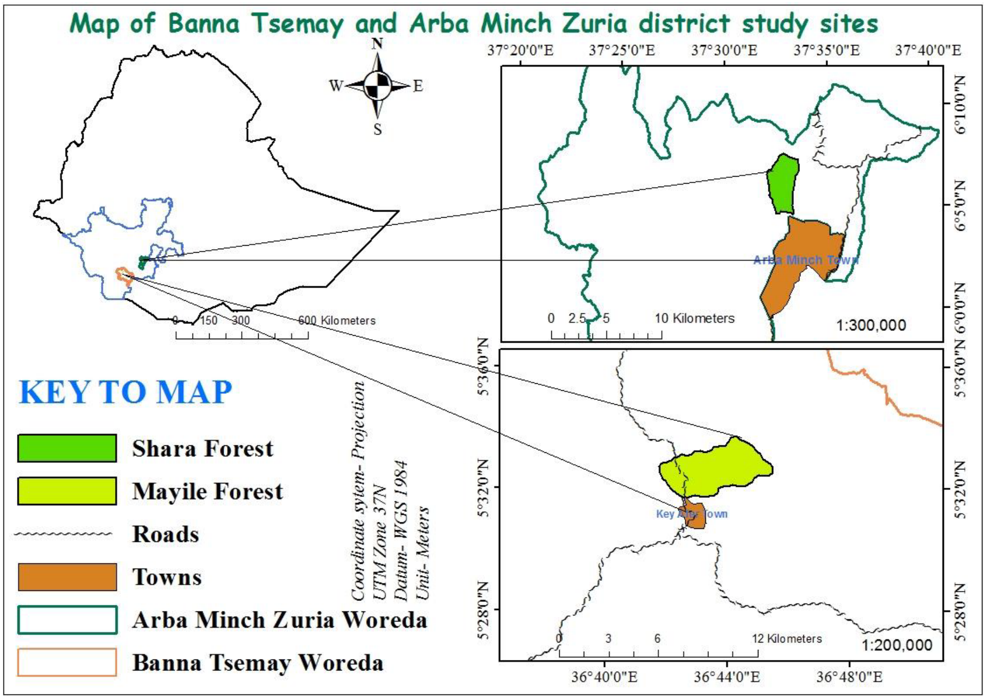

Figure 1: Map of the study area.

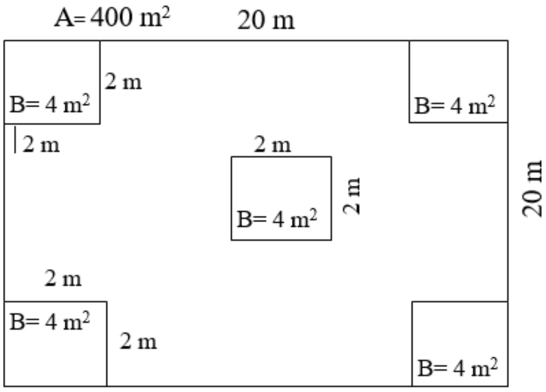

Figure 2: Quadrat Layout design used for field vegetation data collection.

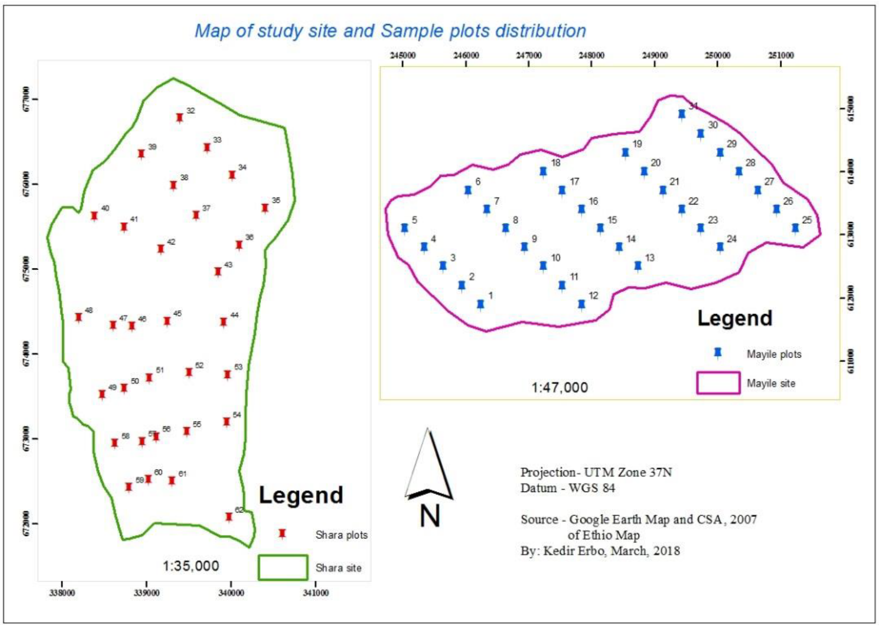

Figure 3: Geographical position of study sites and sample plot distributions.

Inventory of woody species

All woody species including *Osyris* spp. within a larger plot, with diameter at breast height (DBH) ≥ 2.5 cm and total height ≥ 1.5 m were identified and measured. Also, in the sub-plots, seedlings and saplings of all woody species were identified and counted to determine the species composition and regeneration status. The stem diameters were recorded in two perpendicular directions and averaged. In the case of woody plants having more than one stem (multi-stemmed plants), the diameter equivalent equation was used according to Snowdon et al. [21] (Figure 4).

Figure 4: Photograph of a site during field work.

Data analysis

Species abundance and plant community: Species composition and classification of community types were determined by multivariate analyses using R version 3.4.3 vegan package [22]. Hierarchical agglomerative cluster analysis techniques using similarity ratios were used to classify plant community types. Classification analysis was based on the abundance of all species recorded in sample plots. The distinguished plant community types were further refined in a synoptic table and species occurrences were summarized as synoptic-cover abundance values. Synoptic values are the product of the species' frequency and average cover abundance value [23]. Dominant species of each community type were identified based on their synoptic value.

Structural analysis of the species

For structural data analysis, species frequency, height, and diameter at breast height (DBH) were used for description of the *Osyris quadripartita* population.

Density: defined as the total number of individuals of each species in all plots is divided by the total areas sampled in hectare.

Frequency: refers to the degree of dispersion of individual species in an area and usually expressed in terms of percentage occurrence.

Abundance: the total number of individual species in all plots divided by total area in which the species occurred.

Basal Area (BA): the cross-sectional area of stems to be considered in the analysis as one of the most important structural parameter in forest inventory [24].

$$BA=0.00007854 * DBH^2 \quad (1)$$

Where: BA=tree basal area expressed as m^2; DBH is stem diameter at breast height in cm.

Regeneration status of the species was analyzed by comparing saplings and seedlings with the matured trees according to Dhaulkhandi et al. [25] and Tiwari et al. [26]; which means, the status was *good regeneration* if seedlings > saplings > adults; the status was *fair regeneration* if seedlings > or ≤ saplings ≤ adults; the status was *poor regeneration* if the species survive only in the sapling stage (saplings may be ≤ or ≥ adults); and the status was categorized as *not regenerating* if a species is present only in an adult form.

RESULTS AND DISCUSSION

Species composition and community types

A total of 75 woody species, belonging to 29 families, was encountered from both studied sites. Out of 29 total families, Fabaceae had the highest percentage 13 (17%), and the second was Combretaceae 9 (12%) species, followed by four families (Anacardiaceae, Rubiaceae, Oleaceae, and Euphorbiaceae), each of which accounted for 9%, 7%, 5%, and 5%; respectively. Other families were represented by one to three species and the Santalaceae family had only 1.3% species that were encountered in the study areas. This finding is comparable with previous studies [18,13].

The five clusters were designated as plant community types based on the values of their synoptic cover (Table 1).

Five plant community types were identified from the classification strategies. The dendrogram plot (Figure 5) includes codes (C1 – C5) for community types, and their arrangement related to plots along the x-axis.

Community types

C1 - *Dodonaea angustifolia* – *Euclea divinorum*: This community type is located between 1339 up to 1833 m a.s.l. (meters above sea level). It comprises 22 plots and 38 species. Compared to the other communities, this community has the largest number of plots. The indicator species are: *Rhus lancea*, *Olea europaea*, *Combretum molle*, *Euclea divinorum*, *Dodonaea angustifolia*, *Rhus natalensis*, *Osyris quadripartita* and *Carissa spinarum*. Most stands were sampled from Mayile woodland site, West of Key Afer town.

C2 - *Combretum molle* - *Terminalia brownii*: This community occurs between 1275 up to 1791 m a. s. l. It comprises 7 plots and 48 species. The indicator species mentioned in the type include *Acacia senegal*, *Carissa spinarum*, *Combretum collinum*, *Combretum molle*, *Euclea divinorum*, *Gardenia ternifolia*, *Jasminum floribundum*, *Myrsine africana*, *Olea europea*, *Osyris quadripartita*, *Rhus natalensis*, *Terminalia brownii*, *Terminalia laxiflora and Terminalia schimperiana*.

Table 1: Synoptic cover-abundance values of diagnostic species and other species having a value of ≥ 3.0 in at least one community type.

Community Type	C1	C2	C3	C4	C5
Community Size*	22	7	19	9	6
Acacia hockii	0.88	1.64	3.75	**13.67**	2.50
Acacia mellifera	0.34	0.73	1.33	5.33	3.83
Acacia Senegal	0.00	3.36	1.17	2.00	**6.00**
Acacia seyal	0.38	0.36	0.67	**5.33**	4.67
Acanthus pubescens	0.03	0.09	0.42	1.00	**4.17**
Balanithes aegyptica	0.00	0.27	0.83	2.67	**4.83**
Combretum molle	**2.88**	**4.91**	4.33	2.00	1.00
Commiphora confusa	0.00	0.09	0.42	4.33	**6.00**
Dichrostachys cinerea	1.16	6.00	1.83	**8.00**	3.00
Dodonaea angustifolia	5.81	5.91	15.75	**0.33**	0.67
Euclea divinorum	4.16	9.73	15.33	**12.00**	0.83
Euclea racemosa	0.16	3.73	13.33	**8.67**	1.17
Euphorbia ampliphylla	0.00	0.00	0.92	**3.00**	2.83
Euphorbia tirucalli	0.03	0.82	0.58	**0.67**	2.50
Flacourtia indica	0.00	0.27	3.58	**0.67**	0.00
Lantana camara	0.00	0.36	1.08	**5.00**	5.33
Maytenus senegalensis	0.03	3.64	2.67	**3.67**	3.50
Myrsine africana	0.00	4.00	2.67	**0.00**	0.17
Olea europea	1.78	6.55	12.75	**3.33**	0.17
Osyris quadripartita	1.94	5.18	5.75	**6.67**	0.00
Rhus natalensis	1.34	4.82	3.58	**13.33**	4.00
Rhus quartiniana	3.66	0.27	0.83	**1.00**	0.00
Terminalia brownii	1.94	6.00	2.00	**1.33**	2.83
Terminalia laxiflora	0.06	5.09	3.75	**5.00**	2.17
Terminalia schimperiana	0.00	2.82	0.50	**0.33**	1.83
Ximenia americana	0.56	3.00	3.00	**0.67**	0.83

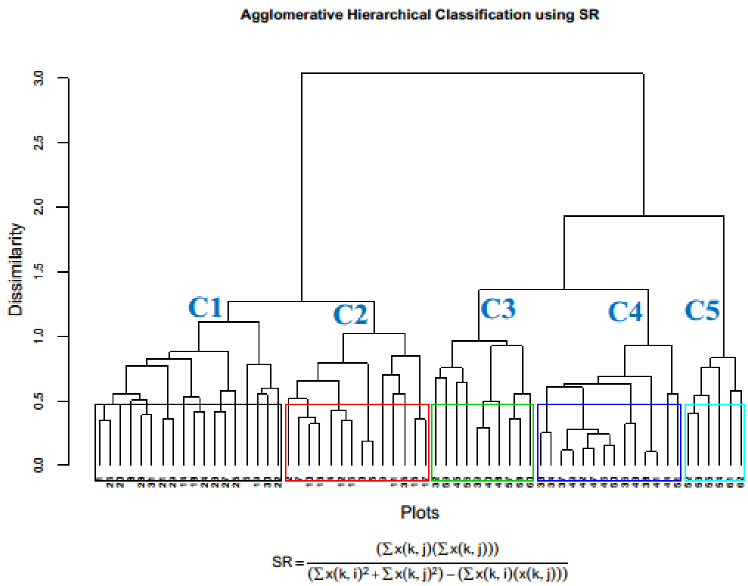

Figure 5: Dendrogram showing community types of the study area.

Like the first community type, the species occur on a somewhat oblique hillside and in a seasonally flooded landscape.

C3 - *Euclea racemose* - *Flacourtia indica* - *Olea europea*: In addition to indicator species, the dominant species include: *Acacia hockii, Combretum collinum, Combretum molle, Dodonaea angustifolia, Euclea racemosa, Euclea schimperi, Osyris quadripartita, Ozoroa insignis, Pappea capensis, Rhus natalensis, Terminalia laxiflora and Ximenia americana.* It is distributed between 1352 up to 1794 m a.s.l. and comprises 19 plots and 60 species. This community is in the second rank among the *Osyris* species richness.

C4 - *Acacia hockii* - *Rhus natalensis* - *Terminalia laxiflora*: Associated species in the community are: *Acacia hockii*, *Acacia mellifera*, *Acacia seyal*, *Acalypha fruticosa*, *Commiphora confusa*, *Dichrostachys cinerea*, *Euclea divinorum*, *Maytenus senegalensis*, *Osyris quadripartita*, *Rhus natalensis* and *Terminalia laxiflora.* It is found between 1380 up to 1762 m a.s.l. and comprises 9 plots and 61 species. In this community *Osyris species* is richer than in community types 2 and 3.

C5 - *Acacia senegal* - *Balanithes* - *Commiphora*: It is found between 1288 and 1390 m a.s.l. and contains 6 plots and 47 species. The indicator species are: *Acacia mellifera*, *Acacia seyal*, *Acacia Senegal*, *Acanthus pubescens*, *Balanithes aegyptica*, *Commiphora confusa*, *Euphorbia ampliphylla*, *Lantana camara*, *Maytenus senegalensis and Terminalia brownii.* It's highly influenced by people collecting firewood, charcoal making and by grazing animals, because of its closeness to new urbanization areas.

Results show that community type I and II occurred in the Mayile forest site; and community type III and V occurred in the Shara site, but community type IV occurred in both sites. There is no clear boundary of species distribution in the area except community type five (V). The most dominant associated woody species with *Osyris quadripartita* are *Euclea divinorum*, *Euclea racemosa*, *Dodonaea angustifolia*, *Dichrostachys cinerea*, *Combretum molle*, *Olea europea and Rhus natalensis* in both study sites. Analysis of synoptic cover-abundance values (Table 1) indicates *Dodonaea angustifolia* had the highest cover dominance values (16%) followed by *Euclea divinorum* (15%) *and Olea europaea* (12%). This is similar with a previous study [27]. Therefore, the dominant species are confirmed as strongly associated with *Osyris quadripartita* plants. The finding was in line with Gathara et al. [28] on prediction of *Osyris lanceolata* in the Kenya forest.

As a result, the synoptic cover-abundance values indicated that the highest species richness and diversity of *Osyris quadripartita* plants were recorded in community types IV, III, and II; in descending order. Likewise, in community types III and IV, the high slope topography of the sites made them less accessible by local people to disturb the vegetation. This may also influence the richness of the species in the areas. Therefore, the highest richness of *Osyris quadripartita* species was recorded in most quadrats, which may result from the optimum environmental conditions associated with elevation. In general, the probable reasons for the variability of *Osyris quadripartita* species richness in the different community types arise from altitude, distance from villages and cover abundance values. Those predictable reasons may influence species richness, diversity, evenness and structure of the plant communities identified in the study areas.

Species population structures

Stem density: The density of *Osyris quadripartita* species in *Mayile forest site* (total=74 ha^{-1}) and in *Shara site* (total=138 ha^{-1}) counted within sampled quadrants in relation to DBH is shown in Table 2.

Diameter at breast height (DBH): The general pattern of DBH class distribution of *Osyris quadripartita* species was observed with many small stems compared to few large ones in both sites (Figure 6a and 6b).

An analysis of species population structure clearly indicated the variability of population dynamics in the study sites. The Stem density and DBH-class of *Osyris* species distribution show similar trends. In the Shara site (138 ha^{-1}) a higher stem density was observed compared to the Mayile site (74 ha^{-1}). The species population pattern was characterized by the highest density in the DBH class one and two, and relatively higher density of individuals in the first DBH class, and decreasing successively towards the higher DBH classes with almost absence in the 4th and 5th classes; particularly in the Shara site. The decreasing density stem towards the higher DBH classes reveals the dominance of small-sized individuals in the area, which was attributed to high regeneration, but poor recruitment and existence growth (Figure 6). This may

Table 2: The number of individuals per ha and Percentage composition of Osyris quadripartita species across Diameter classes in studies areas.

DBH class (cm)	In Mayile Site		In Shara Site		Total	
	Individuals ha^{-1}	%	Individuals ha^{-1}	%	Individuals ha^{-1}	%
<5	31	41.89	125	90.58	78	66.24
5.1-10	25	33.78	11	7.97	18	20.88
10.1-15	8	10.81	2	1.45	5	6.13
15.1-20	6	8.11	0	0.00	3	4.05
>20	4	5.41	0	0.00	2	2.70
Total	74.00	100.00	138.00	100.00	106	100.00

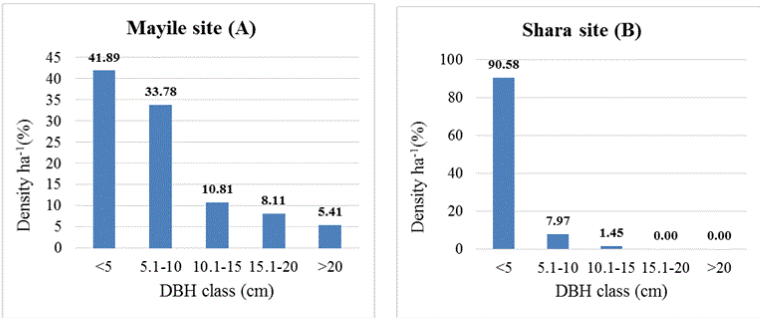

Figure 6: *Osyris quadripartita* stem density distribution across diameter classes.

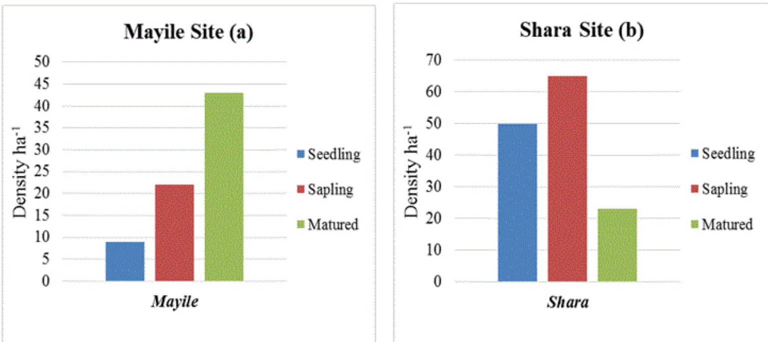

Figure 7: The regeneration status of *Osyris quadripartita* in the study sites.

be due to selective cutting of large-sized individuals as also stated by Senbeta et al. [29]. So, the general pattern of DBH class-size distribution forms an inverted J-shape (Figure 6). The finding is consistent with previous studies on population structure of *Dodonaea angustifolia* in Afro-montane forests, Ethiopia by Bekele [30] and Shrubland [31] vegetation studies by Kebede [31]. Stem density of *Osyris quadripartita* per hectare is higher compared with woody species reported in Oda forest of Humbo district (12 ha^{-1}) by Kuma and Shibru [27].

Regeneration status of the species

The analysis of the regeneration status reveals the sequence of seedling < sapling < matured trees in the Mayile site (Figure 7a). Besides this, in Shara site density ha^{-1} of the species showed that the sequence was seedling < sapling > matured trees (Figure 7b).

In Mayile site, the regeneration status showed that the individual's density ha^{-1} in the seedling and sapling stages lower than matured tree stage. In other words, it shows poor reproduction and recruitment potential of the species, which forms a J-shape plot (Figure 7a). In the site there was vegetation disturbance in the form of grazing, fuel wood collection, and agricultural expansion. In the Shara site, the regeneration status indicated that there was a high distribution of individuals of a species in the seedling and sapling stages. But, in the matured tree stage only a few individuals were recorded. In other words, it shows good reproduction and recruitment potential of the species, which forms an inverted J-shape (Figure 7b). In this site, human interference occurred in the form of selective cutting of matured trees. These findings are comparable with those reported on Population structure of *Dodonaea angustifolia* in Oda forest of Humbo district by Kuma and Shibru [27].

Basal area and dominance

In Mayile site, the average basal area 0.4 m^2 ha^{-1} was recorded for *Osyris quadripartita* species (Figure 8a). Besides this, the mean basal area 0.25 m^2 ha^{-1} was recorded in the Shara site (Figure 8b).

In the Shara site, dominance of species population structure indicated that there was a basal area decrease with increase in DBH classes. The basal area pattern shows absence of individuals in DBH size ≥ 15 cm (Figure 8b). The general distribution pattern indicates a normal distribution (inverted J-shape) of the species and maximum basal area ha^{-1} occurred in the DBH ≤10 cm, and reduced gradually up to DBH 10-15 cm. This pattern represents the dominance of small-sized individuals in the site, which was the attribute indicative of fair status and regeneration potential. In the Mayile site, dominance of *Osyris* species indicated that basal area ha^{-1} increases with increase in DBH classes (Figure 8a). The

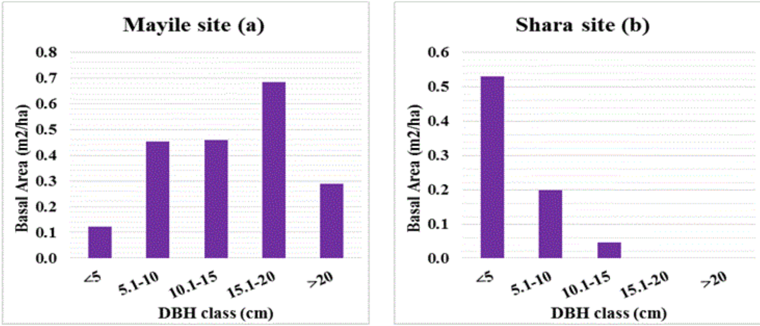

Figure 8: The distribution of basal area across diameter class in the study sites.

general distribution pattern indicates abnormal (Gaussian curve) of the species, which shows minimum basal area ha^{-1} observed in the DBH ≤10 cm, but high basal area recorded in the DBH ≥10 cm. This pattern represents the dominance of few matured individuals in the site, which was the attribute of poor regeneration and recruitment of the species. A similar response has been noted by Bekele et al. [30]. Generally, the population structure of the species indicated the absence of individuals in DBH ≥ 30 cm. The above findings and field observations clearly confirmed the high disturbance in mature trees resulting from selective cutting for oil extraction, medicinal, and household uses in the study areas [32].

CONCLUSIONS

The plant community classification would make future management of the plant habitats more feasible, while acknowledging the home-range of *Osyris quadripartita* species as well as other acknowledged associated woody species. The *Osyris* species distribution potential has been identified in the current study. For instance, larger abundance cover and richness of *Osyris quadripartita* species were found in Community type IV and III, rather than other Communities. The population structure of the species in the Shara site shows an Inverted J-shaped pattern. In contrast, the regeneration status and basal area at the Mayile site have a J-shape pattern.

The anthropogenic factors leading to environmental disturbance influenced the population density, regeneration status and habitats of the *Osyris* species. The few number of small trees and medium number of mature trees of the species in the Mayile site were symptoms of poor regeneration and recruitment potential. If the unsustainable harvesting of matured trees by local people continues, the capacity of the species to maintain in the natural habitat (wild) population will be significantly reduced. Therefore, this needs attention for such a largely local and commercially useful plant. In conclusion, the finding of this paper provides information that is necessary for making more effective conservation and management practices for the *Osyris* species.

REFERENCES

1. Global plants (GBIF). Global biodiversity information facility (GBIF). Plantae in page RDM. The Plant List with literature. Institute of Biodiversity, Animal Health and Comparative Medicine, College of Medical, Veterinary and Life Sciences, University of Glasgow. Checklist Dataset. 2016;10:154-168.
2. Subasinghe U, Gamage M, Hettiarachchi DS. Essential oil content and composition of Indian sandalwood (Santalum album) in Sri Lanka. J. Forestry Research. 2013;3:1-8.
3. CITES Cop16. Sixteenth meeting of the Conference of the Parties, Bangkok (Thailand). Convention on International Trade in Endangered Species of Flora and Fauna. CoP16 Prop. 2013;69:1-10.
4. Mukonyi KW, Kyalo S, Lubia IK, Leitoro E, Mbaka RM. Status of Osyris lanceolata in Kenya. Kenya Wildlife Service Report. 2011.
5. Tshisikhawe MP, Van Rooyen MW, Bhat RB. An evaluation of the extent and threat of bark harvesting of medicinal plant species in the Venda Region, Limpopo Province, South Africa. Int J Experiment Botany. 2012;81:89-100.
6. Githae EW, Gachene CK, Odee DW. Implications of in situ conservation of indigenous species with special reference to Coffea arabica L. population in Mount Marsabit Forest, Kenya. Trop Subtrop. Agroecosyst. 2011;7:15-722.
7. Rai SN, Sarma CR. Depleting sandalwood production and rising prices. Indian Forester. 1990;116:348-355.
8. Srinivasan VV, Sivaramakrishnan VR, Rangaswamy CR, Ananthapadmanabha HS, Sankaranarayana KH. Sandal (Santalum album). Indian Council of Forestry Research and Education, Dehra Dun, India. 1992;233.
9. Coppen JW. Flavors and Fragrances of Plant Origin. Food and Agriculture Organization of the United Nations, Rome, Italy. 1995;101.
10. Ruffo CK, Birnie A, Tengnas B. Edible wild plants of Tanzania, Region Land Management Unit Technical Handbook series 27. RELMA/ (SIDA), Nairobi, Kenya. 2002.
11. Mbuya LP, Msanga HP, Ruff CK, Birnie A, Tegnass B. Useful trees and shrubs of Tanzania: identification, propagation and management for agricultural and pastoral communities. SIDA/RSCU, Nairobi, Kenya. 1994.
12. Wilson B, Osyris lanceolata. The IUCN Red List of Threatened Species. 2018: eT200642A2675362.
13. Gemedo D, Brigitte LM, Johannes I. Plant Biodiversity and Ethnobotany of Borana Pastoralists in Southern Oromia, Ethiopia. Economic Botany. 2005;59:43-65.
14. EBI Annual Report. Ethiopia Biodiversity Institute, Current status of access and benefit sharing from genetic resources report. Addis Ababa, Ethiopia. 2015.
15. Ayenew. Current status of access genetic and benefit sharing implementation in Ethiopia reports. Copenhagen. 2015;1-19.
16. CSA. Population and Housing Census of Ethiopia Result. Addis Ababa, Ethiopia, CTR Publications. 2007;350.
17. NMA-HMSC. National Meteorology Agency, Hawassa Meteorology Service Center, Annual climate report. 2017.
18. Soromessa T, Teketay D, Demisse S. Ecological study of vegetation in Gamo Gofa zone, South Ethiopia. Tropical Ecology. 2004;45:209-221.
19. Assefa A, Abebe T. Ethnobotanical study of wild medicinal trees

and shrubs in Benna-Tsemay District, Southern Ethiopia. Journal of Science & Development 2014;2:17-33.

20. Barnett DT, Stohlgren TJ. A Modified nested-intensity design for surveying plant diversity. Biodiversity Conservation 2003;12:255-278.

21. Snowdon P, Raison J, Keith H, Ritson P, Grierson P. Protocol for sampling tree and stand biomass. National Carbon accounting System, Technical report no. 31. Canberra: Australian Greenhouse Office. 2002 :66.

22. Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR. Package 'vegan'. Community ecology package, version. 2011;9:1-295.

23. Bekele T. Vegetation ecology of remnant afromontane forests on the Central plateau of Shewa, Ethiopia. Acta phytogeogr. Suec. 1993;79:1-59.

24. Kent M, Coker P. Vegetation Description and Analysis,A Practical Approach. Belhaven Press, London. 1992;351.

25. Dhaulkhandi M, Dobhal A, Bhatt S, Kumar M. Community Structure and Regeneration Potential of Natural Forest Site in Gangotri, India. Basic and Applied Sciences. 2008;4:49-52.

26. Tiwari GPK, Tadele K, Aramde F, Tiwari SC. Community structure and regeneration potential of shorearobusta forest in subtropical submontane zone of Garhwal Himalaya, India, Nature and Science. 2010;8:70-74.

27. Kuma M, Shibru S. Floristic Composition, Vegetation Structure, and Regeneration Status of Woody Plant Species of Oda Forest of Humbo Carbon Project, Wolaita, Ethiopia, Journal of Botany. 2015;10:19.

28. Gathara M, Makenzi P, Kimondo J, Mature G. Prediction of Osyris lanceolata (Hochst & Steud.) site suitability using indicator of plant species and edaphic factors in Kenya forests. Journal of Horticulture and Biodiversity. 2014;6:99-106.

29. Senbeta F, Teketay D. Diversity, community types and population structure of woody plants in Kimphee Forest, a virgin Nature Reserve in Southern Ethiopia. Ethiop J Biol Sci. 2003;2:169-187.

30. Bekele T. Plant Population Dynamics of Dodonaea angustifolia and Olea europaea in Dry Afromontane Forests of Ethiopia. Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology. 2000 ;559:47.

31. Kebede B. Ecological Study of the Shrubland Vegetation around Ambo, West Shoa, Ethiopia [M.S. thesis] School of Graduate Studies, Addis Ababa University, Addis Ababa, Ethiopia. 2012;51-53.

32. Koduru S, Grierson SD, Afolayam JA. Ethnobotanical information of medicinal plants used for treatment of cancer in Cape Province, South Africa. Current Science. 2007;92.