Original Research Article||

Diversity, population status and communities' perception towards *Osyris lanceolata* Hochst & Steudel., in selected districts of South Omo Zone

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Abstract

Osyris lanceolata is among the sandalwood species known for the production of fragrant-scented wood from which sandalwood essential oil is extracted. The present study was designed to assess the diversity, population status and community's perception towards O. lanceolata in Hamer and Bena-Tsemay districts, Southern Ethiopia. Multi-stage sampling procedure was employed to conduct this study in purposively selected districts. Data were collected through household survey, local informants' interviews, direct observation, with systematic random sampling design used based on the line-transect approach for vegetation inventory. About seventy-one (71) respondents were selected for the household survey to produce basic information, from which 77.5% were male and 22.5% were female. Quadrants used for vegetation survey were 27 having 20 m x 20 m plot size. Composition of vegetation data associated with *Osyris lanceolata* comprised 46 species, from which 27 and 36 species were in Hamer and Bena-Tsemay districts, respectively. The occurrence of *Osyris lanceolata* showed a decreasing trend in the natural forest due to provision of less attention from the community in terms of the targeted species. Based on the findings of the present study the resource around the pastoral and agro-pastoral community need participatory management strategy to conserve and use important species in a sustainable manner. Less consideration to natural resources brings huge ecological, economic and social problems associated with the extinction of important species.

Key words: Benna Tsemay district, conservation of species, essential oil, Hamer district, *Osyris lanceolata*, tree diversity

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INTRODUCTION

Osyris lanceolata Hochst & Steudel**.** is a widespread shrub in the tropics and subtropics. Originating in the region, it is most commonly known as East African Sandalwood (Kokwaro, 2009). The East African Sandalwood is a shrub growing to a height of up to 6 m, having multi-stems, evergreen hemi-parasitic plant that has a round to irregular canopy and a grey smooth bark. The species grows on the roots of other plants utilizing the root systems of the hosts to get nutrients, but it does produce its own chlorophyll as well. The species is evergreen with many drooping small branches with bluish to yellow-green, sharply pointed leaves (Da Silva et al., 2016). *Osyris lanceolata* is distributed in African countries such as Tanzania and Kenya and is frequently found in arid to semiarid areas, primarily on stony and rocky soils (Kokwaro, 2009). Sporadically, the species is found in rocky sites and along the margins of dry forests, evergreen bushland, grassland, and thickets at an altitude range of 900-2250 m above sea level (Giathi et al., 2011; Kamondo et al., 2012). It is most commonly found in Gallery Forest of *Juniperus*, *Podocarpus*, *Combretum* and *Dodonea* woodland, Erica scrub, *Acacia nilotica*-*Commiphora* scrub, on rocky slopes in areas with a mean annual rainfall of 600 to 1600 mm. In Kenya, the species grow naturally in both humid highland and dry lowland forests (Maundu and Tengnas, 2005). It is found in most Ethiopian regions particularly in hilly slopes and rocky ridges in association with varieties of vegetations.

Osyris lanceolata has been traded for centuries for its fragrance, with medicinal and religious values and also wood carving potential. It is among the sandalwood species known for the production of fragrant-scented wood from which sandalwood essential oil is extracted (Walker, 1966; Mbuya et al., 1994; Ruffo et al., 2002). The main traded products include aromatic oils extracted from the heartwood for making incense, timber for handicrafts, and saw-dust. The excellent blending and antiseptic properties of the oil make it valuable as a fixative for other fragrances (Coppen, 1995). The oil is useful in perfumery, pharmaceutical and religious practices. Exploitation in East Africa for the production of oil and associated products began relatively recently and has apparently led to population decline in Kenya and Tanzania, with harvest reported now to be spreading to South Sudan and Uganda (Kamondo et al., 2014). The exploitation of *Osyris lanceolata* from Africa could soon drive the species to extinction unless proper control measures are put in place to regulate international trades. *Osyris lanceolata* has recently entered the international market as a substitute for the traditional sandalwood oil originally sourced from Asia and Australia. However, the status of the species, distribution, management and socioeconomic importance were not well known and it has not been researched in the selected study area. Regardless of its importance, nowadays the removal of this species particularly the female type used for oil extraction is extensively done by the local communities in the South Omo Zonal administration. This study was initiated to explore population status, management activities and communities' perception towards *O. lanceolata* and draw recommendations for sustainable management and utilization of the species. The study also characterizes the diversity of vegetation associated with *O. lanceolata.*

MATERIALS AND METHODS

Description of the experimental site

The current study was conducted in South Omo zone, located in Southern Nations, Nationalities and People's Regional State. Most of the residents in the South Omo zone are pastoral and agro-pastoral communities that rely heavily on dry forest resources for livestock fodder, income generation, energy source, food and medicine. The study was conducted in two districts of South Omo zone, namely Hamer and Bena-Tsemay. Hamer district is located at 4.5°−5.466° N and 36.15°−36.9° E, and the district capital Demaka is located 739 km away from Addis Ababa. Elevation of sites range from 271 to 2,022 meters above sea level (m.a.s.l). Bena-Tsemay district on the other hand, is located at 5^0.11`−$5^0$.7`N and 36°.20`−37°.04` E, and its capital, Key-Afer is located at about 839 km from Addis Ababa, with elevations ranging from 567−1,800 m.a.s.l (BOFED, 2007). Agro-ecologically, both districts are categorized as dry tropical to tropical desert climates with annual precipitation range of 400-900 mm. Rainfall is bimodal and erratic in distribution in both districts, which affects livestock and crop production. Average annual minimum and maximum temperatures range from 32−38°C in Hamer and 16−40°C in Bena-Tsemay (Terefe *et al*., 2010).

Vegetation of the study districts can be broadly classified as desert and semi-desert scrub, *Acacia-Commiphora* and *Combretum-Terminalia* woodlands. It is a mixture of *Acacia, Boswellia, Commiphora, Balanites* and various woody species and short grasses at varying densities (Soromessa et al. 2004; Admasu et al. 2010). The information obtained from the elderly people reveals that, 40 years ago, land was almost all owned communally. Currently however, pastoralists own small plots of rangeland within enclosures near their farmlands and around their homesteads. The rest of the vast rangeland is still owned communally, and ownership of the rangeland is similar to that in many pastoral areas of the country (Dalle et al., 2005; Kassahun et al., 2008).

Study site selection

Hamer and Bena-Tsemay districts were purposively selected for this study based on the existence of natural forest where the targeted species, *O. lanceolata* is commonly found. In both districts, lowland agro-ecology covers the largest proportion of the areas. From each district two representative kebeles were selected purposively due to presence of the natural forest. Accordingly, in Hamer district, Lalla kebele which is located in the mid-highland and Shanko-Wolfo in the lowland were selected, while in Bena-Tsemay, Argo and Goldya kebeles, which are both located in the lowland were selected for the study. Prior to the selection of the respondents, a preliminary reconnaissance survey and direct field observations were conducted to obtain basic information on vegetation status, utilization and management practices of the natural forest and in order to understand the biophysical and socioeconomic characteristics of the study area.

Source of data

Data for this study were collected from primary and secondary sources. Information from key informants of pastoralist and agro-pastoralists together with vegetation survey data were used as the major primary sources. In order to ensure the reliability and validity of the data collected, triangulation and interviews of key informants (KI) were done during the primary data collection.

Methods of data collection

A combination of various socioeconomic techniques was employed for the collection of qualitative and quantitative data. Key informant interviews, household surveys and field observations were made using standard guides. These methods were used to collect formal and informal data that reflect socioeconomic and biophysical characteristics of the community. From each kebele, key informants were selected using snow-ball method, in which the most frequently referred knowledgeable individuals were selected. Structured household interviews were conducted with household heads using questionnaires. Data were collected from randomly selected households by taking ten percent (10%) from each kebele residing near the forest.

The forest patches where the species existed were identified with the help of informants (KI). . Twenty-seven (27) quadrats (20 m x 20 m size) were laid for vegetation survey to estimate diversity indices, density and importance value index (IVI) of the natural forests. Any two consecutive quadrats were separated from each other by 300 m. The sampling method was based on the line transect approach and systematic random sampling techniques using one transect line. The local name of the species found in the sample plots was recorded by using Hamer Amharic and Bengna languages with the help of knowledgeable individuals from the local area. Identification of the scientific names of species was carried out using the ‘Flora of Ethiopia and Eritrea (Kelbessa and Demissew 2014; Bekele, 2007). Diameter at breast height (DBH) $\geq$ 5 cm (at 1.3 m height) was measured using diameter tape. Seedlings (<1.3 m height) were counted and recorded.

Data analysis

Qualitative data from the informal survey were synthesized, interpreted and analysed, using descriptive statistical methods. Quantitative data obtained from household questionnaire survey were managed manually, entered into computer, analysed and synthesized using SPSS version 16 and MS-Excel.

The data on vegetation inventory were analysed for three-selected kebeles (Shanko-Wolfo in Hamer and Argo and Goldya in Bena-Tsemay) using species diversity indices, and Importance Value Index (IVI). In Hamer district, vegetation data for Lalla kebele is not included due to the occurrence of unexpected heavy disturbances in the natural forest. The tools used in the analysis are presented:

Shannon diversity index (H') relates the proportional weight of the number of individuals per species to the total number of individuals for all species (Kent and Coker, 1992). Shannon diversity index is calculated as:

$$H' = -\sum_{i=1}^{s} pi * lnpi$$

Where: H′= Shannon-Wiener Diversity Index; s = number of species; *Pi* = Proportion of individuals or abundance of the i^{th} species expressed as a proportion of the total cover, Ln = natural logarithm.

Values of the Shannon diversity index (H') usually lies between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5 (Kent and Coker, 1992). Usually, the Shannon diversity index places the most weight on the rare species in the sample (Krebs, 1999).

Equitability (evenness) index

Evenness (equitability) index (J) is calculated from the ratio of observed diversity to maximum diversity. The value of the evenness index falls between 0 and 1 with the higher the value of the evenness index, the more even the species in their distribution within the given area. The equitability index was calculated using the following equation:

$$\text{Equitability (j)} = \frac{H'}{\text{Hmax}} = \frac{H'}{\ln s}$$

Where: H' = Shannon-Wiener Diversity Index; Hmax = lnS; S = total number of species in the sample.

Importance value index

The dominant species, relative density, relative frequency, and relative dominance as well as importance value index are often used to characterize vegetations (Kent and Coker, 1992). The determinations follow the following formulae:

$$Relative\ frequency = \frac{\text{Frequency of a species}}{\text{sum of frequencies of all species}} \times \text{X } 100\%$$

$$Relative\ density = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals of all species}} \times \text{X } 100\%$$

$$Relative\ dominance = \frac{\text{Dominance of a species}}{\text{Total dominance of all species}} \times 100\%$$

$$IVI = relative\ dominance + relative\ denisty + relative\ frequency$$

Where: *IVI* = importance value index

$$Dominance\ for\ basal\ area = \sum\prod \mathbf{D2}/4$$

RESULTS AND DISCUSSION

Socio-economic characteristics of the respondents

The demographic characteristics of the sampled respondents were assessed and presented. About 71 respondents were used in this study, from which 35 were in Hamer and 37 in Bena-Tsemay sites. All (100%) of respondents of Lalla in Hamer and Argo in Bena-Tsemay were agro-pastoralists. In each Kebele, the largest proportion of respondents were male headed. Accordingly, 78.9%, 80%, 64.7% and 85% were male headed households in Lalla, Shanko wolfo, Argo and Goldya kebeles, respectively. The majority of respondents' age group who participated in the study was between 20-30 and 41-50 class in Hamer and Bena-Tsemay sites, respectively. The majority of respondents do not carry out any kind of management activities on the trees. In Hamer district, men family members participate in harvesting the product while in Bena-Tsemay only endowed family members participated in the activity. To collect forest products, the respondents travel an average of 4.21 km, 1.63 km, 5.6 km and 6.4km for Lalla, Shanko-Wolfo, Argo and Goldya kebeles, respectively. Comparatively, respondents from Goldya and Argo travel further distances to harvest *Osyris lanceolata* than Lalla and Shanko-Wolfo.

Natural vegetation in the study area

A total of 46 species of plants belonging to 22 families, were recorded in the study area. Among these, 27 were in Hamer and 36 in Bena-Tsemay districts. The family Fabaceae was represented by the highest number of 10 species, while the other families had three or fewer species (Table 2). In terms of growth form, In Hamer district, four herbaceous, four shrubs, one climber and eighteen tree species were found in association with *Osyris lanceolata* within the sample plots in the natural forest. At Bena-Tsemay on the other hand, four herbaceous, six shrubs, one climber and twenty-five tree species were recorded in association with *O. lanceolata*. The result of the study revealed consistency of trends in species co-occurrence with *O. lanceolata* between the two districts. Tree species cover the highest percentage in both districts with 67% and 69% occurrences in Hamer and Bena-Tsemay, respectively. The rest covered were by shrubs, herbaceous and climber species. A large number of species were recorded in the natural forests found at Shanko-Wolfo kebele in Hamer compared with species at Bena-Tsemay district of Argo and Goldya kebele natural forests.

Extensive exploitation of the vegetation is made for home consumption and income generation purposes. According to the respondents, the existence of targeted species in both districts was abundant before, but it is now decreasing, due to over exploitation for income generation. The harvesting has been handled through private owners who pay money for the pastoralist or agro-pastoralist community. Harvesting is carried out by uprooting, without practicing replanting or any propagation method to ensure sustainable utilization. This increased the speed of degradation in the forest resources, particularly the *O. lanceolata* species.

The information obtained from the household (HH) survey was in agreement with vegetation data assessed from the forest, which shows decreasing trend in *O. lanceolata* due to uncontrolled exploitation from the studied districts, except in Goldya kebele from Bena-Tsemay district, where the resources are protected by the local community, and have access to extension service on natural resource management (Table1). The pastoralist and agro-pastoralist communities give less attention to the sustainable management of *O. lanceolata* species, which affected the diversity of resources. The result of the present study is in line with the findings of USF and WS (2013), reporting that African Sandalwood species are threatened due to unsustainable exploitation in Kenya, United Republic of Tanzania, Uganda, and South Sudan. Similarly, Oloo (2010) reported an increase in demand of *O. lanceolata*, recently leading to a large rate of utilization and exploitation, to an extent that its survival in natural habitats is severely threatened.

Table 1. Responses of sample households towards the current status of *O. lanceolata* in Hamer and Bena-Tsemay districts of South Omo zone

Forest resources	Hamer	Bena-Tsemay

		Lalla (%)	Shanko-wolfo (%)	Argo (%)	Goldya (%)
Existence of natural forest stand (woodland forest)	Yes	100	100	100	100
Occurrence of *Osyris lanceolata*	Yes	100	100	100	100
Abundance	High	-	-	-	15
	Medium	15.8	-	-	55
	Low	84.2	100	100	30
Current trend of *Osyris lanceolata*	Decreasing	100	100	100	35
	Increasing	-	-	-	50
	No change	-	-	-	15
Plant parts used for sell (particularly for *O. lanceolata)*	Stem/trunk	21.1	-	-	70
	Root	5.3	-	-	5
	Stem & root	73.7	100	100	15
	Whole part	-	-	-	10
Impacts of *O. lanceolata*	Yes	47.4	20.0	76.5	15
	No	47.4	80.0	23.5	65
	Don't know	5.3	-	-	20

Table 2. List of vegetation recorded in sample plots in Hamer and Bena-Tsemay districts, South Omo Zone

No	Local name	Scientific name	Family	Life form	The species located
1	Anshale	*Crotolaria spinosa* Hochst. ex A.Rich.	Euphorbiaceae	T	Bena-Tsemay
2	Ara	*Terminalia brownii* fresen	Rutaceae	T	Common
3	Areki	Vachellia sieberiana *(DC.)Kyal. & Boatwr.*	Fabaceae	T	Common
4	Beraze	*Bridelia micrantha* (Hochst.) Baill.	Euphorbiaceae	T	Common
5	Banaki	*Cenearia diacrostadilia*	Asteraceae	T	Bena-Tsemay
6	Chekeniti	*Grewia tenax (Forsk.)* Fioril	Tiliaceae	T	Common
7	Chuliki	*Carissa edulis* Vahl	Apocynaceae	S	Bena-Tsemay
8	Dakali	*Acacia lahai* Bent.	Leguminosae	T	Common
9	Debden	*Combretum molle R.* Br. ex G. Don	Combretaceae	T	Bena-Tsemay
10	"Doferanda	-	-	S	Hamer
11	Erbo	*Ormocarpum mimosoide* S. Moore.	Fabaceae	S	Bena-Tsemay
12	Gadake	*Dalbergia melanoxylon* Guill. & Perr.	Fabaceae	T	Hamer
13	Gal-ukuma	*Tribuluster restris*	Zygophyllaceae	H	Bena-Tsemay
14	Garra	Hyparrhenia hirta (L.) Stapf	Poaceae	H	Common
15	Gelifi	Combretum molle R.Br. ex G.Don	Combretaceae	S	Hamer
16	Golali	*Acacia nilotica (L.)* Del.	Fabaceae	T	Hamer
17	Gali	*Tephrosia sp.*	Fabaceae	-	Bena-Tsemay
18	*Lenquata*	*Grewia villosa DC. var.* villosa	Fabaceae	S	Bena-Tsemay
19	*Gmarda*	*Acacia polyacantha* A.Cunn. ex Benth.	Fabaceae	T	Hamer
20	Ketsi	*Commiphora bruceae Chiov.*	Burseraceae	T	Bena-Tsemay
21	Key	*Rhus lancea*(L.f.)F.A.Barkley	Anacardiaceae	T/S	Common

22	Kufuri	*Albizia lophantha*	Fabaceae	Tree	Common
23	Kalikala	*Hevea brasiliensis*		H	Hamer
24	"Kunsi"	*Maruwa angolenesis*		T	Common
25	Makala	*Ximenia americana*	Olacaceae	T	Common
26	Metsa	*Achenti saspara*		T	Bena-Tsemay
27	Bitsobitso	*Artocarpus ovatus* Blanco		T	Bena-Tsemay
28	Olikenti	*Aloe vera* (L.) Burm.f	Oleaceae	H	Hamer
29	Bitsobitso	*Artocarpus ovatus* Blanco	Moraceae	S	Bena-Tsemay
30	Qelishi	*Faurea rochetiana* (A.Rich.) Chiov. ex Pic. Serm.	Proteaceae	T	Bena-Tsemay
31	Qundulish	*Osyris lanceolata* Hochst. & Steud.	Santalaceae	S/T	Common
32	Remit	*Olea europaea* (Wall. & G.Don) Cif.	Oleaceae	T	Common
33	Sambela	*Dobera glabra* (Forssk.) Juss. ex Poir.	Salvadoraceae	T	Bena-Tsemay
34	Sareko	*Dodonea* angustifolia *(L.f)* Benth.	Sapindaceae	T	Common
36	Sebeh	*Cordia gharaf* (Forssk.)	Boraginaceae	T	Common
37	Shambulo	*Grewia bicolor* Juss.	Malvaceae	T	Common
38	Shebshin	*Albizia schimperiana* Oliv.	Fabaceae	T	Bena-Tsemay
39	Tsaki	*Albizia grandibracteata* Taub.	Fabaceae	T	Bena-Tsemay
40	Tulunigo	*Sclerocarya birrea* (A.Rich.) Hochst.	Anacardiaceae	H	Common
41	Zenake	*Allophylus abyssinicus*(Hochst.) Radlk.	Sapindaceae	T	Common
42	"Zenigayite	-		T	Hamer
43	"Zenzikeli"	-		T	Bena-Tsemay
44	"Zinzake"	-		T	Bena-Tsemay
45	Onoka	*Sarcocephalus latifolius* (Sm.)E.A.Bru ce	Rubiaceae	H	Bena-Tsemay
46	Zurguma	*Avicennia manna* (Forssk.) Vierh.	Acanthaceae	T	Hamer

Table 3. Mean (±SD) diversity indices of woody species in natural forests of Hamer and Bena-Tsemay districts, southern Ethiopia

Diversity indices	Districts		
	Hamer	Bena-Tsemay	
	Shanko wolfo	Argo	Goldya
Shannon index	2.74	2.44	2.30
Evenness index	0.83	0.80	0.74
Simpson index	0.91	0.87	0.84
Species richness	27	21	22

The large-scale exploitation has resulted in high species diversity based on the Shannon, Evenness and Simpson indices, coupled with species richness and abundance of individual species found in sampled plots (Table 3). The results of the current study are in agreement with the findings of Gathara et al. (2014) who reported 14 and 21 tree species found in association with *O. lanceolata* in Gachuthi and Kibwezi forest, respectively in Kenya. The species found in *O. lanceolata* plots are also reported in other studies (Mwang' ingo et al., 2010; Githae et al., 2011).

Importance Value Index

Importance value index shows the importance of individual woody species in natural forest and it helps to evaluate the contribution of each woody species and the desirability of the species in terms of use value by the local community. This also describes the extraction of important species found in natural/communal forest and the intimacy of local people towards the forest resources to product consumption. A similar trend was followed for comparison of the ecological significance of a species (Kent and Coker, 1992; Akwee et al., 2010), where the Importance value index (IVI) was used as a useful parameter; since it reflects the combined effect of species density, frequency and dominance. According to the Importance Value Index (IVI) in natural forests of the study area, *Dalbergia melanoxylon* > *Allophylus abyssinicus* > *Osyris lanceolata* were the top three woody species assessed in Shanko-Wolfo in Hamer district (Table 4, 5 and 6). Here *O. lanceolata* was recorded as the third most dominant species next to *D. melanoxylon* and *A. abyssinicus*.

In Bena-Tsemay district, the contribution of the most dominant species in natural forest is expressed with its importance to the local communities. Species having a high (82.26%) IVI are *Cordia gharaf*, *Dodonaea anguistifolia* and *Grewia tenax*; dominating the other species found in natural forest at Argo kebele. Contrary to this, *O. lanceolata* becomes the first dominant species in Goldya natural forest with its high IVI value; showing that it has strict protection from the local community and needs intensive management to maintain its sustainability (Table 5 & 6). The findings of this study are in agreement with that of Lamprecht (1989), who reported that the IVI value enables prioritizing species for management and conservation interventions, where species with the lowest IVIs might benefit from conservation and management interventions.

Table 4. Summary of IVI value of woody species at Hamer District, southern Ethiopia

Species	RDO	RF	RA	IVI
Acacia toritilis	7.01	3.77	1.86	12.64
Allophylus abyssinicus	21.90	1.89	0.47	24.25
Bridelia micrantha	2.19	5.66	3.26	11.11
Cordia gharaf	5.87	1.89	6.51	14.27
Dalbemergia melanoxylon	34.60	1.89	0.47	36.96
Grewia tenax	4.38	3.77	2.79	10.94
Osyris lanceolata	1.31	9.43	12.56	23.31
Terminalia brownii Fresen	12.26	1.89	0.47	14.62
Other species (19)	10.48	69.81	71.61	151.9
Sum	100	100	100	300

Total density per ha = 2120 at Hamer (Shako-wolfo site) RDE (%) = relative density, RFR (%) = relative frequency, RDO (%) = relative dominance, IVI = Importance Value Index (%)

Table 5. Summary of IVI value of woody species at Argo kebele, Bena-Tsemay District, southern Ethiopia

Species	RDO	RF	RA	IVI
Albizia lophantha	1.41	6.82	6.78	15.01
Brideliamicrantha	3.71	6.82	2.54	13.07
Cordia gharaf	27.43	6.82	8.47	42.72
Crotolaria spinosa	9.64	4.55	1.69	15.88
Dodonaea anguistifolia	1.63	11.36	23.73	36.72
Grewia tenax	3.11	11.36	18.64	33.12
Hyparrhenia hirta	5.19	2.27	0.85	8.31
Osyris lanceolata	1.04	11.36	11.86	24.27
Other species (13)	46.84	38.64	25.44	110.91

Total density per ha = 1070 at Bena-Tsemay (Argo kebele) RDE (%) = relative density, RFR (%) = relative frequency, RDO (%) = relative dominance, IVI = Importance Value Index (%)

Table 6. Summary of IVI value of woody species in natural forest at Goldya kebele, Bena-Tsemay District, southern Ethiopia

Species	RDO	RF	RA	IVI
Achenti saspara	1.28	8.78	2.54	12.60
Carissa edulis	-	7.02	7.28	14.30
Combretum molle	11.23	7.02	6.76	25.01
Cordia gharaf	5.46	10.54	12.68	28.67
Faurea rochetiana	26.32	7.02	3.10	36.43
Grewia tenax	0.64	3.51	6.48	10.63
Osyris lanceolata	0.83	10.54	32.96	44.33
Sclerocarya birrea	7.06	1.75	2.25	11.06
Terminalia brownii	10.27	8.78	13.52	32.57
Other species (13)	34.29	35.04	17.48	84.4
Sum	100	100	100	300

Total density per ha = 1590 at Bena-Tsemay (Goldya site). RDE (%) = relative density, RFR (%) = relative frequency, RDO (%) = relative dominance, IVI = Importance Value Index (%).

Regeneration and population structure of *O. lanceolata*

The population status of *O. lanceolata* is shown in Figures 1, 2 & 3, which indicates that the largest proportion of the tree is at sapling and seedling stages. Analysis of diameter size class distribution showed density of *O. lanceolata* (population per ha) at larger diameter size is low. This is due to the extraction of matured stands of the tree from the existing forest. In Bena-Tsemay district, density of seedlings and saplings under (0-10) diameter class were 154 and 25 ha^{-1} in Goldya and Argo Kebeles, respectively. Within Bena-Tsemay district there is variation in a number of stands between the two sites where the forest was found. Forests near Goldya kebele had the advantage of protection by the local community, with access to extension services on natural resource management. In Hamer, there was high exploitation of *O. lanceolata* from natural forests. Lalla from the selected forest sites in Hamer missed vegetation data, due to over-harvesting of the targeted species. However, in Shanko-Wolfo site both HH survey and vegetation data were collected, in which saplings and seedlings were recorded and their density per ha (65) was found to be less than that of Goldya except in Argo Forest site. The result of the present study contradicts with the reports of Tesfaye *et al*. (2019), who reported the high abundance of *O. species* in selected forests of Borena zone, Ethiopia.

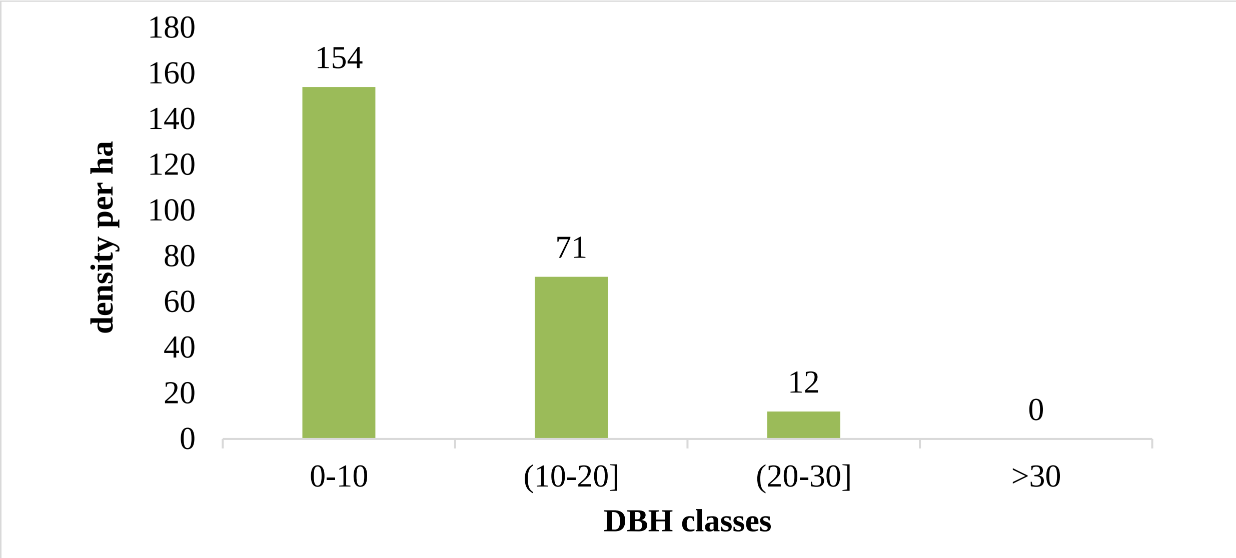

Figure 1. Density of *O. lanceolata* trees with different diameter class in Goldya Kebele, Bena-Tsemay district
Where: DBH (diameter at breast height) in cm, Density ha^{-1}(abundance of *O. lanceolate* in different DBH classes ha^{-1}), not exploited

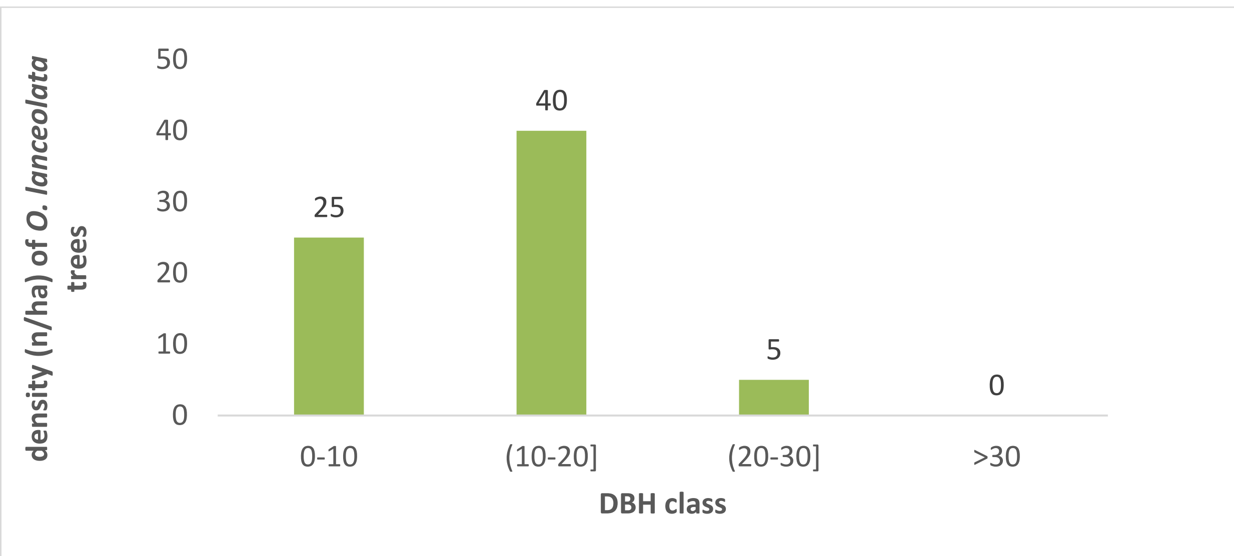

Figure 2. Density of *O. lanceolata* trees with different diameter class in Argo Kebele, Bena-Tsemay district
Where: DBH (diameter at breast height) in cm, Density ha^{-1}(abundance of *O.lanceolata* in different DBH classes ha^{-1}), exploited

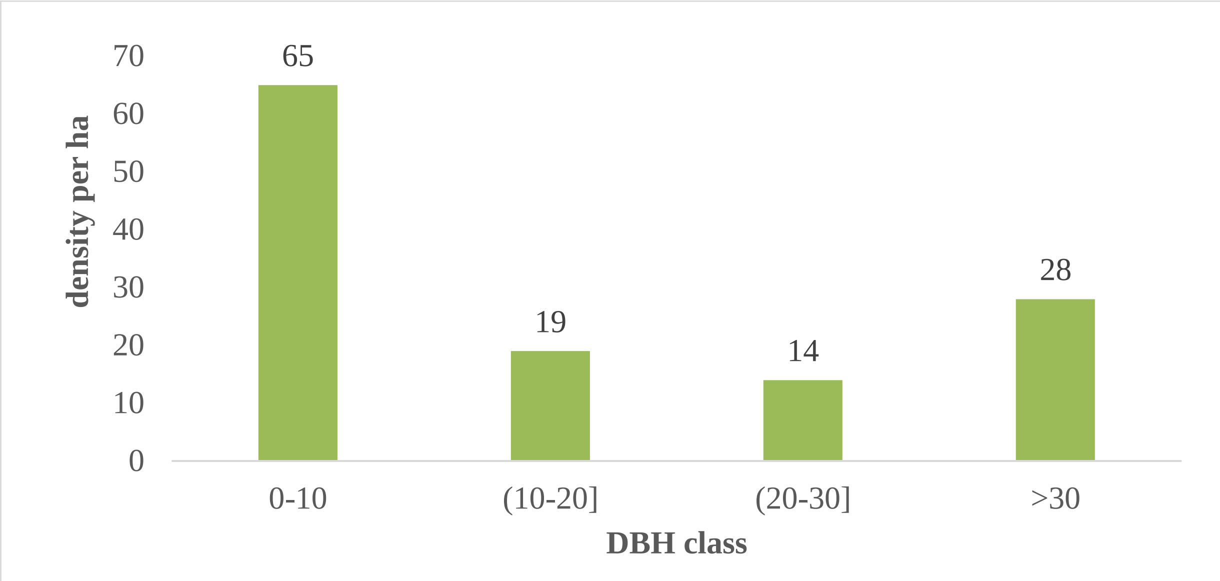

Figure 3. Density of *O. lanceolata* trees with different diameter class in Shanko-Wolfo kebele, Hamer district

Where: DBH (diameter at breast height) in cm, Density ha^{-1}(abundance of *Osyris species* in different DBH classes ha^{-1}), highly exploited

CONCLUSIONS

The study found that the population of *O. lanceolata* in the natural forest was decreasing in both districts of the South Omo Zonal Administration. The decrease in the species is attributed to overexploitation and marketing of the tree for income generation. All interviewed respondents have indicated that the proportion of *O. lanceolata* in the forests is decreasing from time to time, due to overexploitation of the matured stands. Harvesting is commonly carried out using the method of uprooting, further affecting regeneration potential of the species. In the study areas, *O. lanceolata* is mainly used for the extraction of essential oil from its fragrance-scented wood. Moreover, it is used to manufacture farm tools, as energy source and for income generation. The mode of exploitation is mainly through total uprooting with the roots as the most preferred part, and the stems and branches used as the last option. The study showed that the population status of *O. lanceolata* decreased with increasing diameter at breast height; with very low density of mature stands per hectare. The importance value index showed that the *O. lanceolata* was dominated by the first and second-ranked species except in the case of Goldya kebele in Bena-Tsemay district. At Goldya site, *O. lanceolata* has been the first dominant species, with a high IVI.

Based on the findings of this study, the following recommendations are made:

- *O. lanceolata* being an endangered species, due to heavily exploitation by the community, needs immediate intervention where farmers are encouraged to plant the tree on their farmlands;
- The agriculture and forestry extension systems should support communities in raising seedlings of *O. lanceolata*, with special trainings in its management;
- There is also a need for awareness creation among communities and stakeholders about economic and ecological importance of *O. lanceolata* and its management and sustainable utilization;

Further research are required in the areas of developing feasible and effective propagation and silvicultural management methods for *O. lanceolata* to enhance large-scale planting of the species in the study areas and sites elsewhere with similar agro-ecologies and vegetation types.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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