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Population structure, density and natural regeneration of *Boswellia Papyrifera* (Del.) Hochst in Dry woodlands of Nuba Mountains, South Kordofan State, Sudan

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Introduction

Boswellia papyrifera (Del.) Hochst is a deciduous dry-land tree species which belongs to the family Burseraceae. The family is distinguished by the presence of resin ducts in the bark and production of aromatic oils and resins. It is geographically distributed in drier parts of Africa from Nigeria in the west to Eritrea and Ethiopia in the East, being dominant in Ethiopia, Eritrea and Somalia (White, 1983; Ogbazghi, 2001). It is a multipurpose tree species with diverse socioeconomic and ecological importance. Almost all parts of the tree are used for different purposes. Its wood is used for pole and timber locally. It is the source of frankincense (gum olibanum) tapped for cash income and local uses. The leaves and seeds of *B. papyrifera* are highly valued as dry season fodder for goats, camels and other livestock (Adam, 2003; Gebrehiwot et al., 2003). The sweet smelling flowers, that appears when the tree fall its leaves, are important sources of nectar for honey bees.

The leaves, bark, root and the resin are also used as traditional medicines for curing various diseases (Tucker, 1986; Eshete et al., 2005).The species is recommended for economic development and desertification control (Stiles 1988). The major use of the species is the production of frankincense or “olibanum” by tapping the stem (Tucker 1986), and in the Horn of Africa it has an important application in local communities for medicinal uses and during religious and coffee ceremonies (Coppen, 1995). Internationally the resin is an important commodity as it is a source of essential oils in among others the cosmetic and pharmaceutical industry (Chikamai 2002; Lemenih and Teketay, 2003). In addition to its commercial product, *Boswellia* has important ecological role owing to the environmental conditions that the species is naturally distributed.

Boswellia in Sudan is common savanna tree species as a pure stand or mixed with other species like *Sterculia setigera*, *Combretum spp.*, *Terminalia* and *Commiphora* species on slopes and land hills (Salih et al. 2002; Adam 2003).The survival of the species in such marginal areas makes it a key stone species that can provide plant cover and protect the soil and provide shade. It also plays an important role in desertification control since it acts as defense line against desert creeping southwards.

For conservation and proper management of the existing *Boswellia* stands in Nuba Mountains, it is important to understand the species population structure, density and natural regeneration. The objectives of the paper were thus to (i) quantify the population structure and density of *B. papyrifera;* (ii) analyze the natural regeneration status of the species*;* and (iii) assess the harvesting intensity and visible damages on the *Boswellia* trees. In doing so we studied two *Boswellia* stands in reserved and unreserved forests.

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Materials and methods

Description of study area

The study was conducted in Rashad locality in two forests which are located in the Nuba mountains region, Southern Kordofan state about 680 km from Khartoum city. The Nuba mountains range is situated almost exactly in the geographic center of the Sudan covering an area about 5000 km^2. It is situated between latitude 10^0- 13^0 N and longitude 29^0-33^0 E (El Tahir and Gebauer 2004). The climate of the area is classified as sub-humid with annual rainfall ranging from 400 mm to 800 mm annually. The rainy season extends from mid-May to mid-October allowing grazing and seasonal rain-fed agriculture. The region is known for its diverse flora and its potential in providing diverse verities of NTFPs (El Tahir and Gebauer, 2004).

Data collection and analysis

A rapid vegetation assessment survey was conducted in two *Boswellia* stands, Tajmala reserved forest and Kajinat unreserved forest at Umabdella village in order to examine the status of the resource base. The two forest stands correspond to reserved forest and unreserved forests. A total of 33 sample plots of size 20 X 20 m were laid at regular interval along parallel transects with smaller sample plots of size 5X 5 m nested in the center of each plot for regeneration count. The first sample plot was laid randomly and the others systematically at pre-specified intervals to be distributed in the surveyed forests. 21 sample plots were taken from Kajinat reserved forest along three parallel transects with an interval of 500 m and 300 m interval between sample plots. From Tajmala unreserved forest 12 sample plots were taken with similar design as of the Kajinat Forest.

Diameters of all trees with greater than 5 cm DBH and height of selected trees from all diameter classes in the sample plots were measured and species type recorded. In the regeneration plots the number of *Boswellia* seedlings and saplings encountered were counted. Based on visual observation tapping intensity, damage type, possible cause of the damage and number of dead *Boswellia* trees were recorded from each sample plot. The population structure of the species is depicted using frequency histogram of diameter classes and number of regeneration

Results and Discussion

Population structure of *Boswellia*

Population structure (proportion of individuals belonging to different size or age classes), density and regeneration status are commonly used indicators to evaluate impact of NTFP extraction from a given forest area (Silvertown, 1982; Shahabuddin & Prasad, 2004). Information on population structure of a tree species indicates the history of the past disturbance on the species and the environment and hence, used to forecast the future trend of the population of that particular species. The population structure of *B. papyrifera* in Kajinat reserved forest and Tajmala unreserved forest is given in Figure 1 and 2.

The population structure in both forests showed that the population is dominated by mature individuals with complete lack of juvenile and regenerating individuals (<11 cm DBH). All the individuals of the species in both surveyed stands have diameter greater than 11 cm. An inverse J-shaped curve that shows very high proportion of seedlings and saplings in relation to mature trees is considered to represent a healthy regenerating population (Shahabuddin and Prasad, 2004). Sharply declining densities of individuals in successively larger size (or age) classes produces the inverse J-shaped diameter class distribution for a species.

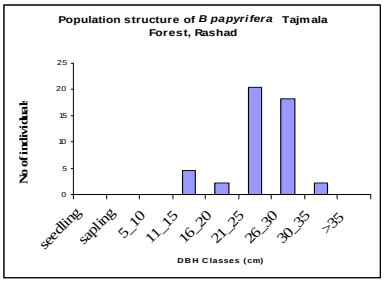

Figure 1 Population structure of *B. papyrifera* in Tajmala unreserved forest, Rashad

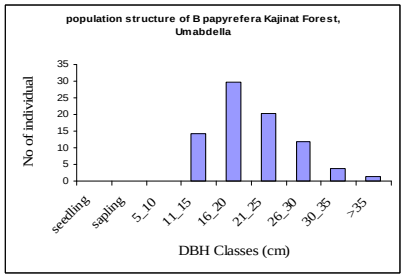

Figure 2 Population structure of *B. papyrifera* in Kajinat reserved Forest, Umabdalla

The bell shaped structure that was found in the surveyed stands in the study area (Fig 1 and 2) indicate that the population of *Boswellia* in the study area is unstable and under threat due to lack of recruitments through regeneration. Similar population structures of *B. papyrifera* were reported from Jebel Marra, West Sudan by Khamis (2001) and Adam (2003). Several studies in Ethiopia (Eshete et al. 2005; Lemeneh et al. 2007) and in Eritrea (Ogbazghi, 2001) have also reported unstable populations of *B. papyrifera* in different sites. This is an indication that the species is under threat not only in the study area but also in several geographical locations in the region of its distribution due to continuous tapping for incense production, human induced fire, overgrazing and climatic anomalies. For instance, Rijkers et al. (2006) illustrated that untapped trees produce three times higher healthy and filled seeds than tapped trees with germination success being highest in stands with untapped trees (> 80%) and lowest in ones with tapped trees (< 16). The same authors also indicated that at tree level, sexual reproduction decreased with increasing tapping regime irrespective of tree size.

Density of *Boswellia* stands

The densities of *B. papyrifera* were 81 ± 79 trees ha^{-1} and 52 ± 50 trees ha^{-1} in Kajinat reserved forest and Tajmala unreserved forest, respectively (Table 1). The density of the tree species observed in the two stands shows variation. The highest density (81 trees ha^{-1}) was registered from Kajinat reserved forest and the lowest (52 trees ha^{-1}) from Tajmala unreserved forest (Table 1). The density indicates the disturbance level of the two stands. These figures are lower than the density of *B. papyrifera* in Jebel Marra, West Sudan (114 trees ha^{-1}) reported by Khamis (2001). Higher densities of *B. papyrifera* trees were also reported in different sites in Eritrea (80-270 trees ha^{-1}) (Ogbazghi et al. 2006) and Ethiopia (64-225 trees ha^{-1}) (Lemenih et al, 2007).

Table 1 Density and frequency of *B. papyrifera* in two forest stands

Forest	Average density of *B. papyrifera trees ha^{-1}*	Density of all tree species *trees ha^{-1}*	Frequency of occurrence %
Kajinat reserved	81 ± 79	126 ± 78	80
Tajmala unreserved	52 ± 50	87 ± 52	82

More than 10 tree species that include *Acacia garradii, Anogysus leicocarp, Combretum hartimanium, Combretum spp., Lannea fructlase, Sterculia setigera, Dalbergia melanoxylen, Ziziphus spinachristy, Tamarindus indica, and Terminalia spp.*were found in association with *B. papyrifera*. The density of all tree species found in the surveyed stands was found to be 126 ± 78 trees ha^{-1} and 87 ± 52 trees ha^{-1} in Kajinat reserved and Tajmala unreserved forests respectively (Table 1). *Boswellia* constitute by respective 64% and 58% of all the tree species in the two stands. Higher frequency of occurrence (percentage of stocked sample plots) of *B. papyrifera* was observed in stands, 80%

at Kajinat forest and 82% at Tajmala forest (Table 1). This shows the uniform distribution of the individuals of the species in both forest stands. There is a visible change in the population of the species. Tribal leaders and local community members indicated that natural mortality, intensive tapping, continuous tapping without resting period, mis-tapping (deep tapping), and insect attack are the major causes for the decline of the population of the species. There is no supervision of production areas and no management and protection activities being carried out. The local community blames the outsiders/ migrant frankincense producers for the death of *Boswellia* trees that since they are not permanent residents in the area they tend to maximize yield from trees by making many tapping spots. On the other hand migrant tappers (outsiders) blame the locals for improper tapping and using improper tapping tools.

Natural regeneration status of *Boswellia*

No seedlings and saplings of the species were encountered in all the sample plots. Khamis (2001) also found that there was no regeneration of *Boswellia* trees in Jebal Marra, West Sudan showing that lack of regeneration and/or establishment of the species is a common problem in the Sudan. However, Adam and El Tayeb (2008) reported that they encountered quite high number of seedlings of the species in the same area. The possible reason for the discrepancies could be the season of the regeneration survey that Adam and El Tayeb (2008) conducted that the regeneration survey immediately after the rainy season and the survey was conducted during the dry season in case of the present study as well as Khamis (2001). The variation in the regeneration results can be taken as an indicator that *Boswellia* has the ability to produce ample quantities of seedlings but these seedlings face difficulties of establishment. The lack of regeneration of the species could be attributed to intensive tapping, continuous tapping of the trees, fire, and over grazing (Khamis 2001; Eshete et al. 2005).

Frankincense harvesting Intensity and Visible Damages on *Boswellia*

In Kajinat reserved forest, tapping intensity (Number of tapping spots per tree) was surveyed to evaluate the harvesting intensity. 6-12 tapping spots were counted on 53% of the tapped trees. The rest 47% were tapped on more than 12 spots. Surprisingly 20% of the trees were tapped on more than 15 tapping spots. Although, there is no scientifically recommended tapping intensity, experienced tappers regard 8-12 tapping spots are normal depending on the tree size. Thus, 43% of the tapped trees are over tapped or intensively tapped. This could be the result of the tappers intention to maximize their yield and hence benefit from a given area. Symptoms of insect attack were also observed on 17% of *Boswellia* trees in the sample plots. Browsing of the bark of the trees by cattle was also observed as another threat that 10.3% of the standing trees were affected by this threat. Moreover, large number of trees were observed dead and fallen in the woodland (17 trees ha^{-1}). Such high mortality coupled with the absence of regeneration and recruitment clearly indicates the challenge on the sustainability of the resource and supply of frankincense. The historical records of frankincense or “olibanum” exports from Sudan show that there is gradual decline in annual export from about 1119 Metric Ton in 2001/2002 to about 182 Metric Ton in 2006/07 (Central Bank of Sudan 2006; 2007) which could likely be associated with the decline in of the tree population and degradation of *Boswellia* stands. Despite the critical problem of lack of regeneration, insect damage, browsing damage and mortality of *Boswellia* trees in the study area; nothing is being done by responsible bodies.

Conclusion

The population structure of *Boswellia* illustrates that natural regeneration is lacking in all two study areas. Additionally, the population of *Boswellia* in the study areas is unstable and under threat due to lack of recruitments through regeneration. Based on the stands structure analysis, it is hypothesized that lack of natural regeneration is primarily caused by livestock grazing pressure and the absence of recruitment is largely caused by lack of seed production by mother trees as the result of intensive tapping of the frankincense. Forest ecosystems have complex interrelationships that extraction of non timber forest products (NTFPs) can seriously affect plant populations as

negatively as timber harvesting (FAO 1995a). The current population status and threats to the species resulted from commercial extraction of the product without proper planning and management of the resource reveals that the commodity chain is unsustainable from the perspective of ensuring steady supply of the product. The assumption that NTFP extraction is less destructive than timber harvesting is unfounded in the case of frankincense in the study area. Sound knowledge of the resource base and regular monitoring is essential to check negative impacts posed to the resource from commercial harvesting of NTFPs to take remedial actions in time.

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