

The Significant, Threats and Management of *Boswellia Papyrifera* (Del.) Hochest Tree Species in Ethiopia: A Systematic Review

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Abstract

Boswellia papyrifera (Del.) Hochst is one of a combretum-terminal deciduous ecosystem with the key dry land tree forest in the world planet which belongs to the family Burseraceae. This review paper presents to review the importance, threat and its management techniques of *Boswellia papyrifera* forest tree species in Ethiopia. *Boswellia papyrifera* woodland provides considerable economic, ecological, socio-cultural, traditional and industrial benefits in the dry lands of Ethiopia. The review showed that in Ethiopia *Boswellia papyrifera* tree population are declining at an alarming rate mainly due to overgrazing, absence of regeneration and saplings, pests, agricultural expansion, over tapping for frankincense production, poor policy and other interrelated factors. There are different important demands being made on the *Boswellia papyrifera* reducing conversion of woodland, using appropriate collection tools and methods, speedy environmental rehabilitation, improving tapping methods and timing, and provision of tree products as soon as possible in Ethiopia. Continuous capacity building training on sustainable utilizations and managements of *Boswellia papyrifera* woodland should also be provided for all relevant stakeholders.

Keywords: *Boswellia Papyrifera*, Management, Threat, Important.

1. Introduction

Boswellia papyrifera (Del.) Hochst is among the key deciduous dry-land tree species native to Ethiopia 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 and widely known for its non-timber forest product (NTFP), frankincense production. Besides, it has also other numerous environmental and socio-economic benefits [1-3].

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 *Boswellia papyrifera* are highly valued as dry season fodder for goats, camels and other livestock [4]. The sweet-smelling flower, that appears when the tree fell its leaves, is important sources of nectar for honey bees Found *Boswellia papyriera* in Ethiopia, Chad, Eritrea, Cameron, Central Africa Republic, Sudan and Uganda. Terminalia–Combretum woodlands ecosystem in which *Boswellia papyri era* is one of the dominant species are no exception.

They contribute to improved livelihoods of dry land local communities in terms of food security and income generation, while also contributing to the national economy being among the few export articles. One of these species is *Boswellia papyrifera*, known to produce a commercially important and widely traded aromatic product called frankincense. Production of frankincense by private and government organizations for commerce has a long history in Ethiopia [5].

Furthermore, the species is valuable for animal fodder, fences, medicines, apiculture, soil and water conservation, carbon sequestration and adaptation to climate change impacts. For example, in 2014, Ethiopia exported about 7,900 tons of frankincense with a value of US\$8.8 million [6-8]. This makes the country one of the major frankincense suppliers to the world market. Despite the wide benefits of the species in Ethiopia, its populations are declining at an alarming rate mainly due to overgrazing, over tapping for frankincense production, poor policy and other interrelated factors [9,10]. This review paper presents to the importance, threats and management techniques of the *Boswellia papyrifera* tree species in Ethiopia.

1.1 Local Name *Boswellia Papyrifera*

Boswellia papyrifera (Del.) Hochst in Ethiopia is widely known commercially as bitter frankincense and belongs to the family Burseraceae. It is known by different local names in Ethiopia as Kererrie and Ye- etan zaf (Amharigna), Galgalem and Kftal (Oromigna), Meqer and Walwa (Tigrigna), Fatuka (Agewigna) and Libeant (Hadigna) Et'an mitta (Borna/shinasegna).

2. Objectives

The objectives of this review article are i) to explore the important roles *Boswellia papyrifera* forest tree and ii) highlight threat and managements of *Boswellia papyrifera* forest tree in Ethiopia.

2.1 Methodology of Review

For the compilation of this articles a set of summaries were drawn in the form of a critical analysis and discussion, by considering a range of awareness of differing arguments, theories and approaches. Guided by the research objective a synthesis and analysis of the related different information and findings which are linked to the theme and rationale of the article were identified and analyzed from various sources. The paper attempted to justify the scope of the relationship among *Boswellia papyrifera* forest tree roles, threat and management by interpreting a number of facts. The review also compared and contrasted the different views and issues of the significant, threats and management of *Boswellia papyrifera* exemplary research studies. The analysis also highlighted the research gaps to be addressed in another further research.

2.2 Botanical Description of *Boswellia Papyrifera*

Boswellia papyrifera (Del) Hochst is one of 20 species in the genus *Boswellia* Roxb., which belongs to the Burseraceae family, which only 5 produce oleo-gum resins of commercial value and it is known to produce an internationally tradable aromatic resin called frankincense.

Boswellia papyrifera is a deciduous tree, reaching a height of 16 m with a rounded pole, thick branches and leaves are deciduous, large, compound, arranged on long stalks with 11 to 29 leaflets which are narrowly ovate to oblong, waved or toothed along the margin. The large compound leaves have 6–8 pairs of leaflets plus one at the tip. Each leaf is oval, 4–8 cm long and densely hairy underneath.

Boswellia papyrifera is a monoecious species with sweet scented flowers to attract honey bees for pollination, which are white to pink, arranged on long red flower stalks, in loose panicles/head at the end of thick branches. The bark is smooth, whitish to pale-yellow brown, peeling off in large papery pieces/flakes. A slash/cut in the bark looks red-brown and a fragrant milky resin drip out [11]. Its fruit is a drupe, about 2 cm long and usually contains three tapered seeds with red capsules. The seeds do not accumulate in the soil for a long period and germinate immediately after dispersal due to lack of dormancy. This implies that its major route of regeneration is through “seed rain” [12].

2.3 Biology of *Boswellia Papyrifera*

Boswellia papyrifera is a deciduous tree that can be as tall as 12 m or more with a rounded crown, thick branches tipped with cluster of leaves. The bark is smooth, whitish to pale-yellow brown, peeling off in large papery pieces/flakes. A slash/cut in the bark looks red-brown and a fragrant milky resin drip out. The leaves are deciduous, large, compound arranged on long stalks with 11 to 29 leaflets, densely hairy below, which are narrowly ovate to oblong, and waved or toothed along the margin. Flowers are sweet scented, which are white to pink, arranged on long red flower stalks, in loose panicles/heads at the end of the thick branch lets. The fruit is a red capsule about 2 cm long, 3-sided with 3 tapered hard seeds inside.

The genus *Boswellia* includes 20 tree species, of which only 5 produce oleo-gum resins of commercial value. The species *Boswellia papyrifera* (Del.) Hochst is one of them and it is known to produce an internationally tradable aromatic resin called frankincense. *B. papyrifera* is a deciduous tree, reaching a height of 16 m with a rounded pole, thick branches and compound leaves that comprise sweet-scented flowers to attract honeybees for pollination. Its fruit is a drupe, about 2 cm long and usually contains three tapered seeds. The seeds do not accumulate in the soil for a long period and germinate immediately after dispersal due to lack of dormancy. This implies that its major route of regeneration is through “seed rain”.

2.4 Ecology of *Boswellia Papyrifera*

In Ethiopia, *Boswellia papyrifera* forest tree species is presented on Combretum-Terminalia Woodland Ecosystem, it is a native multipurpose tree that covers over 1.5 million ha and is mainly found on degraded dry lands within an altitudinal range of 950–1800 m.a.s.l with average temperature of between 20–27 °C and annual rainfall less than 900 mm [13]. It grows on degraded sites with very shallow soils, steep rocky slopes, lava flows or sandy river valleys, within the 950–1,800 m a.s.l. altitudinal range.

2.5 Geographical Distribution of *Boswellia Papyrifera* in Ethiopia

In terms of geographical distribution, *Boswellia papyrifera* is found in Ethiopia, Nigeria, Cameroon, Central African Republic, Chad, Sudan, Uganda and Eritrea. It mainly occurs in the Sudanian regional center of endemism and the Sahel regional transition zone. The center of geographic distribution of the genus *Boswellia* is located in north-eastern parts of Africa where more than 75% of its species are endemic to the area.

In Ethiopia, the distribution of *Boswellia papyrifera* is confined to the dry combretum-terminalia broad-leaved deciduous woodlands of the north, northwest and some of the northern major river gorges [14]. It is widely distributed in Tigray, Gondar, Gojjam, Wellega, Benishangul Gumuz, and thinly in Wello, Shewa and Afar. The *Boswellia papyrifera* dominated woodland mainly existed in Benishangul-Gumuz, Gambella, Oromiya, Amhara and Tigray regions. In Ethiopia, *B. papyrifera* occurs in dry Acacia

– commiphora woodlands in Gonder, Gojam, Shewa upland and Tigray.

Available estimates indicate that about 1.7 million ha of woodlands that hold *B. papyrifera* as their main species composition occur currently in three regional states namely Amhara, Benishangul-Gumuz and Tigray. At present, the species is dominantly found and widely used in Tigray (940000) ha according to (Tilahun, 1997) and Amhara (604000 ha according to regions.

The *Boswellia* pre-dominated woodland, which belongs to the Combretum–Terminalia deciduous woodlands of the dry forests of Ethiopia forms the largest vegetation cover and widespread in the northern and north-western lowland part of the country and found in five regional states, namely Benishangul-Gumuz, Gambella, Oromiya, Amhara and Tigray regions of the area with an altitudinal range of 600–1800 m a s l, with an annual mean temperature of 20–25°C and an annual mean precipitation of less than 900 mm [15][16].

2.6 Importance of *Boswellia Papyrifera* in Ethiopia

Boswellia papyrifera being the chief source of frankincense produced in Ethiopia. It is a multipurpose tree species with diverse socioeconomic and ecological importance. In Ethiopia, *Boswellia papyrifera* woodland provides several socio-economic and ecological benefits [17]. For example, in 2014, Ethiopia exported about 7,900 tonnes of frankincense with a value of US\$8.8 million. This makes the country one of the major frankincense suppliers to the world market [18]. Frankincense collection and its associated trade activities also support the livelihoods of many residents in dry land areas where livelihood options are limited due to harsh environmental conditions. Furthermore, the species is valuable for animal fodder, fences, medicines, apiculture, soil and water conservation, carbon sequestration and adaptation to climate change impacts.

It also plays an important role in desertification control since it acts as defense line against desert creeping southwards. This tree species in such marginal areas makes it a key stone species that can provide plant cover and protect the soil and provide shade.

2.7 Ecological Importance of *b. Papyrifera*

Boswellia papyrifera can the species makes economic use of the marginal areas on which other species could not grow. In those sites, it provides plant cover and produces higher biomass and hence protects the soil and provides shade. Since growing *B. papyrifera* is economically and socially attractive, it increases the attention for the conservation of these degraded sites. Furthermore, the species is valuable for animal fodder, fences, medicines, apiculture, soil and water conservation, carbon sequestration and adaptation to climate change impacts [19].

According to Lemenih and Kassa (2011), they offer better adaptation and mitigation options. The vegetation resources could: help to fight against desertification and soil erosion by

water and wind, contribute to the conservation and enhancement of biodiversity, improve soil fertility and provide opportunity for carbon-sequestration.

Enclosures in Tigray region are in the positive progress of achieving their objectives as they have been played a significant contribution since their establishment up to now in regulating environmental services through the improvement of below and aboveground carbon sequestration, controlling soil erosion, improvement of soil fertility, restoration of native woody plants and improvement of biomass production.

2.8 Economic Importance of *Boswellia Papyrifera*

In Ethiopia, *Boswellia papyrifera* woodland provides several economic benefits. For example, in 2014, Ethiopia exported about 7,900 tonnes of frankincense with a value of US\$8.8 million. This makes the country one of the major frankincense suppliers to the world market. Frankincense collection and its associated trade activities also support the livelihoods of many residents in dry land areas where livelihood options are limited due to harsh environmental conditions .

2.9 Livestock Feed and Bee Fodder

Boswellia papyrifera is a drought resistant tree species that continues to produce leaves and flowers even at times of drought. Its long flowering period is very helpful in bee colony maintenance and boosts honey production. Honeybees frequently visit flowers of *Boswellia papyrifera* during the dry season. Moreover, leaves and seeds of the species are highly valued as fodder for goats, camels and other livestock. The succulent stem is also used as fodder during dry season. These species are valuable for animal fodder and other socioeconomic benefits through production of animal feed.

2.10. Threats to *Boswellia Papyrifera* in Ethiopia

However, the leading frankincense producing tree species, *Boswellia papyrifera*, over the decades is facing uncertain future/ lacking regeneration due to several and interrelated anthropogenic and environmental challenges mainly expansion of agricultural lands, overgrazing, population increase and the ever-growing demand for construction and fuel wood, forest fire, pests and diseases, unsustainable resource utilization are among the major challenges affecting *Boswellia papyrifera* regeneration in Ethiopia. Although the wide benefits of the species in Ethiopia, its populations are declining at an alarming rate mainly due to overgrazing, over tapping for frankincense production, poor policy and other interrelated factors. *Boswellia papyrifera* is threatened as a result of several interrelated factors, which are discussed below;

• Population Pressure

In many *Boswellia papyrifera* growing areas, there has been increased population pressure. This has resulted in the conversion of *Boswellia* woodlands to agricultural lands at a faster rate for extensive farming. The underlying factors, however, are high population influx mainly through resettlement schemes

coupled with weak institutional environment for regulating access and management of the dry forest resources (i.e. Lack of properly organized and planned exploitation. These have led to uncontrolled conversion and unregulated utilization of *Boswellia* dominated woodlands leading to their widespread degradation and deforestation. Addressing these challenges is, therefore, a major requisite to ensure sustainable production and supply of frankincense.

- **Overgrazing**

Unregulated overgrazing has damaged natural regeneration of *Boswellia papyrifera*. It is known that seeds and seedlings of *Boswellia papyrifera* are particularly highly preferred by goats and other livestock. Grazing of *Boswellia papyrifera* seedlings result in the total removal of all above ground vegetative parts, which makes survival difficult.

- **Improper Tapping Practices**

Traditionally, frankincense from *Boswellia papyrifera* is produced through artificial wounding of the trees, a process called tapping. Tapping can cause damage to trees if done at high intensity or by inexperienced tappers. Damage arises because tapping exposes trees to infectious attack by insects and other reduces tree vigor and increases susceptibility to windfall.

It is not uncommon to see over-tapping and use of inappropriate tapping methods by unskilled laborers and over tapping for frankincense production. There is little supervision during tapping. More accessible trees are often tapped continuously with no rest periods. Ogbazghi (2001) reported that seeds from un-tapped stands had high germination rates (94% and 80%) compared to seeds from tapped stands (14% and 16%) in Eritrea. There were more empty seeds in over tapped stands.

The present traditional tapping techniques need to be improved in a way to avoid damage to the biology of the *Boswellia papyrifera* trees and to the surrounding seedlings during incense harvesting. Improper tapping of the tree resulted in damage of adult trees through exposing the tree to fire, worm and other attacks .

- **Biological Factors**

Among the direct factors putting heavy pressure on the populations of *Boswellia* include by biological factors termite and other insect infestation. Tilahun (1997) presented a high incidence of insect attack (17.5%) and also reported that between 20 and 25% of the bulk seeds were attacked by insects. Pest and disease are among the major challenges affecting *Boswellia papyrifera* regeneration in Ethiopia.

- **Wind Damage**

As the roots of *B. papyrifera* are shallow, substantial damage is also caused by wind.

- **Lack of Natural Regeneration**

At present, *Boswellia papyrifera* forests are dealing and its natural regeneration is several challenges due to a number of anthropogenic and natural factors. Several population assessments of *B. papyrifera* in different geographical regions reported that the tree is represented by matured trees, while the smaller sizes (seedlings and saplings) are absent or few, indicating a serious lack of recruitment through natural regeneration and thus an unstable population of the species .

Planting of nursery raised seedlings also demonstrated low establishment successes. The low survival rate can be attributed to the damage from livestock and the lack of silvicultural knowledge of the species, including time of seed collection, nursery practices, choice of appropriate planting sites and post-planting care.

The major population bottleneck with the species both under natural condition as well as in plantation development is not lack of seeds, poor germ inability of seeds nor seedling emergence but high seedling mortality (approximately 100% (Negussie et al.,2008). This is raising doubts regarding the long-term prospect for a sustained supply of goods and services from the species. Generally, the species is considered as an endangered species and in need of priority for conservation.

Even though the wide benefits of the species in Ethiopia, its populations are declining at an alarming rate mainly due to overgrazing, over tapping for frankincense production, poor policy and other interrelated factors, increased frequency of forest fire, regeneration lacking by frankincense producing tree species.

However, the woodland is being reported affected by interrelated factors through which its degradation is framed. Some of the challenges include clearance for cropland expansion, over grazing, intensive and improper tapping, and increased frequency of forest fire. Of these factors, the conversion to agriculture land and lack of regeneration, mining is the main threat in the (Benishangul-Gumuz) northwestern Ethiopia parts.

Recently, the populations of *Boswellia papyrifera* are declining and its natural regeneration is severely hampered due to a number of anthropogenic and natural factors. Among the direct factors putting heavy pressure on the populations of *Boswellia* include; extensive farming, over-grazing, intensive and improper tapping practices, increasing forest fires, and biological factors (termite and other insect infestations).

The underlying factors, however, are high population influx mainly through resettlement schemes coupled with weak institutional environment for regulating access and management of the dry forest resources (i.e., lack of properly organized and planned exploitation (Lementh and Kassa, 2009). These have led to uncontrolled conversion and unregulated utilization of *Boswellia* dominated woodlands leading to their widespread degradation

and deforestation. Addressing these challenges is, therefore, a major requisite to ensure sustainable production and supply of frankincense.

3. Forest Fire

Forest fire is other the major challenges affecting *Boswellia papyrifera* regeneration in Ethiopia. Among the direct factors putting heavy pressure on the populations of *Boswellia* is increasing forest fires.

3.1 Management of *Boswellia Papyrifera* (del.) Hochst

Boswellia papyrifera has a great potential both from an economic and from an ecological perspective. In- situ and Ex- situ conservation practices are implementation in which is cover large area of *Boswellia papyrifera* forest tree species in the Ethiopia.

However, its population is in a critical condition of degradation due to anthropogenic and natural factors. Therefore, providing protection for regenerated seedlings of *Boswellia papyrifera* should be an immediate task in order to rehabilitate these forests. There are different important demands being made on the *Boswellia papyrifera* reducing conversion of woodland, using appropriate collection tools and methods, speedy environmental rehabilitation, Improving tapping methods and timing, and provision of tree products as soon as possible in Ethiopia. Other management-related recommendations of *Boswellia papyrifera* tree species in Ethiopia are improving harvesting methods, management of natural stands for sufficient regeneration, domestication and plantation establishment and improving product handling, quality control and value-adding. Managing certain woodlands to support regeneration and recruitment of *Boswellia papyrifera*, by controlling open grazing and fires and by nursing seedlings, is essential for maintaining viable populations, which, in the long run, is key to ensuring a sustainable supply of frankincense.

Several possible approaches for increasing the production and quality of frankincense are available, such as using appropriate collection tools and methods, improving the management of natural stands and establishing plantations to increase production and improve productivity. Finally, resin over-exploitation must be avoided to maintain the present high seed vitality in the *Boswellia* woodlands, particularly in northern Ethiopia .

4. Conclusions

Boswellia papyrifera (Del.) Hochst is belonging to the family Burseraceae, which a key dry land forest species native to Ethiopia. It is widespread multipurpose forest tree species holds immense actual and potential socio-economic, ecological, traditional, religious and industrial significances in Ethiopia. Though, the population of the species is declining at an alarming rate due to a number of anthropogenic and natural factors such as overgrazing, over tapping, pests, agricultural expansion, poor managements and increase forest fire. Therefore, urgently they are required more efforts in the rehabilitation and management of the species. Most

of the efforts made to improve the natural stock of the species have limited success due to the lack of knowledge on seed collection, nursery practices and post-planting care. Consequently, further they needed integrated with NGO and government management measures and applied research is required for the sustainable production and rehabilitation of the species

Recommendations

- Continuous capacity building training on sustainable utilizations and managements of the woodland should also be provided for all relevant stakeholders.
- Appropriate policies should exist and to be implemented of the use these resources on a sustainable basis, both locally and nationally.
- Researches on the economic benefits of intercropping *Boswellia* tree with agricultural crops to diversify the income from the *Boswellia* wood land to minimize the degradation are required.
- Measures that promote natural regeneration should be adopted and techniques for successful natural regeneration and silvicultural studies on alternative methods of propagation, seed collection, nursery practices, choice of appropriate planting sites and post planting care should be strengthened.

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