

Research Article

Frankincense Production from *Boswellia papyrifera* “(Del.) Hochst” in South Kordofan State, Sudan (Production, Opportunities and Value Chain)

**Kamal Eldin Mohammed Fadul^{1,*} , Abbas Hassan Ali² ,
Muneer Elyas Siddig Eltahir^{3,4} , Idris Musa Adam² , Hatim Abdalla Elkhidir² ,
Sona Mohammed Fadual^{3,4} , Massaud Mohamed Massaud⁵ **

¹Department of Forest Silviculture, Faculty of Forestry, University of Khartoum, Khartoum, Sudan

²Gum Arabic Research Programme, Agricultural Research Corporation, El-Obeid Research Station, El-Obeid, Sudan

³Institute of Gum Arabic Research and Desertification Studies, University of Kordofan, El-Obeid, Sudan

⁴Department of Forest Protection and Conservation, University of Khartoum, Khartoum, Sudan

⁵Forest National Corporation, Kadugli, Sudan

Abstract

Boswellia papyrifera “(Del.) Hochst” is an important multipurpose tree in the Savanna zone of Sudan. The tree produces frankincense which is considered as an important commodity in many African countries. There is lack of information about frankincense production, processing and marketing in Sudan. Therefore, this study aims to provide information about production, tapping, collection and processing and to disseminate this information to the producers, stakeholders such as companies, forest administrations and producers’ association. The methodology includes critical review to current literature on frankincense production and export from Sudan. Key informant interview with FNC staff and analyses of production data in the study area. The results showed that the average frankincense yield in the study area ranged between 1.7 to 2.6kg/tree. The average producer production is ranged between 60-85 quintal/ year. The analysis of the production data for the period 2017 to 2025 showed that the highest frankincense production (432.85 tonne/year) was recorded for Rashad locality followed by (343.32 tonne/year) for Talodi locality, while the lowest frankincense production of (12.3 tonne/year and 13.48 tonne/year) was recorded for Dalanj and Abu Gebiha localities, respectively. The frankincense price in the study area is started from 2700 US\$ in the beginning of the season to 4450 US\$/ tonne by the end of the season. For the value chain about eight actors in frankincense production were identified and their role in production, marketing and export was examined. Those actors include government bodies (Forest National Corporation (FNC), State Ministry of Finance, State Ministry of Agriculture, Zekat, Taxation office, and locality), local leader (Ommads and Sheikhs), Producers, village trader, traders in domestic markets, trader in urban markets and exporters. The study showed that the net revenue at village level is about 230000 SDG/quintal about 92 USD\$, the revenue from domestic market is about 16 USD\$/quintal, while the revenue from the auction market is about 116 USD\$/quintal. The main production constraints in the study area include excessive tapping, lack of fund for tapping and collection, low frankincense price, expansion of cultivation, war, illicit cutting and animal grazing. The study concluded that frankincense production from *Boswellia* is profitable for all actors in the frankincense value chain. The study recommended providing financial support to frankincense producers during tapping and collection and offering credit facilities to local community to get production permit, reduction of taxes and fees. More research is need in production, marketing and supply chain of frankincense in Sudan as general and in South Kordofan in particular.

*Corresponding author: kamaleldin2001@gmail.com (Kamal Eldin Mohammed Fadul)

Received: 22 July 2025; **Accepted:** 11 August 2025; **Published:** 3 September 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

Keywords

Boswellia Papyrifera, Natural Regeneration, Marketing, Tapping, Processing, South Kordofan

1. Introduction

Boswellia papyrifera in Sudan is a common savanna tree that occurs on rocks or hill slopes in high rainfall savanna. It occurs in Blue Nile around Jebel Garrie and Fung and in the eastern Sudan extending from Gala-al-Nahal to Kurmuk [10]. In Kordofan it occurs in the Nuba Mountains (Figure 1), where it grows gregariously on mountain slopes on shallow soils over rocks, it also occurs in Talodi, Rashad and Abu Giebeha in Kordofan [21]. In Dar Fur, *Boswellia* occurs around Zalingei, Rodom and Jebel Marra, it is found on piedmont and massifs 1070-1830 m.a.s.l., dominant on the upper hill slopes forming pure stands on the crests of the basement complex hills or stony soils, usually on quartz pebbles of the clay plains.

In Africa, the tree is found in Ivory Coast to the Horn of Africa and south wards to northern Madagascar. It is also found in the Middle East as well as India [12]. The centre of geographical diversity of the genus is located in north east tropical Africa within the dry lowland areas where more than 75% of its species are endemic.

Boswellia in Sudan is found as a pure stand or mixed with other species like *Sterculia setigera*, *Combretum spp.*, *Terminalia* and *Commiphora* species on slopes and land hills [20]. 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.

The aromatic frankincense from *Boswellia papyrifera* are used in various industries, including pharmacology, cosmetics and perfumery, flavouring, [18, 34]. Aromatic frankincense provides significantly revenues not only to households; national governments also generate a lot of hard currency in their late export trade [6]. The pastoralists in there going collect and sell frankincense as an adaptation option when faced with climate-driven risks [19, 28].

Frankincense is an ancient commercial forest product which currently remains an important commodity. Ethiopia, Eritrea, Kenya, Somalia and Sudan are the major producers and exporters of frankincense [8]. In addition to its environmental benefit, the production and marketing of frankincense offer diverse socioeconomic benefit at local, regional and national levels, including job opportunities and remarkable economic benefit for tappers, traders, exporters, and the national economy at large. Its contribution to the national economy is reflected in its status as one of the forestry export commodities.

Lack of accurate data for decision makers to formulate appropriate policies and legislation to support the commodity development is the main obstacle to meeting the sustainable development and conservation objectives for *Boswellia* species and their products [22]. Although several scientific studies have been conducted regarding the socio-economic and ecological importance of *Boswellia* species, none of them has systematically evaluated the socio-economic contributions of aromatic frankincense to national and regional economies [30].

South Kordofan State is the most important area in Sudan, where *Boswellia papyrifera* trees are abundant and Frankincense tapping is practiced in large scale. These stands witnessed natural and anthropogenic disturbances such as fire hazards, uncontrolled grazing, agriculture encroachment, intensive tapping, etc. This situation has been more aggravated by improper tapping practices. For these reasons, *Boswellia papyrifera* stands experienced rapid changes in structure and composition. This study aimed to provide information about the Frankincense production, propagation, tapping, tapping intensity and processing and to disseminate this information to the frankincense producers, stakeholders such as companies, forest administrations and producers' association.

2. Botanical Description and Distribution

Boswellia is one of the 17 genera described in the family *Burseraceae* in the order *Spinales* [36]. The genus is composed of 20 species. *Boswellia papyrifera* (gum olibanum) is a common savanna trees on rocks or hill slopes in high rainfall savanna. *Boswellia papyrifera* (del.) Hochst, known in Sudan as “Gafal”, “rutrut” and “Taragtarag”, is a small deciduous tree belonging to the family *Burseraceae*; under favorable conditions it reaches up to 10m in height. The bark is pale yellow-brown, papery, peeling off in wide strips. The slash is reddish, exuding fragrant frankincense. Leaves are 30cm long, with 10-13, sessile, opposite or sub opposite leaflets. The inflorescences are panicles clustered at ends of thick branches, with white- creamy flowers tinged with pink, appearing before the leaves, sweet-scented, on red peduncles. The fruits are winged capsules - avocado brown-pink, pear shaped 2.5cm long. The tree usually shed its leaves immediately after the rainy season (September-October) with new leaves appearing in May-June.

Furthermore, the occurrence of *Boswellia* species extends from Ivory Coast to the Horn of Africa and south wards to northern Madagascar. It is also found in the Middle East as well as India [17]. The species was found in the Sudan, Ethiopia, Eritrea, Uganda, Kenya and the Central Africa republic [5].

The species covers large areas in Sudan, south altitude 14° N. In the Blue Nile State it occurs in Jebel El Garri, Ingasana hills and along the Sudan borders with Ethiopia. Many natural forests well stocked with *B. papyrifera*, some of them are reserved and many are proposed for reservation.

In southern Kordofan (Nuba Mountains) it grows gregariously on mountain slopes on shallow soils over rocks [10, 29]. In Western Darfur State it grows in *Jebel Marra*, *Zalingi*, *Elgeneina* and along the border with the Republic of Chad [20]. In southern Darfur State it grows along the border with the Republic of Central Africa.

3. Natural Regeneration

The species face problems of natural regeneration. Lack or absence of natural regeneration of *Boswellia papyrifera* was reported by [21]. In the Blue Nile province Followed by [4] when he found only 9 seedlings per hectare, while [20] reported zero regeneration. Both surveys were conducted in dry season when *Boswellia* has already shed its leaves. This obviously means that the species is decreasing due to absence or difficulties of natural regeneration. In contrast [4] in Jebel Marra found that the number of seedlings per unit area is quite promising. The survival rate of seedlings is (27.6-31.8%) compared to survival rates of 19-27% in Eritrea. They stated that the time of the year at which regeneration surveys of *Boswellia papyrifera* were made is very important. This is because *B. papyrifera* loses its leaves towards the end of the rainy season and can't be differentiated from any straw. This situation coupled with the recent tree use for furniture and fodder, jeopardizes the future presence of this tree. In the dry season seedling mortality due to the damage by wildfires, overgrazing and other anthropogenic activities seriously limits the potential recovery of natural *Boswellia* in the drylands [4]. Additional management interventions such as protection of the species, artificial regeneration to support early seedlings survival or planting of large size cuttings in the proper time will positively affect the restoration of the species in the natural habitat. [4] studied the Natural Regeneration of *B. papyrifera* and other tree species in Jebel Marra Darfur; Sudan. They concluded that the "germination percentage obtained is low, but the number of seedlings per unit area is high. The real problem therefore, is seedlings establishment and their development to saplings and mature trees. The phenomenon of difficult seedling establishment and development though recent, but the overall result will be a total disappearance of the species in the near future if man and his grazing animals continued to disturb the stand in the present manner".

The abundance of *Boswellia papyrifera* tree in South

Kordofan is affected by altitude and land use intensity, most of the trees being found in hilly areas; tree density increased from the foot slope to the hill summit. The natural regeneration is seldom. [3] in his investigation in Population structure, density and natural regeneration of *Boswellia Papyrifera* in Dry woodlands of Nuba Mountains, South Kordofan State, reported that "No seedlings and saplings of the species were encountered in all the sample plots". Furthermore, he reported that "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,. 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. 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 [20]. Higher densities of *B. papyrifera* trees were also reported in different sites in Eritrea (80-270 trees ha^{-1}) and Ethiopia (64-225 trees ha^{-1}) [26].

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 [20, 13].



Figure 1. *Boswellia papyrifera* tree (Ali et al, 2009).

4. Frankincense Production in South Kordofan State

Production of frankincense involves tapping *Boswellia* trees, collecting dried Frankincense from the tree, and drying and packing. The Frankincense productions by localities for the period 2017 to 2025 in South Kordofan State are shown in Figure 3. The production was varied from season to season and from locality to locality within the same State. The highest Frankincense production of 432.85 tonne/year which was recorded for Rashad locality (Figure 2) during 2021 growing season followed by 343.32 tonne/year which was recorded for Talodi locality in 2017 season, while the lowest Frankincense

production of 12.3 tonne/year and 13.48 tonne/year was recorded for Dalanj and Abu Gibeih Localities, respectively. Furthermore, the production no production was reported for Kadugli, Dalanj and Talodi localities during 2024 and 2025. The lowest production may attribute to the war which affected all production sectors especially the forestry sector. Beside that most of the gum tappers came to the South Kordofan from eastern Sudan which located away from the production domain

which is not accessible during the war period.

The *Boswellia Frankincense* total production during 2017 to 2025 in South Kordofan is shown in Figure 4. The figure shows that the highest total production of 840.49 tonne/year in South Kordofan localities was recorded in 2019 followed by 822.4 tonne/year in 2017, while the lowest frankincense production of 122.28 and 190.56 tonne/year was recorded in 2023 and 2024.

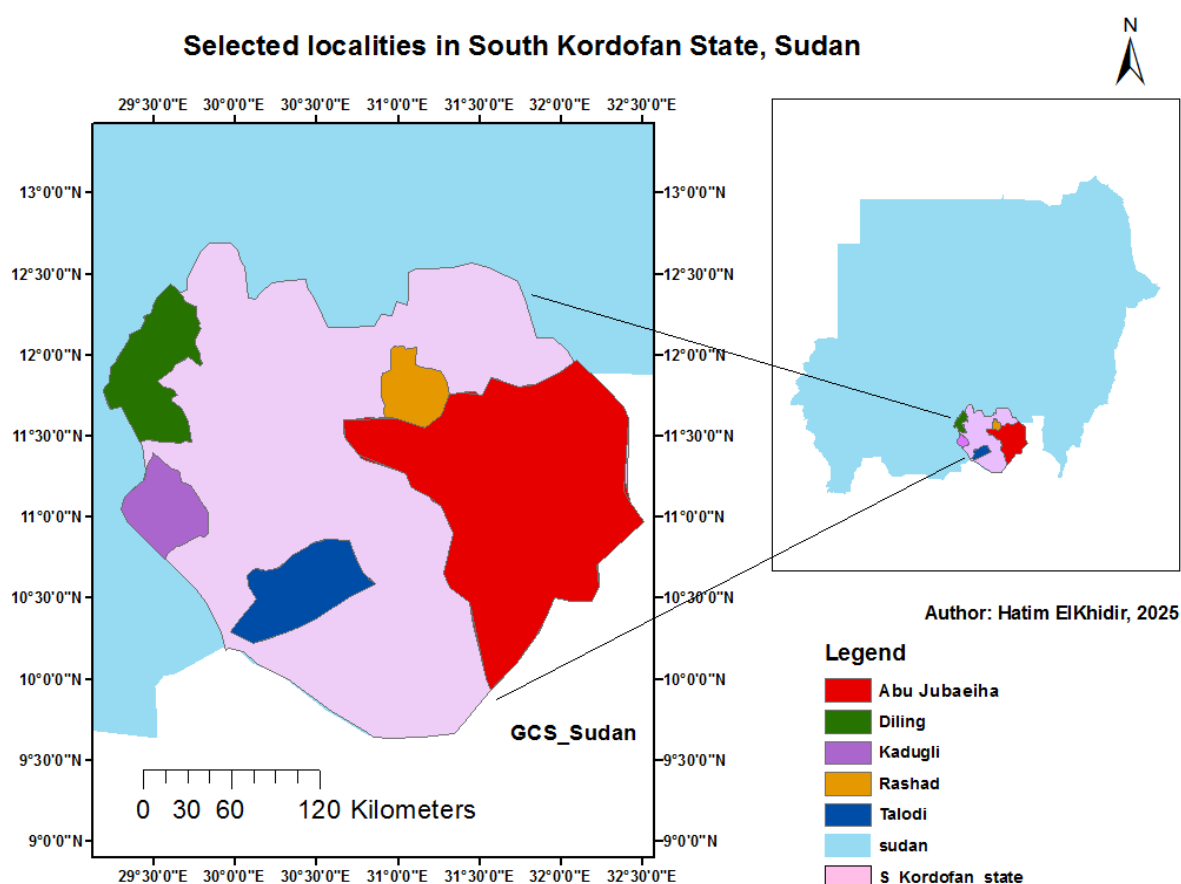


Figure 2. Location of study area.

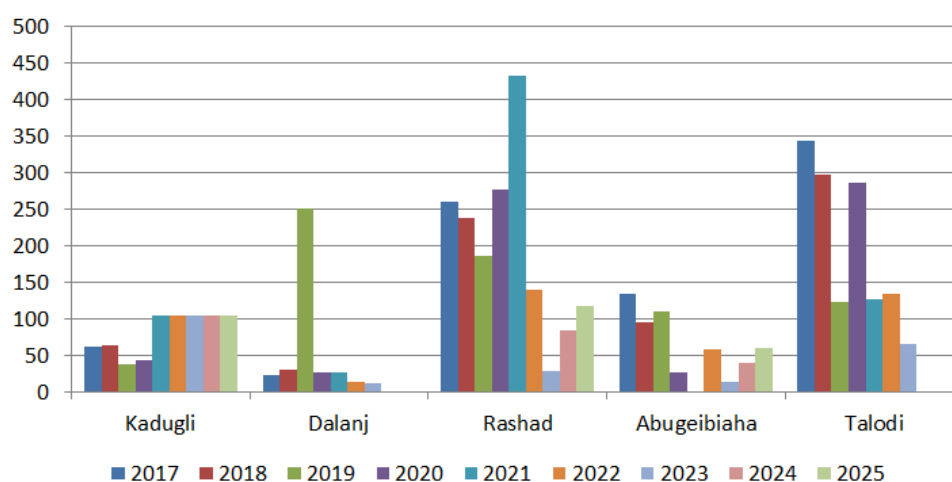


Figure 3. Frankincense Production of *Boswellia papyrifera* (MT/tonne) in South Kordofan State for the Period 2017 - 2025.

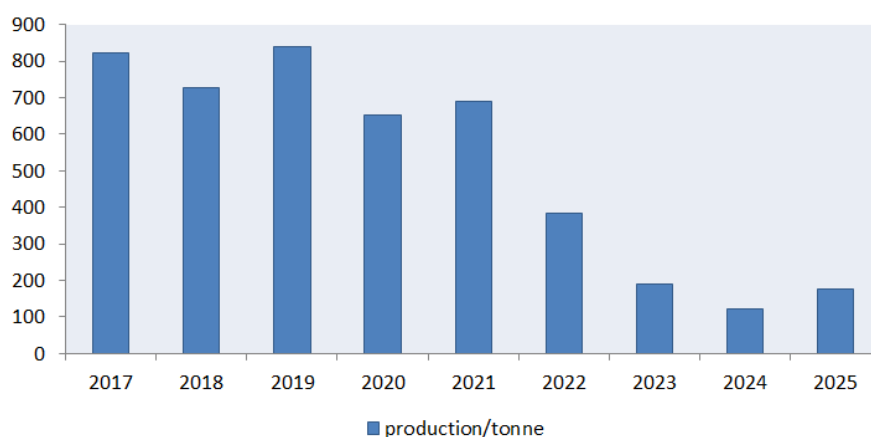


Figure 4. Total Production of *Boswellia papyrifera frankincenses* (ton/year) in South Kordofan State.

5. Marketing and Economical Importance

Internationally, the Frankincense is an important commodity as it is a source of essential oils in among others the cosmetic and pharmaceutical industry [8, 25]. 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 which could likely be associated with the decline in of the tree population and degradation of *Boswellia* stands. The main importers of frankincense from Sudan include countries in Middle East and Europe, the United Arab Emirates, Saudi Arabia, China, France, Germany, and Italy.

According to the Central Bank of Sudan more than 3,700 metric tonne of frankincense was exported from Sudan between 2000/2001 and 2006/2007 with the value of export more than 3.5 million USD from this export in the respective years. However, despite the good resource potential of *Boswellia* stands in the country, its share of the market remains relatively small with regards to its resource potential [31]. The major produced localities in South Kordofan State are Rashad Locality followed by Talodi and Kadgli [2] estimated that the Rashad Locality has an average annual production potential of 8,000 tonne.

Generally, most Sudanese frankincense from *B. papyrifera* is reportedly consumed internally and only a limited amount is exported. Main importers of Sudanese frankincense include UAE, Saudi Arabia, China, France, Germany, and Italy [2]. The frankincense produced in the study area is marketed at rural, urban and central markets and different actors are involved. The product enters the rural market where it is collected by village traders and other middlemen. Then, the village traders and the middlemen transport the product to urban market and central market. The main players at rural markets are local traders and producers. The producers traditionally display their products and negotiate prices with local traders. Selling takes place upon the agreement between

producers and local traders where price is declared by the traders after receiving signals from central and urban markets. Rural markets in the locality are operational on a weekly basis and therefore local traders can attend different markets within a week. Taxes and local duties for frankincense trading are collected at the rural markets when the product is trucked from the market. The product is trucked from rural to urban markets where it is delivered to urban merchants; frankincense is traded at major urban markets such as *Um Rawaba* and *El Rahad* [3].

The frankincense price in 2025 was fluctuated started from 300000 SDG in the beginning of the season to 500000 SDG by the end of the season.

Despite its cultural and economic value, the frankincense trade in Sudan faces significant challenges, including issues of transparency and fairness in the supply chain. Local harvesters often receive a disproportionately small share of the economic benefits derived from frankincense, with middlemen and traders capturing most of the value [11]. This inequity is compounded by external market pressures and instability in harvesting areas, raising concerns about the long-term viability of both the tree populations and the communities reliant on them for sustenance.

Table 1 shows the taxes and duties in the study area. Most of the taxes are collected at the rural market and at the urban market at *Um Rawaba* and *El Rahad*. There are three ways of paying taxes and fees. The first one is paid by village trader or middlemen when tax and fees staffs were present at the level of village market. The second one is paid by frankincense commodity traders. The third one is paid on auction market when the product is shipped to auction market without paying taxes and fees. The highest proportion of the taxes were collected by the state ministry of finance 24000 SDG/quintal for the *Negawa* and 13000 SDG/quintal for *Gishra*, while the lowest taxes were collected by the State Ministry of Agriculture 3000 SDG/quintal. In general the taxes are estimated at 84000 SDG/quintal (Table 1).

Table 2 shows the average production cost and revenue.

The average producer production is ranged between 60-85 quintal/ year. The analysis of the revenue showed that the operation cost (tapping, collection, transportation and storage) is very high estimated about 36.000 SDG/quintal, followed by taxies which about 48.000 SDG. The total production cost for 1 quintal is about 120.000 SDG about 4.8 USD\$. The frankincense price at village market is about 350000 SDG/quintal.

The producers revenue at village level is about 23000 SDG/quintal about 9.2 USD\$ represent 22%, the revenue from domestic market is about 40.000 about 38%, while the revenue from the auction market after processing is about 290.000 SDG/quintal equivalent to 116 USD\$/quintal about 28% [Figure 5](#).

Table 1. Taxes on frankincense production at rural markets.

Fees	Amount (SDG/ quintal)	Beneficiaries
FNC fee	4500	FNC
Locality fee	8000	Locality
Ministry of Finance fee for Ngawa	24000	State government
Ministry of Finance fee for Gishra	13000	State government
Tax	1500	Central government
Ministry of Agriculture fee	3000	State government
Zekat	30000	Central government
Total	84000	

1 USD = 2500 SDG

Source: Authors' analysis based on interview data from producers and FNC

Table 2. Production cost and revenue.

Average producers production 60-85	
Items	Cost (SDG)
Operation cost/quintal	
Tapping	12000
Collection	7000
Transportation	7000
Storage	10000
Taxies	84000
Total production cost/quintal	120000
Price at village market	350000
Revenue at local market (price- production cost)	230000
Frankincense price at domestic market	400000
Transport	10000
Revenue (price at village market+ transport- price at domestic market)	40000
Price at auction market (After gum processing+ transport)	700000
Revenue	290000

Source: Authors' analysis based on interview data from producers and FNC

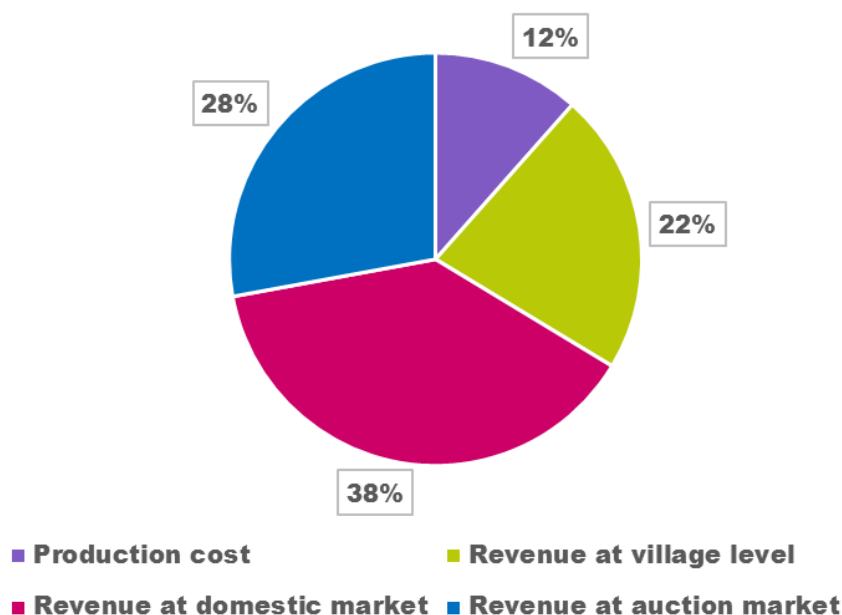


Figure 5. Percentage of Production Cost and Revenue SDG/quintal for frankincense production in South Kordofan.

6. Uses of Frankincense Gum

The use of frankincense gum as a fumigation agent for religious ceremonies, medicine and ritual uses dates back to 2000 B.C. Generally its uses can be summarized as incense, fixatives in perfumes, tooth pastes, plasters and other pharmaceutical products, and flavours and fragrances in food [20]. Nowadays *Boswellia* Frankincense is considered an important commodity in the international market [19, 8, 25]. The frankincense exported from, Sudan in 1993/94 totaled 288 metric tons - equivalent to 0.549 million US\$ [16, 17].

The leaves, bark, root and the frankincense are also used as traditional medicines for curing various diseases [35, 13]. The species is recommended for economic development and desertification control [33]. The major use of the species is the

production of frankincense or “olibanum” by tapping the stem [9] and in the Horn of Africa it has an important application in local communities for medicinal uses and during religious and coffee ceremonies [15].

European consumers are more aware of the importance of a healthy lifestyle, and their understanding of what it means to be healthy is changing. Instead of focusing only on the absence of illness, consumers use health products to prevent diseases and feel good. This trend is driving demand for: Natural health care products and ingredients: There is an increasingly strong view that natural ingredients are safer than synthetic alternatives.

Furthermore, in Europe there are opportunities to use frankincense oil in aromatherapy. In aromatherapy, frankincense oil is mainly used to relieve stress and anxiety and in joint health issues Table 3.

Table 3. Aromatherapy uses of frankincense.

Botanical name	Indication area	Effects /Applications
<i>Boswellia</i> Spp	Joint health	Relieve pain associated with rheumatism and muscular aches
<i>Boswellia sacra</i>	Stress & Anxiety	Mood uplifting and freshening Calming, helps to relieve anxiety

7. Tapping Tools and Tapping Intensity

Frankincense in South Kordofan is produced by tapping *B. papyrifera* trees by using traditional tapping tool namely

Mengaf. Tapping usually started after the rainy season for mid of October to mid of November. Tapping [20] is started by removing external layer of the bark and forming a circular wound of about 1-2cm high, 1-1.5cm wide and 0.5-1.0cm deep (Figure 7). Usually 3 tapping spots are made on each side of the tree, starting at about 0.5 m from the base of the

stem. More than 3 tapping spots can be made depending on the size of the tree. Tapping is repeated every 15-20 days after the first tapping [7]. During the subsequent tapping cycles, older wounds are refreshed and the blaze is moderately widened by removing more bark from the upper edges of the former wound and by carving down 2cm of the lower edge. Tapping continues until the onset of the rainy season. Thus, a tree is tapped 8-12 times a year, and at the end of the production year each wound may attain a width of about 10cm or more. Increasing the number of tapping spots in a tree increases the overall annual yield of frankincense per tree, but it affects the tree's vitality and interferes with its reproductive biology. If a tree has too many wounds, it can produce tears of Frankincense that are too fine or dusty, and thus less attractive to buyers [23]. Indeed, an optimum tapping intensity needs to be applied to ensure a compromise between Frankincense size, total frankincense yield and impact on the tree. The recommended tapping intensity per tree is a total of 6 spots for trees of < 20cm diameter at breast height (DBH), a total of 12 spots (3 spots on each of the 4 sides) for trees of medium DBH (20-30cm) and a total of 16 spots (4 spots on each of the 4 sides) for trees > 30cm DBH.

In Some areas, tapping of the tree started 2-3 weeks before the rainy season [7, 14]. The tapping of the trees is repeated four times and is usually done at between 15 and 30 days intervals. Upon incision, the bark of *B. papyrifera* exudes a white milky liquid, which later hardens on exposure to air into globular or club shaped droplets or tears (Figure 8) called frankincense [20].



Figure 6. Mengaf the traditional tool for tapping *Boswellia* tree. (Photo authorized by Ali et al, 2009).

In Sudan, Since 1970s till now, tapping of *Boswellia papyrifera* trees is continuously in a traditional manner practiced by the Bani Amir tribes of the border region with Eritrea and Ethiopia. Some interested local inhabitants are also involved in tapping which is recently more intensified since the number of tapping wounds and their dimensions have been increased leading to severe damage of many *Boswellia papyrifera* trees and reduction in the production of viable seeds [23]. In, South Kordofan, tapping usually starts in October with a cut removing a strip of bark 2cm in width and 3cm in length -using

a special tool named "Mengaf". The Mengaf has a steel, sharp blade 2cm in width and 4cm in length, tapering back and inserted into a wooden handle (Figure 6). The number of tapping points or wounds depends on the size of the tree, usually ranging between nine points for the large trees, six for medium and three for the smaller trees [25]. After the first tapping the wound turns red and can be seen from a distance as a blood colored spot against the background of the yellow paper bark. The tapping of the trees is repeated four times and is usually done at between 15 and 30 day intervals. During tapping, the cut surface gradually moves upward, and each year a fresh cut is started at a different site immediately above the old wounds [37, 27, 7].



Figure 7. Tapping of *Boswellia* Tree by using Mengaf tool (Photo authorized by Ali et al, 2009).



Figure 8. Frankincense exudation (photo authorized by Ali et al, 2009).

Tapping was reported to negatively affecting both reproduction and natural regeneration potential as well as shorten the life-span of the tree *Boswellia papyrifera* is now considered an endangered species [1]. The tree species is reported as under threat due to mortality from wound and inappropriate frankincense harvesting techniques.

8. Structure of Frankincense Value Chain

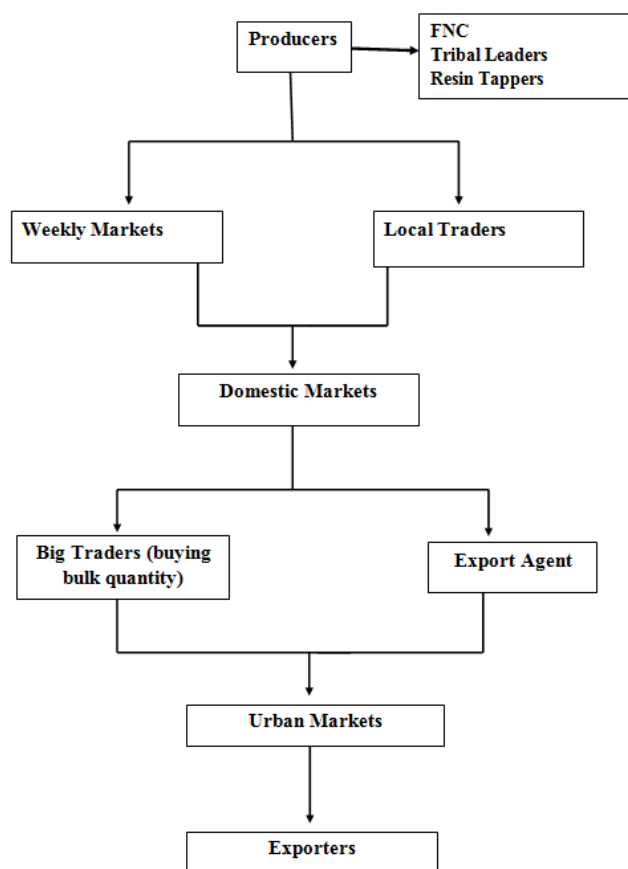


Figure 9. Major actors in frankincense's value chain in South Kordofan State.

Boswellia woodlands at South Kordofan State are under the technical supervision of the FNC, which has legal control over the resource. The harvesting season of frankincense as in South Kordofan commences by producers' gaining legal access to *B. papyrifera* forest land through production permits provided by the FNC for a fee, usually during September to mark the start of harvesting season that ends up by June of the following year.

After getting the licenses (usually tribal leaders or exporter agents) from the FNC they harried the Frankincense tappers. Most of the tappers in the study area are seasonal migratory workers belonging to Bani-Amir tribe originating from Eastern Sudan who have a good experience and knowledge in frankincense tapping and collection and in some time the use or hire local tappers from the local communities around the forest. The tappers were divided to different groups from 3-10 person in each group locally named as Taya (approximately less or more than 50 ha). The producers provide the tappers during the taping and collection period by foods, tea, water, shelter and all the necessary materials for their living. The producers are outsiders belonging to Bani-Amir tribes from Eastern part of Sudan.

In the current study eight major groups of actors in the commodity chain broadly grouped on the basis of their functions and position in the chain. These includes: the government agencies (FNC, Zekat, Ministries, and Taxes), tribal leaders; tappers; producers or licensees; traders (village traders, middlemen, agents of urban merchants, urban merchants); processors; exporters; and wholesalers and retailers. Figure 9 shows the major player in frankincense production and marketing in the study area. Table 4 shows the role of actors in frankincense value chain.

Table 4. The role of actors in frankincense value chain.

Actors	Activities
Government bodies	The FNC which responsible for the management of <i>Boswellia</i> stands and getting the permit and licenses to Frankincense producers, the local government such as ministry of Agriculture and Ministry of Finance who collects different forms of taxes and fees from frankincense producers such tax, Zekat and others.
Tribal leader	Determination of <i>Boswellia</i> woodlands for producers and controlling the resources conflicts.
Producers	License holders for frankincense production and they have good relation with tribal leader. They are hired labor form Eastern Sudan and from the local communities
Tappers	their role include tapping, collection, cleaning and packing the produced Frankincense
Village traders	buy frankincense from the village market weekly, weighing, sorting, packing, collecting produced Frankincenses for agents
Domestic market	collection from village traders, cleaning, transport and baying the fee and taxes
Urban market	Urban merchants own warehouses in urban centers such as El Rahad, Um Rawaba and Khartoum. They buy frankincense in bulk quantity and perform primary processing that is mainly limited to cleaning and grading
Exporters	Exporters are foreign traders and agro-business companies which are smaller in number and are concentrated in the capital city and Port Sudan

9. Frankincense Collection, Processing, Quality Control and Threats

Collection of frankincense starts after 30-35 days and extends up to the end of June. The production from the first picking is low. The second picking is usually made after one month from the first picking. At this stage also the Frankincense is produced in small quantities and is a black-brown colour. The frankincense collected from the first and second picking is usually sold for local consumption in the village markets. After a further 25-35 days from the last picking white gum is collected in commercial quantities [32]. The white color is an indication of good quality Frankincense. Starting from this stage the number and duration of Frankincense collection depends mainly on the weather conditions. Collection is done every two or three weeks - the shorter period in hot weather [20]. Generally, there are 4-9 pickings per season. Pickings of the Frankincense may stop before June if there are early rains. Tapping for a new season starts immediately above the old wounds. The hardened Frankincense is removed at each tapping round, and the tapping wound is re-opened and enlarged [24]. Renewal of the wound at the correct interval of days is critical; otherwise, the old wounds may heal completely [25].

Generally, the producers classify the trees into three categories according to the hardness of the bark (soft, medium and hard bark). The productivity of the soft bark trees is higher compared to the other categories [32]. The total production of each tree per season is estimated to be about 2.8kg/ tree/ years in Jebel Mara in comparison to 2.2kg/ tree/ years in Kordofan State [20].

Using locally made collection vessels, tappers manually pick the frankincense of solidified frankincense from individual trees. These frankincense are dried by spreading them out on mats under temporary shades constructed in the field. Drying is an essential process for avoiding clumping of the gum. The dried frankincense are then packed in sacks and transported to permanent warehouses for further processing [24]. Further processing at warehouses involves cleaning any foreign materials (such as grass, leaves or small stones) off the frankincense (Figures 10 & 11). During this process of manual sorting and grading, the frankincense is sorted into 8 grades based on colour and size, cleaning, sorting and grading play an important role in improving product quality. Sieves of different diameter sizes are used to separate the various sizes of granules. Grading is based on color, granule size and purity. Larger and white lumps are valued more than the smaller powdered and darker ones.

Table 5. Grades of frankincense from *B. papyrifera* in Sudan.

Frankincense grades	Proportion (%)	Description	Exported countries
Grade 1 (super)	15	Big size and white color	Egypt and Dubai
Grade 2	12	Medium size and white color	Turkish and Syria
Grade 3 locally known as <i>Sukskania</i>	18	Small grain size and white in color	Turkish and Syria
Grade 4 Nagawa and Ozala	30	Brown to black color and big grain size stick together	Egypt
Grade 5 <i>Gishra</i> and <i>scartu</i>	17	The bark and some remnant Frankincense not separated from the bark	Local uses
Grade 8 Turabiyaa	8	By-product—the dust remained after separating the other grades	Local uses

In Sudan, five grades of frankincense are recognized. The first three grades which are delivered to export market consist of white granules of different size (Table 5). The fourth grade (Lagawa and Ozala) consists of granules of brown or black color of any size. The fifth grade (*Gishra* and *Scartu*) comprises remnants of Frankincense attached to the bark. The by-product that remains after processing, “Turab”, is sold locally and used as a cementing agent for the construction of mud houses. Similar criteria are used for grading frankincense

in Ethiopia (Table 6), which also uses the five grade system. However, current traditional post-harvest handling practices have several shortcomings that negatively affect product quality. Major problems include: improper storage; seasoning in unclean conditions; use of inappropriate or contaminated containers; and poor hygienic conditions during sorting and cleaning [24]. White frankincense is graded as the best quality and darker one low quality.

Table 6. Grades of frankincense from *B. papyrifera* in Ethiopia.

Grade	Description	Expected proportion from 1 quintal of unprocessed frankincense (%)
1 A	Size ≥ 6 mm; white	22
1 B	Size ≥ 6 mm; creamy white	9
2	Size 4-6 mm	11
3	Size 2-4 mm	8
4 Special	Any size; brown	19
4 Normal	Any size; black	17
5	Powder and bark; no size limit	14

The following practices can be used to delivery of high-quality frankincense requires the following practices.

- (1) The Frankincense tappers should use the appropriate tools in tapping and collection.
- (2) The tappers should avoid the frankincense collection in the dusty weather or during the cold weather.
- (3) The collected frankincense should be cleaned from the foreign materials such as tree barks, woods and grasses.
- (4) Storage the collected Frankincense in clean room with moderate temperature.
- (5) Collectors and cleaners should be clean to avoid contamination.
- (6) Avoid mixing the collected Frankincense with other crops to avoid contamination with Aflatoxin.

This is considering as the most important recommendation for frankincense quality control. This calls for improvement in storage, handling and transportation conditions [26].

**Figure 10.** Frankincense processing (photo authorized by Kamal).

South Kordofan has been affected by civil war for more than three decades and this has a direct effect on vegetation cover in the study area, furthermore, the expansion in the mechanized farming and traditional cultivation, traditional gold mining, drought and desertification especially the

northern part of the state all this factors has sever effect on the vegetation cover and the abundance of *Boswellia* tree. Climate changes especially the fluctuation and uneven distribution of rainfall have sever effect on Frankincense production and the natural regeneration of the species.

**Figure 11.** Women participation in Frankincense processing.

10. Conclusion and Recommendation

The study concluded that frankincense production still attractive for both producers and traders and the frankincense export contribute significantly on the national economy of the country. The natural regeneration of the tree is affected by many factors such as animal grazing, illicit cutting, fire out break and over cultivation. Gum processing and store were done in a very traditional way which affects the frankincense quality. More research is needed in frankincense tapping and processing.

Recommendation

- 1) Providing financial support to frankincense producers especially during the tapping and collection periods.
- 2) Offering credit facilities to local community to get production permit to produce and sell their products themselves.
- 3) Training and capacity building for local communities in

gum tapping, collection and processing.

- 4) Extension campaign for conserving and utilization of the resource base in sustainable manner.
- 5) More research in frankincense tapping, collection, processing, marketing and value chain is needed.

Abbreviations

GRD	Gum Arabic Research Division
SDG	Sudanese Geneih
CBOS	Central Bank of Sudan
FNC	Forest National Corporation
ARC	Agricultural Research Corporation

Acknowledgments

Great appreciation and deep thanks are expressed to Ibrahim Ahmed Mohammed Elnasri from Abu Gebiha FNC office for his valuable support during the data collection.

Author Contributions

Kamal Eldin Mohammed Fadul: Conceptualization, Supervision, and Writing original draft

Abbas Hassan Ali: Conceptualization, Supervision and data management

Idris Musa Adam: Data curation, Analysis and tabulation

Muneer Elyas Siddig Eltahir: Conceptualization - review & editing

Hatim Abdalla Elkhidir: formation of conclusions

Sona Mohammed Fadual: Data curation and reviewing

Massaud Mohamed Massaud: Data curation

Ethics

This article is original and contains unpublished data. The corresponding author confirms that all authors have read and approved the manuscript and the ethical issues are involved.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Abiyu, A., Bongers, F., Eshete, A., Gebrehiwot, K., Kindu, M., Lemenih, M., Moges, Y., Ogbazghi, W., Sterck, F. J., 2010. Incense woodlands in Ethiopia and Eritrea: regeneration problems and restoration possibilities. In: Bongers, F., Ten-nigkeet, T. (Eds.), 144-163. Degraded Forests in Eastern Africa Earth Scan, London.
- [2] Abteu, A., Pretzsch, J., Mohmoud, T. & Adam, Y., 2012. Commodity chain of Frankincense from the dry woodlands of Nuba Mountains, South Kordofan State, Sudan. Small-scale Forestry, 11(3), pp. 365-388.
- [3] Abteu, A., Pretzsch, J., Mohmoud, T. & Adam, Y. O., (2011). Population structure, density and natural regeneration of *Boswellia Papyrifera* (Del.) Hochst in Dry woodlands of Nuba Mountains, South Kordofan State, Sudan, Tropentag, 2011, University of Bonn, 5-7, 2011.
- [4] Abuelgasim A. Adam, and Abdalla M. El Tayeb (2008). A Comparative Study of Natural Regeneration of *B. papyrifera* and Other Tree Species in Jebel Marra Darfur; Sudan. Research Journal of Agriculture and Biological Sciences, 4(1): 94-102, 2008.
- [5] Adam, A. A., Abdalla M. El Tayeb, 2004. State of *Boswellia papyrifera* (Del) Hochst, (Olibanum gum tree) Stands in Jebel Marra, Darfur Sudan. Sudan Silva, 10(1): 57-71.
- [6] Adilo, M.; Woldemariam, T.; Yadessa, A. Counting on forests: Non-timber forest products and their role in the households and national economy in Ethiopia. In Proceedings of the 8th Annual Conference of Agricultural Economics Society of Ethiopia, Addis Ababa, Ethiopia, 24-26 February 2005.
- [7] Ali AH, Fadl KEM, Adam IM. 2009. Effect of position of tapping, tree stem diameter and tapping tools on frankincense yield of *Boswellia papyrifera* in South Kordofan State, Sudan. For Trees Livelihoods 19: 19-26.
<https://doi.org/10.1080/14728028.2009.9752651>
- [8] Chikamai B. N. 2002. Review and synthesis on the state of knowledge of *Boswellia* species and commercialization of Frankincense in the dry lands of Africa, FAO/ EU/ FORNESS AFREA, Forest research net work for sub-sahara Africa, Nairobi, Kenya.
- [9] Coppen J. J. W. 1995a. Gums, Frankincense and latexes of plant origin, FAO Non-Wood Forest Products, number 6, Italy.
- [10] EL Amin, H. M. 1990. Trees and shrubs of the Sudan. Ithaca Press Exeter, Guildford, UK.
- [11] El Tahir BA, Gebauer J (2004) Non-timber forest products: opportunities and constraints for poverty reduction in the Nuba Mountains, South Kordofan, Sudan. October 5-7, 2004. Conference on International Agricultural Research for Development. Deutscher Tropentag, Berlin.
<http://www.tropentag.de/2004/abstracts/full/93.pdf> Accessed March 2011.
- [12] El Toum, M, A. (2025). Performance of Frankincense tree in Sudan. www.Researchgate.net
- [13] Eshete A, Teketay D, Hulten H (2005) The socio-economic importance and status of populations of *Boswellia papyrifera* (Del.) Hochst. in Northern Ethiopia: the case of North Gonder Zone. Forests, Trees and Livelihoods 15, 55-74.
- [14] Fadl K. E. M. and Gebauer J. 2004. Effect of different tolls and different tapping positions on (talh gum) yield of *Acacia seyal* var *seyal* in South Kordofan, Sudan. A full paper online publication of the conference on International Agricultural Research Development 1-6, <http://www.Tropentag.de>

- [15] Fadl, K. E. M. and Gebauer, J. 2006. Effect of Time and Intensity of Tapping on the Gum Yield of *Acacia seyal* var *seyal* in South Kordofan, Sudan. *Journal of Forests, trees and livelihoods*, 2006, Vol, 16, pp, 219-225. 2006 AB Academic publishers- printed in great Britain.
- [16] FAO and FNC (1996). National forest Inventory, Darfour region, Khartoum, Sudan.
- [17] FAO, 2002. Review and Synthesis on the state of knowledge of *Boswellia* species and commercialization of Frankincense in the dry lands of Eastern Africa. Rome, Italy.
- [18] FAO. Guidelines on Sustainable Forest Management in Drylands of Sub-Saharan Africa. In *Arid Zone Forests and Forestry*; Working Paper 1; FAO: Rome, Italy, 2010.
- [19] Hassan, B.; Glover, E. K.; Luukkanen, O.; Chikamai, B.; Jamnadass, R.; Iiyama, M.; Kanninen, M. The Role of *Boswellia* and *Commiphora* species in Rural Livelihood Security and Climate change adaptation in the Horn of Africa: Case study of northeastern Kenya. *Int. J. Soc. For.* 2011, 4, 86-112.
- [20] Khamis MA (2001) Management of *Boswellia papyrifera* stands for Frankincense production in Jebel Marra Area, Western Sudan. present situation and future prospects. Msc Thesis. Technische Universität Dresden. Germany.
- [21] Khan, M. A. W., 1972. Propagation of *Boswellia papyrifera* through branch cuttings. *Indian-forester*. 98(7): 437-440.
- [22] Leakey, R. R.; Tchoundjeu, Z.; Schreckenberger, K.; Shackleton, S. E.; Shackleton, C. M. Agroforestry tree products (AFTPs): Targeting poverty reduction and enhanced livelihoods. *Int. J. Agric. Sustain.* 2005, 3, 1-23.
- [23] Lemenih M, Kassa H. 2009. Management Guide for Sustainable Production of Frankincense. CIFOR, Forests and Livelihoods Program, Dry Forest Project, Addis Ababa, Ethiopia. <https://doi.org/10.17528/cifor/003477>
- [24] Lemenih M, Kassa H. 2011. Tapping and post-harvest handling. In: Lemenih, Kassa (eds). Management Guide for Sustainable Production of Frankincense. Center for International Forestry Research. Bogor, Indonesia.
- [25] Lemenih M, Teketay D (2003) Frankincense and myrrh resources of Ethiopia. II. Medicinal and industrial uses. *SINET Ethiopian Journal of Science*. Faculty of Science, Addis Ababa University, 2003.
- [26] Ogbazghi W, Bongers F, Rijkere T, Wessel M (2006) Population structure and morphology of the frankincense tree *Boswellia papyrifera* along an altitude gradient in Eritrea. *Journal of the Drylands* 1(1): 85-94.
- [27] Rushash H. A. (1992). Processes of *Boswellia* (Tarag tarag) Frankincense production, Kordofan State, Sudan. (Arabic). Unpublished.
- [28] Ruz, R. V.; Harasawa, H.; Lal, M.; Wu, S.; Anokhin, Y.; Punsalma, B.; Honda, Y.; Jafari, M.; Li, C.; Ninh, N. H. Climate Change 2007: Impacts, Adaptation and Vulnerability. In Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change; Parry, M., Canziani, O., Palutikof, J., van der Linden, P., Hanson, C., Eds.; Cambridge University Press: Cambridge, UK, 2007; pp. 433-467.
- [29] Saad, Z. A., 1979. Forest resources of South Kordofan province. Proceedings of the symposium on use of home grown wood in building 6-8 February 1979. Published by Building and Road Research Institute, Univ. of Khartoum.
- [30] Salah, Y. M. S. The Role of Indigenous Gums and Frankincenses in Pastoralists' Livelihood Security and Climate Change Adaptation in Garba Tula Area of Northern Kenya; Early Career Fellowship Programme: Brighton, UK, 2014.
- [31] Salih AA, Yousif El, Khamis MA (2002) Country report for Sudan. In: Review and synthesis on the state of knowledge of *Boswellia* spp. and commercialization of Frankincense in the dry lands of Eastern Africa. KEFRI, Nairobi.
- [32] Sanjak E. S. (2005). Strengthening the production and quality control of Frankincense in Southern Kordofan State, Sudan. Faculty of Forestry, University of Khartoum.
- [33] Stiles D (1988) Arid and plants for economic development and desertification control. *Desertification Control Bulletin* 17: 18-21.
- [34] Teshome, B.; Kassa, H.; Padoch, C.; Mohammed, Z. Contribution of Dry Forest Products to Household Income and Determinants of Forest Income Levels in the Northwestern and Southern Lowlands of Ethiopia. *Nat. Resour.* 2015, 6, 331-338.
- [35] Tucker A (1986) Frankincense and myrrh. *Econ Bot* 40(4): 425-433. <https://doi.org/10.1007/BF02859654>
- [36] Vollsen, K., 1989. Burseraceae. In: Hedberg, I., and Edwards, S., (editors): *Flora of Ethiopia*, Volume 3. Addis Ababa University, Asmara University and the Department of Systematic Botany, Uppsala University, Sweden., pp: 442-447.
- [37] Woldie TM. 2011. Physiological Ecology of the Frankincense Tree. (Thesis). Wageningen University, The Netherlands.