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Population structure of *Boswellia elongate* at Homhil, Socotra Island

DIPLOMA THESIS

2015 Bc. Salem Ahmed Saeed Hamdia

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Abstract

The study was conducted in Leeyah (Homhil Protected area), Socotra Archipelago Governorate, Yemen Republic. The study area was situated from Wadi Homhil to the southwest. The trees in the central area were measured in addition to two gardens out planted by the Czech project. A total number of 940 trees and 71 *seedlings* were measured for the following parameters: height of tree, perpendicular crown diameters (W+E, N+S), height of stem, and diameter at breast height (DBH), and for *seedlings* it were height and density. The total area of research reached up 75 ha. The population structure was measured using field survey and satellite imaginary. DBH, total height of tree and height of stem was measured in both living and dead trees. Also the number of seedling in the fenced area and free area were counted and compared. No *seedlings* out of the fence or the free area were found.

The result showed that natural regeneration of *Boswellia elongate* absent in study area and this situation is caused mainly by overgrazing by breaded livestock in the area.

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Abbreviations

Crown W+E – West + East direction of crown diameter measurement

Crown N + S – North + South direction of crown diameter measurement

DBH OR (GBH)− Stem diameter (girth) at breast height

EPA− Environmental Protection Authority

FAO − Food and Agricultural Organization

FIAS – The Foreign Investment Advisory Service

FRA − Forest Resource Assessment

IFAD – International Fund for Agriculture Development

IUCN – International Union for Conservation of Nature

ma.s.l. − Meters above sea level

NTFP − Non−Timber Forest Products

PRA − Participatory Rural Appraisal

SCDP − Socotra Conservation and Development Program

SGBP − Socotra Governance and Biodiversity Project

SWDA – Socotra Women Development Association

UNFF − United Nations Forum on Forests

UNCCD : United Nations Convention to Combat Desertification

UNDP: United Nations Development Programme

1. Introduction

1.1 Background

The Socotra Island is an isolated Island. It lies among three bio−geographic regions of Africa, Oriental and Palaearctic and symbolizes a kind of living laboratory that has kept its unique endemic ecosystems(Olson and Dinerstein 1998). Its xerophytic flora and fauna have been in balance with the environment. This unique Island is situated in the conservation hotspot and center of plant diversity and endemic bird area. Forests of this unique Island have completely Non−Timber products importance. Over 80% of the population of developing countries depends on Non−timber forest products for their livelihood (Sunderlin, et al. 2005)

The major products of Socotra forests are *Boswellia* and *Commiphora* resins, resins from the *Dragon blood* tree, Aloe sap and honey (Pswarayi−Riddihough 2002). These products are used in diverse ways such as for medicinal purposes (the *Aloe* sap is used as purgatives, antibacterial and also to treat malaria), skin / beauty creams and repelling insects. Resins from The *Dragon Blood* tree (*Dracaena cinnabari*) is used for pottery, painting nails and lips. It also has anti−inflammatory, anti−allergenic and anti−hemorrhage attributes hence it is incorporated into drinks for nursing mothers (Huang, et al. 2013).

1.2 Socotra Island

Socotra is a part of archipelago which has four Islands and a couple of islets in the Indian Ocean between 12 06` −12 42` N and 52 03− 54 32` E; Abd al Kuri, the most western Island, lies around 80 km from Cape Guardafui in Somalia, and Socotra around 380 km south of the Arabian Peninsula (Attorre, et al. 2011). The Socotra Archipelago comprises the Islands of Socotra, Abd al Kuri, Samha and Darsa and alternate rocks outcrops of Ka`alFirawn and Saboniya(Fritz and Okal 2008). The archipelago was shaped by tectonic fracturing and subsidence in an adjacent the Gulf of Aden, beginning in the Mesozoic and proceeding into the Paleogene(d'Acremont, et al. 2005). This prompted the partition of the Socotra stage from its most punctual position as a component of Afro−Arabia; close Dhofar in South−western Oman. Amid the long stretch of disengagement, development of the Islands, flora and fauna has continued in bizarre, if regular, isolated bearings (Damme and Banfield 2011). The highest top of Socotra is Mt. Jebel Skand in the central Haggeher mountain range with a height of 1540 m (Habrová 2004). The Socotra Archipelago (Yemen) is all inclusive perceived for its extraordinary biodiversity and endemism, assigned on this premise an UNESCO World Heritage Site in 2008 (Damme and Banfield 2011).

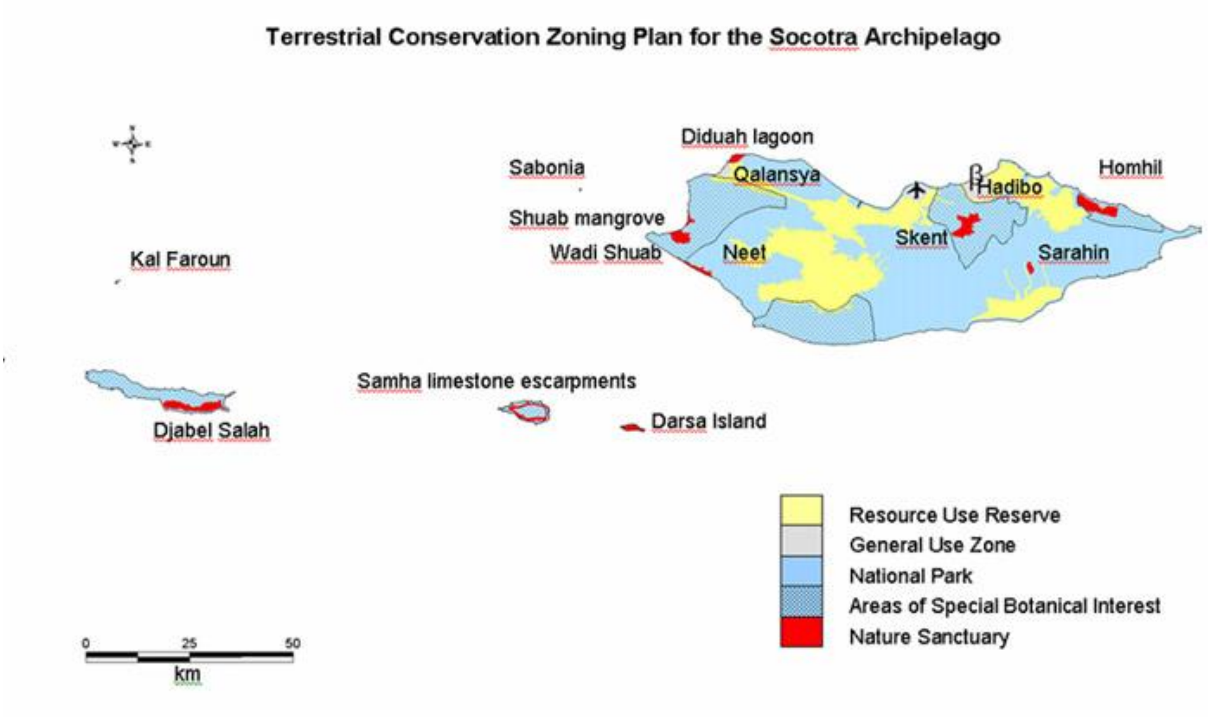


Figure1: Map of Socotra conservation and development zoning plan (SCDP – EPA, 2000)

1.3 Geographical position

Socotra Island lies in the Indian Ocean close to the ancient direct ocean courses from the Red Sea to India and Africa. Voyagers and researchers have since a long time ago considered the Island to have archeological potential. The Socotra Island has additionally been a material for scholars. Moreover there is an abundance of material for pros in the fields of plant science (Brown and Mies 2012). The Socotra archipelago contained four Islands and a couple of islets in Indian Ocean. Altogether Archipelago covers a surface territory of around 380 km, Socotra is the biggest Island the region of around 133 km from the west to the east. Socotra archipelago has a place regionally to Yemen. The nearest indicate on Socotra the terrain is Ras'Fartak in the southern Yemen. The most elevated mountain in Socotra archipelago is

Haggeher mountain (Attorre, et al. 2007)most elevated around 1,500 m a.s.l , and the most elevated point in the second Island Abdal−kuri around 743 m a.s.l.

Socotra can be subdivided into three geomorphological zones: dominatingly alluvial coast and inland fields, limestone levels and Haggeher Mountain(Van Rampelbergh, et al. 2013). In the north the beachfront plain is narrower, hindered by Wadi frameworks ending in harsh pools differentiated from the ocean by spits and pods. The limestone levels, portrayed by Karstic highlights (OCEAN), cover more than 50% of the area and are for the most part somewhere around 300 and 700 m. a.s.l, coming to 800 m at Ma 'alah in the west and 1000 m at Diksam(Scholte and De Geest 2010).

1.4 Natural and Culture conditions of Socotra Island

Socotra archipelago has 308 endemic flowering plant species out of an expected 825, a 37% level of endemism (De Sanctis,− et al. 2013). The archipelago considered as high variety and endemism in plants, the archipelago has been pronounced a WWF Global 200 Ecoregion, a Plant life International Center of Plant Diversity and is incorporated in the Horn of Africa Biodiversity Hotspot (Olson and Dinerstein 2002). These are added to assignments of UNESCO World Natural Heritage and UNESCO Man and Biosphere Reserve.

Socotra's characteristic and social legacy initially moved the interest of European researchers in the 1880, with the landing of surveyors, botanist, zoologists, geologists, archeologists, anthropologists, language specialists etc. One of the first to arrive was British botanist Isaac Baylesy Balfour who reported in 1880 (Choo,− et al. 2014). His plant accumulations from the Island incorporated approximately 565 types of flowering plants, from which 206 Endemic species (Felix, et al. 2012). Balfour had been initially a student at Edinburgh University, got a DSc degree in 1875 (Ayres 2015).

A German gathering comprising of two researchers; the geologist Emil Riebeck and botanist Georg Schweinfurt, cruised along the bank of Arabia, inevitably docking in Socotra on the 9th of April 1881. The political of Resident at Aden, Captain Hunter, gathered a couple of plants from the Island in 1876 and sent them to Edinburgh. In 1882, Isaac Balfour depicted three types of *Bowsellia* in Socotra: *Boswellia ameero*, *Boswellia elongata* and *Bowellia socotrana* (Balfour 1888).

He considered that *Boswellia ameero* was the standard resin creating tree in the Island and depicted the resin of *Bowellia elongata* as being not as fragrant as *Boswellia ameero*, however the resin of *Boswellia socotrana* is utilized as incense in the mosque.

In the year 2000, The Socotra Island Protected Area (362,500 ha) and Socotra Biodiversity Project created The Conservation Zoning Plan for the Socotra archipelago supported by Presidential Decree 275 which secured the National Park and Nature Sanctuaries and The Socotra Archipelago Development master plan (Fig1). The Socotra Conservation & Development Program (SCDP) replaced the Biodiversity Project. In 2003, Socotra Archipelago made an UNESCO MAB Biosphere Reserve, and in 2008 Cabinet Decrees Nos.45 to 49 were passed, accommodating expanded insurance for the Islands, restricting harm from street building, advancing practical ecotourism, diminishing the impacts of touching by uncontrolled domesticated animals, and securing financing for an administration structure.

1.5 Non−timber forest products in Yemen

The fundamental usage of the forests in Yemen is firewood, timber, feed, organic products, cosmetics and medicine. The zone of woodlands and natural forests are little in Yemen. The aggregate forest region has been assessed at 2.4 million hectares, i.e. more or less 5% of the aggregate surface zone. Of this, in the range of 0.4 million hectares are comprised of agro−forestry service and date palm. Forestry service involves a fourth place (US$ 55.7 million) fundamentally on the grounds that forest items are gathered complimentary from regular stands and are considered without value. In this way, the forestry administrations financial and social in Yemen are Non− timber land items. Numerous nearby individuals in Yemen rely upon the woods asset.

Yemen is wealthiest on forests and tree asset that give NTFP, for example, Resins, Honey, Fruits, Tannins, and different fragrant and Medicinal plants. The well known species in the Islands, for example, *Boswellias spp*. *Ziziphus spina cristi*, *Commiphora spp*. Expansion to different renowned types of plants which are merchant and utilized by neighborhood, national and universal markets. The local people are almost harvesting all species in Yemen.

1.6 Non−timber forest products in Socotra archipelago

Socotra's *Boswellia* species has enormous input to the biodiversity of the Island likewise other endemic plants species. *Boswellia* comprises eight species with different growth distributions. The *Boswellia* species of Socotra have two distinct growth forms (Attorre,− et al. 2011). The first group is called cliff−root species. Examples of these growth forms are *Boswellia bullata, dioscorides, nana and popoviana*. The other group is called ground−rooted species. They are *Boswellia ameero, elongata, socotrana* (Attorre,− et al. 2011).

The ground root species of *Boswellia* produces the best gum for *frankincense*. The general name for the ground root species is *emiro*. *Boswellia elongata and socotrana* are the main ground root species for the production of the gum (De Sanctis,− et al. 2013).

1.7 The aim of the work

Boswellia elongate which happens to be one of the main gums producing *Boswellia* species is currently in the red list of the International Union for Conservation of Nature (IUCN) (Hughes and Miller 2002). The loss of this very important *Boswellia* species threatens the biodiversity of the Island as well as the livelihood for the population to a large extent. Knowledge of the population structure of any plant species under the threat of extinction is always a giant step in the efforts to prevent its extinction.

For this reason, this research seeks to measure the population structure of the *Boswellia elongate* at Homhil, which has the largest number of this *Boswellia* species. This study will mainly consider the effects of Nature, Human and livestock to the reducing population of this important *Boswellia* species. The study will be aimed to get information about population structure and regenerations status of *Boswellia elongata*at at Homhil, as a background for conservation management planning.

2. Literature review

2.1 Description of *Burseraceae*

The family *Burseraceae* most likely has its origin in the Eocen period, in North America(De-Nova, Medina et al. 2012). It passed through the tropics and subtropics and these movement lead to about around 18 known genera and 700 species circulated all through Southern America and Europe, later it got to Africa, Asia and Oceania. Until now, it was classified as Order Rutales but was classified into the Order Sapindales, class *Dicotiledoneae* and subclass *Rosidae*. In Neotropics, *Burseraceae* comprises 228 species which has 8 genera and may be put into three tribes: *Bursereae* (*Beiselia Forman*, *Bursera* Jacq. ca.,*Commiphora* Jacq. ca.), *Canarieae* (*Dacryodes* Vahl and *Trattinnickia orhoifolia* Willd.) and *Protieae* (*Crepidospermum* Hook f., *Protium*Burn. f., *Tetragastris*Gaertn.) (Rudiger,− et al. 2007). *Protium* is the most heterogeneous sort in the family. It is the fundamental family in South America and can be divided into 135 known species. Recognizable proof of trees from *Protium species* is not a simple undertaking during the period where it is not flowering. They are mostly often hidden within different types of the *Burseraceae* family. Also, because of the resins from the stem, sapopemas (kind of tabular roots) and created leaves, the identification deception may incorporate some different types of *Anacardiaceae* (Sapindales). Then again, some particular insect−plant interaction may create trademark modifications in leaf of *Protium* species that may be a valuable apparatus to their recognizable proof.

Triterpenic resins have been customarily utilized as the principal constituents of pictorial varnishes and adhesive media hence the examination of these natural items has asserted significant consideration in the culture of the people lately. Among them, *elemi*, from the *Burseraceae* family, has been utilized as constituent of varnishes, where other terpenoid items are incorporated, to change their consistency. These resins have been incorporated in various formulas for the production of varnishes from the nineteenth century (De la Cruz−Cañizares,− et al. 2005). Over the twentieth century elemi sap was added to waxes in relining methods (Dutch Process) for raising the tackiness. In addition, elemi sap is every now and again included in formulas of varnishes for toys, furniture, wagons and carriages, metals and swords, violin and musical instruments, gildings, and so on (Buck 1972).

The *Burseraceae* family comprises more than 600 species of resin yielding plants that are utilized in some degree for art purposes(Siani,− et al. 2004). The genus *Canarium* grows in Australia, South−East Asia and Africa (Yen 1995). A number of resin producing species from this genus have, at different times, been put in the European showcase under the name elemi. Specifically, the item known as Manila elemi from the Philippine Islands, yielded from the species *Canariumluzonicum* or *Canarium* collective has been basically utilized as a part of Fine Arts (West 1920). These materials were brought to Europe, at most recent, by the mid seventeenth century in spite of the fact that references to them are found in records from fifteenth century. Different species of the genera *Amyris*, *Bursera* and *Icica*, are to a great extent dispersed from Central and South America. Their products are known in Mexico under the name "copal" related with "copalli" that was the Aztec name for all resinous materials. These days, Mexican specialists utilize these saps, which are effortlessly accessible in the business sector, as adhesive medium for works of art together with linseed oil, wax and other triterpenic resins, for example, *Manila elemi*, *dammar or mastic*.

Brazilian elemi is a greenish−yellow, fragrant, translucent sap coming from trunks of a few species of *Icica* (e.g. I. *icicariba*) and *Protium* (Stacey,− et al. 2006). Various resins utilized for aesthetic designs are gotten from the genus *Protium.* Therefore, the *Caraná amber* utilized as *frankincense* and as varnish fixing is gotten from *Protium carana* (Humb.) L. Also, a strong light yellow resin acquired from *P. icicaribo*, *P. guianense* and *P. leicaelemifera*, is utilized as plasticizer of varnishes.

African elemi or *oriental elemi*, oozed from *Boswellia frereana*, happens in tears, pieces or vast stalactitic pieces whose crack is shell−like, displaying a transparent golden yellow inside(Mathe,− et al. 2009). The *Burseraceae* family additionally yields a few resins, which contain water−solvent gums in some degree. *Myrrhs* from the genus *Commiphora* (*C. abyasimica, C. Schimperi*) and *Olibanum* (*frankincense*) from the genus *Boswellia* (*B. carteri, B. papyrifera*) are resinous items that have been essentially utilized to cure diseases and for cosmetic purposes.

In spite of the numerous usages of *Burseraceae* resins, just a few species have been deliberately explored. As a result, studies have made reports on essential oils (i.e. *C. luzonicum)* or on the triterpenoid division (i.e. *C. Zeylanicum*). α− and β−amyrin, once secluded from Amyris resins, have been distinguished as the fundamental component of the triterpenoid portion of elemi resins. These compounds together with diverse *elemi* acids from the *euphane* group have been accounted for as compounds happening just in *Manila elemi*(Villanueva,− et al. 1993).

Like the remarkable Asiatic and African *Burseraceae* species (*myrrh, frankincense*, and so on) the colossal significance of the *Protium* species is exclusively and undoubted bestowed to their ability to deliver copious fragrant oleoresins(da Silva,− et al. 2013). Trees within this genus are named by a progression of well known names that infer this conspicuous property, for example, *anine, caraño, animecillo, copal, copalillo, almécega, almíscar, galbano, breu, breubranco, breuvermelho, jauaricica, goma−limão or Brasilian−elemi*. In the wake of discharging their volatile compounds, the exudates turn to a moldable yellowish material that turns to a hard gray gum on remaining on the injured trunks. This material is utilized as a part of the constituents of varnishes and colors or to fix and make any sort of wooden boat impermeable. The resin is likewise regularly blazed to light up the houses in the woods and drive away insects. Its burning produces sweet−smelling smokes for some religious ceremonies. Fruits of *Protium* species are exceptionally sweet−smelling. *Protiumicicariba* produces eatable organic products containing more than 10% in sugar; their seeds deliver 25% of clear tasty greasy oil, at times recommended as a substitute for olive oil (Rudiger,− et al. 2007).

2.2 Description of *Boswellia* species in the world

The *genus Boswellia* has around 25 species of small trees and bushes found in dry area districts from West Africa to Arabia and from South to Northeast Tanzania, in India, and one species in Madagascar (Sultana,− et al. 2013, Zhang,− et al. 2013). The family is focused in North−east Africa where around 75% of the species are endemic to the region. They are trees or shrubs frequently with latex, resins, or oils which are emphatically sweet−smelling.

Frankincense, *gum olibanum*, or *olibanum* are the basic names given to the *oleogum* resin which is acquired through cuts made in the trunks of trees of the *genus Boswellia* (family *Burseraceae*) (Ben−Yehoshua,− et al. 2012). It is plant product and falls under the group of sweet−smelling gums and resins which contain odiferous substances.

Frankincense comprises vital oils, gum, and terpenoids (Young,− et al. 2012). It is a complex of 30–60% alcohol soluble gums (diterpenes, triterpenes) (Hamm,− et al. 2005), 5–10% key oil, which is dissolvable in organic solvents, and the rest is comprised of polysaccharides (gum), which are dissolvable in water(Siddiqui 2011). Its key oil segment is made out of ester (62.1%), alcohol (15.4%), monoterpene hydrocarbons (9.9%), diterpenes (7.1%), and sesquiterpenes. Gum part is made out of pentose and hexose sugar and resin share is chiefly made out of pentacyclic triterpene acid of which boswellic acid is the active moiety. Mono and sesquiterpenes are very unstable compounds, diterpenes show low volatility, triterpenes display very low volatility, and polysaccharides are not volatile.

Figure 2: Oil and gum of *frankincense*

Source:

http://drleonardcoldwell.com/2015/03/30/frankincense−superior−to−chemotherapy−in−killing−late−stage−ovarian−cancer−cells/

Diverse commercial varieties of *frankincense* can be recognized by the substance constituents of their key oil. The constituents of the fundamental oil of *frankincense* were initially researched by Stenhouse and he recognized fourteen monoterpenoic constituents (Al−Harrasi and Al−Saidi 2008). Substance examination by Basar on the key oil of *Boswellia neglecta* and *Boswellia rivae* prompted disengagement and distinguishing proof of monoterpenes (Basar 2005). The main compounds recognized in *Boswellia neglecta* were α−thujene (21.3%), α−pinene (21.3%), sabinene (1.3%), −3−carene (1.9%), p−cymene (11.8%), terpinen−4−ol (5.3%), and verbenone (2.1%) (Dekebo,− et al. 2002). *Boswellia rivae* resin oil arrangement is truly like that of *Boswellia neglecta* which comprises of cara−2,4−diene (1.8%), α−thujene (2.9%), α−pinene (16.7%), o−cymene (3.9%), −3−carene (17.3%), p−cymene (3.2%), and limonene (21.1%)(Basar 2005). In the study, triterpenoic constituents, namely, α−amyrin (9.1%), β−amyrin (0.7%), epi−α−amyrin (1.6%), β−amyrenone (1.4%), α− and β−amyrin (3−,12−dien−α−amyrin (3.4%), and 3−,12−dien−β−amyrin (1.1%), were also identified from pyrolysate of *Boswellia neglecta* (Bekana,− et al. 2014). Similarly, 24−norursa−3,12−diene (18.7%), α−amyrin (4.2%), β−amyrin (0.9%), α−amyrenone (2.8%), β−amyrenone (2.3%), and epi−β−amyrin (0.9%) were found in the pyrolysate of *Boswellia rivae*(Bekana, Kebede et al. 2014). Dekebo et al. reported the keyoil constituents of the *Boswellia papyrifera* resin and identified n−hexyl acetate (1%), α−pinene (2.6%), limonene (6.5%), n−octanol (8.0%), linalool (3.2%), octyl acetate (56%), caryophyllene oxide (21%), and β−elemene (29%)(Bekana, Kebede et al. 2014).

Although Ethiopia is endowed with large *frankincense*, not much exploitation of it has been done in a proper way till now thus there is a weak export market due to varying supply and confusion of grades (Leminih and Teketay 2003). The most traded of the three *Boswellia* species found in Ethiopia for its *frankincense* resin *is Boswellia papyrifera* mostly accounting for over 90% of the natural gum exported (Eshete,− et al. 2005). Those gotten from *Boswellia rivae* and *neglecta* species are yet to reach export standard. Some authors have stated that there should be a revision of the export price so that the prices could reflect the content of ingredients the buyers seek for. Ethiopia will stand to benefit a great deal from the exports if efforts are made to better the current situation of production and sales. However, there is lack of information on chemical quality assortments between the export standard *frankincense* (*Boswellia papyrifera*) and the other two *Boswellia species* (*rivae andneglecta*) which have not reached export standard.

Boswellia is native to the tropical regions of Africa and Asia (Weeks,− et al. 2005). It is a sizable flowering plant which could be a tree or a shrub. It is mainly distributed in the tropics with its greatest diversity currently in Africa and India. It is a dioecious plant. The flowers may have 4−5 faintly connate but imbricate sepals with the same number unique, imbricate petals. Again, the stamens, that may contain nectar discs, have unique glabrous filaments appear in 1−2 whorls and in numbers same or two times the number of petals; the tricolporate pollen is found within 2 locules of the anthers that open longitudinally along slits. The gynoecium contains 3−5 connate carpels, one style, and one stigma that is head−like to lobed. The 1−5 pitted fruit is a drupe that opens it matures.The endosperm is usually not found in the embryo.

Boswellia has long been part of the Ayurvedic medicine (Jain 1994). Recently, the boswellic acid which is a constituent of the resin has been used to treat asthma and various inflammatory conditions (Anthoni,− et al. 2006). In Western Africa, the bark of *Boswellia dalzielii* is used to treat fever, rheumatism and gastrointestinal problems (Yunusa,− et al. 2014).*Boswellia* incense could bring relieve to depression.

There are four vital or major species of *Boswellia* which produce original *frankincense*. They are: *Boswellia sacra, frereana, papyrifera and serrata. Resins* from these species come in a variety of grades and this mainly has to do with the harvesting time. Hand sorting is employed to ensure quality.

Boswellia sacra**:** is known as *frankincense* or olibanum tree in the *Burseraceae* family. It is the fundamental tree in the genus *Boswellia* from which *frankincense* is got. It is growing to a height of about 2−8 meters with one stem or more. The bark can easily to removed due to its texture which kind be likened to that of paper. The leaves of this species are compound and its numbering is odd growing opposite each other along the branches. It has tiny yellow−white flowers which are made up of five petals; ten stamens and a cup with five teeth are found in clusters. The fruit of this species is a capsule which is close to a meter long. New leaves are covered with a fine down. Single trees growing on steep slopes develop some buttressing that extends from the roots up into the base of the truck. This cushions the tree and ensures certain stability.

Figure 3: ***Boswellia sacra***

Source: http://pixshark.com/Boswellia−sacra.htm

Figure 4: The resin of *Boswellia sacra*

Source: http://pixshark.com/Boswellia−sacra.htm

Boswellia sacra can tolerate the most critical situations and is often on rocky slopes and mostly in calcareous soil (Abbas,− et al. 2010). It begins to produce resin when it is close to 8−10 years old. The resin is extracted by making a small, shallow incision on the trunk or branches of the tree or by removing a portion of the crust of it. The resin is drained as a milky substance that coagulates in contact with air and is collected by hand. Growing conditions vary significantly, affecting both tree development and resin produced. Recent studies have points out that *frankincense* tree populations are reducing due to too much exploitation. Research proves that trees exposed to heavy taping produce seeds with percentage germination of 16% where as seeds of not so tapped trees has a germination percentage of over 80% (Raju,− et al 2012.). Regeneration is almost inhibited by the constant browsing of the foliage, flowers, and *seedlings* by animals especially goats. This act is causing the mature trees to gradually die.

Boswellia serrata**:** is *frankincense,* also known as olibanum, is the resin from the trees of the genus *Boswellia* and *Burserceae* family, native to Arabia and India. The plant can originally be found in India and the Punjab region closest to Pakistan. In Ayurvedic medicine Indian *frankincense* has been for hundreds of years employed to treat arthritis (Ke, et al. 2012). *Boswellia serrata* is used in the production of an anti−wrinkle agent called "Boswelox", which is seen by many asnot effective (Lodén,− et al. 2007).

Boswellia papyrifera**:** *Boswellia papyrifera* is one of those plant species with various monetary and ecological profits in Africa. It is found in Ethiopia, Nigeria, Cameroon, Central African Republic, Chad, Sudan, Uganda and Eritrea (Tolera, et al. 2013). The species is broadly known for its *frankincense*. In spite of its different profits, *Boswellia papyrifera* is these days in predicament conditions and needs urgent protection (Gebrehiwot, et al. 2003). It is reducing in population because of over cultivation, overgrazing, poor incense gathering, fires, and shifting cultivation, termite and other infestations by insects (Tadesse, et al. 2007, Tadesse, et al. 2008). *Boswellia papyrifera* is a deciduous tree which can be as tall as 12 m, with an adjusted crown and a straight consistent bole. The bark is whitish to pale brown which peels off in substantial flakes. The bark contains schizogenous *olea−gum−sap* pockets (Gebrehiwot,− et al. 2003). Leaves are huge, compound, found on long stalks with 11 to 29 leaflets. *Boswellia papyrifera* is a moneocious plant species with sweet scented flowers which are white to pink, organized on red stalks. At the point when the bark of the tree is incised, a white gum−oleo tar flows out. This emulsion of fragrant oils later dries into globular, pear or club molded tears, known as *frankincense*. *Frankincense* constitutes 3−8% unstable oil, 60−70% alcohol dissolvable gum and 27−35% water dissolvable gum (Gebrehiwot, Muys et al. 2003)

The wood is utilized predominantly for fencing, making agro−tools, furniture for the house, matchboxes, particleboard, pencils, plywood, picture frames and veneer. Different plant parts and items are used for conventional and medicinal purposes.

Boswellia frereana: *Boswellia frereana* is a type of plant local to northern Somalia where local people call it "Dhidin" or "Maydi" or the King of all *frankincense* (Van Beek 1958). It is otherwise called the Yigaar tree and by the regular name for all *frankincense*, Luban. Other than its fragrant uses, local people likewise utilize it for disease curative purposes. It is processed into a paste called "malmal" and applied on the joints to treat arthritis and inflammations. It is accounted for to be cultivated in Yemen, however this could be in light of a 1870 record by Dr. G. Birdwood referring to that *Boswellia frereana* was seen in Sir Robert Playfair's garden in Aden (Yemen). Playfair had brought *Boswellia frereana* from Somalia and cultivated it in his garden in Aden (Hepper 1969). There have been some rumors that it also grows in Oman, botanical evidence confirms it can neither grow nor be cultivated there. *Boswellia frereana gum*, notwithstanding, is once in a while found in Omani markets in the bigger urban areas as a less extravagant and more tasty chewing gum in contrast with the local Omani *frankincense*, *Boswellia sacra*, which is known more for its therapeutic and fragrant properties. In the West, *Boswellia frereana* is called "*Coptic Frankincense*" as this is the sort and grade utilized by the Coptic Church of Egypt (Baeten,− et al. 2014). 80% of *Boswellia frereana* generation is sold to Saudi Arabia where it is generally brought home by Muslim pilgrims. The remaining 20% is sold worldwide (Abdullahi 2001).

2.3 Description of *Boswellia* species in Socotra Island

Boswellia species on Socotra Island have two distinct habits: they are eight species cliff−rooting or ground−rooting. The cliff−dwelling species have swollen “holdfast” at the base of their trunks that enable them to hang on the cliffs (Banfield,− et al. 2011). The group called cliff−root species are *B. bullata, B. dioscorides, B. nana, B. popoviana.* The second group called ground−rooted species are *B. ameero, B. elongata, B. socotrana*(Attorre,− et al. 2011)

***Boswellia ameero*:** The height is from 5 to 8 m, the trunk with yellowish flaking bark, leaves size 10−30 x 2−15 cm, pinnate winged rachis absent; leaflets 14 to 25 cm, dark green above and below, 1.5−9x2–6 cm, entire to crenate−serrate, glabrescent above. Flowers are in dense (8−15 cm) paniculate racemes; petals red or dark pink, glabrous, oblong, < 7 or 8x2 mm, glabrous (Miller and Morris 2004)

It is natural habitat in the Island during the resting season. Socotra *ameero*, produces chewing gum that can be picked off the branches in the hotter months. This arrangement replaces the *Commiphora ornifolia* woodland at around 600 m. It is a closed arrangement, at some point it is regarded as a forest, with a thick bush layer, growing on granite.

Figure 5: *Boswellia ameero*

Source: http://botany.cz/cs/Boswellia−ameero/

***Boswellia bullata*:** Height 5m, rooted on cliffs; trunk pale grey, smooth (sometimes flaking). Leaves 8−15 x 3–8 cm, pinnate, winged rhachi; leaflets 9 to 17, dark green above, white−felted beneath, 1−4 x o,5−15 cm, crinkly, deeply irregularly crenate−serrate, puberulent above, thickly tomentose beneath. Flowers in open raceme−like panicles; pelats greenish yellow or red, oblong, 3−4 mm, puberulous outside. Fruits 6−valved, globose, c. 6x7 mm. (Miller and Morris 2004)

*Boswellia bullata*is a newly described species found mainly in the northern part of Socotra, growing on limestone and vertical cliffs. Also in the western part of Island in the area around Qalansiyah, but a population in north−central of Socotra (Eslameih 2011). *B. bullata* in the ground acclimates very quickly and can withstand severe temperatures and low humidity.

Figure 6*: Boswellia bullata*

Source: http://www.panoramio.com/photo/81529064

<u>Boswellia dioscorides</u>: the height of the tree to 7 m, rooted on cliffs; trunk brown or greenish, flaking. Leaves 15 −20x 4–8 cm, pinnate, winged rhachis absent; leaflets 11 to 17, glaucous, 2−4 x 1.5−4.5 cm, obscurely crenate−serrate, glabrous. Flowers in long, open panicles; petals cream or white sometimes tinged pink, ovate, 5−6 x c. 3 mm, glabrous. Fruits 7−11 x 4−5 mm (Miller and Morris 2004)

Boswellia dioscorides is a medium to large tree in its natural habitat, with diverse forms ranging from a freestyle structure to a flattop canopy with intricate branching, limestone plateaus and escarpments in succulent shrub land. The resin of *B. dioscorides* was to be collected and locally used in various ceremonies, particularly funerals, in the area of the type locality.

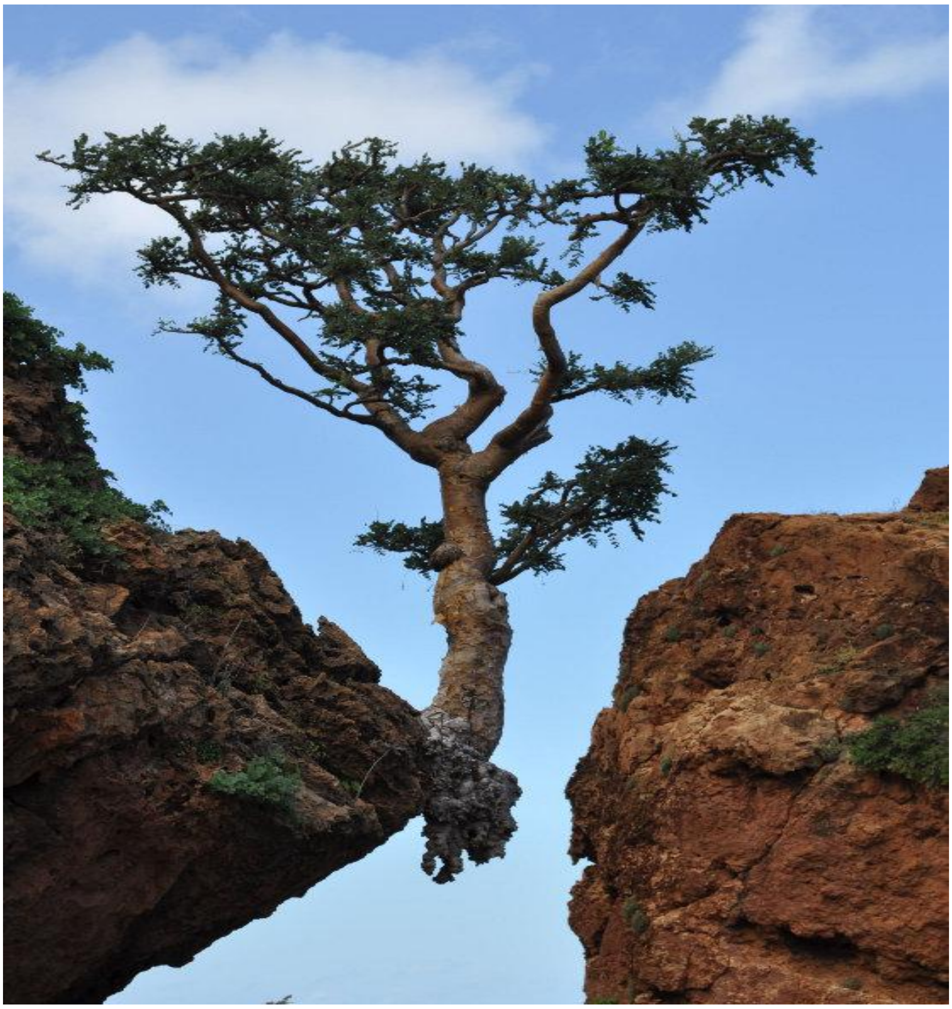


Figure 7: ***Boswellia dioscorides*** **growing on the rocks of cliffs**

Source: http://www.plantarium.ru/page/image/id/222703.html

__Boswellia nana__: shrub or small tree height to 4m, sometimes prostrate, rooted on cliffs; trunk pale grey. Leaves 4−18x0.5 cm, simple (Miller and Morris 2004). Leaves crowded especially at tip s of short−shots; blade simple, 3−5 x 1−1.6 cm. Flowers terminal, fasciculate (or up to 3 supported on a peduncle), with pedicele 8–18 mm long, tomentose, furnished with minute bracts. Fruits become purple (Eslamieh 2011).

Boswellia nana is shrub or small tree found on the limestone cliffs and areas of flat limestone in the northeast of Socotra, shows great variation in the degree of the division of the leaves and in the growth habits, needs heat humidity to thrive, also demands on the cool nights.

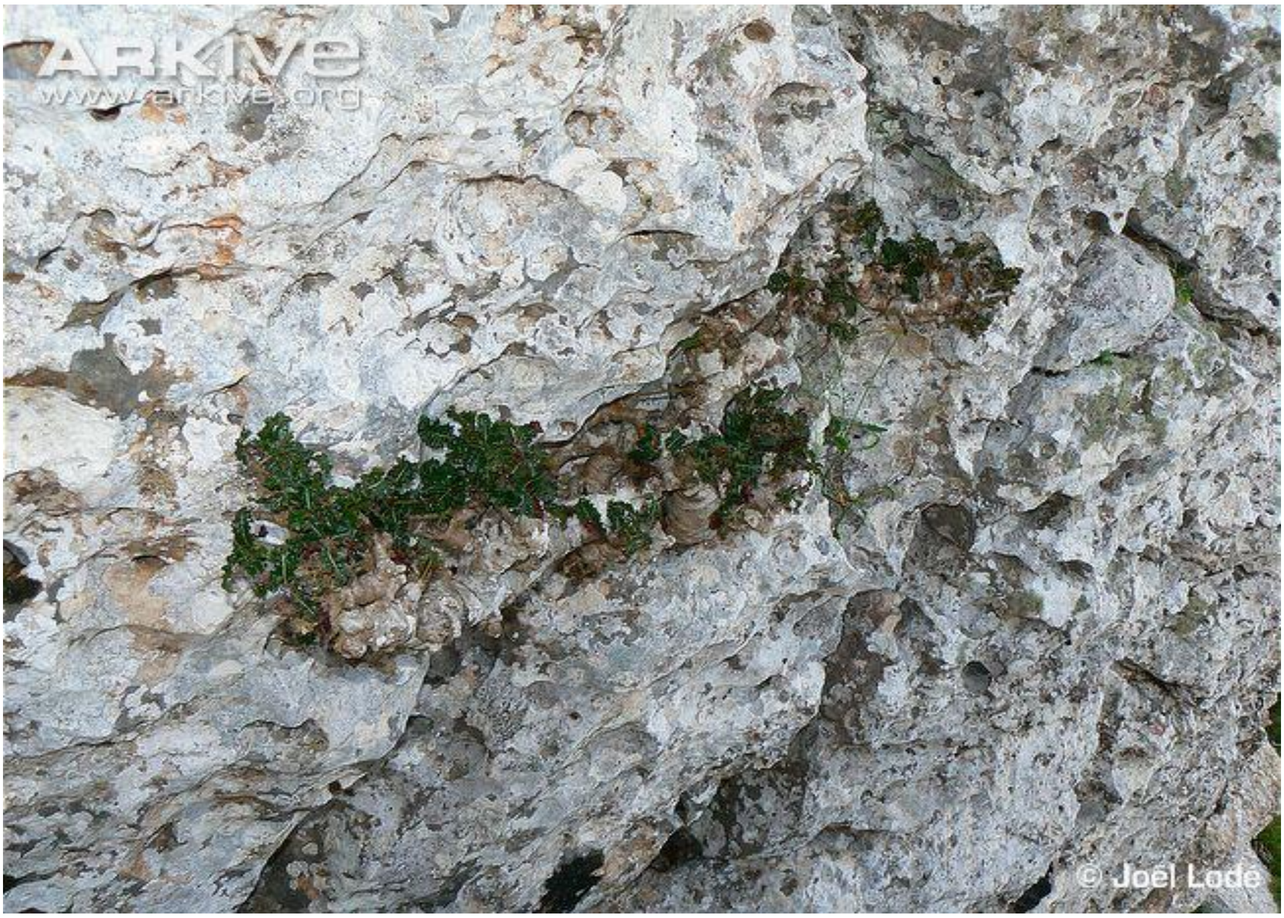


Figure 8: ***Boswellia nana*** **growing on rock and cliffs.**

Source: [***http://www.panoramio.com/photo/81529064***](http://www.panoramio.com/photo/81529064)

Figure 9: ***Seedling*** **of** ***Boswellia nana***

Source: http://cludwigfr.dyndns.org/gallery.asp?d=%5CSocotra

***Boswellia popoviana*:** The height of tree to 5m, grows on the rooted cliffs; trunk pale grey, smooth or with yellowish flaking. Leaves of two types: either (form 1) uniformly simple, 6−12 x 2–5 cm, margins regularly crenate, or (from 2) lobed below, 7−16 x 3.5–10 cm, margins irregularly crenate and sinuate often somewhat undulate, both forms glabrous or minutely puberulous above and densely white−felted beneath. Flowers in long (10−20 cm) many flowered panicles; petals cream and reddish tinged, ovate, 4–5 mm, glabrous. Fruit 10 − 15 x c. 55 mm, 3 to 5−valved (Miller and Morris 2004)

Figure 10: *Boswellia popoviana* growing on the cliffs

Source: http://www.bihrmann.com/caudiciforms/subs/bos−pop−sub.asp

Boswellia popoviana is scattered on limestone cliffs in dry, semi−deciduous woodland. 20−550 (−1050) m, the populations have shown no sign of regeneration, suggesting and a decline in the quality of habitat (Miller and Morris 2004).

Figure 11: Flowers and leaves of *Boswellia popoviana*

Source: http://www.bihrmann.com/caudiciforms/subs/bos−pop−sub.asp

Boswellia socotrana: the height of tree to 5m, trunk grey or reddish brown, smooth or somewhat flaking. Leaves small, 1−12 x 0.5−2 cm, pinnate, winged rhachis present; leaflets 7 to 31, pale or grayish green, 0.1−1.5 x 0.1−0.8 cm, entire or lobed, glabrous or puberulent. Flowers in short (c.5 cm), spare panicles; petals cream or pale yellow, ovate, c.3 mm, glabrous. Fruits subglobose, c.6 x 5 mm, ripening red (Miller and Morris 2004)

Boswellia socotrana is medium− sized tree that varies in forms and styles from the lowland Plato to the high elevation areas (Eslamieh 2011), widely distributed in dry− deciduous woodland, and less commonly in *Croton socotranus* Shrubland from 50− 600 m, growing, a ground−dwelling tree, distinguished from other *Boswellia* species on the Island by the leaves which have winged stalks and numerous, small leaflets and the inconspicuous pale yellow flowers which are borne in short, spare panicles (Miller and Morris 2004).

Figure 21: *Boswellia socotrana* growing in the ground

Source: http://www.panoramio.com/photo/81526110

Figure 13: Leaves and fruits of *Boswellia socotrana*

Source: http://commons.wikimedia.org/wiki/File:Socotra−*Boswellia*_socotrana.jpg

Boswellia elongata: Height of the *B. elongata* Tree to 8 m, trunk pale brown, strongly flaking bark, leaves 15−35 x 6−20 cm, pinnate, sometimes simple, winged rhachis absent; leaflets 13 to 29, glossy green above, whitish beneath, 3−10 x 1−3 cm, shallowly crenate to deeply crenate−serrate, glabrescent above, densely tomentose beneath. Flowers in long (15−30 cm) panicles or racemes, petals red or cream to yellowish−green, pale greenish−pink, glabrous, oblong, 6−8 mm. Fruits 10−13 x 7−11 mm (Miller and Morris 2004).

Boswellia elongata forest is found on the limestone plateau around 300 and 450 m, on stony (35%) soils. It is an open arrangement and the herbaceous layer has high estimations of spread in light of the richness and high water maintenance of the karst soils. It is hard to tell if this forest is a characteristic arrangement that has been corrupted by overgrazing or if is a remainder of previous areas for gum production, since *Boswellia elongata*, among the seven endemic *frankincense* types of Socotra, is the species delivering the most profitable incense (Attorre et al. 2011). The anthropogenic sources of these developments are likewise obvious in the lack of endemic species.

Figure 14: ***Boswellia elongata*** **in the wind season**

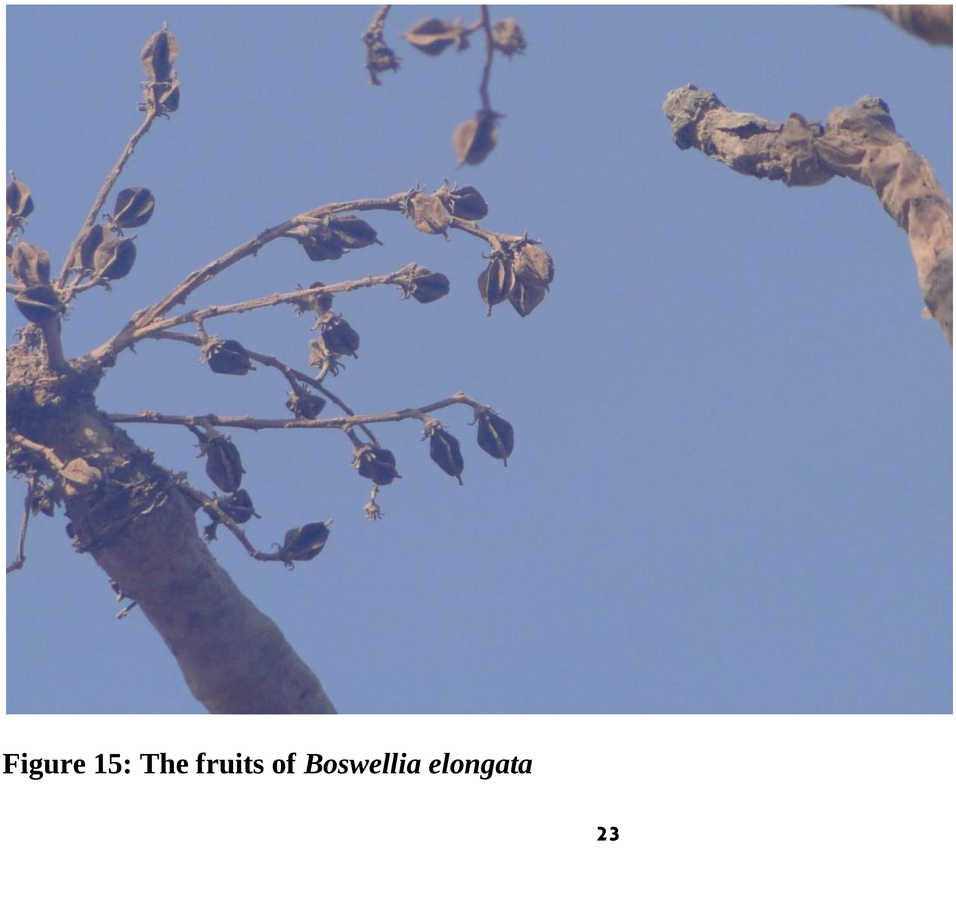


Figure 15: The fruits of ***Boswellia elongata***

2.4 Cultivation of *Boswellia* species

The environment of *Boswellia* species, the natural habitats are divided into dry−tropical and humid−tropical zones. Understanding their distinct environmental diversity plays a significant role in creating a proper environment for cultivation (Eslamieh 2011).

Cultivation of *B. elongate* many gardens had grown to almost nine feet tall. It is one of the most adaptable species under diverse condition; leaves are simple when the plant is in juvenile stage (1−2years old). Then become pinnate when the plant reaches two or more feet tall – usually after the second year. The color varies from grey, to purple, to light green depending upon the environment (Eslamieh 2004).

Growing zones seeds that had been collected from various locations in Socotra. At the three−years – old reached approximately 16 feet tall with a trunk size of over four inches in diameter, compared to the other seedling, which had only reached 3−4 feet tall the same amount time ((Eslamieh 2004)

Some species have adapted to different climates, for this reason demand greenhouse environments for growing. Consider *B. sacra,* with its diverse habitat, and *B. elongata and B. dioscorides* (E− Socotra) in a very small and specific habitat. These three species have adapted to the Sonoran Desert climate which has very low humidity for most of the year and occasional freezing temperatures during the winter. Both conditions are a major contrast to their natural habitat, yet all three have been forgiving to this change (Eslamieh 2011). But, B. *ameero*, B. *popoviana*, and *B. nana*, (E− Socotra), have not adapted to the Sonoran Desert and not only show signs of stress, but will not thrive without a controlled greenhouse environment and proper humidity, heat, and frost protection. (Mahr 2012).

The dry habitats start in Sudan and continue through Ethiopia and Somalia, crossing the Red Sea to Yemen and Oman, and then crossing the Persian Gulf to southern Iran, and the humid tropical starts at Ivory Coast, continues through northeastern Tanzania, and then crosses the Indian Ocean to India, which includes Sri Lanka, the Tirumala Hills, and ends in Burma (Myanmar). (Eslamieh 2011).

The species in the dry tropical subsist in habitats often with little season rainfall. The absence of rainfall in the dry tropics is made up for by the humidity and fog providing ample (plenty) moisture for the plants. For Socotra Island, thick fog passes over the Island through, so much of that the dew actually runs down trees, watering the root systems. The annual rain fall of Socotra is 120 to 400 mm per year (Fleitmann,− et al. 2007).

The humid tropical *Boswellias* are limited to *B. serrata* and *B. ovalifoliolata* of India, *B. dalzielli* of Ghana and Nigeria. And potentially the tropical *B. papyrifera* from Ethiopia, Eritrea, and Sudan, and *B. pirottae*, from Ethiopia in Tekeze, Abay and the Gibe River system. Almost species in the humid−tropical zones, *seedlings* of which grown in cultivation as geophytes, slowly develop an above−ground stem within a few years, and then finally begin to form into a plant that will permanently remain above the soil. Some of them, such as *B. ovalifoliolata*, develop a trunk much quicker than *B. serrata, B. dalzielii*, or even *B. papyrifera.*

There are a small number of nurseries worldwide that have begun sometimes offer seeds and plants of a few common species, like *B. sacra, B. neglecta, B. dioscorides, B. popoviana, B. nana, and B. serrata.* For collecting seeds or plants is very difficult and challenging, because most countries with *Boswellia* habitats have strict regulations, and in some case the exportation of plants or any parts of plants is absolutely forbidden (Eslamieh 2011).

Soil in dry tropical *Boswellia* species is used a soil medium with equal parts 1/4” − 3/8” soil granular material (pumice, clay balls, decomposed granite or equivalent), perlite, and organic material such as sterilized mulch. This is a basic mixture that allows the plant to obtain oxygen and nutrient while preventing waterlog or salt buildup. But the humid− tropical *Boswellia* species in fact do much better with consistent moisture during their active. Use 50% organic material, 25% one−quarter−inch (¼”) screened solid materials, and for the remaining 25%, use coarse sand and prelate in equal amounts.

Watering, *Boswellia* species love water running through their root systems, and with each watering the plants get the oxygen they need to develop strong root systems, and consequently a strong structure. New *seedlings* of most *Boswellias* are too fragile to water overhead with a wand or even a watering can in the first few weeks after germination. Any droplets of water that falls upon the *seedlings* could cause them to fall and become permanently damaged, but *B. nana, and B. popoviana* produce very strong *seedlings* and overhead watering is not a problem in most cases (Eslamieh 2011).

2.5 *Frankincense*, its history and foreign trade

2.5.1 History

The utilization of *frankincense* has a long history in human civilization (Van Beek 1960). The original oil content and unique scent reminiscent of *frankincense* made it alluring to be utilized as a part of sanctuary ceremonies as incense, as a base for perfumes and for curative properties since old times (Groom 1981). The initially recorded notice was found on a fifteenth century B.C tomb in Egypt. *Frankincense* is said 22 times in the Bible; 16 times for religious worship, twice as a tribute of honor, once as an article of stock, and 3 times as a result of the product Solomon's garden (Moldenke and Moldenke 1952). As indicated by Tucker (1986) any *frankincense* utilization said in the Old Testament of the Bible would have been from *Boswellia papyrifera* (Gebrehiwot,− et al. 2003). *Frankincense* was incorporated in the gifts given by the three wise men to the newborn child Christ together with gold and myrrh (Mathew 2011).

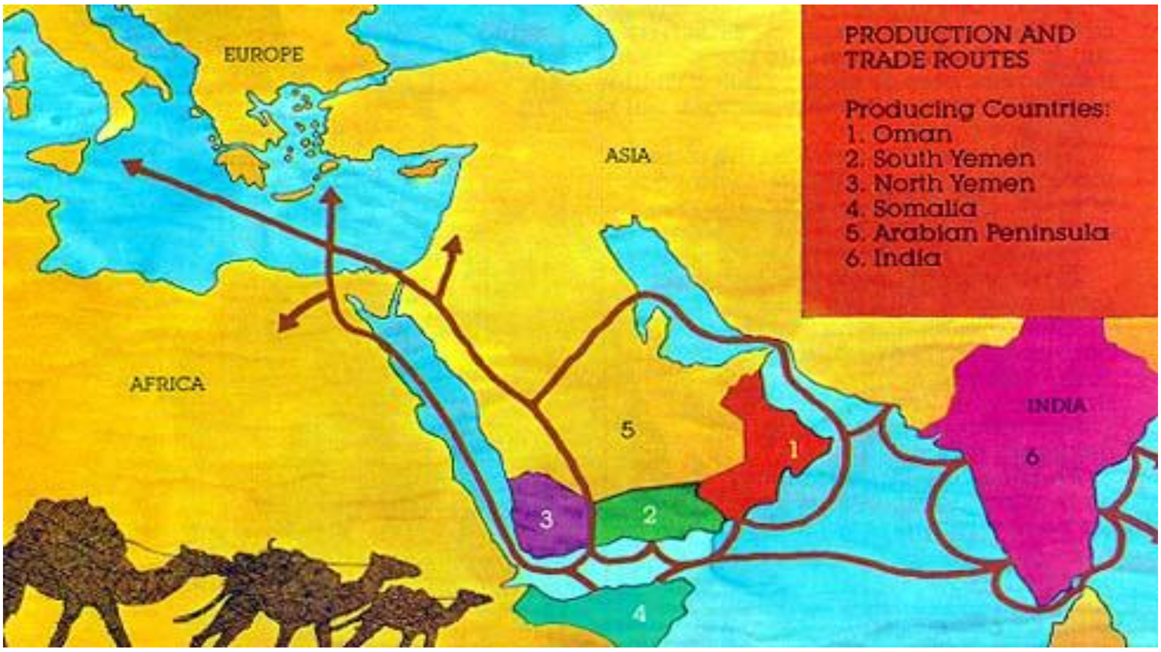


Figure 16: Production and trade routes of *Frankincense*.

2.5.2 Ancient exchange or trade

Some records on the historical backdrop of *frankincense* trade can be found in Groom (1981). *The frankincense* trade depended much for its presence on the camel, domesticated by 1300 B.C. (Gebrehiwot,− et al. 2003). Through the utilization of the camel and enhanced area courses around eleventh century B.C. *frankincense* was conveyed from Qana to Gaza. Via ocean it went straight from Qana to India. By 1000 B.C. *frankincense* had officially had its effect on the ancient world including Babylon, Egypt, Rome, Greece and China. *Frankincense* was held by the Romans to be the incense second to none and its high cost mirrored the tremendous interest for it (Groom 1981). The primary course in those times led from Dhofarvia ocean to the port of Qana, then overland into northern Arabia for transshipment to Athens and Rome (Abercrombie 1985). Southern Arabia had transported more than 3000 tons of incense every year to Greece, Rome and the Mediterranean world in the second century A.D.

2.5.3 Present International Market

In the current global business, there is confusion in deciding the demand and supply for *frankincense* as it is regularly categorized as 'natural gums, resins and balsams.' Besides, there likewise exists a lot of informal trading over the outskirts of the producing nations. Somalia, Sudan and Ethiopia are by a wide margin the greatest producers of *frankincense.* The export from Ethiopia somewhere around 1995 and 1999 is indicated in Figure (16). *Indian frankincense* is utilized locally for making incense sticks, and a normal of around 90 tons every annum have been traded from 1987 to 1993 (Coppen 1995). China was the biggest business sector for *frankincense*, and it transported in more than 1000 tons in 1984. In Europe and Latin America, around 500 tons of *frankincense* was utilized by the Orthodox and Roman Catholic holy places in 1987. Comparable amounts of higher quality *frankincense* are foreign made into North African nations and Saudi Arabia where it is utilized for chewing. Lower standard or grade olibanum has been utilized for burning as a part of the Middle East, in spite of the fact that its utilization has declined for other fragrance materials, for example, sandalwood. Around 50 tons of *frankincense* every annum is utilized in Europe for the creation of vital oils and extracts.

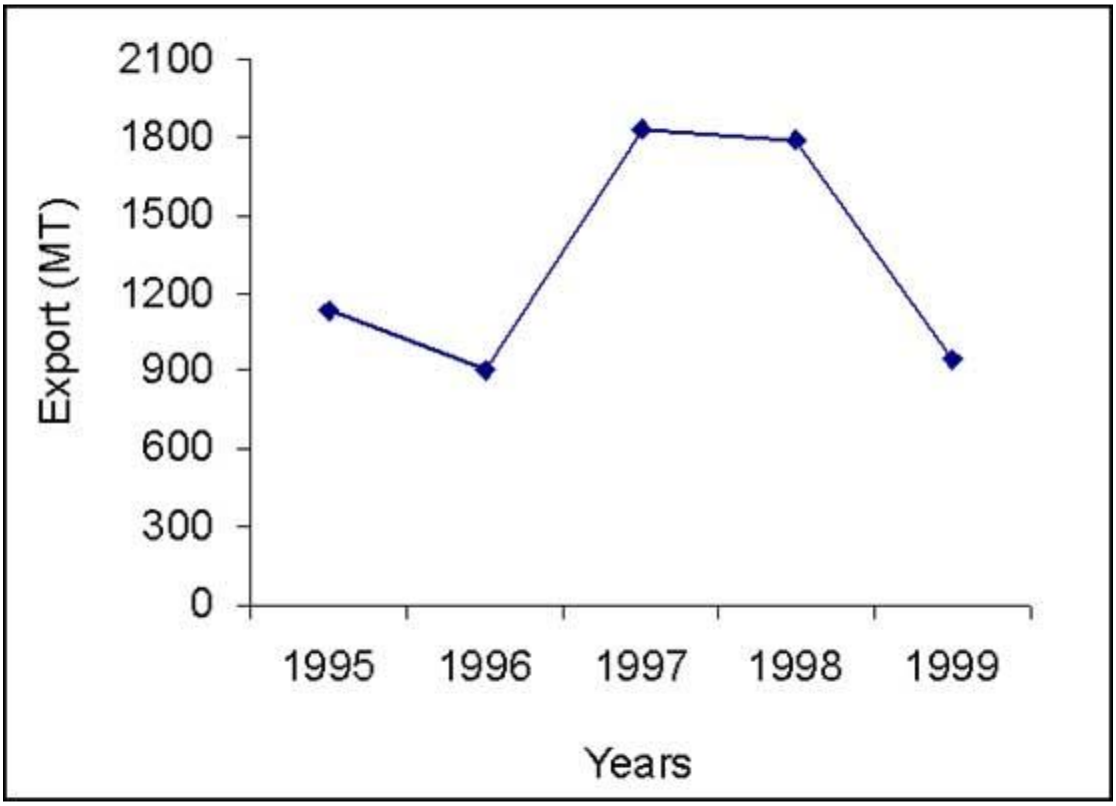


Figure 17*: Frankincense* trade from Ethiopia from 1995 to 1999 in metric ton

2.5.4 Uses of *frankincense* in the International Market

Burning incense: Incense has been connected with religious services everywhere throughout the world since time immemorial. *Frankincense* was brought into chapel functions toward the start of Christianity (Gebrehiwot,− et al. 2003). Since then, the solidified resin burns in the Roman Catholic, Greek Orthodox, Ethiopian Orthodox and Coptic Churches all through the world.

Perfume industry: *Frankincense* has had an ancient use in beauty care products. *Frankincense* is utilized by perfumers as an outright (by alcohol extraction), oil, or resinoid (via hydrocarbon extraction). Both dissolvable extracts can be utilized as fixatives as a part of perfumes. Oils are gotten from the crude resin by steam distillation and are then ordinarily utilized whole for flavoring and fragrance applications (Gebrehiwot,– et al. 2002). This oil from *frankincense* can take up to six hours to dissipate, making it and constituent in a lot of perfumes.

Medicinal uses: Limited data exists on the industrial therapeutic employments of *Boswellia papyrifera*. By and by, the customary therapeutic uses by the locals and encounters with different types of the variety (for instance, *Boswellia serrata*) highlight the potential utilization of *Boswellia papyrifera* for modern therapeutic purposes also. *Boswellic* acids (which constitutes around 50−70% of the oil) separated from *Boswellia serrata* in India is commercially utilized against arthritis and inflammations (Gebrehiwot,− et al. 2003). Those extracts from *B. serrata* were discovered to be more advantageous, less poisonous, and more powerful than standard mitigating medications for inflammations.

Other industrial and household uses: *Frankincense* is additionally utilized as a part of the manufacture of varnishes, glues, fumigation powders and pastilles. It gives flavor backings, milk items, distinctive alcoholic and soda drinks. The unmistakable flavor of *frankincense* additionally makes it exceedingly significant for chewing gum businesses. Around 500 tons of *frankincense* was brought to North African nations for chewing purposes in 1987 (Coppen and Hone 1995). Incense is additionally utilized as an element for cream, soaps, ointments, to wound plasters, tooth paste and mouth wash.

2.6 Tapping and grading

2.6.1. Tapping

Strategies of tapping and gathering of *frankincense* remained basically the same since old times (Gebrehiwot,− et al. 2002).. A tree could be tapped 8–12 times amid the dry times of the year. The initial 3−4 tapping are attempted in range of 21–30 days while the range gets to be shorter by approximately 10−15 days, at a later stage when the normal day by day temperature comes to over 25°C. At each tapping, a white emulsion comes out which dries and solidifies into globular, pear or club molded tears on exposure to air (Gebrehiwot,– et al. 2003). One to three kilogrammes of *frankincense* is gathered from a tree every year (Gebrehiwot, − et al. 2002). The quantity may vary due to the diameter of the tree, site productivity and season. The species can keep delivering incense up to the age of 50−60 years.

Figure 18: Tapping and gathering of *frankincense* in northern Ethiopia

Figure 19: Tapped *Boswellia papyrifera* in Tigray, northern Somalia

2.6.2 Sorting and grades of *frankincense*

Gathered *frankincense* is then sorted and graded using their size, color and how pure it is. In Ethiopia, there are five assortments or grades of *frankincense* from *Boswellia papyrifera* which are as follows:

a. First and foremost grade: white granule more than 6 mm in diameter

b. Second grade: white granules of 4 − 6 mm diameter

c. Third grade: white granules of 2 − 4 mm diameter

d. Fourth grade: dark colored or brown granules of any size

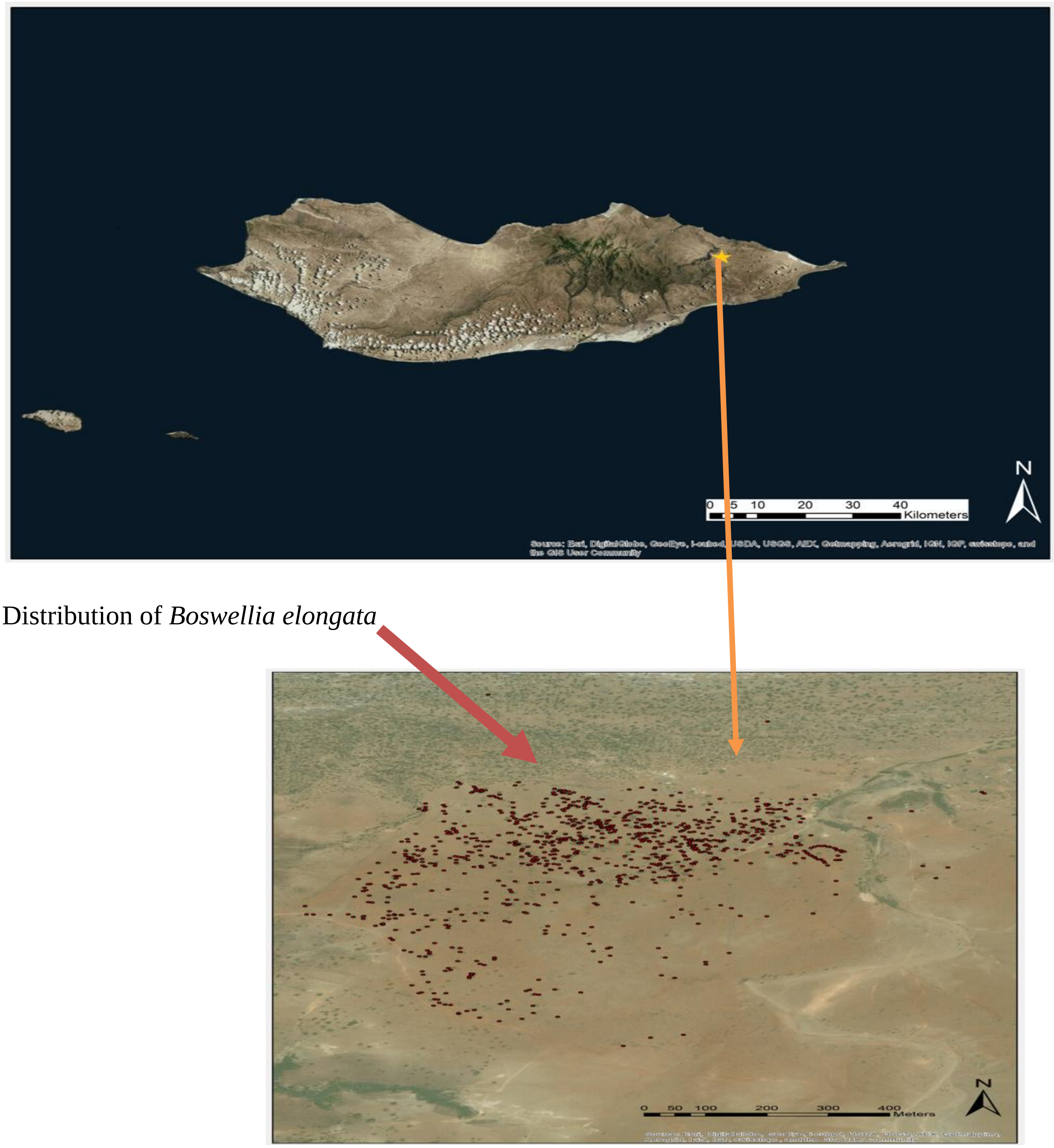
e. Fifth grade: powder with less than 2 mm diameter and measurement and bark with no size restrictions.

3. Materials and Methods

3.1 Study area

Leeyah locality, Homhil protected area, north–east of the Socotra Island, Republic of Yemen. The area under study is 75 hectares. Homhil is a tropical dry deciduous forest or woodland and hosts the largest population of *Boswellia elongata*in Socotra.

Figure 20: Map of study area (Homhil– Leeyah)



3.3 Field work

The field work was in two categories. The first dealt with the *seedlings* and the second dealt with the mature trees. The population of the *seedlings* at Homhil was assessed in the agroforestry garden (fenced area by the Czech developmental project. The garden was divided into rows with intervals of 5 meters. 1x1 square meter plots were created. These square plots were 5 meters from the fence and 5 meters between them. The number of *seedlings* in the square plots was counted and their respective heights duly measured.

The second category of measurement dealt with measurement of naturally growing trees in the Homhil protected area. Each specimen in study area was measured and its position was fixed by GPS coordinates. Measurements of tree height, stem height, GBH and two perpendicular crown diameters were taken. The measurements start from the North−east of the area to the south−west and accounted for 950 trees.

3.4 Data analysis

The field data records were re−typed into computer in Excel software. In this program the table and graphs were created. The crown area was counted according to formula for area of ellipse. The population structure was expressed by abundance of specimens in tree and stems heights, GBH and crown area classes. The GPS coordinates of trees were used for creation of map of *Boswellias* distribution. As a background map were used the ArcGIS online map, the distribution map was created in ArcGIS program.

Figure 21: Rows in the garden during the field work

Figure 22: ***Seedlings*** **in the garden**

Figure 23: Measurement of height *seeding* in garden

Figure 24: Measurement of crown diameter of *Boswellia elongata*

Figure 25: Measurement of height

Figure 26: GBH measurement

4. Results

4.1 Natural regeneration

The fenced area was established within the Czech developmental project in 2012 to try learning if there is a potential of natural regeneration. 71 *seedlings* were found inside 36 research plots in summer 2014. The *seedlings* density reached 1.97 specimens per square meter, it is 19 722 *seedlings* per hectare during one year and 11 months of fenced garden lifetime. The average height was 13 cm, with maximum 50 cm and minimum 2 cm. The distribution of *seedlings* in height classes shows Figure 27. The highest abundance of *seedlings* is in height classes 5−10 cm and 1−5 cm, it means mostly 1 and half years old *seedlings*. There were not found any *seedlings* outside of fenced garden.

Figure 27: The abundance of *seedlings* Height classes

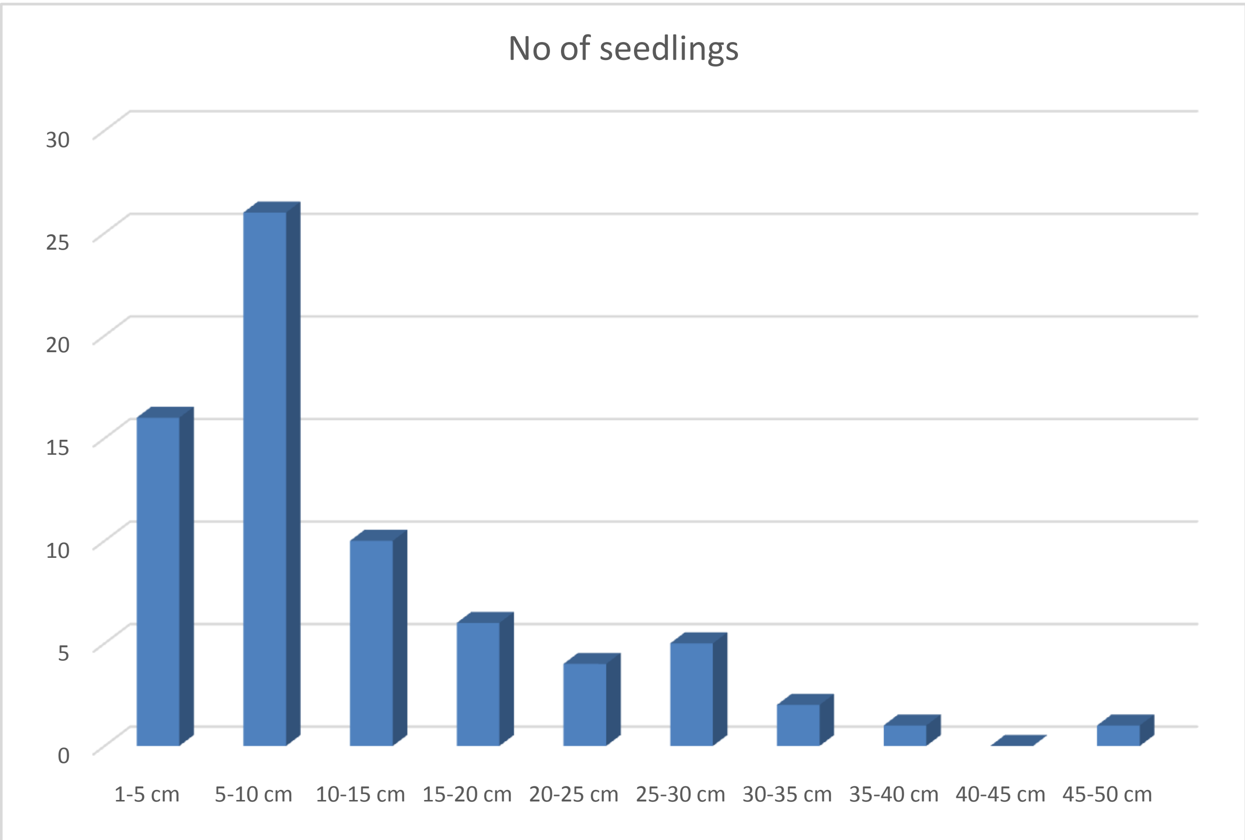


Table 1: The abundance of *seedlings* in Height classes

Height of class	No of seedlings
1−5m	16
5−10m	26
10−15m	10
15−20m	6
20−25m	4
25−30m	5
30−35m	2
35−40m	1
40−45m	0
45−50	1
Total	71

Table 2: number of squares, total area of squares, total number of squares and density of seedlings.

36 squares		
Total area of squares	36	squares meters
Total No of seedlings	71	
Seedlings density	1.972222	Seedlings per square meter
	19722.22	Seedlings per hectare

4.2 The population of *Boswellia elongata*

Totally, 940 adult trees were measured. 21 of them were dead, it is 2.24%. The population area is 75 ha, the population density of living trees reached 12.25 trees per ha. No juvenile trees were found inside the population, there is visible lack of regeneration during last decades**.**

Table 3: Basic biometric characteristics of the population structure of the *Boswellia elongata*

	The height of tree	**The height of stem**	**GBH**	**Crown area**
Mean	**4.94**	**2.02**	**1.01**	**41.17**
Min	**2.10**	**1.00**	**0.40**	**1.57**
Max	**8.82**	**5.00**	**2.62**	**129.53**
Number of the living trees	**919.00**	**97.76%**		
Number of the dead trees	**21.00**	**2.24%**		

4.2.1 Height structure of tree within population

Figure 28: Abundance of tree in Height classes.

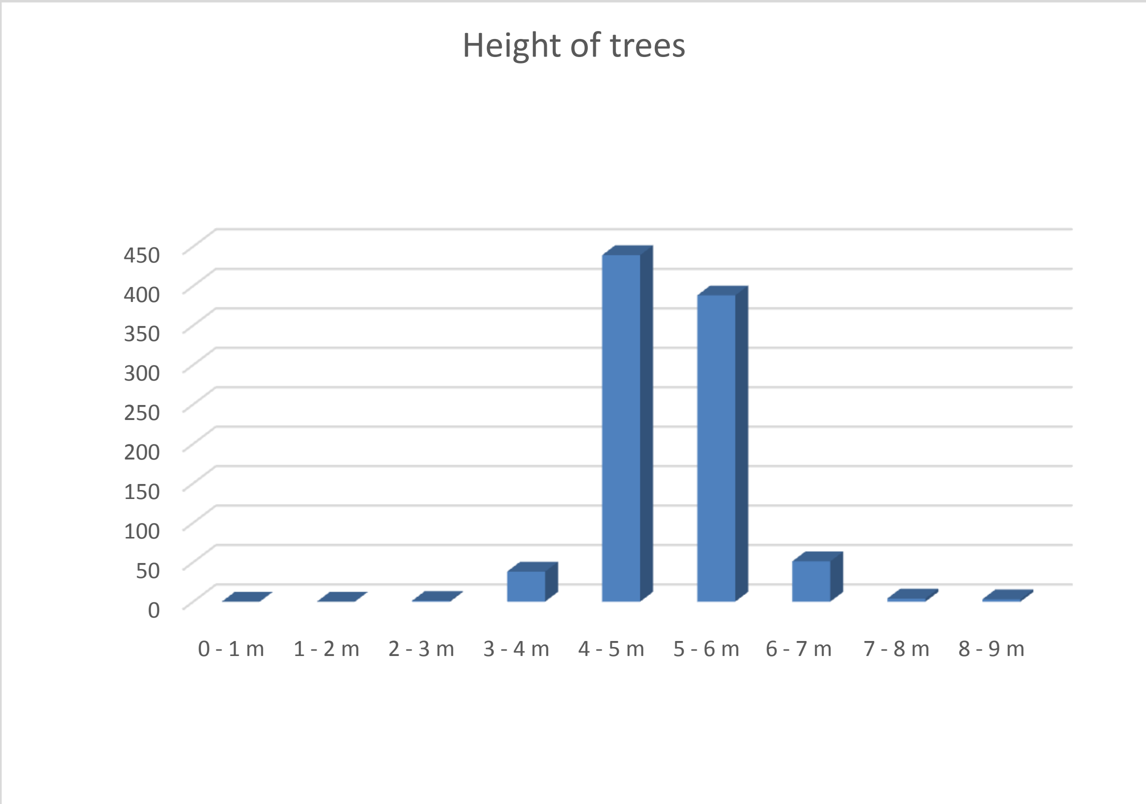


Table 4: Height classes and abundance of individuals at Homhil area

HT classes	No of individuals
0 – 1m	0
1 – 2m	0
2 – 3m	1
3 – 4m	38
4 – 5m	439
5 – 6m	388
6 – 7m	51
7 – 8m	4
8 – 9m	3

This Fig.28 and the Table.4 show the height of tree structure in *Boswelli aelongata* at Homhill area. The population has abnormal structure, the highest abundance is in HT classes 4− 6 m, which considered the highest abundance, According to Miller and Morris (2004), the height of *B. elongate* reaches up to8 m, but I have observed during my field work at Homhil about 3% of the trees reached to up 9 m., According to the table the number of the trees which reach to 3−4 m is 38 trees, but from class 0−2 m I did not found any specimen in the forest of study area. The result indicates to the overgrazing of livestock.

4.2.2 Stem height structure within population.

Figure 29: Abundance of trees in stem height classes.

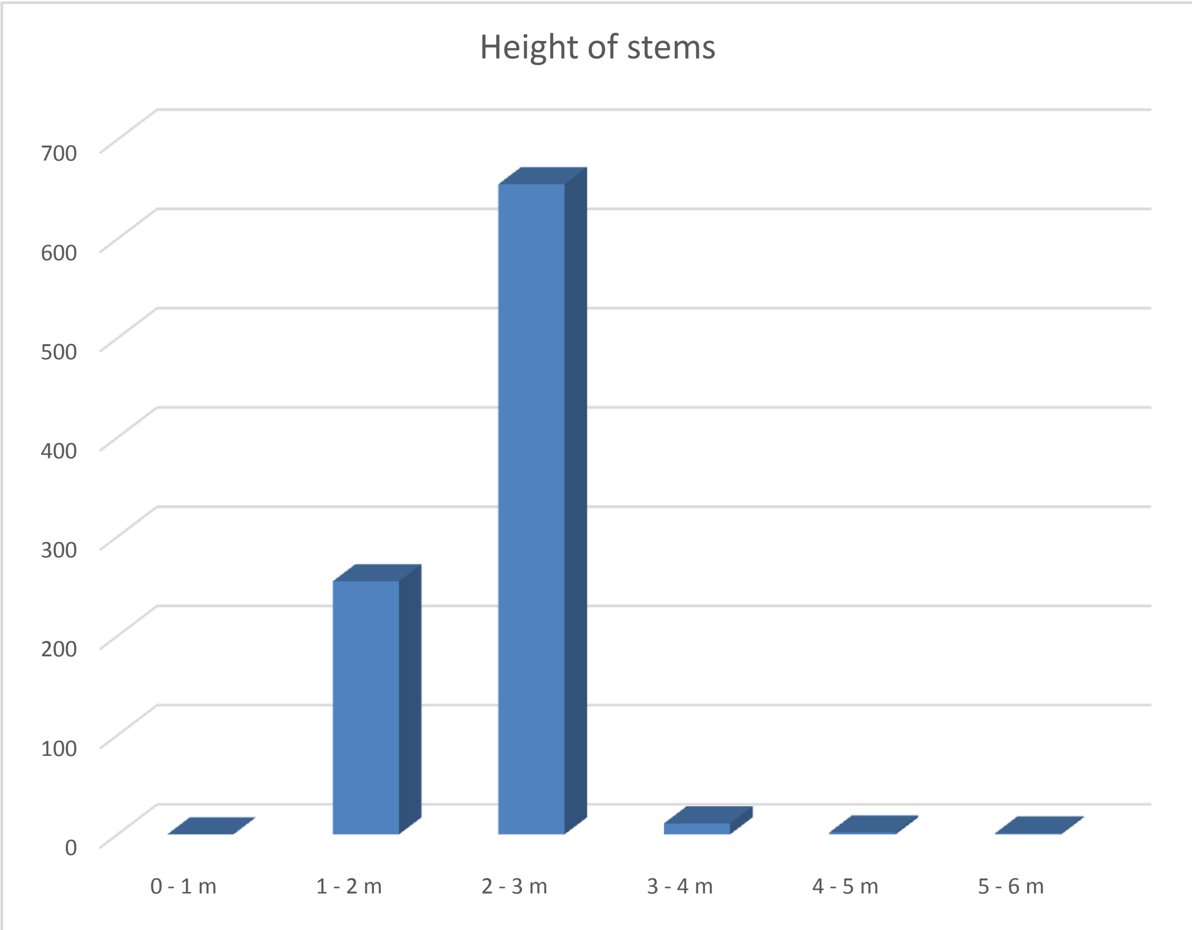


Fig. 29 shows the height of stem structure of *Boswellia elongate* population in Homhil area, stem height classes 1− 3 m contain more than 90% of the trees of *Boswellia elongata*, but the height of the stem reaches in some trees to 6 m. We can conclude from this result the similar conclusions as previous chapter. No presence of young trees indicates lack of natural regeneration.

Table 5: Stem height classes and abundance of individuals at Homhil area.

HS classes	No of individuals
0 – 1m	**0**
1 – 2m	**255**
2 – 3m	**655**
3 – 4m	**11**
3 – 5m	**2**
5 – 6m	**1**

4.2.3 GBH structure within *Bowellia elongata* population in the Homhil area.

Fig. 30 and Tab. 6 show the GBH structure within *Boswellia elongata* population in the Homhil protected area. The most of trees belong to classes 1–2 m. approximately 5% specimens are in class 0.5–1 m and only specimens in class 0 – 0.5 m. The results again confirm previous conclusions about lack of natural regeneration within *Boswellia elongata* population.

Figure 30: Abundance of trees in GBH classes.

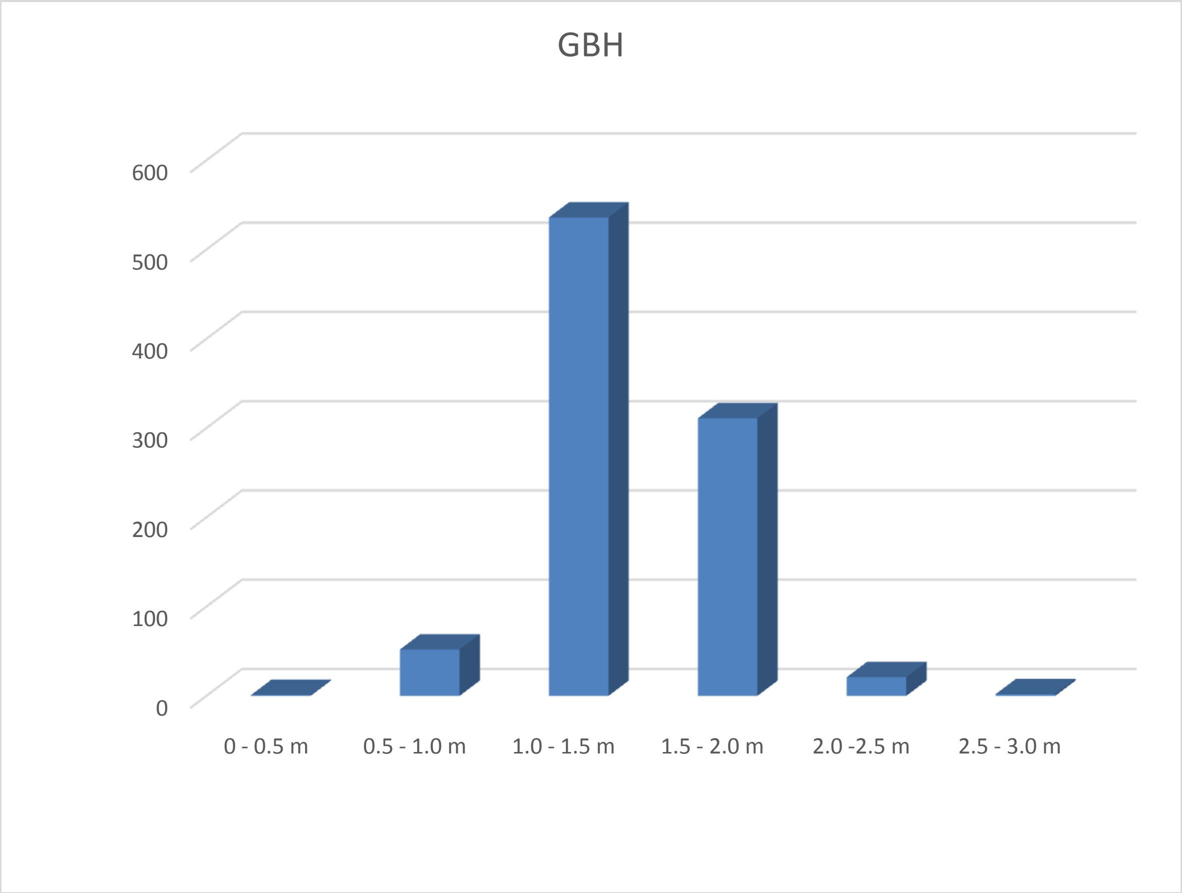


Table 6: GBH classes and abundance of individuals at Homhil area.

GBH classes	No of individuals
0– 0.5m	1
0.5– 1.0m	52
1.0–1.5m	536
1.5– 2.5m	311
2.0–2.5m	21
2.5– 3.0m	2

4.2.4 Crown area of sampled trees in the Homhil area.

The crown area distribution within population (Fig. 30 and Tab. 7) shows more balanced structure, than height of tree, height of stem or GBH. It is probably caused by application of silvo–pastoral system, when shepherds cut branches as a fodder for livestock in dry period and the crown area is so decreasing.

Figure 31: Crown area structure within population of *Boswellia elongata*

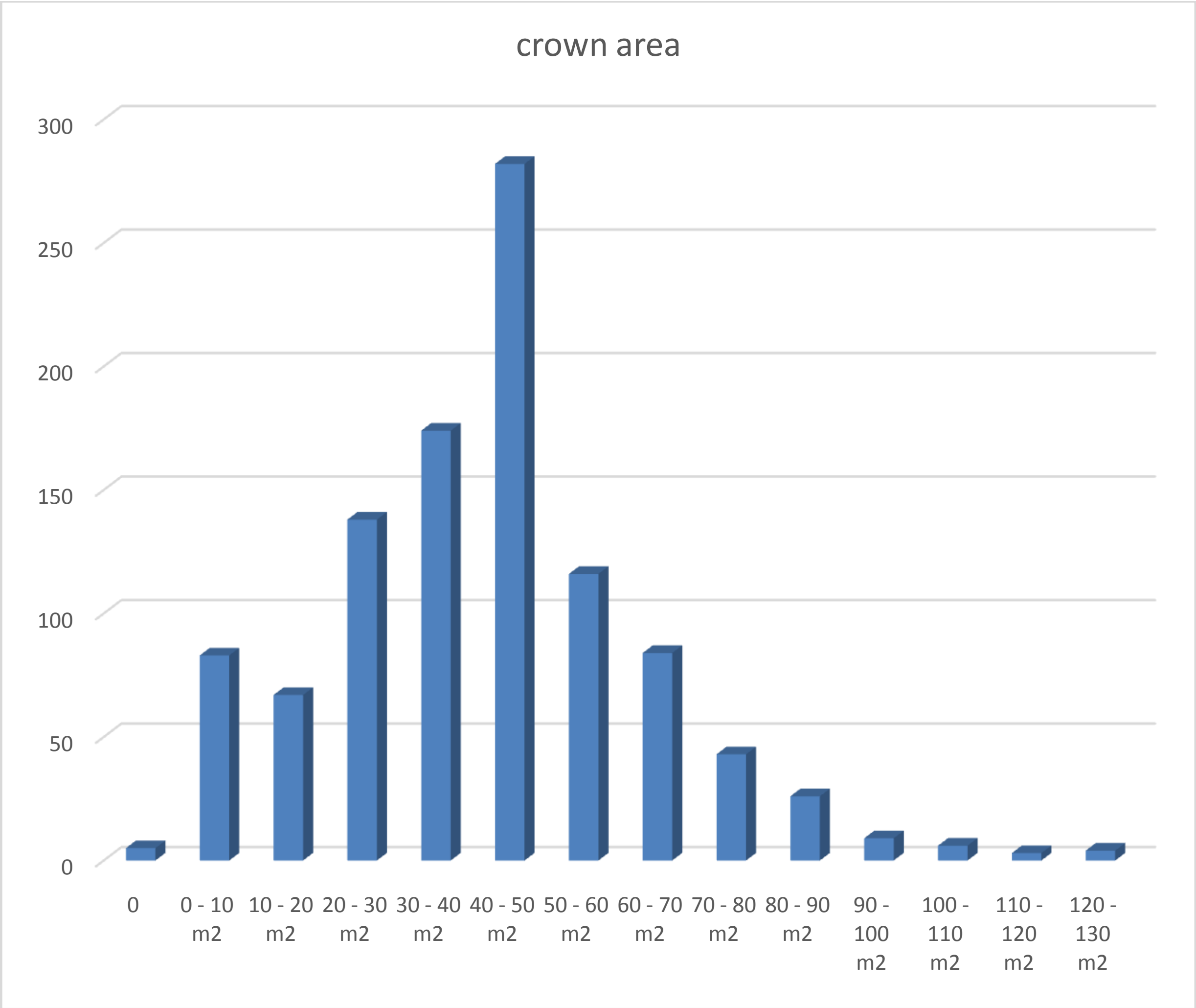


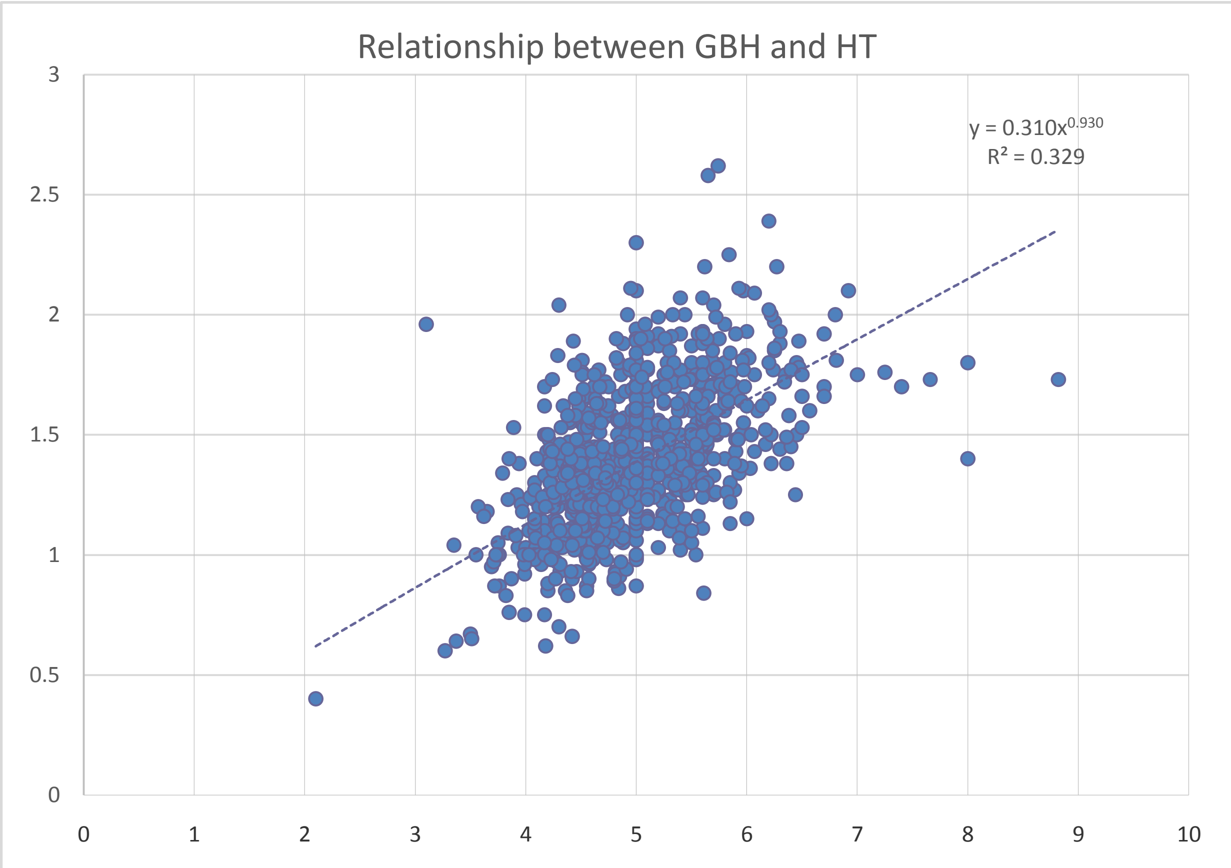
Table 7: Crown area classes and the abundance of individuals at Homhil area.

Crown area classes	N of individuals
0	5
0 – 10m	83
10 – 20m	67
20 – 30m	138
30 – 40m	174
40 – 50m	282
50 – 60m	116
60 – 70m	84
70 – 80m	43
80 – 90m	26
90 – 100m	9
100 −110m	6
110 – 120m	3
120 – 130m	4

4.2.5 The relationship between the GBH and the height of the sampled trees

From the relationship between the height and GBH of *B. elongata* trees measured (Fig.32), it can be realized that the R squared value is very small thus about 33%. This goes to show that, the differences in the GBH values of the trees measured cannot directly be accounted for or explained by the differences of the heights of trees measured, hence there should be other prominent factors responsible for the variations in the GBH. Nevertheless the relationship between GBH and height of tree expressed by correlation in Fig. 32 is relatively fit. Both mutually correlating characteristic is possible use for indirect expression of age structure of population.

Figure 32: Relationship between GBH and Height of trees.



4.3. Trees distribution within *Boswellia elongata* population

The Fig.33−36 show the distribution of *Boswellia* specimens in studied population. It is well visible, northern part of population is more dense than southern part. In southern part, the SE quadrant has the lowest density; the SW part has a little bit higher density.

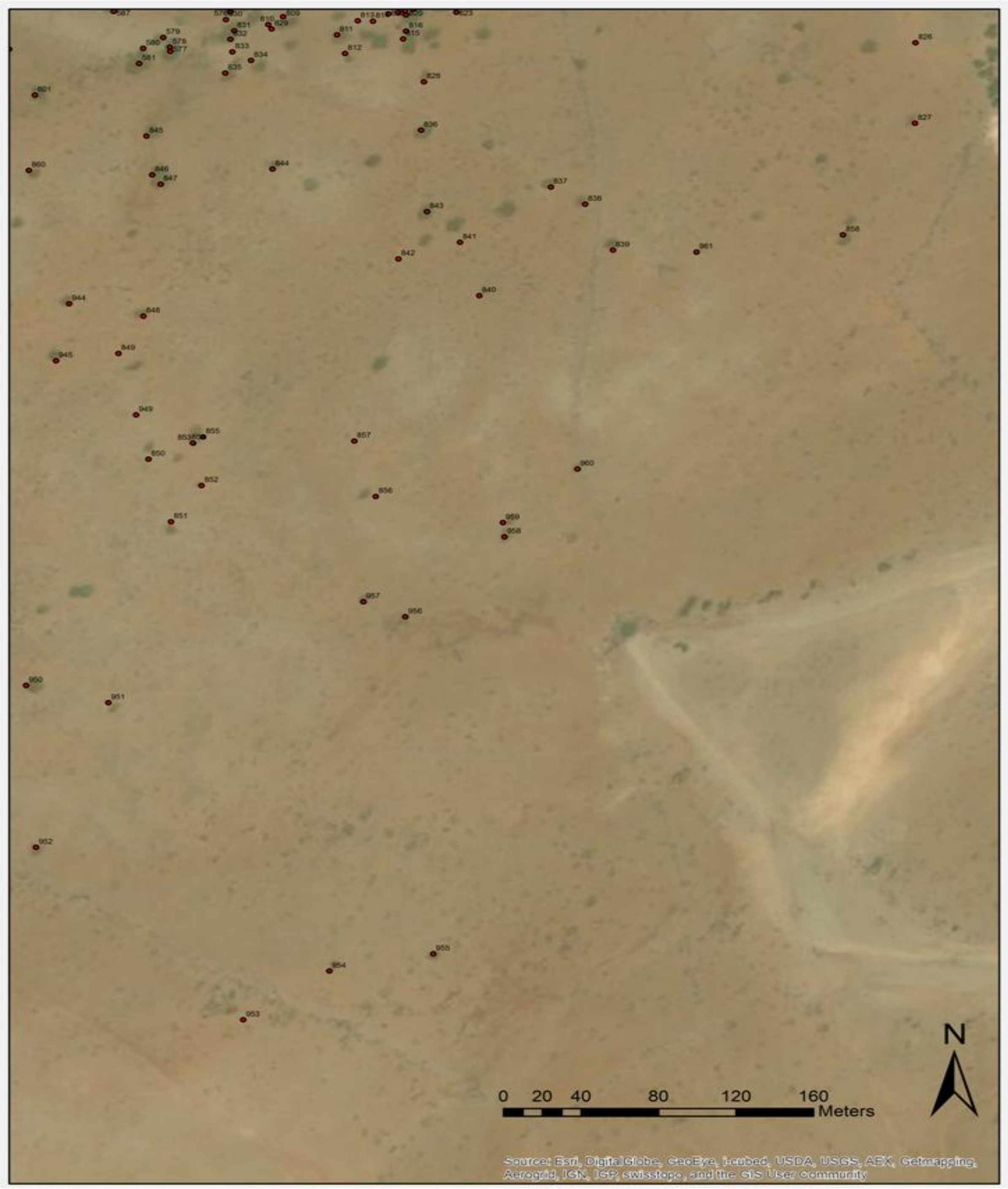


Figure 33: The South−East.

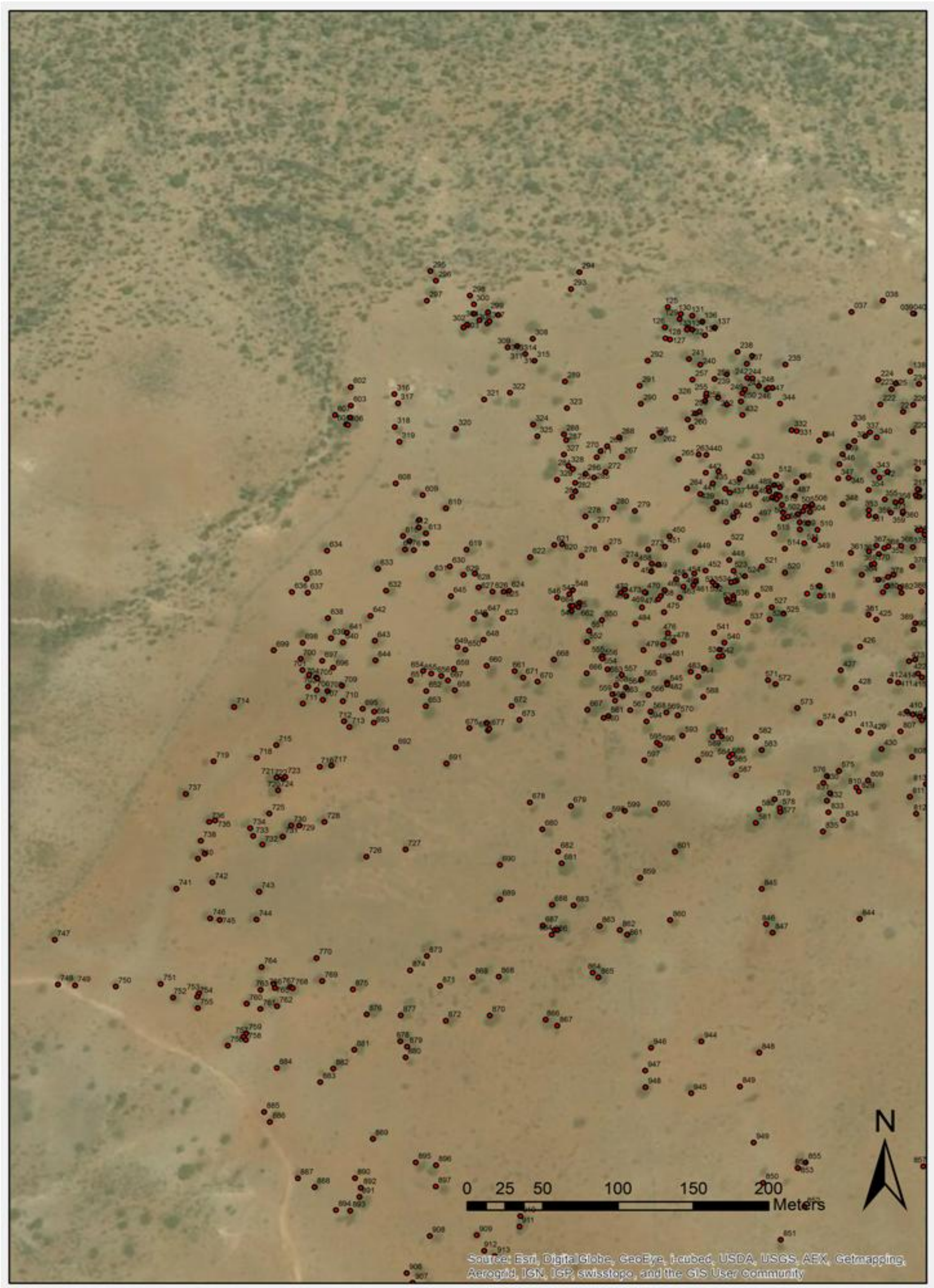


Figure 34: The North−West.

Figure 35: The North−East.

Figure 36: The South−West.

5. Discussion

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 (Non−Timber Forest Products) extraction from a given forest area. 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 (Asmamaw 2011). The population structure of *Boswellia elongata*in Socotra Island at Homhil reserved forest is given in Figure 27, 28, 29, 30 and 31.

The population structure in the studied forest showed that the population is dominated by mature individuals with complete lack of juvenile and regenerating individuals (<1.0 GBH) Fig (29). All the individuals of the species in the forest surveyed stands have diameter greater than 1m. 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; Alemu 2011).

The bells shaped structure that were found in the surveyed stands in the study area (Fig 27, 28, 29, 30 and 31) 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 like by *Boswellia elongata* at Homhil forest were reported in study of *Boswellia papyrifera*in dry woodlands of Nuba Mountains, South Kordofan State, Sudan, and Jebel Marra, West Sudan by Khamis (2001) and Adam (2003). In Ethiopia (Eshete et al. 2005; Lemeneh et al. 2007). Our result are in accordance with study published (Attore et al. 2011), where authors reported weak natural regeneration in ground−rooted *Boswellias.*

Grazing can have a negative impact on the regeneration of ground species, and soil surface by animals can result in *seedlings* mortality and soil compaction that limits recruitment and seedling establishment (Attorre et al. 2011). This is an indication that the species is under threat in the study area but also other species of *Boswellia* in several geographical locations in the region of its distribution due to continuous tapping for incense production, human induced fire, overgrazing and climatic anomalies.

The mortality higher than 2% indicates the beginning of population decline. With growing age of population the mortality rate will increase. Missing regeneration and accelerating mortality are two main reasons, why the population at Homhil area is extremely endangered by extinction in a near future.

The huge potential of natural regeneration was proved in fenced area. The *seedlings* density reached 1.97 specimens per square meter, it is 19 722 *seedlings* per hectare during two years of fenced garden lifetime. The growth of *seedlings* is relatively, average height was 13 cm, with maximum 50 cm and minimum 2 cm.

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, livestock and human impacts are the major causes for the decline of the population of the species. In the other hand, there is no supervision of production areas and no management and protection activities being carried out to protect the species.

Therefore, in accordance with regeneration results, it is necessary to persuade the local community to start with *Boswellia* population fencing and temporary interruption of grazing inside. This process has to be financial supported by EPA or foreign development aid. The beginning should be in places with lower population density and after securing of regeneration to continue in part of population with higher density. The priority places for start fencing establishment is possible to determine according to published maps (Fig 33−36).

6. Conclusion

The population structure of *Boswellia elongata* illustrates that natural regeneration is lacking in study areas. The population of *Boswellia elongate* in the study area is unstable and under threat due to lack of recruitments through regeneration. Based on the stands structure analysis, and other survey study such as Attorre et al (2011) and Miller and Morris (2004), it is hypothesized that lack of natural regeneration is primarily caused by livestock grazing pressure.

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 grazing and silvo−pastoral system results in gradual degradation of the population and its natural regeneration as our investigation argues. The situation of the *B. elongata* in Homhil area calls urgent actions for conservation of the species. Proper management plan is required.

Our result shows, that potential of natural regeneration is already presented and it is possible to use it for population rejuvenation.

7. Recommendations

Controlling grazing in Socotra Island is very difficult but fencing some areas is possible such as Leeyah area at Homhil. Tree damage by harvesting of *Boswellia* species resin or other human impacts can be organized. And other Re‒activation such as tourism police can be effective solution for controlling forest activities.

All previous activities should be organized within management plan, a plan which includes forest production functions such as *Dragon's blood* resin harvesting and trading and ecotourism and protection functions such as regeneration program, harvesting monitor program and soil protection and monitoring program. People will be fully participating in planning and implementing the management plan.

Being the forest in Socotra owned by tribes, the government has the right to protect public interest and the Island within the framework of a conservation law. Local government should open a discussion with the local communities in a sustainable ways of harvesting *Boswellia* species resin and protected forests. The management of the forests in the Island is under EPA Socotra with good trained staff and high participation from the local people, who are familiar with working with local and international organizations.

8. Summary

Socotra Island is the place, where the highest diversity of *Burseraceae* family members in the world came from. Seven or eight species of *Boswellia*, all of them endemic, and five species of *Commiphora*, four of them endemic grow there. All species belong to the zone of dry land deciduous tree or shrub vegetation. Some species colonize lowlands (*Boswellia popoviana*, *Commiphora ornifolia*, *C.socotrana*), some species grow only in the highlands (*B.ameero*, *C.planiforns*). *Frankincense* trees are divided into two groups. Species from first group belong to ground rooted trees (*B. ameero*, incl. *B. sp. A*, *B. elongata* and *B. socotrana*). Second groupis composed of cliff rooted species (*B. popoviana*, *B. dioscorides*, *B. bullata* and *B. nana*). Generally, ground rooted species are more endangered, because of strong influence of grazing on the regeneration. *Frankincense* trees have high socio−economic and cultural value since ancient times. The olibanum was a product of high importance and it was harvested a few thousand years ago. Socotra wasn´t exception. But local people use these trees in their special silvo−pastoral system cutting branches as a fodder for cattle, in traditional medicine and as a source of nectar for honey bees.

In past decades, decline of *frankincense* and myrrh tree populations is evident, due to lack of the regeneration of ground rooted species caused by grazing of livestock. There is also lack of systematic studies that could examine the population status of the species and thus lack of proper management and conservation.

From 1999, a group of Czech researchers from Mendel University in Brno work on reforestation activities through forest nurseries support followed by out plantings. One of such example of reforestation effort is located at Homhil protected area, north−east of Socotra, Leeyah locality, where fenced garden of approximately 0.3 ha has been established in 2012 within Czech Development Assistance project.

Homhilis famous for its one of the biggest population of *Boswellia elongata* on Socotra, and after two years, population structure of old trees and the survey of potential of regeneration was carried out. The objective was to quantify density and population structure of *B. elongata* and to analyse the natural regeneration status of the species. The *seedlings* were investigated in regular nets of square plots 1 x 1 m with spacing 5 m; in total, 36 squares (36 m^2) were investigated. The *seedlings* inside research squares were counted and its height was measured. The size of research area for assessing population structure of old trees was 75 ha representing

part of Homhil plain. The position of each tree was measured by GPS and height of tree, height of stem, diameters of crown in two perpendicular directions and GBH were recorded.

The current grazing and silvo−pastoral system results in gradual degradation of the population and its natural regeneration as our investigation argues. The situation of the *B. elongata* in Homhil area calls urgent actions for conservation of the species. Proper management plan is required.

9. References

Abbas, H., et al. (2010). "*Conservation status of Cadabaheterotricha stocks (Capparaceae): an endangered species in Pakistan."* Pak. J. Bot 42(1): 35−46.

Abdullahi, M. D. (2001*). Culture and customs of Somalia, Greenwood Publishing Group*.

Al−Harrasi, A. and S. Al−Saidi (2008). "*Phytochemical analysis of the essential oil from botanically certified oleogum resin of Boswellia sacra (Omani Luban)."* Molecules 13(9): 2181−2189.

Anthoni, C., et al. (2006). "*Mechanisms underlying the anti−inflammatory actions of boswellic acid derivatives in experimental colitis."* American Journal of Physiology−Gastrointestinal and Liver Physiology 290(6): G1131−G1137.

Asmamaw.A. et al (2011). *Population structure, density and natural regeneration of Boswellia Papyrifera* (Del.) Hochst in Dry woodlands of Nuba Mountains, South Kordofan State, Sudan.

Attorre, F., et al. (2007). "*Will dragonblood survive the next period of climate change? Current and future potential distribution of Dracaena cinnabari (Socotra, Yemen).*" Biological Conservation 138(3): 430−439.

Attorre, F., et al. (2011). "*Developing conservation strategies for endemic tree species when faced with time and data constraints: Boswellia spp. on Socotra (Yemen)."* Biodiversity and Conservation 20(7): 1483−1499.

Ayres, P. (2015). "*Isaac Bayley Balfour, Sphagnum moss, and the Great War* (1914−1918)." Archives of natural history 42(1): 1−9.

Baeten, J., et al. (2014). "*Holy Smoke in medieval funerary rites: chemical fingerprints of frankincense in southern Belgian incense burners."*PloS one 9(11): e113142.

Balfour, I. B. (1888).*Botany of Socotra, R. Grant*.

Banfield, L. M., et al. (2011).*Evolution and biogeography of the flora of the Socotra archipelago (Yemen), Cambridge University Press: Cambridge, UK.*

Basar, S. (2005).*"Phytochemical investigations on Boswellia species*." Hamburg University Istanbul: Turkey.

Bekana, D., et al. (2014). "*Comparative Phytochemical Analyses of Resins of Boswellia Species (B. papyrifera (Del.) Hochst., B. neglecta S. Moore, and B. rivae Engl.)* from Northwestern, Southern, and Southeastern Ethiopia." ISRN Analytical Chemistry 2014.

Ben−Yehoshua, S., et al. (2012). "*1 Frankincense, Myrrh, and Balm of Gilead: Ancient Spices of Southern Arabia and Judea."* Horticultural Reviews 39(chapter 1): 1−76.

Brown, G. and B. Mies (2012). *Vegetation ecology of Socotra, Springer Science & Business Media.*

Buck, R. D. (1972). "*Someapplications of rheology to the treatment of panel paintings*." Studies in conservation 17(1): 1−11.

Choo, T., et al. (2014). "*Nomenclature and typification of the name Crinum balfourii Mast.(Amaryllidaceae).*" Taxon 63(4): 921−922.

Coppen, J. and G. Hone (1995). "*Gum naval stores: turpentine and rosin from pine resin*." Rome: FAO ix, 62p. ISBN 661102253.

d'Acremont, E., et al. (2005). "*Structure and evolution of the eastern Gulf of Aden conjugate margins from seismic reflection data.*" Geophysical Journal International 160(3): 869−890.

da Silva, E. R., et al. (2013). "*Essential oils of Protium spp. samples from Amazonian popular markets: chemical composition, physicochemical parameters and antimicrobial activity.*" Journal of Essential Oil Research 25(3): 171−178.

Damme, K. V. and L. Banfield (2011). "*Past and present human impacts on the biodiversity of Socotra Island (Yemen): implications for future conservation.*" Zoology in the Middle East 54(sup3): 31−88.

De- Nova, J. A., et al. (2012). "*Insights into the historical construction of species‐ rich Mesoamerican seasonally dry tropical forests: the diversification of Bursera (Burseraceae, Sapindales).*" New Phytologist 193(1): 276−287.

De la Cruz−Cañizares, J., et al. (2005). "*Study of Burseraceae resins used in binding media and varnishes from artworks by gas chromatography–mass spectrometry and pyrolysis−gas chromatography–mass spectrometry.*" Journal of chromatography A 1093(1): 177−194.

De Sanctis, M., et al. (2013). "*Classification and distribution patterns of plant communities on Socotra Island, Yemen."* Applied Vegetation Science 16(1): 148−165.

Dekebo, A., et al. (2002). "*Triterpenes from the resin of Boswellianeglecta."* Bulletin of the Chemical Society of Ethiopia 16(1): 87−90.

Eshete, A., et al. (2012). "*Frankincense production is determined by tree size and tapping frequency and intensity."* Forest Ecology and Management 274: 136−142.

Eshete, A., et al. (2005). "*The socio−economic importance and status of populations of Boswelliapapyrifera (Del.) Hochst. in northern Ethiopia: the case of North Gonder Zone*." Forests, Trees and Livelihoods 15(1): 55−74.

Eslamieh, J. (2011). "*Commiphoragileadensis."* Cactus and Succulent Journal 83(5): 206−210.

Eslamiel, J. (2011). "*Cultivation of Boswellia*" Sacred trees of *Frankincense* pp 8−77−79

Felix, R., et al. (2012).*"Annotated checklist of the Carabidae (Coleoptera) of the Socotra Archipelago."* Insect biodiversity of the Socotra Archipelago. ActaEntomologicaMuseiNationalisPragae 52(supplementum 2): 75−106.

Fleitmann, D., et al. (2007). "*Holocene ITCZ and Indian monsoon dynamics recorded in stalagmites from Oman and Yemen (Socotra)."* Quaternary Science Reviews 26(1): 170−188.

Fritz, H. M. and E. A. Okal (2008). "*Socotra Island, Yemen: field survey of the 2004 Indian Ocean tsunami."* Natural Hazards 46(1): 107−117.

Gebrehiwot, K., et al. (2002).*Boswelliapapyrifera (Del.) Hochst: a tropical key species in northern Ethiopia*. Conference on International Agricultural Research for Development. DeutscherTropentag, Kassel−Witzenhausen.

Gebrehiwot, K., et al. (2003). *"Introducing Boswelliapapyrifera (Del.) Hochst and its non−timber forest product, frankincense."* International Forestry Review 5(4): 348−353.

Groom, N. (1981). "*Frankincense and myrrh. A study of the Arabian incense trade*." Longman: London & New York 285: 96−120.

Habrová, H. (2004). "*Geobiocoenological differentiation as a tool for sustainable land−use of Socotra Island."*Ekologia(Bratislava)/Ecology(Bratislava) 23: 47−57.

Hamm, S., et al. (2005). "*A chemical investigation by headspace SPME and GC–MS of volatile and semi−volatile terpenes in various olibanum samples*." Phytochemistry 66(12): 1499−1514.

Hepper, F. N. (1969). "*Arabian and African frankincense trees."* The Journal of Egyptian Archaeology: 66−72.

Huang, H.−C., et al. (2013). "*Two anti−inflammatory steroidal saponins from Dracaena angustifoliaRoxb.*" Molecules 18(8): 8752−8763.

Hughes, M. and A. Miller (2002).*"A new endemic species of Begonia (Begoniaceae) from the Socotra Archipelago."* Edinburgh Journal of Botany 59(02): 273−281.

Jain, S. (1994). "*Ethnobotany and research in medicinal plants in India*." Ethnobot. Search New Drugs 185: 153−168.

Ke, F., et al. (2012). "*Herbal medicine in the treatment of ulcerative colitis."* Saudi journal of gastroenterology: official journal of the Saudi Gastroenterology Association 18(1): 3.

Leminih, M. and D. Teketay (2003). "*Review Article: Frankincense and myrrh resources of Ethiopia: I distribution, production, opportunities for dryland development and research needs."* SINET: Ethiopian Journal of Science 26(1): 63−72.

Lodén, M., et al. (2007). "*Changes in European legislation make it timely to introduce a transparent market surveillance system for cosmetics."*Actadermato−venereologica 87(6): 485−492.

Mahr, D. (2012). "*Commiphora: An Introduction to the Genus: Part 1: Distribution, Taxonomy, and Biology."* Cactus and Succulent Journal 84(3): 140−154.

Mathe, C., et al. (2009). "*THE STUDY OF NABATAEAN ORGANIC RESIDUES FROM MADÂ'IN SÂLIH, ANCIENT HEGRA, BY GAS CHROMATOGRAPHY–MASS SPECTROMETRY**." Archaeometry 51(4): 626−636.

Miller, A. G. and M. Morris (2004).*Ethnoflora of the Soqotra Archipelago, Royal Botanic Garden Edinburgh.*

OCEAN, I. "*BIODIVERSITE DES POISSONS ESTUARIENS DE L'ILE DE SOCOTRA* (NORD−OUEST DE L'OCEAN INDIEN)."

Olson, D. M. and E. Dinerstein (1998). "*The Global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions*." Conservation biology 12(3): 502−515.

Olson, D. M. and E. Dinerstein (2002). "The Global 200: Priority ecoregions for global conservation." Annals of the Missouri Botanical garden: 199−224.

Pswarayi−Riddihough, I. (2002).*Forestry in the Middle East and North Africa*: an implementation review, World Bank Publications.

Raju, A. J. S., et al. (2012)*Entomophily, Ornithophily and Anemochory in the Highly Self−incompatible Boswelliaovalifoliolata Bal. & Henry (Burseraceae), an Endemic and Endangered Medicinal Tree Species*. Series B: Biological Sciences.

Rudiger, A., et al. (2007). "*The chemistry and pharmacology of the South America genus ProtiumBurm, f.(Burseraceae)."*Pharmacognosy Reviews 1(1): 93.

Scholte, P., et al. (2011). "*When conservation precedes development: a case study of the opening up of the Socotra archipelago, Yemen."* Oryx 45(03): 401−410.

Scholte, P. and P. De Geest (2010).*"The climate of Socotra Island (Yemen): a first−time assessment of the timing of the monsoon wind reversal and its influence on precipitation and vegetation patterns."* Journal of Arid Environments 74(11): 1507−1515.

Siani, A. C., et al. (2004).*"Protiumicicariba as a source of volatile essences."* Biochemical systematics and ecology 32(5): 477−489.

Siddiqui, M. (2011).*"Boswelliaserrata, a potential antiinflammatory agent: an overview."* Indian journal of pharmaceutical sciences 73(3): 255.

Stacey, R., et al. (2006).*"CHEMICAL CHARACTERIZATION OF ANCIENT MESOAMERICAN 'COPAL'RESINS: PRELIMINARY RESULTS*."* Archaeometry 48(2): 323−340.

Sultana, A., et al. (2013).*"BoswelliaserrataRoxb. A traditional herb with versatile pharmacological activity: A review*." Int J Pharm Sci Res 4: 2106−2117.

Sunderlin, W. D., et al. (2005). "*Livelihoods, forests, and conservation in developing countries: an overview."* World development 33(9): 1383−1402.

Tadesse, W., et al. (2007). "*Natural gum and resin bearing species of Ethiopia and their potential applications."* Investigaciónagraria. Sistemas y recursosforestales 16(3): 211−221.

Tadesse, W., et al. (2008). "*Especiesproductores de resina y gomasnaturalesenEtiopía y la aplicaciónpotencial de susproductos."* Forest Systems 16(3): 211−221.

Tilahun, M., et al. (2007). "*Economic analysis of closing degraded Boswelliapapyrifera dry forest from human interventions—A study from Tigray, Northern Ethiopia.*" Forest Policy and Economics 9(8): 996−1005.

Tolera, M., et al. (2013).*"Resin secretory structures of Boswelliapapyrifera and implications for frankincense yield."* Annals of Botany 111(1): 61−68.

Van Beek, G. W. (1958).*"Frankincense and myrrh in ancient South Arabia."* Journal of the American Oriental Society: 141−152.

Van Beek, G. W. (1960).*"Frankincense and myrrh."* The Biblical Archaeologist: 70−95.

Van Rampelbergh, M., et al. (2013).*"Mid−to late Holocene Indian Ocean Monsoon variability recorded in four speleothems from Socotra Island, Yemen."* Quaternary Science Reviews 65: 129−142.

Villanueva, M. A., et al. (1993).*"The composition of Manila elemi oil."*Flavour and fragrance journal 8(1): 35−37.

Weeks, A., et al. (2005). *"The phylogenetic history and biogeography of the frankincense and myrrh family (Burseraceae) based on nuclear and chloroplast sequence data."* Molecular Phylogenetics and Evolution 35(1): 85−101.

West, A. P. (1920).*Phillippine Resins, Gums, Seed Oils, and Essential Oils*, РиполКлассик.

Yen, D. E. (1995).*"The development of Sahul agriculture with Australia as bystander."* Antiquity 69(265): 831−847.

Young, D. G., et al. (2012).*Frankincense chewing gum,* Google Patents.

Yunusa, A., et al. (2014). *"Bioactive Compound Determination and Curative Effects of Aqueous Stem Bark Extract of Boswelliapapyrifera (Del.) in Carbon Tetrachloride−Induced Liver Damage in Rats."* ActaBiologicaMalaysiana 3(3): 91−101.

Zhang, Y., et al. (2013).*"Triterpenoid resinous metabolites from the genus Boswellia: pharmacological activities and potential species−identifying properties."* Chemistry Central Journal 7(1): 153.