Sustainable Frankincense Production Systems in Somaliland

A Management Guide

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Introduction

Frankincense, the resin produced by a number of *Boswellia* tree species, has been used by humans for thousands of years as an incense and for medicine. Frankincense was supposedly given as a gift at the birth of Jesus, and has been found in ancient Egyptian tombs—Queen Hatshepsut (1507-1458 BCE) is said to have led an expedition to the ancient Land of Punt, in part to secure more resin. While all species of *Boswellia* produce resin, only a few species are considered to produce resin in both quality and quantity: *B. carterii, B. frereana, B. sacra, B. papyrifera*, and *B. serrata*.

The first two, *Boswellia carterii* and *Boswellia frereana*, are found only in Somaliland and Puntland. While some have held *B. carterii* as synonymous with *B. sacra*, recent studies have shown that the two species have distinct chemical profiles in their resin (Woolley et al. 2012). *B. carterii* and *B. frereana* are considered to produce some of the best quality resin in the world, which is today used in aromatherapy, perfume, cosmetics, and emerging medical applications. Recent studies suggest that compounds in the resin may fight cancer and arthritis (Chen et al. 2013, Ahmed et al. 2015, Khan et al. 2016).

Frankincense is the second largest export in Somaliland, after livestock. Thousands of people and dozens of communities directly rely on the frankincense trade, which generates in excess of $10 million per year. Both demand and resin prices have steadily risen since 2010, as more and more international buyers seek to add the resin or oil to their products.

Unfortunately, this increasing demand has put significant pressure on local harvesters to produce as much resin as possible in order to take advantage of the high prices. Recent analysis of the frankincense growing region revealed high levels of over tapping and improper tapping, as well as the worrying practice of bark stripping. Trees in many areas are stressed and in decline thanks to a combination of drought, over tapping, and pests.

This management guide outlines the basics of the frankincense tree biology and the social systems surrounding it, as well as best practices for harvesting, resin handling, and forest management. It then proposes additional measures that need to be taken to ensure that the frankincense forests remain healthy and that the communities that depend on them can flourish.

1. Boswellia Tree Biology

1.1 Basic Description of the Trees

Both *Boswellia carterii* and *Boswellia frereana* are members of the Burseraceae family, also known as the Incense Tree family, so-called for the aromatic resins these species produce. The genus *Boswellia* contains 20 species, which are spread across the dry paleotropics. *Boswellia* species are found from Cote d'Ivoire to Tanzania, as well as the Arabian Peninsula, Madagascar, and India. Four species of *Boswellia* occur in Somaliland (*B. rivae, B. carterii, B. frereana, B. neglecta*), though only *B. carterii* and *B. frereana* are tapped extensively for resin (Thulin 2006).

Both *B. carterii* and *B. frereana* are small trees, from 1.5 meters up to 8 meters in height. *B. carterii* may be single trunk or multi-trunked near the base, while *B. frereana* is nearly always multi-trunked from very near a characteristically swollen base at the ground. Both trees feature pale brown flaky bark with a deep brownish red inner resinous layer. When wounded, the trees exude an aromatic white-red resin that hardens on contact with air. The trees feature compound leaves with X pairs of leaflets. Each leaflet is 10-30cm long, oblong to oval, generally subglabrous. The leaves of *B. frereana* are distinguished from those of *B. carterii* by a characteristic undulating pattern and a lighter shade of green. Flowers are in small, dense racemes 6-30cm long. In *B. carterii* petals are white with yellow-orange disk. In *B. frereana* petals are reddish to greenish-red, with disk yellowish, greenish, or purplish. Fruits are pear-shaped, in *B. frereana* 6-celled and 5.5-9 x 3-7 mm, in *B. carterii* 3-4 celled and 8-12 x 3.5-9 mm (Thulin 2006).

1.2 Distribution

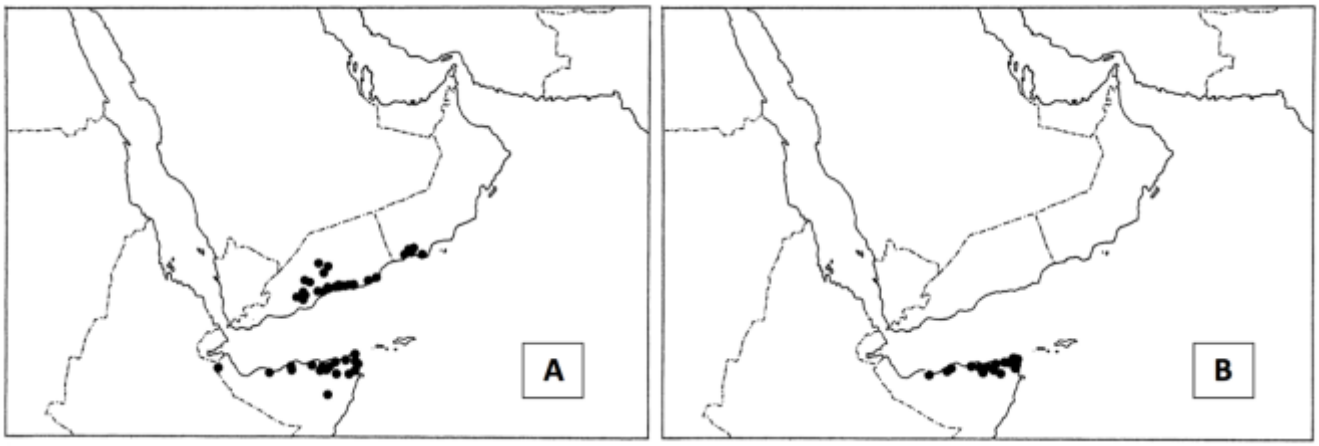

Figure 1. Distribution of *Boswellia carterii* (A) and *Boswellia frereana* (B) based on herbarium specimens, site records, and other reliable reports. Figures from Thulin and Warfa (1987).

Boswellia carterii

B. carterii is found throughout northern Sanaag and Bari regions, primarily centered on the Cal Madow, Cal Miskeet, and Cal Bari mountain ranges, the Cal Madow being the center of the frankincense collection. There is a single record from western Somaliland, but this has not been

confirmed extant. The trees can be found from 5-1500 meters, though their core range is 500-1250 meters. *B. carterii* prefers to grow on exposed rocks primarily of volcanic origin, often on cliffs or boulders. In higher precipitation areas it is more randomly distributed, but in more xeric environments it is often associated with gullies and water drainages. It is typically found in association with *Acacia tortilis*, *A. etbaica, A. melifera, Dracaena ombet*, and *Commiphora*; at higher elevations it may be found near *Buxus hildebrandtii, Dodonea viscosa*, and *Cadia purpurea* (Thulin and Warfa 1987, Thulin 2006).

Figure 2. *B. carterii* (L) and *B. frereana* (R).

Boswellia frereana

B. frereana is found in northern Sanaag and Bari regions, in a smaller, more northerly geographic range than *B. carterii*. It can be found from 5-750 meters, with a core range of 5-500 meters. They prefer to grow on exposed rocks of primarily volcanic origin, often on boulders or cliffs. *B. frereana* shows a clear affinity for gullies and water drainages. It is found in association with species of *Acacia* and *Commiphora*, as well as *Moringa peregrina, Lannea obovata, Boswellia neglecta, Dobera glabra, Cadaba longifolia*, and *Adenium obesum*. At its upper range it may be found mixing with *B. carterii* (Thulin and Warfa 1987, Thulin 2006).

1.3 Flowering and Reproduction

Boswellia phenology in Somaliland is not well understood, but it may commence flowering in April-May with the onset of the rainy season. Pollination ecology has not been studied in either *B. carterii* or *B. frereana*, but both *B. serrata* in India and *B. sacra* in Oman were pollinated primarily by bees and to a lesser extent wasps, flies, ants, and butterflies (Sunnichan et al. 2005, Lippi et al. 2011). The white color of *B. carterii* flowers is consistent with apiphily. However, the reddish coloration of *B. frereana* flowers suggests a possible affinity for butterflies.

Fruiting may occur in August. The lack of fleshy fruit points to anemochorous seed dispersal. No data exist on the seed set or fertility of either species, though congeners boast abundant, fertile seeds (Lemenih and Kassa 2011). High levels of insect attack and overtapping may significantly reduce fecundity (Ogbazghi et al. 2006, Rijkers et al. 2006). Percentage recruitment levels are unknown but likely to be extremely low.

1.4 Natural Causes of Mortality

The most significant cause of natural mortality is a pest called Xare, which burrows into the wood and kills the tree. While not yet taxonomically identified, xare are likely Cerambycid and/or Buprestid beetles (Strumia et al. 2007). Two types of xare are known, one which burrows into the center of the tree and one which primarily attacks the cambium. Drought may also play a significant role, as trees produce less resin, a defense mechanism, in times of water stress (PDRC 2003).

2. Harvesting and Handling Practices

2.1 Factors Associated with Resin Yield

The frankincense trees grow in a range of altitudes and precipitation regimes, and not all produce equivalent yields of resin (Eshete et al. 2012, Al-Aamri 2014, Pers. Comm. with 4 landowners). Trees that experience high levels of rainfall or less water stress produce more resin than trees that are stressed (Pers. Comm. with 4 landowners). Trees at higher altitudes and those that have a northern sun exposure also produce more—these factors could be related to either precipitation, which is positively correlated with altitude and northern aspect, or to temperature (PDRC 2003). Trees at higher altitudes also produce better quality resin (PDRC 2003). Trees that have roots in both rock and soil produce higher yields than trees growing only on rocks (Pers. Comm. with 4 landowners)

Tapping regime also influences resin output, with disruption of the tapping cycle reducing the amount of resin the tree produces (PDRC 2003). Different sources report that 1 year of resting following 2 years of tapping, and limiting tapping to a single season per year, facilitates higher yields (PDRC 2003, Farah 1994, Al-Aamri 2014, Appendix 1, row 13). Resin yield is variable between individuals, and though there is a weak correlation between tree size and resin yield, it is not sufficient for a predictive model (Eshete et al. 2012, Lemenih and Kassa 2011, Al-Aamri 2014, pers. comm. with 4 landowners).

2.2 Harvest Cycle

B. carterii and *B. frereana* are subject to different harvesting cycles.

B. carterii is traditionally harvested from April to September (Farah 1994, PDRC 2003, Appendix 1, row 11). The trees undergo 8-10 tapping cycles, with the first 3-5 cycles producing small yields of low-quality resin (Farah 1994, Appendix 1, row 13 & 14). These initial taps serve to 'prime the cycle', as both yield and quality increase with further tapping. Traditional knowledge suggests that trees should not be tapped for more than 6 months, and 3 months of tapping is ideal (Appendix 1, row 12).

There are two recognized crops: the summer crop (Xagaa), and the autumn crop (Deyreed). Hot weather is thought to be good for *carterii* resin, as it is more easily washed off than *frereana* resin. Consequently, the Xagaa crop is considered to produce high quality *carterii* resin, while the Deyreed produces low quality resin (Farah 1994, pers. comm. with 1 elder). Harvesters should only tap during the Xagaa—tapping during the Deyreed is highly damaging to the trees and can lead to declining tree health and eventually death, as the trees need to be rested following the Xagaa tapping season (Pers. Comm. with 4 landowners).

B. frereana, by contrast, is harvested from August/September to June (Farah 1994, PDRC 2003, Appendix 1, row 11). Trees undergo 8-12 tapping cycles, with the best resin coming in the later cycles. Unlike with *B. carterii*, the Xagaa season produces low quality *frereana* resin, while the Deyreed produces high quality resin (Farah 1994, pers. comm. with 1 elder).

2.3 Tapping Procedures

The frankincense trees grow slowly, and only begin being tapped when they are approximately 40 years old, though some particularly healthy trees in areas of high precipitation may be able to produce resin as young as 15 years old (Appendix 1, row 10). Generally speaking, trees should only be tapped once they are larger than 10cm diameter at breast height (Al-Aamri 2014). Though the trees today, and even in the past, experience numerous taps, traditionally trees would only have 6-10 cuts at a time, on only one or two sides of the main trunk (Appendix 1, row 16). Small trees, being tapped for the first time, should receive no more than 3-4 cuts (Appendix 1, row 16). All wounds should be made in a channel along opposite sides of the trunk only—no cuts should be made on branches or within 150cm of the tree's base (Al-Aamri 2014, Appendix 1, row 18). At lower elevations, the wounds should be made on sides opposite the dominant winds and sun. At higher elevations, wounds should be made on sides facing the winds (Pers. Comm. with 5 harvesters).

Figure 3. A proper first cut, with resin (L) and a well-managed tree (R).

A general rule to prevent overtapping is that the individual cuts should be at least the length of a tapper's forearm and hand apart (Pers. Comm. with 2 elders). The first wound that is made in a tapping cycle should not be larger than 3cm by 4cm, and should only remove the very outer layer of the bark. Each tapping cycle, the cuts are widened and deepened, with a maximum depth of 0.25cm and a maximum size of 6cm by 10cm (Appendix 1, row 17).

Not all trees produce good resin in general, and even trees that generally produce good resin will not produce in some years. When the first cut is made, the harvester should look to see the color of the resin. If it is white and comes out immediately, the tree may be tapped. If the resin does not come out quickly, or the resin is red in color, the tree must be rested (Pers. Comm. with 5 harvesters).

Resin seeps out of the wound and hardens on the surface. Harvesters must wait 15-20 days to harvest the *B. carterii* resin, and 15-30 days to harvest the *B. frereana* resin and re-open the cut for another cycle (Appendix 1, row 13). In *B. frereana*, some resin forms on the wound while the bulk runs down and forms tears. Only the resin on the wound is harvested during each cycle, while the tears are left to be harvested during the final cycle. *B. carterii* resin only forms on the wounds, and is harvested during each cutting cycle. Resin should only be removed when it is no longer sticky (Appendix 1, row 19).

Figure 4. Trees that are being overharvested. There are far too many wounds on these trees.

Putting too many cuts on a tree and failing to rest the trees causes them to decline and die (Pers. Comm. with 1 elder, Appendix 1, row 2), and there are issues with resin quality and tree health if the tree is tapped too early or too late in the traditional cycle (Farah 1994). Furthermore, the practice of "Jaqeyn"—making deep cuts at or near the regular taps—temporarily increases resin yield but results in the rapid decline of the trees (Farah 1994, PDRC 2003). The same is true of burning bark near the taps (Farah 1994).

Harvesters can follow a system of rotational management, where only some of the trees are tapped each year. Trees should be tapped for two consecutive years and then rested for one year. Therefore, in each year, 2/3 of the trees in the farm should be tapped, while 1/3 should be rested. This will ensure a continuous harvest each year, while ensuring the health of the trees.

2.4 Post-Harvest Handling

The resin is typically collected in small baskets, then packaged in plastic sacks and taken by truck to sorting houses where it is cleaned and any bark remaining on the resin is removed. Leaving the resin out in the sun results in partial melting, making cleaning very difficult. Furthermore, the exposure to high heat, storage in unclean or contaminated containers, and transport with petrochemicals can result in significant reductions in valuable volatile essential oils and a consequent drop in market value (Lemenih and Kassa 2011). Therefore, it is critical that once the resin is harvested, harvesters ensure:

- That the resin is kept out of direct sunlight and stored in the coolest locations possible.
- Containers for transporting the resin should be clean and ideally airtight.
- Storage or transport with petrochemicals such as gasoline or diesel, or other oils, salts, etc., should be avoided.

Following these guidelines will help maintain the market value of the frankincense.

2.5 Tapping Best Practices Chart

	B. Carterii (Beeyo)	B. Frereana (Maydi)
Age of First Harvest	First tapping at 15-40 years old Only tap trees greater than 10cm DBH	First tapping at 15-40 years old Only tap trees greater than 10cm DBH
Harvesting Season	April-October (Xagaa) Harvesting outside this season is highly damaging to the trees.	September-June (Deyreed) Harvesting outside this season is highly damaging to the trees.
Resting of Trees	Tap trees for 2 consecutive years, then rest for 1 year Not all trees produce good resin If the milk does not immediately come out when cut, the tree should be rested. If the resin is red, the tree should be rested.	Tap trees for 2 consecutive years, then rest for 1 year Not all trees produce good resin If the milk does not immediately come out when cut, the tree should be rested. If the resin is red, the tree should be rested.
Harvesting Rounds	8-10 cutting cycles maximum First 3-5 cycles produce little resin. High resin production on cycles 6-8. 15-20 day intervals between cutting cycles	8-12 cutting cycles maximum Best resin produced in the later cycles 15-30 day intervals between cutting cycles
Number of Wounds	Trees should receive 3, 6, or 9 cuts depending on size Young trees should not have more than 3 cuts each season The largest, oldest trees should not have more than 10-12 cuts each season	Trees should receive 3, 6, or 9 cuts depending on size Young trees should not have more than 3 cuts each season The largest, oldest trees should not have more than 10-12 cuts each season
Size of Wounds	The first cut should not be bigger than 3cm x 4cm Each cutting cycle makes the wound slightly larger and deeper The final would should not be bigger than 6cm x 10cm and 0.25cm deep	The first cut should not be bigger than 3cm x 4cm Each cutting cycle makes the wound slightly larger and deeper The final would should not be bigger than 6cm x 10cm and 0.25cm deep
Placement of Wounds	Wounds should be made in a channel along opposite sides of the trunk only Wounds should be at least 30cm apart At low elevations, wounds should be made on sides opposite winds and sun.	Wounds should be made in a channel along opposite sides of the trunk only Wounds should be at least 30cm apart

	At high elevations, wounds should be made on sides facing winds.	
Gathering Resin	Resins should be removed at each 15-20 day cutting interval Resins should only be removed when they are no longer sticky Resin should be harvested at each interval	Resins should be removed at each 15-30 day cutting interval Resins should only be removed when they are no longer sticky Resin on the wound should be harvested at each interval, but resin running down to form tears should be harvested on the final cycle

3. Supply Chain and Traditional Regulation

3.1 Current Frankincense Supply Chain

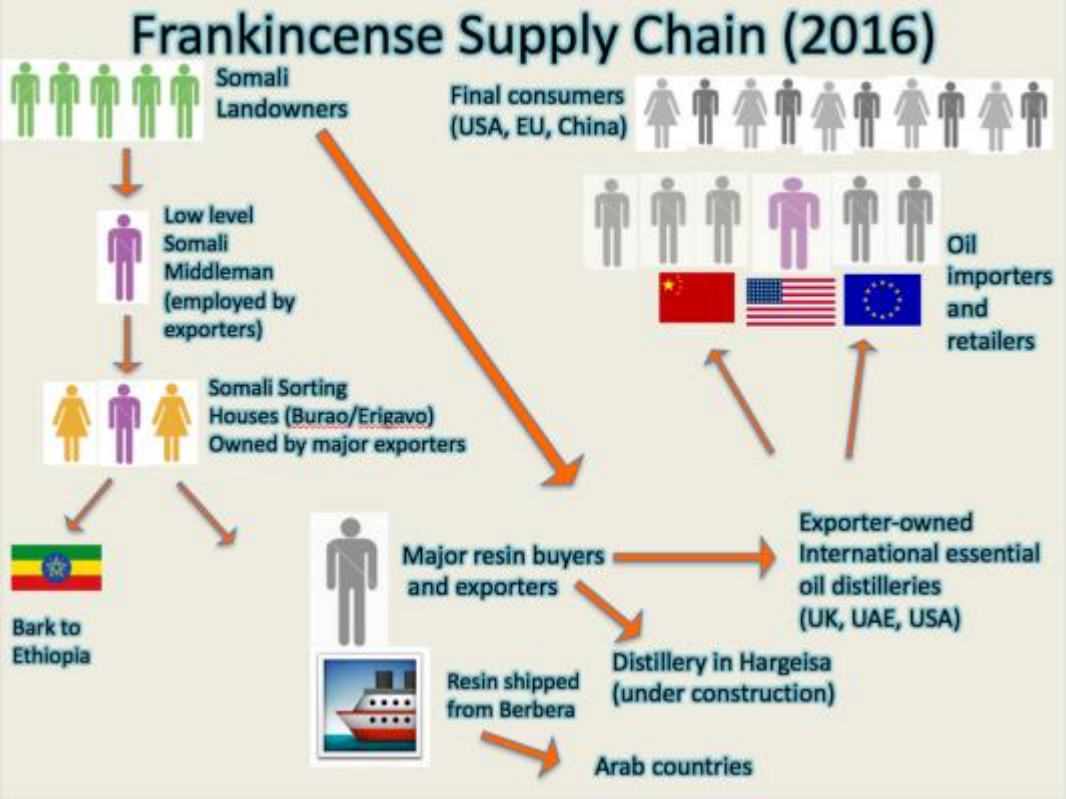

Figure 5. Somaliland frankincense supply chain in 2016.

Somali-owned and international frankincense exporting businesses are major actors that negotiate directly with landowners, control Somali supply for the international market, and significantly influence price and harvesting practices. Consequently, the exporter-landowner relationship is critical to achieving sustainability in the supply chain.

Demand for resin has been increasing over the last few years. Over the last five years, Asli Maydi has become the largest exporting company (based on preliminary analysis of Maersk shipping records). The exporters, including Asli Maydi Ltd., Som Gum Trading Ltd. (Internationally Maydi Frankincense), NeoBotanika, Ismael Imports (Internationally Böswellness) and Luban Aromatics typically purchase resin directly from the landowners via middlemen they employ. A number of these companies also harvest resin from their own private lands. An unknown quantity of resin, potentially up to 30% of the total, comes from Puntland.

Some of the companies clean the resin at sorting houses they own or rent. The majority of this sorting takes place in Burao, though some is done in Erigavo. The resin is then shipped to exporter-owned or partner distilleries in the UK, UAE, USA, and EU where it is distilled into essential oil, a process that adds significant value. In an attempt to benefit the local economy,

NeoBotanika has recently constructed a steam distillery in Hargeisa, though it is not yet operational. Additionally, bark, both sorted from resin and stripped off of trees, is sold to Ethiopia for low-grade incense.

After distillation, oils and other byproducts are largely sold to companies that typically use them in cosmetics, perfumes, medicines, and aromatherapy applications (Figure 5). International demand for essential oils has increased as research and marketing have branded frankincense as the 'King of Essential Oils' (Moussaieff and Mechoulam 2009; Prakash et al. 2014; Carmarda et al. 2007; Banno et al. 2006; DoTerra 2016).

3.2 Land Ownership System

All land in Somalia is owned not by individual people but as the collective property of the clan. Those who control sections of these lands, so-called land-owners, in fact own the resources on the land, as opposed to the land itself. In the context of frankincense, it means that the landowners really own a group of trees in a designated area, rather than the actual land the trees grow on. The trees were originally community-owned until the king allowed harvesters to stake claims to particular sets of trees, at an unspecified date between 1809-1818 (PDRC 2003).

Today, the fields are owned by individuals, who pass them down through to direct male heirs. Females cannot inherit lands, in adherence to Xeer traditional law (see below) but in contradiction to Sharia law. These lands may be worked by the owners or, just as commonly, rented out to harvesters. Rent may be in the form of a set lease payment, or in the form of shareholding, whereby both the owner and harvesters gain a share of the frankincense harvested. Interestingly enough, renting of trees is actually against Sharia law, as the trees are wild rather than cultivated.

3.4 Traditional Xeer Law

Xeer law is the traditional legal system in Somali culture. Not surprisingly, it contains sections dealing with frankincense trees and the harvesting of resin.

As issues arise, a jury of elders will be assembled to rule on the matter according to Xeer. If the issue involved a particular field of frankincense, they are obligated to meet and hold court on the land. Harvesters, landowners, and traders are all obligated to comply with the jury's decisions (PDRC 2003). Below is a summary of key Xeer laws:

- Gaafeysi (Rotating control): If more than one person owns the frankincense field, such as if multiple brothers share ownership, they are obligated to share the production of the field equitably by rotating who is exploiting the field each season.
- Awaaji (Rent contract): The rent contract establishes the agreement between a harvester and the owner of the land. Renters must pay seasonal rent on schedule and must comply with the rules of exploitation. The owner must refrain from renting the field to another collector or breaching the contract without good reason.
- Rules of exploitation:

    - Overtapping: harvesters should not make more cuts than appropriate for the tree's size and condition, and should not tap for more cycles than appropriate in a single harvest season.
    - Jaqeyn: This is the practice of cutting deeply into the tree at the last tapping to extract more resin. While effective in the short term, it leads to the decline and death of the trees. This practice is proscribed by Xeer.
    - Qayo or Tarara'yn: harvesters should not wound the outer protective bark of the trees when scraping the resin from the trees. Doing so opens the trees to attack by xare.
    - Cutting branches: livestock like to eat the leaves of the frankincense, but no one, including harvesters, should cut branches from the trees to feed the livestock. Doing so opens the trees to attack by xare.
    - Gaa'hin: harvesters need to let the B. frereana trees rest one year after every two years of successive harvesting.
- Contract to sell: traditionally, traders will supply harvesters with food and other essentials on credit before the harvest season. The harvester is then obligated to sell the resin to the trader. In the current situation, traders negotiate prices with the harvesters before the season. Xeer would obligate them not to break this contract.
- Aas Hiji: The king or extant ruling authority may, for one reason or another, take a frankincense field away from the owner. This may be done for the king's benefit or to transfer it another party, as was done as part of a Diyah payment by King Osman (1865-1927), transferring a field from the Reer Sha'ib family to the Dir clan.
- Fadhi (Settler's right): If a harvester has been working and living in a field for a long period of time—typically 30+ years—they are afforded certain rights. The owner cannot evict the harvester or raise the rent price, and the harvester's children may harvest the trees after he dies. As long as the field is for rent, the harvester has the right to rent the field. Occasionally this results in the long-time settler refusing to pay rent or challenging the ownership of the land, which is then resolved by the elders.
- Male-only inheritance: Only male heirs may inherit frankincense fields. Women cannot. However, this rule also obligates a male heir to provide financial support from the frankincense income to sisters who may be in need of it. This rule goes against Sharia law, and in 2003 elders, educated people, and religious officials were already denouncing it. Therefore, while the rule still holds, it may be weakening.
- Hadhiino (Rent only): if a woman is the only descendent of a frankincense owner, she may receive the right to receive income from renting the field during her lifetime. When she dies, though, the field passes to the next male relative. Her children, male or female, cannot inherit the field.
- Eviction of harvesters: a landowner can evict a harvester if they do any of the following:
    - Fail to pay seasonal rent.
    - Claim ownership of the land.
    - Overexploit the frankincense trees.
    - Fail to report appropriation of part of the owner's land by usurpers.
    - Or, if the owner genuinely need to exploit the field himself.

4. Additional Practices Necessary for Sustainability

[This is a general overview of extremely important mechanisms and processes for sustainability, each one of these sections could be a whole report in and of themselves. We acknowledge that there is no verification process in place and companies and researchers are now working to develop a verification process which will have its own manual and procedures.]

4.1 Verifiable Supply Chain

Ensuring that frankincense trees are well managed will require both that international buyers demand sustainable resin and that harvesters are compensated for cutting the trees less, by receiving higher prices for their sustainably harvested resin. This will require instituting a sustainable supply chain, where resin can be certified sustainable and verified from the tree to the final consumer. There are international sustainability certification programs, such as Fairwild, that may or may not work in Somaliland for frankincense. A verification process developed for and based in Somaliland, is likely the best option for certifying frankincense.

Harvesters will need to adhere to the best practices for harvesting outlined in Section 2. Harvesters who do so, verified through periodic inspections of their trees, will receive higher prices for their resin. In turn, the exporting companies will clearly mark sacks containing certified resin and ensure that the sustainable resin is sorted and distilled separately. The exporting companies should require that the harvesters adhere to the guidelines, or not buy from them. Realizing that best practices might not be instantaneously implemented and might require one or two harvesting seasons to find application, exporting companies should roll out a plan for incentivizing adoption of best practices. The condition of the trees should be checked periodically to ensure that the resins are indeed sustainably harvested. This will need to be done by a third party verifier.

Internationally, the United Nations Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity seeks to ensure that benefits arising from resources such as frankincense are equitably shared with the producing parties. However, since Somaliland does not have recognition as a country, it is not expected that the protocol would be ratified, but it can be used as a framework guide.

The Nagoya Protocol emphasizes the need to include community compensation. Community asset funds should be established, as was done in Virunga, DRC. Common Asset Funds can be created by putting a percentage of profits from the exporting companies, distilleries, and international formulators/retailers. The funds can then be used for water and sanitation projects, healthcare, education, etc.

The international buyers have a responsibility to take into account how the high demand impacts the primary forest and that only paying a higher price per kilo is not enough to be socially responsible. Given the unique situation in Somaliland where the government does not

have the resources to enforce best management practices, companies must step up to encourage sustainability. Considering the high profits made from the sale of frankincense oil, companies have a vested interest to support the communities through common asset funds and protect the trees by rewarding best practices and disincentivizing overharvesting.

4.2 Reducing Pest Impact

A significant cause of death is the pest Xare. Overharvesting and drought reduce the amount of resin the tree can produce, which limits its ability to defend against the xare. Cutting the tree also offers numerous places for the xare to enter the tree. Limiting the number of cuts in accordance with Section 2 Best Practices will reduce the susceptibility of the trees to xare. Additionally, “tree bandages”, or silicon dioxide paste that hardens and covers to wound to limit water loss and prevent xare from entering the tree may be employed to reduce mortality.

4.3 Implementing Alternative Economic Opportunities

The frankincense forests in Somaliland face a dual challenge of increasing population with a decreasing number of trees. In many communities throughout the growing region, frankincense harvesting is the only, or by far the dominant, industry. Taking pressure off the frankincense trees will require alternative opportunities in the long term.

Incentives may come in the form of reforestation initiatives and payments for ecosystem services, small-scale ecotourism, development of alternative non-timber forest products such as honey, and agricultural production of drought-resistant plants such as aloes, yeheb nuts, and date palms.

Additionally, funds could be made available for microloans for small businesses starting up. This would act both to stimulate the development of alternative economic options and to provide otherwise unemployed youth with meaningful opportunities.

4.4 Forest Protection Unit and Enforcement

Illegal harvesting is consistently reported as being a significant problem. Even if harvesters and landowners treat their trees well and harvest sustainably, high levels of illegal harvesting will continue to threaten the trees. Therefore, a Forest Protection Unit should be implemented and funded by a combination of government and private funds. This unit would patrol the harvesting regions with the use of technology. The unit would need to be empowered by clan and government so that it can enforce controls.

5. Issues for Continued Research

A number of aspects of frankincense ecology, chemistry, and economy require additional research to understand. Further research should focus on:

- Understanding Boswellia phenology, ecological associations, reproductive biology and regeneration.
- Propagation of seedlings and the use of plantations for production.
- The effect of tapping practices on the resin chemical profiles and whether these profiles can be used to monitor sustainability.
- The importance of geologic and edaphic factors for frankincense survival.
- Management of xare and other pests.
- Best ways to implement the Nagoya Protocol and return benefits to the communities.
- Socio-economic drivers of tree health (e.g. economic status, quality of life, remoteness, norms and beliefs, etc.)

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Appendix 1:

	Total Participants: 179		
Row	**Issue**	**Participants**	**Sources**
1	High levels of overharvesting	49	12 (EFE/CF 10/9; GB 10/8; MMH 10/11; GBC 10/12; RQ 10/13; AJC 10/13; BWP 10/15; GE 10/10; BH 9/30, HSH 10/23; BOS 11/2; GBCH 10/12; NBC 10/20; AMW 10/12)
2	Adult trees are dying	38	8 (IJ 10/6; EFE/CF 10/7; GB 10/8; MMH 10/11; RQ 10/13; BWP 10/15; GBC 10/12; GE 10/10)
3	Lack of industry regulation/cooperation causing conflict	49	13 (BH 9/30; EFE/CF 10/9; GB 10/8; MMH 10/11; GBC 10/12; IJ 10/6; BWP 10/15; NBC 10/20; AJC 10/13; AD/A 10/5; HSH 10/23; AMW 10/14; BOS 11/2)
4	Distrust of the World Bank and other NGOs	86	5 (BAM 10/6; MMC 10/11; GBC 10/12; RQ 10/13; AJC 10/13)
5	Distrust of Central (Hargeisa) government	76	6 (BAM 10/6; GBC 10/12; RQ 10/13; MP 10/19; HSH 10/23; AJC 10/13)
6	Feel that companies have abandoned them	25	3 (MMC 10/11; RQ 10/13; AJC 10/13)
7	Communities need projects (Infrastructure, education, clinics, etc.)	52	3 (EFE/CF 10/9; GBC 10/12; RQC 10/13)
8	Dwindling resin output and quality	42	6 (MMC 10/11; MH 10/16; NBC 10/20; GBC 10/12; HSH 10/23; BOS 11/2)
9	Multi-level cooperation necessary to protect trees	26	5 (GBC 10/12; NBC 10/20; BH 10/20; HSH 10/23; AJC 10/13)
	Total Participants: 23		
	Traditional Practices	**Participants**	**Sources**
10	Age of first harvest is 40 years or ~ 10cm	3	3 (Al-Aamri 2014; GE 10/10; MSM 1/27)
11	Tapping cycle is May-Oct for carterii and Sept-May for frereana	9	4 (IJ 10/6; GB 10/8; HSH 10/23; GE 10/10) + Farah 1994; PDRC 2003

12	No more than 6 months of tapping; 3 months is ideal	6	MMS 1/16, MK 1/17, MSM 1/27
13	8-12 tapping cycles for frereana, 8-10 for carterii; 15-30 day intervals	7	PDRC 2003; Farah 1994; MSM 1/27; MK 1/17; HSH 10/23; MK 1/20; Al-Aamri 2014
14	Last cycles yield best resin	3	PDRC 2003; Farah 1994; MSM 1/27
15	Trees must be rested after 2 years of tapping	5	PDRC 2003; Farah 1994; MSM 1/27; GE 10/10; Al-Aamri 2014
16	No more than 10-12 wounds/tree	11	EFE/CF 10/9, GE 10/10, MSM 1/27, Al-Aamri 2014; Eshete et al. 2012
17	Wounds should be small and shallow	9	MMS 1/16, GE 10/10, MSM 1/27, Al-Aamri 2014, Eshete et al 2012, Farah 1994
18	Wounds in a channel on opposite sides of the tree	5	GE 10/10, CF 10/9, Al-Aamri 2014; Eshete et al. 2012, MSM 1/27
19	Gather resin at each cutting interval, when non-sticky	7	PDRC 2003; Farah 1994; MSM 1/27; MK 1/20; HSH 10/23; MK 1/17; Al-Aamri 2014