CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES
OF WILD FAUNA AND FLORA

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BOSWELLIA SPECIES IN INTERNATIONAL TRADE: IDENTIFICATION, SUPPLY CHAINS, & PRACTICAL MANAGEMENT CONSIDERATIONS

1. This information document has been prepared by the Secretariat and is submitted in relation to document CoP19 Doc. 63 on *Boswellia trees (*Boswellia *spp.)*.*

2. An unformatted version of the report “*Boswellia species in international trade: Identification, supply chains & practical management considerations*” commissioned by the Secretariat in support of the implementation of Decision 18.205 and referred to in draft Decision 19.AA in paragraph B of the Secretariat’s comments on document CoP19 Doc. 63 is attached as an Annex to the present information document.

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Report: *Boswellia* species in international trade: Identification, supply chains & practical management considerations

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Boswellia species in international trade: Identification, supply chains, & practical management considerations

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Boswellia species in international trade:

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Chapter 1: Introduction

Authors: A.B. Cunningham, with the exception of Section 1.7, which was written by S. Johnson, A. DeCarlo, J. Brinckmann.

1.0 Overview

Following the 18th meeting (CoP18; Geneva, 2019) where the Conference of the Parties adopted Decisions 18.205 to 18.208 on *Boswellia* species, this report reviews and synthesizes available data on *Boswellia* species in international trade. The genus *Boswellia* (Burseraceae), comprises about 24-25 species. No *Boswellia* species are currently included any CITES Appendices (I, II or III). And the vast majority of oleo-resin production from *Boswellia* species is from wild harvest. Due to the wide variation in governance across *Boswellia* range States and the diversity of factors affecting populations of different *Boswellia* species, a systems approach is essential.

This report assesses *Boswellia* species in international trade frankincense from West Africa (*B. dalzielii,* B. *papyrifera*), the Horn of Africa[1] (*B. carteri*, *B. frereana*, *B. neglecta*, *B. occulta*, *B. papyrifera* and *B. rivae*), the Arabian Peninsula (*B. sacra*) and Asia (*B. serrata*). In this report, *B. carteri* (which occurs in northern Somalia) and *B. sacra* (occurring in Oman and Yemen) are treated as separate species. This perspective is supported by recent chemotaxonomic and genetic studies (Khan et al., 2019; Khan, pers. comm., 2022), and by prior taxonomic (Hepper, 1969)[2] and phytochemical perspectives (Woolley et al., 2012[3]; Schmeich et al., 2019[4]) on *B. carteri* and *B. sacra*. As well as the widespread view of the fragrance industry. But is at odds with the recent taxonomic review of the genus *Boswellia* by (Thulin, 2020)[5].

In the Horn of Africa, the *Burseraceae* (from *Boswellia* and *Commiphora* species) and gum arabic (from *Acacia senegal* and *A. seyal*) are leading non-timber products from dry forests and woodlands. These dry forests and woodlands are also important in terms of carbon sequestration, with *Boswellia* species often a dominant (or even mono-dominant) component. In arid and semi-arid drylands, the economic importance of frankincense to local people's livelihoods should not be glibly dismissed as a "poverty trap". In the East Golis mountains of the Somaliland Autonomous Region of Somalia, 225750 people in the Bari and Sanaag areas earn 55-60% of their income from frankincense, goats and fish. With wealthier households earning 30% more from frankincense than poorer ones (FAO, 2016)[6]. In southern Ethiopia, frankincense harvesting provided the second most important livelihood activity (after livestock) to Borana households, and while the income range across households was wide (4-77%, average 35%), this income was particularly important to poorer households (50% of total cash income) (Berhanu et al., 2021)[7]. Even in mixed farming systems, while net income was highest for sesame, it was intermediate and more consistent for frankincence (and lowest for cotton production (Dejene et. al., 2013)[8]. It is likely that >500000 people earn an income from the

[1] The Horn of Africa region approximates to the region covered by the Intergovernmental Authority for Development (IGAD), with the Member States of Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda (www.igad.int). The focus of this report is on frankincense exporting countries within the Horn of Africa, with additional attention to *B. serrata* and *B. ovalifoliolata* in India.
[2] Hepper, F.N., 1969. Arabian and African frankincense trees. *The Journal of Egyptian Archaeology*, *55*(1): 66-72.
[3] Woolley, C.L., Suhail, M.M., Smith, B.L., Boren, K.E., Taylor, L.C., Schreuder, M.F., Chai, J.K., Casabianca, H., Haq, S., Lin, H.K. and Al-Shahri, A.A., 2012. Chemical differentiation of *Boswellia sacra* and *Boswellia carteri* essential oils by gas chromatography and chiral gas chromatography–mass spectrometry. *Journal of Chromatography A*, *1261*, pp.158-163.
[4] Schmiech, M., Lang, S.J., Werner, K., Rashan, L.J., Syrovets, T. and Simmet, T., 2019. Comparative analysis of pentacyclic triterpenic acid compositions in oleogum resins of different *Boswellia* species and their in vitro cytotoxicity against treatment-resistant human breast cancer cells. *Molecules*, *24*(11), p.2153.
[5] Thulin, M., 2020. The Genus *Boswellia* (Burseraceae): the frankincense trees. Acta Universitatis Upsaliensis.
[6] FAO. 2016. Somalia livelihood profiles. East Golis Frankincense, Goats and Fishing (Zone S007), June 2016. pp. 91-102. Food Security and Nutrition Analysis Unit (FSNAU) and Famine Early Warning Systems Network (FEWSNET)
[7] Berhanu, Y., Vedeld, P., Angassa, A. and Aune, J.B., 2021. The contribution of frankincense to the agro-pastoral household economy and its potential for commercialization-A case from Borana, southern Ethiopia. *Journal of Arid Environments*, *186*, p.104423.
[8] Dejene, T., Lemenih, M. and Bongers, F., 2013. Manage or convert *Boswellia* woodlands? Can frankincense production payoff?. *Journal of arid environments*, *89*: 77-83.

frankincense trade in the Horn of Africa[9]. Similarly in India, thousands of tribal people earn an income from tapping *B. serrata*, with the Government of India expressing concern to CITES (2021)[10] that a CITES Appendix II listing would have a serious impact of people's livelihoods. There are a growing number of businesses that do value-added processing (such as frankincense oil distillation) within Range States (e.g: Burkina Faso, India, Oman and the Somaliland Autonomous Region of Somalia, rather than the export of graded, but otherwise unprocessed frankincense. These initiatives and livelihoods would be jeopardized in both of the world's major frankincense exporting countries (Ethiopia (exporting 3500-7900 tonnes per year) and Somalia (exporting 1400 - 3000 tonnes per year)) if CITES listings triggered *de facto* trade bans. This is due to long-running CITES trade suspensions in Djibouti (CITES Notifications No. 2011/010 and No. 2018/015) and Somalia (No. 2004/055). Trade suspensions would affect land-locked Ethiopia's re-exports of *B. papyrifera* frankincense through the port of Djibouti (which handles 95% of Ethiopia's maritime trade)[11] and Ethiopia's alternative port of Bosaso, in the Somaliland Autonomous Region of Somalia. A trade ban would stimulate stockpiling, increase trade across porous borders and cause a "ripple-effect" demand on other wild populations of boswellic-acid rich *Boswellia* species (*B. dalzielii, B. papyrifera*, *B. serrata* and possibly *B. rivae*). This would impact the livelihoods of people in the Horn of Africa when the region is facing the driest conditions since 1981, with 13 million people facing famine[12]. While at the same time undermining one of the few economic incentives to maintain dry forests and woodlands and manage *Boswellia* populations wisely.

1.1 Characteristics of the genus and of *Boswellia* species

In Africa, the Arabian peninsula and Asia, *Boswellia* species can be a dominant component of seasonally dry forests and woodlands. Including along maritime escarpments in otherwise arid systems, such as the Hawf (Yemen), Dhofar (Oman) and the Cal Madow and Golis mountains (Somaliland Autonomous Region of Somalia) that get moisture from the seasonal monsoon. Even the newly described species *B. occulta*, which has a very restricted distribution (an AOO of <500km^2), is a locally common, dominant tree species where it occurs along west-facing limestone hillslopes (Thulin, 2020)[13]. The same also applies at the centre of *Boswellia* diversity and endemism on Socotra, where *Boswellia* species such as *B. ameero* is locally common dominant on Socotra (Yemen) (Thulin, 2020). Consequently, the biomass per hectare and densities of widely distributed *Boswellia* species such as *B. serrata*, *B. papyrifera* and *B. dalzielii* can be high. In the Shivpuri division, Madhya Pradesh, India, *Boswellia serrata* forms the largest portion (7.943 tonnes/ha) of the total biomass in dry forest (of 34.72 ± 0.41 tonnes/ha) (Bung et al., 2021[14]). *B. papyrifera* also occurs at high densities in the three Range States that have been studied in the major frankincense exporting countries (Ethiopia, Eritrea, Sudan). Much less is known about the *B. papyrifera* populations in seven other Range States (Cameroon, Chad, Central African Republic, Djibouti, Kenya, Nigeria and South Sudan). In Sudan, Abtew et. al., (2011)[15] recorded *B. papyrifera* densities of 81 ± 79 trees/ha and 52 ± 50 trees/ha, while in the Jebel Marra, Khamis (2001)[16] recorded 114 trees/ha. *B. papyrifera* populations studied

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[9]based on c. 200 000 tappers in Ethiopia and >225750 tappers in just two parts of the Somaliland Autonomous Region of Somalia (Bari and Sanaag)[9] with unknown, but significant numbers of commercial tappers in Erirea and Sudan.

[10] CITES. 2021. Addendum to Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Online, 2-4, 21 and 23 June 2021. https://cites.org/sites/default/files/eng/com/pc/25/Documents/E-PC25-25-Add.pdf

[11] https://issafrica.org/iss-today/djibouti-looks-to-ethiopia-to-gauge-its-economic-future

[12] https://www.wfp.org/news/13-million-people-facing-severe-hunger-drought-grips-horn-africa

[13] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.

[14] Bung, S., Rajmohan, S., Bhutia, S., Pandey, H. and Mitra, M., 2021. Estimation of Biomass and Carbon Sequestration by Non-Destructive Method in Dry Deciduous Forest of Shivpuri, Madhya Pradesh, India. In *IOP Conference Series: Earth and Environmental Science* (Vol. 943, No. 1, p. 012020). IOP Publishing.

[15] Abtew, A., Pretzsch, J., Mohamoud, T. & Adam, Y., 2011. *Population structure, density and natural regeneration of Boswellia papyrifera (Del.) Hochst in Dry woodlands of Nuba Mountains, South Kordofan State, Sudan.* Bonn, DITSL GmbH, p. 245.

[16] Khamis, M. A. 2001. Management of *Boswellia papyrifera* stands for resin production in Jebel Marra Area, Western Sudan. present situation and future prospects. MSc thesis, Technische Universität Dresden. Germany

in Sudan by Nour (2002) were even higher (270 trees/ha)[17]. In Ethiopia and Eritrea, *B. papyrifera* densities are in a similar range. With 80-270 trees/ha in Eritrea (Ogbazghi et al. 2006)[18] and 64-225 trees/ha in Ethiopia (Lemenih et al, 2007)[19]. In Burkina Faso, West Africa, the density of adult *B. dalzielii* trees was 82.37 ± 6.57 trees/ha in intact woodlands, 62.00 ± 3.98 trees/ha in fallow systems and 30.02 ± 1.63 trees/ha in farmland (Prospère et al., 2021)[20], making the Burseraceae very important in terms of ecological values, carbon sequestration and as a commercial source of aromatic resins.

1.2 Geographic distribution

The Extent of Occupancy (EOO) and Area of Occupancy (AAO) of most commercially traded *Boswellia* species still needs to be calculated, but estimates are possible based on geographic distribution data. *B. occulta*, which is tapped and internationally traded is endemic to northern Somalia, with an AOO of <500km^2. At the other end of the scale of geographic distribution are *B. serrata* and *B. papyrifera*. *B. serrata* is the most widely distributed of all *Boswellia* species (Thulin, 2020), Occurring across 16 States in India (Dubey, 2021)[21], with an estimated EOO >1.5 million km^2. *B. papyrifera*, is the second most widely distributed species, occurring from Ethiopia to Nigeria (with an esimated EOO of >1.2 million km^2). In Ethiopia, in just three administrative regions there are 1.7 million ha of woodlands where *B. papyrifera* is a dominant species (MAPROW, 2019)[22] and a total of 2.9 million ha of *B. papyrifera* woodlands in Ethiopia (Eshete et al., 2005)[23]. The widely used "seven forms of rarity" matrix developed by Rabinowitz et al. (1986)[24], which takes geographic distribution, habitat specificity and relative population size into account in ranking "commonness or rarity" is a useful way of considering the nine *Boswellia* species in international trade.

1.3 Threats to Boswellia species in context: "non-trade" vs. "trade" factors.

Most of the impacts on *Boswellia* populations (such as conversion of woodlands to farmland, fire, lopping of *Boswellia* trees for fodder and impacts of unmanaged livestock (goats, camels, cattle, sheep) are not directly related to the frankincense trade (Figure 1.1). The future of frankincense depends, however, on <u>all</u> of these factors in being addressed[25]. Including climate change, which clearly is an issue of global concern that has to be tackled at a global scale. In the case of *Boswellia*, the effects of climate change have been modelled for *Boswellia serrata* (Rajpoot et. al., 2020[26]). With *B. neglecta*, for example, Mokria et. al., (2017) showed that rainfall is the primary factor influencing

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[17] Nour, L.A.M. 2002. Production and Productivity of *Boswellia papyrifera* in Jebel Elgarrie area (Blue Nile State). MSc degree, Faculty of Forestry, University of Khartoum.

[18] Ogbazghi W, Bongers F, Rijkere T, Wessel M (2006) Population structure and morphology of the frankincense tree *Boswellia papyrifera* along an altitude gradient in Eritrea. Journal of the Drylands 1(1): 85-94.

[19] Lemeneh M, Feleke S, and Tadesse W (2007) Constraints to small-holder production of frankincense in Metema district, North-western Ethiopia. Journal of Arid Environments (71) 393–403.

[20] Prospère, S.A.B.O., Ouédraogo, A., Gbemavo, D.C., Salako, K.V. and KAKA, R.G., 2021. Land use impacts on Boswellia dalzielii Hutch. an African frankincense tree in Burkina Faso. *BOIS & FORETS DES TROPIQUES*, *349*, pp.53-65.

[21] Estimate given in a questionnaire prepared during a sustainability assessment for PLT Sustainability. Cited with permission from P. Flowerman (pers. comm., 2022)

[22] MAPROW. 2019. Species Data Fact Sheet: Medicinal and Aromatic Plant Resources of the World. Cited in CITES (2020). Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Geneva (Switzerland), 17 and 20-23 July 2020

[23] Eshete, A., Teketay, D. and Hulten, H., 2005. The socio-economic importance and status of populations of *Boswellia papyrifera* (Del.) Hochst. in northern Ethiopia: The case of North Gonder Zone. *Forests, trees and livelihoods*, *15*(1): 55-74.

[24] Rabinowitz, D., Cairns, S. & Dillon, T., 1986. Seven forms of rarity and their frequency in flora of the British Isles. In: M. Soule, ed. Conservation Biology, the Science and Scarcity of Diversity. Sunderland, Massachusetts: Sinauer, p. 182–204.

[25] as pointed out by Germany at the on-line meeting of Twenty-fifth meeting of the Plants Committee 2-4, 21 and 23 June 2021.

[26] Rajpoot, R., Adhikari, D., Verma, S., Saikia, P., Kumar, A., Grant, K.R., Dayanandan, A., Kumar, A., Khare, P.K. and Khan, M.L., 2020. Climate models predict a divergent future for the medicinal tree Boswellia serrata Roxb. in India. *Global Ecology and Conservation*, *23*, p.e01040.

growth. This is a concern for arid zone *Boswellia* species as well (e.g: Attore et al., 2007[27]). The East African–Asian monsoon, for example, is one of the world's main weather systems and is critical to *Boswellia* populations along the maritime escarpments of northern Somalia and the "fog oases" of Dhofar (Oman) and the Hawf region (Yemen). In addition to climate change, there are multiple drivers impacting *Boswellia* populations (both "non-trade" and "trade") that need to be dealt with, ideally through development and implementation of appropriate management plans by Range States. In many cases, local community involvement is essential for management plan implementation (see Recommendation 5). Focusing solely on the frankincense trade will not solve the problem. Particularly if *de facto* trade bans resulting from CITES trade suspensions in Djibouti and Somalia undermine one of the few economic incentives to maintain dry forests and woodlands and manage *Boswellia* populations wisely.

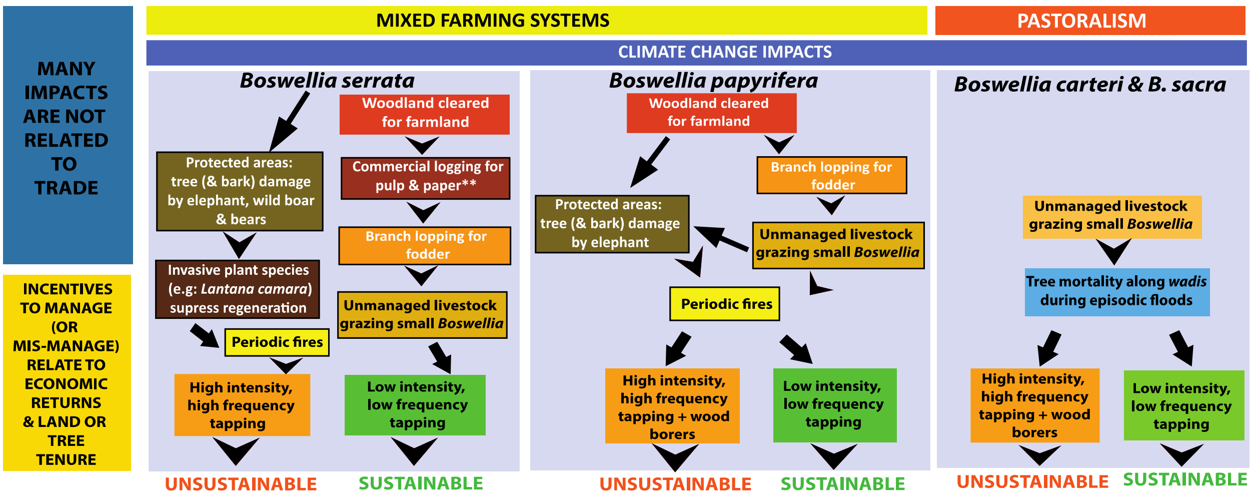

Figure 1.1. A systems approach is essential. Both the obvious impacts (such as conversion of dry forests and woodlands to farm-land) and "cryptic" effects of *Boswellia* populations vary with bio-climatic conditions and land-uses as well as according to social, cultural and economic factors. The climate change and the impacts of unmanaged livestock on *Boswellia* populations apply across all land-use types; even elephant impacts apply to many Burseraceae in protected areas in both Africa and Asia. In contrast, large scale commercial logging applied only to the largest species (*B. serrata*) in Madyha Pradesh, c.20 000 tonnes of *B. serrata* was felled annually for over 40 years to supply a major pulp and paper mill (from c. 1947-1996).

1.4 Habitat Conservation

Boswellia species are recorded from conservation areas in Africa, the Arabian peninsula and India. *B. papyrifera* is recorded from Kidepo National Park, Uganda and the Awash and Gibe Sheleko National Parks, Ethiopia and probably several other national parks across the wide geographic range of this species. In Kenya, *B. neglecta* is recorded from Kora National Park (1788 km2), Meru National Park, Kenya (870 km2) and Tsavo East National Park (13747 km2). While *B. carteri* occurs within the Daallo (or Daloh) Forest Reserve in the Cal Madow (or Al Mado) range north of Erigavo (Thulin, 2020)[28]. In India, *B. serrata* occurs in many forest reserves, sanctuaries andnational parks. Including the Biligiri Rangaswamy Temple Tiger Reserve (BRT), Cauvery Wildlife Sanctuary (1097 km^2) (Soumya

[27] Attorre, F., Francesconi, F., Taleb, N., Scholte, P., Saed, A., Alfo, M. and Bruno, F., 2007. Will dragonblood survive the next period of climate change? Current and future potential distribution of *Dracaena cinnabari* (Socotra, Yemen). *Biological conservation*, *138*(3-4), pp.430-439.

[28] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.

et al., 2019a)[29], Gir Lion Sanctuary and National Park, Madhav National Park (Ravan and Roy, 1995)[30], Malai Mahadeshwara Tiger Reserve (Soumya et al., 2019a)[31], Nawegaon National Park (Malhotra and Rao., 1980)[32], Panna National Park (Porwal and Singh., 2009)[33] and the Sariska National Park (Tiwari et al, 1990)[34]. In Oman, both wild and planted populations of *B. sacra* occur within a UNESCO World Heritage Site (the Wadi Dowkah Frankincense Park)[35], with large populations in the 4500km^2 Jabal Samhan Nature Reserve (Farah, 2008). In 2000, however, there were only 43 harvesters extracting frankincense inside Jabal Samhan Nature Reserve (Farah, 2008). Compared to about 2000 in the 1970's (Farah, 1994), before the nature reserve was proclaimed and before a general decline in *B. sacra* tapping due to other income earning opportunities.

For some *Boswellia* populations, however, being inside a protected area does not necessarily mean being protected or that threats are managed. In Gibe Sheleko National Park, most (71%) of people used the national park for grazing livestock, with 48% collecting firewood within a park also affected by agricultural expansion, new villages, bushmeat hunting and invasive species (Kiros and Bekele, 2021)[36]. Unmanaged invasive species (i.e: *Lantana camara*) are considered a more serious threat to *B. serrata* populations than oleo-resin harvests threat in conservation areas in Tamil Nadu, India (Soumya et al., 2019a)[37]. Debarking of *Boswellia* trees by wild herbivores is also an issue in many protected areas. In Gir Lion Sanctuary and National Park (Gujarat, India), debarking of *B. serrata* trees by sambar deer killed 2.8% of the *B. serrata* population during a drought (Khan et al., 1994)[38]. And the impacts of high elephant populations on both *Boswellia* populations are well documented in both Africa and Asia. In the Mudumalai Wildlife Sanctuary (Nilgiri Hills, India), elephants eliminated *Boswellia serrata*, with the exception of remnant *B. serrata* populations on inaccessible hilly areas (Sivaganesan & Sathyanarayana 1995[39], cited in Manakadan et al., 2010[40]), and currently debark *B. serrata* (Soumya et al., 2019b)[41] in three protected areas in the western Ghats. Similarly in Kenya, Tsavo East National Park, populations of *Boswellia neglecta* disappeared from monitored plots, with other Burseraceae (*Commiphora* species also severely impacted (Laws, 1970[42]; Leuthold, 1977[43]; van Wijngaarden, 1985[44])). Under these circumstances, incentive-based conservation of *Boswellia* populations outside protected areas is important, where well-designed community-based

[29] Soumya, K.V., Shackleton, C.M. and Setty, S.R., 2019. Impacts of gum-resin harvest and Lantana camara invasion on the population structure and dynamics of Boswellia serrata in the Western Ghats, India. *Forest Ecology and Management*, *453*, p.117618.
[30] Ravan, S.A. and Roy, P.S., 1995. Landscape ecological analysis of a disturbance gradient using geographic information system in the Madhav National Park, Madhya Pradesh. *Current Science*, pp.309-315.
[31] Soumya, K.V., Shackleton, C.M. and Setty, S.R., 2019. Impacts of gum-resin harvest and Lantana camara invasion on the population structure and dynamics of Boswellia serrata in the Western Ghats, India. *Forest Ecology and Management*, *453*, p.117618.
[32] Malhotra, S.K. and Rao, K.M., 1980. The Vegetation of Nawegaon National Park and its Environs (Maharashtra). *Nelumbo-The Bulletin of the Botanical Survey of India*, *22*(1-4), pp.1-11.
[33] Porwal, G. and Singh, S., 2009. Geo-spatial approach for phytodiversity characterization in Panna National Park (part), MP (India). *Journal of the Indian Society of Remote Sensing*, *37*(1), pp.51-67.
[34] Tiwari, A.K., Kudrat, M. and Bhan, S.K., 1990. Vegetation cover classification in Sariska National Park and surroundings. *Journal of the Indian Society of Remote Sensing*, *18*(3), pp.43-51.
[35] see http://whc.unesco.org/en/list/1010
[36] Kiros, S. and Bekele, A., 2021. Assessment of conservation challenges in and around Gibe Sheleko National Park, southwestern Ethiopia. *Global Ecology and Conservation*, *32*, p.e01912.
[37] Soumya, K.V., Shackleton, C.M. and Setty, S.R., 2019a. Impacts of gum-resin harvest and Lantana camara invasion on the population structure and dynamics of *Boswellia serrata* in the Western Ghats, India. *Forest Ecology and Management*, *453*, 117618.
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[39] Sivaganesan, N. & Sathyanarayana, M.C. (1995) Tree mortality caused by elephants in Mudumalai Wildlife Sanctuary, Tamil Nadu, south India. In: A Week with Elephants. Daniel, J.C. & Datye, H. (eds.) Bombay Nat. Hist. Society. pp 314-330.
[40] Manakadan, R., Swaminathan, S., Daniel, J.C. and Desai, A.A., 2010. A Case History of Colonization in the Asian Elephant: Koundinya Wildlife Sanctuary (Andhra Pradesh, India). *Gajah*, *33*(01): 17-25.
[41] Soumya, K.V., M Shackleton, C. and R Setty, S., 2019b. Harvesting and Local Knowledge of a Cultural Non-Timber Forest Product (NTFP): Gum-Resin from *Boswellia serrata* Roxb. in Three Protected Areas of the Western Ghats, India. *Forests*, *10*(10), p.907.
[42] Laws, R.M., 1970. Elephants as agents of habitat and landscape change in East Africa. Oikos 21: 1–15
[43] Leuthold, W., 1977. Changes in tree populations of Tsavo East National Park, Kenya. East African Wildlife Journal 15: 61–69.
[44] Van Wijngaarden, W., 1985. Elephants–trees–grass–grazers. Relationships between climate, soils, vegetation and large herbivores in a semi-arid savanna ecosystem (Tsavo, Kenya). ITC Publication Number 4. Ph.D. thesis, Wageningen University, Wageningen.

management and monitoring plans involving customary land owners and resource users can play a role.

1.5 Status and trends

The nine *Boswellia* species in international trade are listed below in order of their increasing IUCN Red List conservation status at a global level. *B. pirottae* (an Ethiopian endemic) and *B. ovalifoliolata* (endemic to Andra Pradesh, India, with an AOO of 2000 km^2) are not included, as they are (yet) recorded in international trade. However, they are already vulnerable due to effects on their habitat. Dam construction in the case of *B. pirottae* (Vulnerable C1) (Awas et al., 2021)[45]. And habitat loss, fire and oleo-resin tapping (presumably for the domestic market) (Saha et al., 2015) in the case of *B. ovalifoliolata* (Vulnerable (A2cd; B1ab(i,ii,iii)), with a 30% population decline over the entire range of *B. ovalifoliolata* (in Andra Pradesh) in three generations (75 yrs).

Boswellia serrata: Least Concern (Joshi and Shringi, 2104[46]; Thulin, 2020)[47]. Widespread in India. The main concerns are habitat loss through clearing *B. serrata* woodlands for farming, poor recruitment of young *B. serrata* trees into the population due to grazing and browsing by livestock. Mass felling of mature *B. serrata* trees in the 1970's for pulpwood production also had a long-term impact.

Boswellia dalzielii: Least Concern at this stage: *B. dalzielii* is the only *Boswellia* species restricted to West Africa and occurs in 9 Range States (Benin, Burkina Faso, Cameroon, Chad, Ghana, Mali, Niger, Nigeria, Togo) (Thulin, 2020)[48]. The conservation status of this species may change if current debarking for local medicinal plants markets is compounded by a rapid increase in tapping if CITES Appendix II listings trigger trade suspensions in Ethiopia and Somalia. This would create a shortfall of boswellic acid rich oleo-resins and a possible "ripple effect" on *B. dalzielii* populations.

Boswellia neglecta: Least Concern (Thulin, 2020). Commercial collection of oleo-resins is not an issue of concern. Unlike the *Boswellia* species listed above, tapping does not normally take place. Instead, oleoresins are collected after Buprestid and Cerambycid beetles bore into the bark and wood. In addition, Bongers et. al.'s (2019)[49] concern about fuelwood collection is overstated as there is an abundance of a much more favoured and more easily accessible fuelwood (from *Vachellia tortilis*) in the area (H. Sommerlatte, pers. comm., 2022).

Boswellia rivae: Least Concern (Alemu et al., 2021)[50] and Thulin (2020). Resin production by local people is sustainable and does not kill the tree but with increased demand it is not known how this species will be affected by trade. Future threats could be: (i) unsustainable harvesting of resin using non-traditional methods; (ii) increased commercial demand. Either as a niche marketed frankincense oil in Europe (e.g: by Hermitage Oils)[51] and companies in the USA (e.g: Nomadic)[52] or as an additive to blends used by large companies in the USA (e.g: doTERRA).

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[45] Awas, T., Birhanu Belay, Sebsebe Demissew, Sileshi Nemomissa, Efrata Mekbib, Atnafu, H., Alemu, S. & Alemu, S. 2021. *Boswellia pirottae* (amended version of 2018 assessment). *The IUCN Red List of Threatened Species* 2021: e.T34394A208225865. https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T34394A208225865.en. Accessed on 25 May 2022.
[46] Joshi, S. & Shringi, S., 2014. Floristic Diversity with Special Reference to Rare and Threatened Plants of Jawahar Sagar Sanctuary Area near Kota Rajasthan. *Biological Forum – An International Journal,* 6(1), pp. 84-91
[47] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.
[48] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.
[49] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.
[50] Alemu, S., Alemu, S., Atnafu, H., Awas, T., Bahdon, J., Birhanu Belay, Sebsebe Demissew, Luke, W.R.Q., Efrata Mekbib, Musili, P. & Sileshi Nemomissa. 2021. *Boswellia rivae* (amended version of 2018 assessment). *The IUCN Red List of Threatened Species* 2021: e.T128044164A208229310. https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T128044164A208229310.en. Accessed on 12 January 2022.
[51] see https://hermitageoils.com/product/frankincense-rivae-essential-oil/
[52] https://frankincense.us/

Boswellia sacra: Lower risk/Near Threatened (Thulin, 1998)[53] and re-assessed as Vulnerable (A2cd) across the entire range (including *B. carteri*) (Thulin, 2020). In Oman, Patzelt (2014)[54] considered *B. sacra* as "Near Threatened" downgrading Ghazanfar's (1998)[55] assessment of Vulnerable (A,1+cd) for Oman. The major issue in Oman is not tapping. It is intensive, frequent browsing by camels. This includes camels eating the bark from *B. sacra* trees, particularly during January – April in landscapes where no other fodder is available.

Boswellia carteri: Uncertain and needs evaluation as *B. carteri* was not treated as a separate species by Thulin (1998, 2020). There is limited field data on which to base a threat category, which may be Lower risk, Near Threatened or Vulnerable. Traditional tapping methods, when done correctly, minimise impacts on *B. carteri* trees. Under customary law (*xeer)*, livestock are kept away from tapping areas. In addition, due to steep terrain, many *B. carteri* populations are less accessible to livestock. But demand is high, particularly from large companies in the USA. High intensity, high frequency tapping was documented during rapid surveys in important production areas near Erigaavo (DeCarlo et al., 2016[56]; 2017[57]). In contrast, drone footage taken in for the Swiss frankincense importer Firmenich shows large, apparently healthy *B. carteri* populations in the Golis mountains[58].

Boswellia papyrifera: Not previously on the IUCN Red List, this species has a preliminary listing as Vulnerable (A2cd + 3cd) by Thulin (2020) following Bongers et al. (2019)[59] paper. This is controversial. While *B. papyrifera* is the best studied *Boswellia* species, facing multiple threats (habitat loss, branch lopping for fodder, grazing/browsing and in some cases, high intensity and high frequency tapping), the Vulnerable (A2cd + 3cd) status extrapolates a dire situation in Ethiopia (with studies of some populations in Eritrea and Sudan) to all 10 Range States. Which may reflect the "worst case" situation in Ethiopia. Due to a combination, policy factors in the past (1974 – 1991) that affected customary tenure, a "worst case" bias due to study plots relatively close to roads (van Wyk, B-E., pers. comm., 2022), in a country with Africa's largest livestock population, which increased from 54.5 million livestock in 1995 to over 103.5 million in 2013, with average annual increase of 3.4 million (Leta and Mesele, 2014)[60], and where livestock are herded to markets also located near roads.

Boswellia frereana: Vulnerable (C1) (Thulin, 2020). Endemic to northern Somalia. Thulin's (2020)[61] assessment was based on a *B. frereana* population estimate of "fewer than 10000 trees", with an expected population decline of 10% over three generations. Based on field observation, S. Johnson (pers. comm., 2021) considers that the *B. frereana* population very much larger than Thulin (2020) suggests. The trade data also suggest a far larger population, as resin production per tree rarely exceeds 0.5-1kg per tree in other *Boswellia* species studied. The main concern is the growth in the frankincense market, which is unregulated (high intensity and high frequency tapping (DeCarlo et al., 2020)[62].

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[53] Thulin, M. 1998. *Boswellia sacra*. *The IUCN Red List of Threatened Species* 1998:e.T34533A9874201. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T34533A9874201.en. Accessed on 12 January 2022.
[54] Patzelt, A. 2014. *Oman Plant Red Data Book*. Diwan of Royal Court, Oman Botanic Garden.
[55] Ghazanfar S. A. 1998. Status of the flora and plant conservation in the sultanate of Oman. *Biological Conservation* 85: 287–295.
[56] DeCarlo, A., Elmi, A.D., and Johnson, S. 2016. Frankincense in Peril: Analysis of the Resin Economy in Somaliland. Publication of A. DeCarlo, Vermont, USA.
[57] DeCarlo, A., Elmi, A.D., and Johnson, S. 2017. Somaliland's frankincense trade: challenges, choices and sustainability. Publication of A. DeCarlo, Vermont, USA.
[58] Firmenich. Ch. 15. Frankincense. https://www.youtube.com/watch?v=_dygsqQrKK8
[59] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.
[60] Leta, S. and Mesele, F., 2014. Spatial analysis of cattle and shoat population in Ethiopia: growth trend, distribution and market access. *SpringerPlus*, *3*(1), pp.1-10.
[61] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis
[62] DeCarlo, A., Ali, S. and Ceroni, M., 2020. Ecological and economic sustainability of non-timber forest products in post-conflict recovery: A case study of the Frankincense (*Boswellia* spp.) Resin Harvesting in Somaliland (Somalia). *Sustainability*, *12*(9), p.3578.

Boswellia occulta: Endangered (B2a) (Thulin, 2020). The Endangered status of this species is due to its small area of occupancy (<500 km^2) in possibly less than five locations. Qualifying this species for CITES App. II listing, as unregulated harvest (high intensity and high frequency tapping) could become a concern for the restricted range species. However, cessation of economic incentives that occur through trade might generate worse outcomes (Dhunkal, A. pers. comm. to S. Johnson, 2019).

1.6 Domestic and international trade

In addition to a significant domestic trade in frankincense in range States like Ethiopia and Oman, there is a lucrative international trade. Major importers are China, the USA and Europe (particularly to Bulgaria, Germany, Switzerland, Spain, France and the UK). The UAE is an important trans-shipment point and a location for value-added distillation. Supply chains are complex, with significant differences in the final product markets. In China, *Boswellia* oleo-resins are used for incense and as an ingredient in Chinese traditional medicine (*ru xiang*). In Europe and North America, demand is from the fragrance market (for essential oils and aromatherapy), cosmetics, and for boswellic acids. The significance of the frankincense fragrance market is illustrated by the fact that the "top 8" companies have a combined annual revenue of c. US$21 billion per year (for all products, not just frankincense)[63]. Large enterprises range from relatively new companies in the USA (such as dōTERRA (established in 2008) and Young Living (established in 1993) to long established European companies established over 126 years ago (such as the Swiss companies Givaudan and Firmenich (both established in 1895). The large new companies in Salt Lake City, Utah, USA using very large quantities of *Boswellia* oleo-resins. In a public address in 2021, David Stirling (dōTERRA, Founding Executive CEO) stated that the company uses 5 tonnes of frankincense oil per year[64]. To produce this would require equivalent to ca. 800-1000 tonnes of frankincense/year).

In Europe, large gum and resin import-export traders in Hamburg have historically played a role in the *B. carteri* and *B. sacra* trade. However, there have been significant recent changes in trade routes due to distillation units set up in Bulgaria, Oman, Spain, and the UAE, and due to companies based in Utah, United States (such as dōTERRA and Young Living Essential Oils). For example, exports from the Somaliland Autonomous Region of Somalia to Bulgaria have increased rapidly since 2017, with value-added distillation of frankincense oils in Bulgaria for export to the USA. Important frankincense oleo-resin suppliers in the Somaliland Autonomous Region of Somalia include Asli Maydi Exports and Imports Company, Kobac General Trading, and NeoBotanika. The main frankincense oil production is by Esseterre Bulgaria EOOD (Dobrich, Bulgaria), which is owned by the American company dōTERRA (Pleasant Grove, Utah) using *B. carteri*, *B. frereana*, and *B. papyrifera* oleo-resins. There is also major production in Seville, Spain (by Young Living), United Kingdom and France. This change is evident from trade data, showing that Bulgaria has become the largest importer of HS 130190 frankincense from Somalia. In 2019, Bulgaria imported 1,395.37 MT of HS 130190 gums and resins, of which 1,020.48 MT (73.1%) were exported from Somalia and 135 MT (9.7%) from Ethiopia. In 2020, Bulgaria imported 804.06 MT of HS 130190, of which 649.56 MT (80.1%) were from Somalia and 90 MT (11.2%) were exported from Djibouti. This drop is likely related to COVID-1-based disruptions.

1.7 Identifying *Boswellia* species in trade: avoiding the "look-alike" problem

There is detailed evidence showing that is it possible to identify products (oleo-resins and essential oils) from individual *Boswellia* species through chemical markers and characteristic compositions.

[63] This total (US$21 billion per year) includes the reported annual income of International Flavors & Fragrances (IFF), a US company formed in 1958, which in 2020 had annual revenue of $5.1 billion), but not of Takasago International Corporation (Japan). Annex 6 excludes both of these companies, as less is known about their Boswellia supply chains.
[64] David Stirling: The Miracle of Frankincense. https://www.youtube.com/watch?v=-B9P0NYkXYM

Boswellic acids are key genus markers, present in all *Boswellia* species except *B. frereana (*lupeol*, 3-epi*-lupeol*)*. *Boswellia papyrifera*, *B. occulta*, and *B. serrata* are also readily identifiable, with unique marker compounds in their volatile compositions. *Boswellia papyrifera* can be identified by the high level of octyl acetate and incensole acetate, *B. occulta* by the presence of methoxyalkanes, and *B. serrata* by the presence of methyl chavicol and/or methyl eugenol with α-thujene. Other species are more similar, often with volatile profiles dominated by α-pinene, and there is occasional overlap in the compositions of the resins and essential oils. However, species can still be reliably identified by unique combinations of the dominant volatile constituents, mixture of which boswellic acids are most abundant, and which monoterpene enantiomers are most abundant. Various technologies have been used to determine the compositions of frankincense products, including gas chromatography-mass spectrometry (GC-MS), chiral GC-MS, high pressure liquid chromatography (HPLC), thin-layer chromatography (TLC), and direct analysis in real time (time of flight) mass spectrometry (DART-TOFMS). Of these techniques, HPLC, GC-MS, and chiral GC-MS are most useful to analyze both volatile and non-volatile components. There are some look alike genera that contain species that produce resins similar to frankincense; there is not enough research to know all possible species that may be look alikes, but most can be identified by the lack of boswellic acids or by differences in the volatile and non-volatile profiles.

1.7.1 Identification in practice

This report suggests practical steps that can be taken and their relative costs. For example, a sample set of frankincense resins and essential oils can be used for first-pass organoleptic testing to help identify shipments for further testing. This will cost around US$250 annually per lab. GC-MS and HPLC testing are the best detailed testing options. HPLC can identify the presence of boswellic acids or other heavy components like lupeol, to determine if a sample contains frankincense and to give an indication of the species. A new HPLC unit will cost around US$40,000 to US$50,000 with a sample cost of US$2-$5 per sample and modest ancillary costs. A GC-MS unit can be used to positively identify species from either resins or essential oils. A unit will cost approximately US$30,000 to US$65,000, with a sample cost of US$2.50 to US$3.00 for essential oils and US$4.00 to US$5.00 for resins, with modest ancillary costs. A chiral column can be used for further aid in identifying individual species. Thin-Layer Chromatography is not recommended as it does not offer high enough resolution. DART-TOFMS may be an option, but costs of this new technology are uncertain and it is currently not widely deployed.

1.8 Artificial propagation

While propagation is technically possibly in nurseries, whether from seed or vegetatively from cuttings (DeCarlo, 2021[65]), long-term survival and successful plantation production is an entirely different situation. With local community support, enrichment planting using cuttings from local genetic stock would be possible, if young plants are protected from livestock in what are confusingly called "farms" or "plantations" in Somalia (e.g: FAO, 2016)[66]. When "farms" and "plantations" are in fact managed wild populations under the customary tenure of clans and sub-clans. Plantation research trials are certainly possible where government agencies have tenure over the land and where the economic costs of fencing (to keep out livestock) and water for the trees are subsidized. In the 1970's in Sudan, for example, a 10 hectare[67] *Boswellia papyrifera* plantation trial was

[65] DeCarlo, A. 2021. Propagation of Boswellia In Situ. 1st Edition. Save Frankincense, Somaliland/United States. www.savefrankincese.org

[66] FAO. 2016. Somalia livelihood profiles. East Golis Frankincense, Goats and Fishing (Zone S007), June 2016. pp. 91-102. Food Security and Nutrition Analysis Unit (FSNAU) and Famine Early Warning Systems Network (FEWSNET)

[67] Based on the area of 24 *feddans* given in Nour (2002). A *feddan* (فدّان) is an area unit used in Egypt, Oman, Sudan and Syria (equivalent to 0.42 hectares).

implemented at a government research station (Nour, 2002)[68]. More recently, in 1998, a *B. sacra* plantation research trial was established Oman by the Ministry of Fisheries and Agriculture. And at the World Heritage Site at Wadi Dowkah in Oman, *B. sacra* are cultivated in a fenced and watered area using seedlings from a nursery established in 1990. *Boswellia* cultivation also occurs on relatively small scales in Djibouti, Israel and Yemen and the USA (Canney-Davison et. al., 2022[69]; Eslamieh, 2011[70]; Thulin & Warfa, 1987). In both Ethiopia and Somalia, private individuals, many of them expatriate entrepreneurs investing back in their home countries, have established cultivation trials. But scaling-up plantations to provide commercially viable quantities of frankincense will be hugely challenging in arid and semi-arid Range States. It may stimulate potential conflicts over water and land, with cultural perspectives on ownership of the cuttings taken from clan land an additional complexity. Conflicts over land and water could increase with greater drought frequencies. A shift to cultivation of *Boswellia* species and a move away from the wild harvest that currently provides the bulk of the world's frankincense thus carries many risks. Including drawing attention away from what is needed the most: management and implementation to deal with the diverse factors that threaten wild *Boswellia* populations.

[68] Nour, L.A.M. 2002. Production and Productivity of *Boswellia papyrifera* in Jebel Elgarrie area (Blue Nile State). MSc degree, Faculty of Forestry, University of Khartoum.
[69] Canney Davison, S., Bongers, F and Phillips, D. 2022. The future of frankincense: understanding the plant's diversity is a key to its conservation. Herbalgram 133: 40-59.
[70] Eslamieh, J. 2011. Cultivation of *Boswellia*: Sacred trees of Frankincense. A-Z Books, Phoenix.

Chapter 2: Recommendations

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"[The sustainable use]…. concept is at the core of CITES, which falls in the nexus between trade, conservation, and development. Its mandate spans from conserving biodiversity, to building opportunities for resilient and sustainable livelihoods and economic opportunities for communities who most closely rely on nature" (Higuero, 2021)[1].

2.1 Background context to recommendations

The recent focus by the CITES Secretariat on the genus *Boswellia* and trade in oleo-resins from *Boswellia* species[2], backed up by the synthesis of 25 years study on *Boswellia papyrifera* (Bongers et al., 2019) was a positive development in that it stimulated input from range States, frankincense companies[3] and the Global Frankincense Alliance (GFA), which organised an on-line survey on key steps for frankincense sustainable use and conservation and held a three-day workshop (15-18 March 2021) to develop a "road map" on a way forward (Appendix 4)). This report builds on comments to the CITES Secretariat from Range States and the frankincense industry (CITES, 2021) and builds on the recommendations made by Bongers et. al., (2019) and others (e.g: Al Aamri, 2014[4]; DeCarlo and Ali, 2014[5]; DeCarlo et. al., 2017[6]; GFA., 2021 (Appendix 4). It is important that the CITES Secretariat does not let the frankincense trade "drop off the radar screen". Instead, the Secretariat should recognize that an opportunity exists to create positive outcomes for *Boswellia* conservation by following the recommendations made below, with careful attention to three factors:

Firstly, listing decisions should carefully consider all possible consequences of a listing—both positive and negative—in order to ensure that the listing ultimately has the desired conservation effect. This is highly relevant to the weak governance situation in several *Boswellia* Range States. CITES Appendix II listing of *Boswellia* or species within the genus will trigger cessation of frankincense exports from Somalia and possibly Ethiopia. It will likely also incentivize and enhance "invisible" (and in some cases, illegal) cross-border trade, which is already taking place but would likely be increased if formal trade opportunities were blocked. This is due to long-running CITES trade suspensions for all ports in Somalia (including the autonomous states of Puntland and Somaliland) and Djibouti (the major port for landlocked Ethiopia). This situation must be carefully considered due to the livelihood importance of gums and resins for many people in rural areas of the Horn of Africa. The current drought has affected all *Boswellia* producing areas of Somalia, and large areas of southern and south-eastern Ethiopia and northern Kenya (FAO, 2022[7]).

[1] Higuero, I. 2021. Sustainable use: a powerful tool to ensure the conservation of species of wild fauna and flora. https://cites.org/eng/CITES_S-G_Presentation_ReversetheRed_IUCN_Congress_sustainableuse_06092021
[2] Where at the 18th meeting (CoP18; Geneva, 2019), the Conference of the Parties adopted Decisions 18.205 to 18.208 on *Boswellia* trees (*Boswellia* spp.)
[3] CITES, 2021. Addendum to Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Online, 2-4, 21 and 23 June 2021.
[4] Al-Aamri, M. M. 2014. Sustainable Harvesting of Frankincense Trees in Oman (Environment Society of Oman).
[5] DeCarlo, A. & Ali, S. H. 2014. Sustainable Sourcing of Phytochemicals as a Development Tool: The Case of Somaliland's Frankincense Industry. Institute for Environmental Diplomacy & Security.
[6] DeCarlo, A., Elmi, A. D. & Johnson, S. 2017. Sustainable Frankincense Production Systems in Somaliland. A Management Guide (Conserve the Cal Madow).
[7] https://www.fao.org/emergencies/crisis/drought-hoa/intro/en

Livestock mortalities are high as a result of the drought, and as a result, collection of gums and resins is one of the few stable sources of income to local people in many areas in Somalia, Kenya, and Ethiopia. If, as the FAO suggests, an estimated 225,000 people derive 57-72% of their income from frankincense and related services in Somaliland and Puntland alone, this is hardly the time for a CITES Appendix II trade suspension for frankincense exports from Somalia.

Secondly, if CITES Range States use the "*precautionary principle*" (followed since 1994 as a default position in response to uncertainty) to push CITES Appendix II listing for *Boswellia*, then this is likely to have negative outcomes (see Recommendations 2, 3 & 5). As Challender et al (2022) point out, "*the precautionary principle which underpins conservation policy is not unidirectional and it cannot be assumed that tighter regulation of international trade, including bans, is always the most precautionary policy option"*[8]. Indeed, listing does not always enhance protection of the species listed, and it does not necessarily result in practical conservation action by range States (Morton et al. 2022[9], Foster and Vincent 2021[10], Dumenu 2019[11], Cunningham et al. 2016[12]). This is likely to be particularly true in major *Boswellia* range States, where governance and resources are limited and political gridlock, infighting, and corruption are commonplace. In these cases, an alternative approach is needed. In response to the question "*What most needs to be done to ensure the long-term future of the Frankincense trees and the communities that harvest them*?" in the on-line survey conducted by the Global Frankincense Alliance (2021), the top response (by 205 out of 303 respondents) was to: *"invest in the harvesting communities to support their development and incentivize sustainable tree management".* Market-based initiatives, whether through private companies or properly functioning co-operatives, are well-placed to undertake the necessary sustainability initiatives. These are already underway in some areas; how widely stronger sustainability standards will be adopted is yet to be seen (see Recommendation 4, below). It is essential, therefore, that the CITES Secretariat and CITES authorities in range States carefully consider whether CITES Appendix II listing of *Boswellia* species will have positive or negative outcomes for *Boswellia* conservation and sustainable use. We suggest the negative impacts of any CITES Appendix II listing are highly likely to outweigh any positive impacts for sustainable use, livelihoods or *Boswellia* conservation, particularly where an Appendix II listing will likely function as a *de facto* trade ban.

Thirdly, as *Boswellia* species are important medicinal plants in trade, we have followed the earlier CITES (2020) recommendation to "*liaise with key players of medicinal and aromatic plant trade supply and value chains to raise awareness and understanding of CITES regulations for medicinal and aromatic plant species and of the impact of the trade in medicinal and aromatic plants on the conservation of CITES-listed medicinal and aromatic plant species in the wild".* The majority of those interviewed in relation to the *Boswellia* trade echoed the sentiment of almost a century ago by Aldo Leopold, the American ecologist and father of wildlife management *"…that game should be positively produced, rather than negatively*

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[8] Challender, D.W., Brockington, D., Hinsley, A., Hoffmann, M., Kolby, J.E., Massé, F., Natusch, D.J., Oldfield, T.E., t Sas-Rolfes, M. and Milner-Gulland, E.J., 2022. Accurate characterization of wildlife trade and policy instruments: Reply to D'Cruze et al.(2022) and Frank and Wilcove (2022). *Conservation Letters*, *15*(1).
[9] Morton, O., Scheffers, B.R., Haugaasen, T. and Edwards, D.P., 2022. Mixed protection of threatened species traded under CITES. *Current Biology* 32: 999–1009.
[10] Foster, S.J., and Vincent, A.C.J. 2021. Holding governments accountable for their commitments: CITES Review of Significant Trade for a very high volume taxon. Glob. Ecol. Conserv. 27, e01572.
[11] Dumenu, W.K., 2019. Assessing the impact of felling/export ban and CITES designation on exploitation of African rosewood (*Pterocarpus erinaceus*). *Biological Conservation*, *236*, pp.124-133.
[12] Cunningham, A.B, Anoncho, V. F., & Sunderland, T. 2016. Power, policy and the *Prunus africana* bark trade, 1972–2015. *Journal of Ethnopharmacology*,*178*, 323-333

protected" (Leopold, 1925, in Meine and Knight, 1999)[13]. This applies not only to "game", but also to "positive production" of wild harvested plant exudate, which can be sustainable if rules affecting tree size and tapping intensity and frequency are followed. Examples of wild harvested exudates that are in commercial trade include frankincense (Bongers et al, 2019), benzoin (Harada and Munthe, 2022)[14], damar (Kusters et al., 2009[15]), Manila elemi (Ella and Domingo, 2009)[16], maple syrup (Whitney and Upmeyer, 2004) and pine resin (Heinze et al., 2021[17]). Sustainable harvest of all of these exudates requires the development of wise management practices and implementation of harvesting guidelines requires "buy-in" at the local producer level. This is as true for frankincense as for maple syrup (Whitney and Upmeyer, 2004[18]) or pine resin (Egloff, 2019[19]; Heinze et al., 2021).

2.2 RECOMMENDATIONS

RECOMMENDATION 1: CITES Appendix II listing of the entire genus (of 24 species) is not recommended, as *Boswellia* parts in trade can be effectively distinguished to species level by chemical analysis, and many species are not being hurt by international trade. The major species in trade can be clearly distinguished from each other by a combination of chemical markers, characteristic compositions, and molecular ratios. Heavily processed materials, such as standardized boswellic acid extracts, may be difficult to trade to a single species origin, but the vast majority of the materials in international trade can be distinguished to species level by a few different commonly used analytical techniques. As a result, a genus listing is not needed to ensure single species can be effectively controlled or to avoid a "look alike" problem. As a genus listing is not required in order to control trade in individual species, it is highly inadvisable as it would affect many species that are not negatively affected by trade, such as *B. neglecta, B. rivae, B. dalzielii*. This also supports the response made by India in previous feedback to the CITES Secretariat (CITES, 2021[20]).

RECOMMENDATION 2: The CITES Secretariat and *Boswellia* range States should not, in the case of *Boswellia*, take the CITES "precautionary approach". Although poor harvesting practices clearly have negative effects on some *Boswellia* populations, the economic value of frankincense resin to local communities also functions as an incentive to protect those trees from more destructive forms of use, such as land clearing or branch cutting. Removing those incentives, for instance through a listing for trees in Somalia, would likely result in local communities transitioning to using the trees for livestock fodder, bark stripping for low-grade incense used in informal cross-border trade, and cutting of trees for charcoal or firewood. Similarly, listing may encourage land conversion of *B. papyrifera* woodland in Ethiopia or

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[13] Meine, C.D. and Knight, R.L. eds., 1999. *The essential Aldo Leopold: quotations and commentaries*. Univ of Wisconsin Press.

[14] Harada, K. and Munthe, L., 2022. Production and commercialization of benzoin resin: Exploring the value of benzoin resin for local livelihoods in North Sumatra, Indonesia. *Trees, Forests and People*, *7*, p.100174.

[15] Kusters, K., Ruiz Perez, M., de Foresta, H., Dietz, T., Ros-Tonen, M., Belcher, B., Manalu, P., Nawir, A. and Wollenberg, E., 2008. Will agroforests vanish? The case of Damar agroforests in Indonesia. *Human Ecology*, *36*(3), pp.357-370.

[16] Ella, A.B. and Domingo, E.P., 2009. Improved Tapping of Philippine Canarium Trees For Manila Elemi: Helping Alleviate Climate Change. *IUFRO World Series Volume 27*, p.50.

[17] Heinze, A., Kuyper, T.W., García Barrios, L.E., Ramírez Marcial, N. and Bongers, F., 2021. Tapping into nature's benefits: values, effort and the struggle to co-produce pine resin. *Ecosystems and People*, *17*(1), pp.69-86.

[18] Whitney G., and Upmeyer, M., 2004. Sweet trees, sour circumstances: The long search for sustainability in the North American maple products industry. Forest Ecology & Management 200:313–333

[19] Egloff, P., 2019. Tapping *Pinus oocarpa*: assessing drivers of resin yield in natural stands of *Pinus oocarpa.* MSc thesis, Wageningen University, AV2019-25.

[20] CITES, 2021. Addendum to Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Online, 2-4, 21 and 23 June 2021.

Sudan. This would cause listing to have the exact opposite impact from what was intended. As a result, we caution that listing should not be considered precautionary in the case of *Boswellia*.

<u>RECOMMENDATION 3:</u> *Boswellia occulta* likely meets the criteria for listing under CITES, but doing so would most likely stimulate damage to all or some of the four known populations of this species further due to the CITES trade suspension that applies to Somalia and the socio-economic and cultural context of the areas where this species grows. This species appears in trade both as a commercially harvested and traded species, and as an adulterant of *B. carteri* resin and essential oil (Johnson et al. 2019[21]). Of all the *Boswellia* species in commercial trade, *B. occulta* is unique in having a very small distribution. It is known only from a small area in northern Somalia, with an estimated to Area of Occupancy (AOO) of less than 500 km^2 (Thulin 2020). Furthermore, it is reported to have been intensively harvested over the last decade, although no studies have been conducted on its ecology or regeneration status (Hassan, F., pers. comm. 2020). It is also easily identifiable by its unique chemical signature, a predominance of a chemical constituent called methoxydecane that has not been recorded from any other known *Boswellia* species. As a result, this species likely meets the criteria for listing.

However, a listing would likely generate more negative outcomes than positive outcomes for the species and the communities that collect its resin. As it grows only in Somalia, which is under a long-standing trade suspension, an Appendix II listing would act as a *de facto* trade ban. The blow to communities where this species grow would be significant, and likely to push them to use the trees in more destructive ways. When asked what would happen if trade were cut off, a *B. occulta* harvester responded, "we will strip the bark off the trees. At least we can always sell the bark for incense" (Dhunkal, A. pers. comm. 2019). Use of the trees for livestock fodder (the only other major livelihood in the area) and/or firewood or charcoaling is also possible. Given these conditions, an effective ban on harvesting would require a conservation plan integrating extensive community consultations and advocacy, support for transitions to alternative livelihoods, and effective monitoring of both the trees and informal trade to ensure there isn't a transition to more destructive forms of use, or conflict within and between communities based on the perception of discrimination. Given the very limited resources of both the Somalian Federal and Somaliland Regional Governments, it is extremely unlikely that these conditions will be met. As a result, a listing of *B. occulta* would likely be more damaging than helpful to the species, and cannot be recommended.

<u>RECOMMENDATION 4:</u> A decision on CITES Appendix II listing should be delayed until at least the 20th Conference of the Parties in 2025. The sustainability of *Boswellia* trade is deeply complex and as yet not fully elucidated; however, there is ongoing research into this topic. Delaying a vote until CoP20 would allow greater clarity on taxonomic issues, population sizes, conservation statuses, and drivers of management practices in key range states. Furthermore, it would allow the necessary time to see if private companies will rise to the challenge of significant supply chain improvement and implementing the necessary sustainability safeguards, as has already begun. Benefits to delaying a decision include:

(i) Testing whether private industry will support supply chain sustainability and equity. As discussed in Recommendation 4, there is a strong potential to leverage the economic value of the frankincense trade to support improved practices, especially in Range States where governance resources are limited and a listing is likely to cause negative unintended consequences. Private companies have already started to

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[21] Johnson, S., DeCarlo, A., Satyal, P., Dosoky, N., Sorensen, A., Setzer, W.N.S. 2019. Organic certification is not enough: the case of the methoxydecane frankincense. *Plants, 8*(4), https://doi.org/10.3390/plants8040088.

engage with sustainability initiatives, and the consideration of *Boswellia* by CITES has already galvanized further awareness and discussion within the industry. The three year period between CoP19 and CoP20 would provide enough time for industry players with legitimate intentions to roll out or expand ethical supply chain initiatives, as well as support sustainability research. In essence, this period could act as a litmus test to determine whether a private industry-based sustainability approach will function well over the long-term, and in which supply chains.

(ii) Improved *Boswellia* taxonomy: The recent book by Thulin (2020)[22] provides a synthesis of the genus *Boswellia*, following Thulin and Warfa's (1987), and concluded that the name B. *carteri* was illegitimate and that based on plant anatomy (from herbarium specimens and earlier fieldwork), *B. sacra* was a morphologically variable species that should include *B. carteri*. However, *Boswellia sacra* and *B. carteri* in trade can also be distinguished from each other by chemical means (Chapter 2). And new genomic evidence (Khan, A.L., pers. comm, 2022), backs up previous chemo-taxonomic studies (e.g: Woolley et al., 2012; Schmeich et al; 2019[23]), strongly supports earlier taxonomic views. Birdwood (1874), for example, subdivided *B. carteri* into two varieties, one in the Arabian peninsula (Yemen and Oman) and the other in Somalia. Hepper (1969) considered *B. carteri* (in Somalia) and *B. sacra* (in Yemen and Oman) as separate species, as did Duperon (1993)[24]. From a CITES policy perspective, this is not a trivial issue. In terms of governance, supply chains and resource management, there are significant differences and opportunities facing *B. carteri* in Somalia and *B. sacra* in Yemen and Oman. Interestingly, influential books on Chinese traditional medicine (e.g: Zhao,2004[25]; Qian, 2007[26]) and a significant number of research studies continue to refer to *B. carteri* as a separate species (e.g: Bailly, 2020[27]; Jones, 2021[28]), as do many exporters and importers, who consider *B. carteri* and *B. sacra* as separate species sources of frankincense due to their different chemistry.

(iii) Additional data on population sizes and the conservation status of several species to better inform decisions by the CITES Secretariat and CITES Authorities in range States: Important links between the IUCN Red List and CITES have been emphasized by Higuero (2019) and others (e.g: Rodrigues et al., 2006)[29]. Public perceptions of IUCN Red List status and CITES listings can negatively influence consumer buying behaviour (and consequently income to tappers). The loss of South Africa's *Aloe ferox* export market to Japan due to the inclusion of this widespread species on CITES Appendix II is a case in point, due to Japanese buyers and consumers thinking that only endangered species were included on CITES. This occurred when the entire genus *Aloe* was listed by CITES, lumping together both common and rare species (Van-Wyk, B-E., pers comm., 2022). More data is also needed on populations of lesser known *Boswellia* species whose oleo-resins enter commercial trade, such as *B. rivae* (Ethiopia, Kenya, Somalia) (Demissew, S., pers. comm., 2022), which is considered of Least Concern under the IUCN Red List

[22] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.

[23] Schmiech, M., Lang, S.J., Werner, K., Rashan, L.J., Syrovets, T. and Simmet, T., 2019. Comparative analysis of pentacyclic triterpenic acid compositions in oleogum resins of different Boswellia species and their in vitro cytotoxicity against treatment-resistant human breast cancer cells. *Molecules*, *24*(11), p.2153.

[24] Duperon, J., 1993. L'encens et les *Boswellia*: historique. Apport de l'anatomie à la systématique de trois Boswellia de Somalie et du Yemen. *Revue de cytologie et de biologie végétales, Le Botaniste*, *16*(3-4), pp.185-209.

[25] Zhongzhen, Z., 2004. *An illustrated Chinese materia medica in Hong Kong*. School of Chinese Med., Hong Kong Baptist University, Hong Kong.

[26] Qian, X-Z. 2007. An illustrated atlas of the commonly used Chinese Materia Medica. Vol III., People's Medical Publishing House, China.

[27] Bailly, C., 2020. Xihuang pills, a traditional chinese preparation used as a complementary medicine to treat cancer: An updated review. *World Journal of Traditional Chinese Medicine*, *6*(2), p.152.

[28] Jones, M.A., 2021. *The chemotherapeutic potential of Boswellia carterii oleoresins*. PhD thesis, University of Salford.

[29] Rodrigues, A.S., Pilgrim, J.D., Lamoreux, J.F., Hoffmann, M. and Brooks, T.M., 2006. The value of the IUCN Red List for conservation. *Trends in ecology & evolution*, *21*(2), pp.71-76.

categories. Additional population estimates would also be useful. For example, Thulin (2020) listed the population size of *B. frereana* as "fewer than 10 000 individuals", which was made more worrying by the "poor recruitment" observation of *B. frereana* cited in the desktop review for the German Nature Conservation Agency (BfN) (Cunningham et al., 2005[30]). Neither appear to be correct. Based on field observation in northern Somalia, the *B. frereana* population is likely to be much higher than 10 000 individuals (Johnson, S., pers comm, 2021), and based on discussions during this contract with Ulrich Feiter (pers. comm, 2021), the "poor recruitment" comment (communicated to Dr T. Brendler in 2004 and used in Cunningham et al., 2005), was a miscommunication that in fact referred to *Commiphora myrrha*, not *B. frereana*. Instead, as *B. frereana* grows in often inaccessible rocky terrain, out of reach of livestock, recruitment is better than reported.

(iv) On the conservation status of *B. papyriphera*, and whether the species would warrant a listing in CITES Appendix II: T. Cunningham and A. DeCarlo maintained differing perspectives which are contrasted in Annex 1 to this report.

RECOMMENDATION 5: Range States need to develop, implement management plans for dry woodlands that deal with the diverse factors that drive *Boswellia* population loss and make existing data on the status of *Boswellia* populations more readily available. The effectiveness of management plants needs to be monitored. As the GFA (2021a) has already recommended, this includes the need to select areas to conserve and to prevent conversion to other land uses" "*all those involved along the value chain need to engage in community and forest management and maintenance, not only in profiting from the resin*" (GFA, 2021a). This requires action and monitoring at multiple scales. Where governance is weak, then there is an opportunity for key interest groups (particularly local communities with tenure over the land or trees and commercial enterprises) to develop management plans. Forestry Departments in Ethiopia (for *B. papyrifera*) and India (for *B. serrata*) have already gathered quantitative data on *Boswellia* populations. In Madhya Pradesh for example, *B. serrata* populations have been assessed every five years or so, gathering quantitative data using belt transects and quadrat methods (Dubbey, P.C., 2021)[31]. This data is used to assess changes in tapped *B. serrata* populations. It would be extremely useful if this data could be published or at least made accessible.

RECOMMENDATION 6: Fundamental transformation of the frankincense value chains should be supported by industry, in conjunction with importing state regulations. Commercial trade, whether by companies or well-run cooperatives has the potential to have significant positive impacts, but needs greatly enhanced transparency and due diligence mechanisms to realize its potential. Strong customary tenure over tapping areas and *Boswellia* trees in Somalia and Oman (and formerly in Ethiopia) combined with better returns to tappers can provide an incentive for improved tapping techniques (and possibly better livestock management) in *Boswellia* woodlands. Increasing resin prices to local tappers and communities is critical, but must also be done alongside strong ecological monitoring programs so the higher prices can be tied to good tapping and management practices (see Recommendation 4 above). In this way, higher total income to tappers can be tied to positive management outcomes, rather than just higher total volume of resin collected. A CITES Appendix II listing would likely be counterproductive to these kinds of private sector efforts if it affects the frankincense market (as it did in halting *Aloe ferox*

[30] Cunningham, A.B., Brinckmann, J., Brendler, T. 2015. *Boswellia frereana*. Unpublished report to the German Nature Conservation Agency (BfN), Bonn.

[31] Responses provided in a questionnaire by Dr P C Dubbey (retired PCCF, India Forestry Department) in an audit process for PLT Sustainbility, USA (cited with permission from P. Flowerman)

exports from South Africa to Japan). The risk of this is particularly dire in *Boswellia* range States where trade suspensions are triggered. This will have a drastic effect on the two major frankincense exporting countries: Ethiopia (by default, as Ethiopia is landlocked and exports mainly through the port of Djibouti, which has had a CITES trade suspension) and Somalia (which has a long running trade suspension for c. 20 years). In these cases, where government resources to support conservation are already very limited, listing would act to stifle one of the few major opportunities to incentivize conservation of *Boswellia* trees.

RECOMMENDATION 7: Companies involved in frankincense sourcing should commit to strong environmental and social governance plans, ideally with third party verification either through certifications or other means. While there has been some movement towards voluntary supply chain improvements and sustainability initiatives, greenwashing and baseless claims of sustainability remain far more common than genuine action. While a number of companies make grand claims about their sustainability initiatives, the data being shared uniformly indicated initiatives at a small scale and/or in their infancy. Consequently, these initiatives should be encouraged and expanded, so that stronger, substantive data can be produced. The use of technologies like blockchain can support the needed transparency; this is already being implemented by at least one company in Somalia and could be expanded. Procedures to verify payments and money flows, for instance through using digital mobile banking payments, should be considered as higher payments for resin could be a key incentive for sustainable tapping. The limited formal governance, gender discrimination, and in some cases, undocumented workers, means these supply chains are often socially high risk (Schindler et al. 2022[32]), so implementing controls to ensure fair treatment of people needs to be a key priority alongside a focus on encouraging sustainable harvesting.

Although the weak governance in many *Boswellia* Range States makes effective implementation of regulatory controls difficult, the regulations in importing states can play a key role in promoting ethical supply chain actions by private industry. For instance, the EU Due Diligence Act in particular provides a legal framework for holding large companies accountable for their raw material supply chains in the EU, and imposing penalties should lapses occur. In the USA, the Lacey Act has already stimulated compliance to supply chain transparency by Young Living, a major US company. Utilizing importing-side regulatory frameworks to support compliance with improved sustainability practices can provide an important mechanism for accountability of private industry, while avoiding the problems plaguing the implementation of exporting-side controls. The CITES Secretariat should support the organization of an industry workshop to map a way forward towards improved ESG and transparency in frankincense supply chains.

RECOMMENDATION 8. Due to trade suspensions at ports, coupled with weak governance in some range States, a CITES Appendix II listing of many *Boswellia* species is likely to be counter-productive to sustainable use. As Eshete et al (2021)[33] and others have pointed out for Ethiopia, fostering community involvement in forest management and shifting to community managed forests is important. Under Somali customary law (*xeer*), the opportunities for this already exist in Somalia (DeCarlo et al. 2020, Johnson and Ablard 2020), although adherence to these customary rules has degraded in recent years

[32] Schindler, C., Heral, E., Drinkwater, E., Timoshyna, A., Muir, G., Walter, S., Leaman, D.J., Schippman, U. (2022). Wild Check—Assessing Risks and Opportunities of Trade in Wild Plant Ingredients. Rome, FAO. https://doi.org/10.4060/ cb9267en

[33] Eshete, A., Kassa, H. and Livingstone, J., 2021. Inclusive frankincense value chain development in Ethiopia. *A historical perspective on forest governance and reforms for better livelihoods and conservation outcomes. PENHA, Addis Ababa, Ethiopia and Tropenbos International, Ede, the Netherlands*.

given the larger harvester population, increasing reliance on the resource for livelihoods, and pervasive low local resin prices that have incentivized intensive exploitation to meet even basic livelihood needs. As a result, effective adherence to these traditional rules will require economic incentives as well, given the poverty in which most tapping communities live. Ethical trade programs have the potential to play a key role in maintaining and incentivizing traditional good practices if implemented on a wider scale (see Recommendation 5, above). Encouraging sustainable use and getting "buy in" along the supply chain will enable CITES to contribute to the UN's Millenium Development Goals (MDG's). This includes continuing to work with appropriate organizations on Voluntary Certification Standards (VCS) and compliance with other mechanisms (such as the EU Due Diligence Act and the Lacey Act. Based on discussions held during this contract, we suggest that working with selected frankincense exporting and importing companies would be productive. Several companies have claimed to work with their suppliers to improve tapping techniques, increase supply chain transparency and create better profit structures along frankincense supply chains, although this is only a start and improvements have to be made in transparency and sharing data to back up claims. For CITES and partners to cooperate with actors along the supply chain in a positive way is preferable to inadvertently penalising companies (and tappers) who have done the right thing. Listing would also negatively affect livelihoods of c.500 000 people during the current major drought in the Horn of Africa (a situation that periodically repeats).

The decline of a *Boswellia* species is best documented in the large data-set from the three (of 9) *Boswellia papyrifera* Range States that are the major exporters of frankincense (Ethiopia, Eritrea and Sudan), which shows that many *B. papyrifera* populations are declining due to multiple factors. Woodlands are cleared for farmland, fire, grazing by livestock and opportunistic resin harvest rather than careful tapping that can be sustained (which in turn leads to infestation by wood-boring beetles (Lemenih & Kassa, 2011a[34]; Lemenih, et al., 2014[35]). While trade requires tapping—a stress factor—the economic value of the frankincense resin due to the trade market also acts to protect the trees from clearing for agriculture, cutting for firewood, etc. Indeed, this is a condition echoed by tappers in Somalia, who stated that if the market for frankincense resin were to disappear, they would likely strip the trees of their bark for low-grade incense in order to still obtain some economic value from them. As a result, trade can act as both a threat factor and a protection factor for these trees. It is not clear, however, which force is stronger, i.e. whether international trade has a net negative or net positive effect on these trees, and therefore, whether a listing would benefit the species. It is important to note that, while in normal circumstances a listing could serve to promote trade as a net positive, the limited governance and trade suspensions mean that a listing would in all likelihood remove all trade, thus negating the positive benefits. Likewise, in Somalia, an Appendix II listing would serve as a *de facto* trade ban, eliminating the positive protective benefits of trade (as well as endangering 225,000 or more livelihoods). As a result, an Appendix II listing is likely to be counter-productive to the conservation and sustainable use of these species.

<u>RECOMMENDATION 9:</u> The CITES Secretariat should support research that leads to a better understanding of how land and tree tenure and harvesting rights vary across and within Range States, and work with non-profit organizations and ethical industry partners to build on existing initiatives (see Recommendation 7), including on the need to improve data collection on harvest impacts (in line with

[34] Lemenih, M. & Kassa, H. eds., 2011a. *Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia.* Bogor: CIFOR.

[35] Lemenih, M., Arts, B., Wiersum, K. & Bongers, F., 2014b. Modelling the future of Boswellia papyrifera population and its frankincense production.Journal of Arid Environments. *Journal of Arid Environments,* Volume 105, pp. 33-40.

CITES non-detriment finding (NDF) requirements. Supporting high quality data collection on the ecology, conservation status, and harvesting impacts of the major species in trade should be a top priority, so that any interventions are based on and supported by strong field data. Formal scientific studies can be combined with participatory data collection and monitoring, leveraging the field experiences of communities directly working with the *Boswellia* trees. For instance, using smart phones linked to user friendly technology designed for local people with excellent field knowledge (but in some cases poor numeracy and literacy), there is potential to develop a "community of practice" that uses Cybertracker (see www.cybertracker.org) (or other similar applications) modified for monitoring tapping impacts on *Boswellia*.

RECOMMENDATION 10: Range States, private companies, and other supply chain actors should refrain from production increase programs, particularly distributing harvesting tools, unless conducted in combination with appropriate training and controls. A number of projects aimed at promoting local livelihoods by increasing harvesting of *Boswellia* resins have been conducted over the past ten years: communities in Somaliland reported that a large international NGO had distributed harvesting tools for *B. carteri* (A.D., pers. obs. 2016); a private company in Kenya distributed metal tools and encouraged tapping in the traditionally un-tapped *B. neglecta* (A.D. pers. obs. 2021); the Ethiopian government organized frankincense harvesting cooperatives for former soldiers to harvest and benefit from *B. papyrifera* (Johnson, S., pers. comm. 2022). While well-intentioned, these programs rarely provide sufficient training or monitoring of new harvesters and their conformance to good harvesting practices. As a result, they run the risk of encouraging destructive practices by harvesters who don't know how to collect resin sustainably. This is true even in areas where there is a tradition of harvesting (such as Somalia or parts of Ethiopia), as proper harvesting techniques are not generally known cultural knowledge, but are a specific skill set developed with time and practice. The importance of proper training and ongoing monitoring is well-displayed by harvesting sites in Ethiopia. Some (but not all) of the areas being harvested in 2018 by the now-defunct government-owned company Natural Gum Processing and Marketing Enterprise (NGPME) were remarkably well-managed, with very few deviations from the correct number and type of taps as a result of both good initial training and ongoing on-site monitoring of new tappers by experienced tappers (Johnson, S., pers. comm. 2022). By contrast, the area harvested by a cooperative of former soldiers, who did not receive the same training or support, showed much higher intensity tapping as well as damaging practices such as cutting all the way to the wood of the trees. Consequently, any kind of production enhancement program should be conducted only with strong, ongoing support and training for the harvesters involved, to avoid unintended damage to the trees.

Chapter Three

Species-Specific Identification of *Boswellia* Parts and Derivatives in Trade

Authors: Anjanette DeCarlo and Stephen Johnson

3.0 Summary

Although the literature has complications, there is substantial evidence that it is possible to identify the essential oils, resins, and extracts of individual *Boswellia* species in trade by looking for chemical markers and indicators, and looking for chemical compositions characteristic to each species. Most samples can be effectively identified by relatively simple means (organoleptics, thin-layer chromatography, etc.), and virtually all of the more "difficult" samples can be successfully identified using more sophisticated technologies. Boswellic acids are key genus markers, present in all *Boswellia* species except *B. frereana (*lupeol*, 3- epi*-lupeol*)*. *Boswellia papyrifera*, *B. occulta*, and *B. serrata* are also readily identifiable, with unique marker compounds in their volatile compositions. *Boswellia papyrifera* can be identified by the high level of octyl acetate and incensole acetate, *B. occulta* by the presence of methoxyalkanes, and *B. serrata* by the presence of methyl chavicol and/or methyl eugenol with α-thujene. Other species are more similar, often with volatile profiles dominated by α-pinene, and there is occasional overlap in the compositions of the resins and essential oils. However, species can still be reliably identified by unique combinations of the dominant volatile constituents, a mixture in which boswellic acids are most abundant, and based on which monoterpene enantiomers are most abundant. Various technologies have been used to determine the compositions of frankincense products, including gas chromatography-mass spectrometry (GC-MS), chiral GC-MS, high pressure liquid chromatography (HPLC), thin-layer chromatography (TLC), and various other techniques such as direct analysis in real time (time of flight) mass spectrometry (DART-TOFMS). Organoleptic analysis (the direct analysis of material based on its scent, appearance, taste, etc.) can be used by comparing the scent and visual appearance of unknown material to that of known essential oils or resins to differentiate the majority of samples; TLC provides another simple and inexpensive tool to help differentiate between species. More sophisticated techniques, particularly HPLC, GC-MS, and chiral GC-MS, are useful to analyze both volatile and non-volatile components for definitive species identification of more difficult samples. There are some look alike genera that contain species that produce resins similar to frankincense; there is not enough research to know all possible species that may be look alikes, but most can be identified by the lack of boswellic acids or by differences in the volatile and non-volatile profiles. Small amounts of look alikes as adulterants in frankincense may be difficult to detect reliably; however, the presence of frankincense in shipments claimed to be a look alike species should be detectable in most cases. Based on the chemical compositions of the volatile and non-volatile profiles, some *Boswellia* species are likely interchangeable for industrial purposes, while others are not. The essential oils of *B. carteri*, *B. sacra*, *B. frereana*, *B. neglecta*, *B. dalzielii*, and *B. rivae* may be somewhat interchangeable (although the scent profiles have differences), while *B. serrata*, *B. papyrifera*, and *B. occulta* are fairly unique. The boswellic acid contents of *B. serrata*, *B. papyrifera*, *B. sacra*, *B. dalzielii*, and *B. carteri* are more or less interchangeable, while those of *B. neglecta*, *B. rivae*, and *B. frereana* have too few or no boswellic acids to be useful. The decision trees in Figures 3.1 and 3.2 summarize chemical markers and indicators to identify *Boswellia* essential oils and resins of species that dominate international trade. Markers and indicators are further summarized in tabular form in Annex 2 to this report.

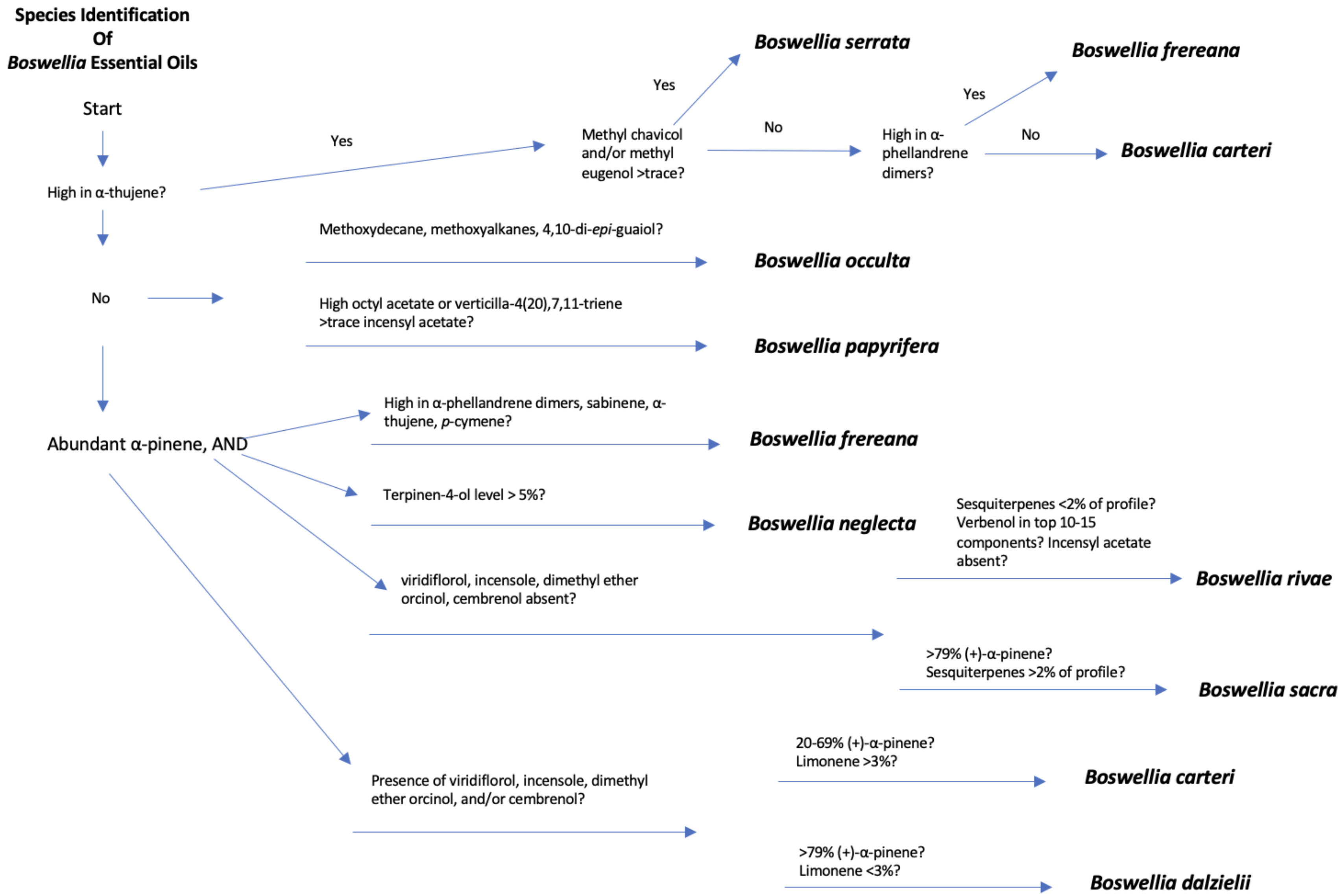

Figure 3.1 Chemical markers and indicators to identify *Boswellia* essential oils.

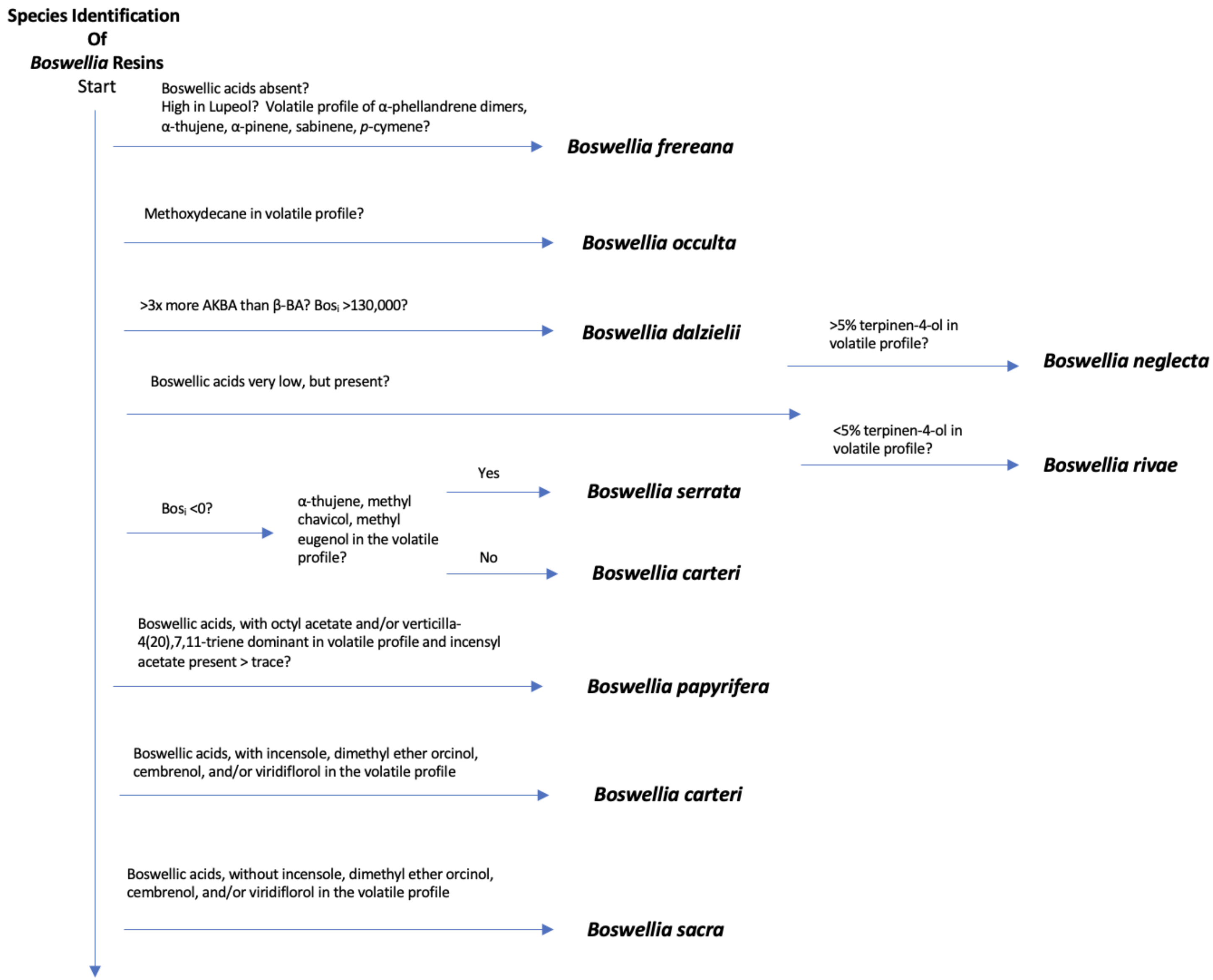

Figure 3.2 Chemical markers and indicators to identify *Boswellia* resins.

3.1. Parts and derivatives being analyzed

3.1.1. Essential oils

The resins of many species of *Boswellia* are distilled into essential oils. This process involves immersing the resin in boiling water (hydrodistillation) or steam (steam distillation), which partially dissolves the resin and allows the volatile terpenes in the resin to mingle with the steam. The steam is then captured, condensed to water, and the essential oils are separated out from the water. Frankincense resins typically yield between 1-10% w/w in essential oils, although some resins occasionally yield a higher percentage. The essential oils consist of monoterpenes and sesquiterpenes, sometimes with small percentage of diterpenes as well. However, essential oils do not contain the carbohydrate-based gum or triterpene fractions of the resin, which constitute the majority of the resin. As a result, the essential oils do not contain boswellic acids (pentacyclic triterpenes that are characteristic of most frankincense species) (DeCarlo et al. 2019a[1]).

The majority of commercial distillation and extraction takes place outside of *Boswellia* range states and/or outside of the original states of resin production. The exception to this rule is India (*B. serrata* range state), where there is significant local distillation and extraction capacity for *B. serrata* and imported *Boswellia* resins, and Oman, where the majority of *B. sacra* essential oil is produced in local distilleries. Kenya (*B. neglecta* and *B. rivae* range state) also has a number of distilleries, exporting both *B. neglecta* and imported *B. carteri* and *B. frereana* essential oil. Distillation capacity is increasing in Somalia, and there are some small distilleries in Ethiopia. However, the majority of frankincense essential oil distillation takes place in Bulgaria, France, Spain, the United Kingdom, Germany, the United Arab Emirates, the United States of America, Greece, and China.

3.1.2. Whole resins and extracts

The majority of international trade in *Boswellia* from range states is the export of whole frankincense resin. This is the raw resin material containing all volatile and nonvolatile chemical components as well as the carbohydrate gum fraction.

Extracts of the resin are also commonly traded. These differ from essential oils in that they are produced through various chemical extraction processes rather than through distillation. Common methods involve supercritical fluid (often carbon dioxide) extraction, or extraction using solvents such as ethanol, methanol, hexane, etc. Unlike essential oils, extracts contain some of the non-volatile triterpene components in addition to the volatile terpenes. As a result, both the volatile and non-volatile components can be used to identify the species.

3.1.3. Incense

A major use of frankincense is the production of incense. Incense may be as simple as the pure resin itself (covered above), or it may be a powdered blend of multiple different fragrance materials (such as sandalwood, myrrh, or synthetic fragrance ingredients). Additionally, incense may be produced from the

[1] DeCarlo, A., Dosoky, N. S., Satyal, P., Sorensen, A., & Setzer, W. N. (2019). The Essential Oils of the Burseraceae. In S. Malik (Ed.), *Essential Oil Research: Trends in Biosynthesis, Analytics, Industrial Applications and Biotechnological Production* (pp. 61–145). Springer International Publishing. https://doi.org/10.1007/978-3-030-16546-8_4

remaining material post-distillation (the non-volatile triterpene resin fraction, but lacking the volatile terpene essential oil and carbohydrate gum).

3.1.4. Look alike genera within Range States

We consider here other genera that occur within *Boswellia* range states and that are sufficiently similar to *Boswellia* for the two to be confused. While there are other resins that resemble frankincense, such as mastic in Greece and sandarac in Morocco (Langenheim 2003[2]), there are few resins that closely frankincense in scent and appearance within *Boswellia* range states. *Commiphora*, a sister genus to *Boswellia*, produces resins such as myrrh and opoponax. The main commercially harvested species (such as *C. myrrha*, *C. guidottii*, *C. erythraea*, *C. holtziana*, *C. kataf* and *C. kua*), produce resins that are distinct both in their appearance (often dark, reddish, and clumped rather than light colored with more defined tears), scent, and chemical compositions (Shen *et al*. 2012[3], Hanus *et al*. 2005[4]).

However, some species of *Commiphora* are known to produce resins that resemble frankincense. *Commiphora confusa*, which co-occurs with *B. neglecta* in Kenya, is known to produce a resin with an appearance and scent almost identical to *B. neglecta* resin (H. Sommerlatte, pers. comm., 2021). Although the chemical composition of *C. confusa* essential oil has not been well described in the literature, it is likely to be very similar to *B. neglecta* essential oil. It is frequently mixed into *B. neglecta* resin, and for that reason, existing descriptions of *B. neglecta* chemistry may well be describing mixtures of *B. neglecta* and *C. confusa* resins or essential oils. Similarly, *Boswellia rivae* resin is collected from naturally exuding trees in rangeland where they grow with various species of *Commiphora* (Lemenih and Kassa 2011[5]). It is likely that people collecting the resin also collect *Commiphora* resins that look similar. Given that existing studies have not used resin samples from vouchered trees, it is impossible to say whether they describe pure samples of *B. rivae* resin and essential oil or whether they describe a mixture.

There are over 150 species of *Commiphora*, many of which co-occur with species of *Boswellia* (Shen *et al*. 2012). The chemistry of most species has been little researched, with no data at all for many species. The essential oils of many *Commiphora* species that have been investigated are dominated by sesquiterpenes, and furanosesquiterpenoids are characteristic for this genus (Shen *et al*. 2012, Hanus *et al*. 2005). However, there are some species reported, like *Commiphora tenuis* in Ethiopia (Asres *et al*. 1998[6]) and *Commiphora wildii* in Namibia (Sheehama *et al*. 2019[7]), that have resin essential oils composed primarily of monoterpenes, with compositions that look similar to those of *Boswellia*. As a result, it's possible that other *Commiphora* species co-occurring with *Boswellia* could be added to frankincense shipments.

Gum Arabic (Figure 3.3), the gum produced by *Acacia* trees, may also be added to bags of frankincense resin to increase the weight. However, the gum is fairly easy to identify, as it is orange, glassy, transparent to translucent, and completely soluble in water.

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[2] Langenheim, J. H. (2003). *Plant Resins: Chemistry, Evolution, Ecology, and Ethnobotany*. Timber Press, Incorporated.

[3] Shen, T., Li, G.-H., Wang, X.-N., & Lou, H.-X. (2012). The genus Commiphora: A review of its traditional uses, phytochemistry and pharmacology. *Journal of Ethnopharmacology*, *142*(2), 319–330. https://doi.org/10.1016/j.jep.2012.05.025

[4] Hanus, L. O., Rezanka, T., Dembitsky, V. M., & Moussaieff, A. (2005). Myrrh-Commiphora Chemistry. *Biomed. Papers*, *149*(1), 3–28.

[5] Lemenih, M., Kassa, H., & eds. (2011). *Opportunities and challenges for sustainable production and marketing of gums and resins in Ethiopia*. Center for International Forestry Research (CIFOR), Bogor, Indonesia. https://doi.org/10.17528/cifor/003478

[6] Asres, K., Tei, A., Moges, G., Sporer, F., & Wink, M. (1998). Terpenoid Composition of the Wound-Induced Bark Exudate of Commiphora tenuis from Ethiopia. *Planta Medica*, *64*(5), 473–475. https://doi.org/10.1055/s-2006-957489

[7] Sheehama, J. T., Mukakalisa, C., Amakali, T., Uusiku, L. N., Hans, R. H., Nott, K., Nott, A., & Louw, S. (2019). Chemical characterization and in vitro antioxidant and antimicrobial activities of essential oil from Commiphora wildii Merxm. (Omumbiri) resin. *Flavour and Fragrance Journal*, *34*(4), 241–251. https://doi.org/10.1002/ffj.3495

Figure 3.3. Photos above: (L) Gum Arabic. Photo by Tarig A. Eltom/CC-BY-SA-3.0. (R) Commiphora myrrha resin. Photo by Stephen Johnson.

3.2. Biomarkers

3.2.1 Genus-Specific Biomarkers

The most useful biomarker of *Boswellia* is the presence of boswellic acids (Al-Harrasi et al. 2019[8]). These are pentacyclic triterpenes, the non-volatile components of the frankincense resin. As a result, these components are found in the whole resin, extracts, and incense, but are not found in the essential oils. Boswellic acids have been found in all *Boswellia* species analyzed, with the exception of *Boswellia frereana*, but have not been found in any other genera thus far. Some species of *Boswellia*, such as those on Socotra island and *B. ovalifoliolata* in India, have not been assessed, but the main commercial species except for *B. frereana* are known to contain these components. *Boswellia frereana* can be identified by other means (see below).

3.2.2 Species-Specific Biomarkers

There is a significant body of literature describing the chemical compositions of various *Boswellia* species and attempting to distinguish between species. This provides a good base of research to identify distinguishing characteristics of each species. However, there are several important points to consider.

First, many studies have been conducted on samples obtained from commercial sources outside of the original range states. The majority of papers list herbal shops, commercial markets, or botanical supply companies as the sources of materials, resulting in uncertain origins and species identities of the materials being analyzed. Indeed, there seems to be a number of incidences of *B. papyrifera* being misidentified as *B. carteri* (Basar 2005[9], Chen *et al*. 2013[10], Hayashi *et al*. 1998[11], Marongiu *et al*. 2006[12],

[8] Al-Harrasi, A., Khan, A. L., Asaf, S., & Al-Rawahi, A. (2019). *Biology of Genus Boswellia* (1st ed. 2019 edition). Springer.
[9] Basar, S. (2005). *Phytochemical investigations on Boswellia species* [PhD Dissertation, University of Hamburg]. http://ediss.sub.uni-hamburg.de/volltexte/2005/2503/pdf/Dissertation-Simla_Basar.pdf
[10] CHEN, Y., ZHOU, C., GE, Z., LIU, Y., LIU, Y., FENG, W., LI, S., CHEN, G., & WEI, T. (2013). Composition and potential anticancer activities of essential oils obtained from myrrh and frankincense. *Oncology Letters*, *6*(4), 1140–1146. https://doi.org/10.3892/ol.2013.1520
[11] Hayashi, S., Amemori, H., Kameoka, H., Hanafusa, M., & Furukawa, K. (1998). *Comparison of Volatile Compounds from Olibanum from Various Countries*. https://doi.org/10.1080/10412905.1998.9700833
[12] Marongiu, B., Piras, A., Porcedda, S., & Tuveri, E. (2006). Extraction of Santalum album and Boswellia carterii Birdw. volatile oil by supercritical carbon dioxide: Influence of some process parameters. *Flavour and Fragrance Journal*, *21*(4), 718–724. https://doi.org/10.1002/ffj.1718

Mikhaeil *et al*. 2003[13], Wahab *et al*. 1987[14]); the distinction between *B. carteri* and *B. sacra* is also blurred, as they have variously been considered the same or different species in the chemical literature. There are also a number of low quality papers that report very unusual compositions or components that are known as markers of synthetic chemical addition (indicating the material being studied has already been adulterated) (Hido et al. 2020[15], Ranjbar Dounchaly et al. 2016[16], Ahmed et al. 2015[17], Singh et al. 2007[18]). Questionable studies have been excluded from the analysis here.

More recently, efforts have been made to take resin samples directly from trees or harvesting villages in the correct range states and obtain voucher specimens of the trees being analyzed to ensure the species are correct. This has yielded important insights (such as the differentiation of *B. occulta* from *B. sacra*/*B. carteri*) but has not yet been done in all species or with large numbers of samples. As a result, we here have to rely on a large number of samples that were obtained through commercial means but that are believed to be the correct species.

Second, the use of artificial hormones or chemical stimulants to increase resin production may affect the chemical composition. Artificial stimulants such as 2-chloroethylphosphonic acid have been used in resin and gum-producing species such as *Commiphora wightii* and *Acacia nilotica* to increase production (Bhatt et al. 1989[19], Harsh et al. 2013[20]). This stimulant appears to be effective in *Boswellia* as well (Yamamoto et al. 2020[21], Sinha et al. 2016[22]). However, its use may affect the boswellic acid composition (Sinha et al. 2016), which would affect the identification of the resins. More research is needed to understand the impact of stimulants on resin chemistry.

Third, identification of species sometimes depends on characteristic compositions or characteristic ranges of key components, rather than unique biomarkers. This means we are relying on existing sample sets to determine how broad the variation in each component for each species is, potentially resulting in a restricted definition of the target species (i.e. we risk excluding genuine samples of material simply because they fall outside of the range established by limited studies). Particularly in the case of the boswellic acids, there are not yet universally accepted quantification methods, leading to different laboratories calculating different levels of boswellic acids for the same sample of resin. Consequently,

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[13] Mikhaeil, B. R., Maatooq, G. T., Badria, F. A., & Amer, M. M. A. (2003). Chemistry and immunomodulatory activity of frankincense oil. *Zeitschrift Fur Naturforschung. C, Journal of Biosciences*, *58*(3–4), 230–238. https://doi.org/10.1515/znc-2003-3-416

[14] Wahab, S. M. A., Aboutabl, E. A., El-Zalabani, S. M., Fouad, H. A., Pooter, H. L. D., & El-Fallaha, B. (1987). The Essential Oil of Olibanum. *Planta Medica*, *53*(4), 382–384. https://doi.org/10.1055/s-2006-962745

[15] Hido, A., Tolera, M., Lemma, B., & Evangelista, P. H. (2020). Population Status and Resin Quality of Frankincense Boswellia neglecta (Burseraceae) Growing in South Omo, Southwestern Ethiopia. *Journal of Sustainable Forestry*, *39*(6), 620–634. https://doi.org/10.1080/10549811.2020.1721302

[16] Ranjbar Dounchaly, A., Jaimand, K., & Mozaffari, S. (2016). Comparison of Essential Oils Compositions of Boswellia carteri Birdwood as a Food and Non-food in Different Distillation from Iranian Market. *Journal of Medicinal Plants and By-Product*, *5*(1), 39–44. https://doi.org/10.22092/jmpb.2016.108922

[17] Ahmed, H. H., Abd-Rabou, A. A., Hassan, A. Z., & Kotob, S. E. (2015). Phytochemical Analysis and Anti-cancer Investigation of Boswellia Serrata Bioactive Constituents In Vitro. *Asian Pacific Journal of Cancer Prevention*, *16*(16), 7179–7188. https://doi.org/10.7314/APJCP.2015.16.16.7179

[18] Singh, B., Kumar, R., Bhandari, S., Pathania, S., & Lal, B. (2007). Volatile constituents of natural Boswellia serrata oleo-gum-resin and commercial samples. *Flavour and Fragrance Journal*, *22*(2), 145–147. https://doi.org/10.1002/ffj.1772

[19] BHATT, J. R., NAIR, M. N. B., & RAM, H. Y. M. (1989). ENHANCEMENT OF OLEO-GUM RESIN PRODUCTION IN COMMIPHORA WIGHTII BY IMPROVED TAPPING TECHNIQUE. *Current Science*, *58*(7), 349–357.

[20] Harsh, L. N., Tewari, J. C., Khan, H. A., & Ram, M. (2013). Ethephon-induced gum Arabic exudation technique and its sustainability in arid and semi-arid regions of India. *Forests, Trees and Livelihoods*, *22*(3), 204–211. https://doi.org/10.1080/14728028.2013.818514

[21] Yamamoto, F., Iwanaga, F., Al-Busaidi, A., & Yamanaka, N. (2020). Roles of ethylene, jasmonic acid, and salicylic acid and their interactions in frankincense resin production in Boswellia sacra Flueck. Trees. *Scientific Reports*, *10*(1), 16760. https://doi.org/10.1038/s41598-020-73993-2

[22] Sinha, S. K., Pathak, J. G., Mehta, A. A., & Behera, L. K. (2016). Tapping Methods in Salai Guggal (Boswellia serrata Roxb.) for Sustainable Yield of Oleo-Gum Resin: A Case Study. *International Journal of Forest Usufructs Management*, *17*(2), 13–18.

caution should be used when interpreting a sample purely based on component ranges, especially when species have similar compositions.

Ideal biomarkers would meet two criteria. First, they would be unique to the species, or unique to only a few species (helping to narrow down the possible origin of the material if not definitely determine the species). Second, they would be present in all or almost all genuine samples of the material. As a practical matter, few *Boswellia* species present such clean markers. More often, there are a series of components that are often present in the species, and are rarely found in other species, but that are not, strictly speaking, unique to that species. There is natural variation in the chemical compositions of *Boswellia* resins, and there will be some unusual examples of genuine material that lack the indicated marker. Still, as long as the marker is present in the majority of samples, and not often in other species, it is useful to use in identifying commercial shipments. This is important to consider, as a number of studies conclude biomarkers based on a small number of samples, which don't capture the full range of variation of the species (either for the species said to have it, or for the other species from which it is being differentiated). As a result, with the exception of a few species that do have clear biomarkers (*B. papyrifera*, *B. serrata*, and *B. occulta*), most identifying compositions and components listed below should be thought of as indicators, rather than definite markers. The vast majority of commercial samples and shipments can be successfully identified using these indicators. However, we cannot exclude the possibility of a rare, individual shipment showing an anomalous profile.

Schmiech et al. (2019) have constructed a formula using the concentrations of three boswellic acids (AKBA, β-BA, and β-ABA) to give an index number indicating the species being analyzed. This Boswellic Acid Index (Bos_i) is calculated as follows:

$$\mathrm{Bosi} = ([\mathrm{AKBA}] - 1)\ \mathrm{x}\ \left(\frac{[\beta\mathrm{ABA}] + 1}{[\beta\mathrm{BA}] + 1}\right) \mathrm{x}\ ([\mathrm{AKBA}] + [\beta\mathrm{ABA}] + [\beta\mathrm{BA}] + 1)\ \mathrm{x}\ ([\mathrm{A}\beta\mathrm{BA}] - [\beta\mathrm{BA}])$$

This may be a useful indicator to support other evidence of a species identification. However, there is overlap between the indices of different species (for instance, a Bos_i of 25,000 would fall within the range of *B. papyrifera*, *B. sacra*, and *B. carteri* while a Bos_i of 100 would fall within the range of both *B. carteri* and *B. neglecta*), and the existing ranges are likely to be expanded as more authentic samples are examined. As a result, it should not be taken as a definitive species marker alone, but rather an indicator to support a presumptive species identity.

Finally, this is a topic of ongoing research. Various companies and university researchers are currently undertaking studies with larger sample sets than most prior literature to test how well species can be differentiated by various analytical techniques and how well potential adulterants (such as *Commiphora* resins) can be detected. We expect that the ability to accurately differentiate species and identify adulterants will continue to improve as the results are published.

3.2.2.1 *Boswellia carteri* (Somalia)

The essential oil of *B. carteri* is most often dominated by α-pinene, limonene, myrcene, viridiflorol, β-caryophyllene, and other mono- and sesquiterpenes. Although the most common composition is a moderate to high level (20-50%) of α-pinene with a moderate level (5-20%) of limonene, various samples have been analyzed that closely resemble samples of *B. rivae*, *B. neglecta*, and *B. sacra* (DeCarlo *et al*. 2018, Hamm *et al*. 2005, Camarda *et al*. 2007, Woolley *et al*. 2012). However, differences in chirality can be used to tell the species apart. *Boswellia sacra* is dominated by (+)-α-pinene (79-99%), while *B. rivae* is ~50% (+)-α-pinene, and *B. carteri* is only 20-59% (+)-α-pinene. As a result, there is some overlap with *B. rivae*, but the latter is normally has δ-3-carene as a major component while in *B. carteri* it is rarely in the top ten most abundant components (Basar *et al*. 2003[23], Basar 2005, Camarda *et al*. 2007, Bekana *et al*. 2014[24]). Furthermore, *B. carteri* almost always contains incensole and/or incensyl acetate, while *B. rivae* does not contain these components. There are no data on the chirality of *B. neglecta*, but *B. carteri* can be distinguished from *B. neglecta* by the absence or low level of terpinen-4-ol and limited amount of *p*-cymene in *B. carteri*. Viridifloral, cembrenol, dimethyl ether orcinol, and incensole have been suggested as markers to tell *B. carteri* apart from *B. sacra* (Woolley *et al*. 2012). However, these components are not present in all samples of *B. carteri* (Niebler and Buettner 2016[25], DeCarlo *et al*. 2018), and may occur in rare *B. sacra* samples (DeCarlo *et al*. *in preparation,* Al-Harrasi et al. 2019). As a result, these should be considered indicators rather than definitive markers. Many of these components occur in other *Boswellia* species as well, so they cannot be used as unique species markers, they can only be used to distinguish between *B. carteri* and *B. sacra*.

There is another chemotype reported for *B. carteri*, which is dominated by α-thujene and closely resembles the composition of *B. frereana* essential oil (DeCarlo *et al*. 2018). It is differentiated from *B. frereana* by the low content of α-phellandrene dimers, though, which are the signature of *B. frereana*.

Boswellia carteri generally shows a pattern of dominance of β-BA and β-ABA in the boswellic acid profile, with very little AKBA. This is in contrast to *B. sacra*, in which AKBA is normally one of the most abundant boswellic acids. Some samples break this pattern, though, and individual samples of *B. carteri* can be indistinguishable from *B. sacra* with respect to the boswellic acid profile. The Bos_i numbers vary significantly, from roughly -5,000 to +46,000.

3.2.2.2 *Boswellia dalzielii*

Boswellia dalzielii essential oil has two known chemotypes, one dominated by α-pinene (26-77%), and a much rarer chemotype rich in myrcene (up to 20%). Samples from Nigeria seem to be higher in α-pinene than samples from Burkina Faso, but the latter include a larger percentage of sesquiterpenes (DeCarlo *et al*. 2019b, DeCarlo *et al*. 2019c, Schmiech et al. 2021). The oil is often similar in composition to *B. sacra* or *B. carteri*, but there are a few key differences. First, the essential oil is characterized by a very low level of limonene; *B. dalzielii* almost always has less than 3% limonene, while *B. carteri* and *B. sacra* almost always have more than 3% limonene. However, occasional samples in each species will break this rule, so it cannot be used as a definitive marker. Second, several components, such as carvacrol, carvone, α-campholenal, and *trans*-verbenol, are often present at levels of 1-5% in *B. dalzielii* essential oil, but are rarely abundant in *B. carteri* or *B. sacra* essential oils (although they may be present at lower levels, they are rarely the most abundant sesquiterpenes in these oils).

[23] Başer, K. H. C., Demirci, B., Dekebo, A., & Dagne, E. (2003). Essential oils of some Boswellia spp., Myrrh and Opopanax. *Flavour and Fragrance Journal*, *18*(2), 153–156. https://doi.org/10.1002/ffj.1166
[24] Bekana, D., Kebede, T., Assefa, M., & Kassa, H. (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*, e374678. https://doi.org/10.1155/2014/374678
[25] Niebler, J., & Buettner, A. (2016). Frankincense Revisited, Part I: Comparative Analysis of Volatiles in Commercially Relevant Boswellia Species. *Chemistry & Biodiversity*, *13*(5), 613–629. https://doi.org/10.1002/cbdv.201500329

Third, the α-pinene in *B. dalzielii* is 98% or more (-)-α-pinene, while in *B. carteri* it is only 41-80% (-)-α-pinene, and in *B. sacra* it is 79-99% (+)-α-pinene. As a result, this chirality can be used to positively identify *B. dalzielii* essential oil.

A high AKBA to β-BA ratio (at least 3:1) in the resin seems to be unique to *B. dalzielii* (Schmiech et al. 2019). Although samples from other species may have more AKBA than β-BA, *B. dalzielii* is the only species that consistently has a minimum of three times the AKBA compared to the β-BA content (Schmiech *et al*. 2019). *Boswellia dalzielii* also has a significantly higher total AKBA content than other *Boswellia* species (Schmiech *et al*. 2021).

3.2.2.3 *Boswellia frereana*

The essential oil of *Boswellia frereana* is typically characterized by a high level of α-thujene and/or α-pinene (20-65%), along with sabinene (3-8%), *p*-cymene (2-17%), and dimers of α-phellandrene (1-20%) (Johnson *et al*. 2021[26], Basar 2005, Van Vuuren *et al*. 2010, Hamm *et al*. 2005, Niebler and Buettner 2016). Niebler and Buettner (2016) suggest that two components, *trans*-sabinene hydrate acetate and α-phellandrene dimers, are found only in *B. frereana* and not in *B. carteri*, *B. sacra*, *B. serrata*, or *B. papyrifera*. These components do not seem to occur in *B. rivae*, *B. neglecta*, or *B. dalzielii* either (although *trans*-sabinene hydrate is seen in *B. dalzielii*, its acetate is not) (Basar *et al*. 2003, Basar 2005, Hamm *et al*. 2005, DeCarlo *et al*. 2019b, DeCarlo *et al*. 2019c[27]). *Trans*-sabinene hydrate acetate is not found in all samples of *B. frereana*, however, so it cannot be considered a definitive marker. The presence of α-phellandrene dimers is generally consistent across all samples of *B. frereana*. Interestingly, some samples of *B. frereana* resin from individual trees show few or no α-phellandrene dimers, but α-thujene, *p*-cymene, and sabinene were all present in substantial quantities (Johnson *et al*. 2021). Furthermore, commercial samples represent many trees' resin together, so the effect of variation in individual trees would be reduced. While the α-phellandrene dimers occur in small or trace amounts in *B. carteri* or *B. serrata* (Hamm *et al*. 2005), they can be considered a strong marker component for *B. frereana*.

Boswellia frereana is unusual among the *Boswellia* in that its resin contains very few or no boswellic acids (Schmiech *et al*. 2019, Schmiech *et al*. 2021, Blain *et al*. 2010[28], Johnson *et al*. 2021, Mathe *et al*. 2004[29]). Instead, the heavy components are composed primarily of lupeol, 3-*epi*-lupeol, and α- and β-amyrins (Johnson *et al*. 2021, Mathe *et al*. 2004, Blain *et al*. 2010). These components are all commonly found in other plant species, including in resins such as copal from Mexico (Hernández-Vázquez *et al*. 2010[30]). However, the presence of α-phellandrene dimers as one of the top ten components along with α-pinene or α-thujene dominance in the essential oil, is unique and diagnostic of *B. frereana*.

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[26] Johnson, S., DeCarlo, A., Satyal, P., Dosoky, N., Sorensen, A., & Setzer, W. (2021). The Chemical Composition of Single-Tree Boswellia frereana Resin Samples. *Natural Product Communications*, *16*, 1934578X2110437. https://doi.org/10.1177/1934578X211043727

[27] DeCarlo, A., Johnson, S., Ouédraogo, A., Dosoky, N. S., & Setzer, W. N. (2019). Chemical Composition of the Oleogum Resin Essential Oils of Boswellia dalzielii from Burkina Faso. *Plants*, *8*(7), 223. https://doi.org/10.3390/plants8070223

[28] Blain, E. J., Ali, A. Y., & Duance, V. C. (2010). Boswellia frereana (frankincense) suppresses cytokine-induced matrix metalloproteinase expression and production of pro-inflammatory molecules in articular cartilage. *Phytotherapy Research*, *24*(6), 905–912. https://doi.org/10.1002/ptr.3055

[29] Mathe, C., Culioli, G., Archier, P., & Vieillescazes, C. (2004). High-Performance Liquid Chromatographic Analysis of Triterpenoids in Commercial Frankincense. *Chromatographia*, *60*(9), 493–499. https://doi.org/10.1365/s10337-004-0417-3

[30] Hernández-Vázquez, L., Mangas, S., Palazón, J., & Navarro-Ocaña, A. (2010). Valuable medicinal plants and resins: Commercial phytochemicals with bioactive properties. *Industrial Crops and Products*, *31*(3), 476–480. https://doi.org/10.1016/j.indcrop.2010.01.009

3.2.2.4 *Boswellia neglecta*

Boswellia neglecta essential oil is characterized by dominance of α-pinene (16-51%), α-thujene (8-21%), *p*-cymene (2-12%), and terpinen-4-ol (5-30%), as well as verbenone (2-7%) in some samples (Basar *et al*. 2003, Basar 2005, Bekana *et al*. 2014, Schmiech *et al*. 2021). While terpinen-4-ol is seen in other species as well, the level of terpinen-4-ol (>5-7% typically) is characteristic of *B. neglecta*. Some individual samples of *B. carteri* or *B. frereana* may overlap this range slightly, but in general this level of terpinen-4-ol is indicative of *B. neglecta*.

Linalyl acetate may be a useful component to distinguish *B. neglecta* from *B. rivae*. However, this component also occurs in *B. carteri* and *B. sacra*, so it cannot be taken as definitive in identification. Niebler and Buettner (2016) tentatively identified borneol as a marker for *B. neglecta* essential oil; however, Basar *et al*. 2003 did not identify it in their sample and it doesn't appear in all samples of commercial *B. neglecta* oil.

The literature on the boswellic acid contents of *B. neglecta* is mixed. Samples from Kenya and Ethiopia show very low levels of all boswellic acids (Schmiech *et al*. 2021, Schmiech *et al*. 2019, Basar 2005). However, samples from Somalia show a relatively high level of boswellic acids, comparable to other species of *Boswellia*. These samples are dominated by β-boswellic acid (at least twice the concentration of other types of boswellic acid), and have very little acetyl-11-keto-β-boswellic acid (AKBA). The only other species that shows this pattern is *B. carteri* (in some samples) (Schmiech *et al*. 2021, Schmiech *et al*. 2019), which is distinguished from *B. neglecta* by the much lower level of terpinen-4-ol.

3.2.2.5 *Boswellia occulta*

Boswellia occulta contains a mixture of boswellic acids, comparable to those found in *B. carteri* and *B. sacra* (Schmiech *et al*. 2019). However, it is noted for the presence of methoxyalkanes, particularly 1-methoxydecane (decyl methyl ether). Methoxyalkanes are a group of aliphatic methyl ethers that are not known from any other *Boswellia* species or indeed from any other plant species aside from a single report from a Chinese tree peony (*Paeonia rockii*; Zhao et al. 2012[31]). The presence of methoxydecane is considered diagnostic of *B. occulta*, as it is consistently observed in the species but not observed in any other *Boswellia* species (Johnson et al. 2019). The scent of both the resin and essential oil of *B. occulta* is distinctive as well. There has not been enough research on the composition of the boswellic acids or heavy components of *B. occulta* resin to identify any definitive markers or patterns.

3.2.2.6 *Boswellia papyrifera*

Boswellia papyrifera essential oil is noted for its high levels of octyl acetate (typically 50-80%) and octanol (typically 5-15%), as well as the unique scent (Bekana *et al*. 2014, Camarda *et al*. 2007, Dekebo *et al*. 1999[32], Hamm *et al*. 2005, DeCarlo *et al*. *in press*). The boswellic acid composition is similar to that

[31] Zhao, J., Hu, Z., Leng, P., Zhang, H.-X., & Cheng, F.-Y. (2012). Fragrance Composition in Six Tree Peony Cultivars. *Korean Journal of Horticultural Science and Technology*, *30*, 617–625. https://doi.org/10.7235/hort.2012.12055

[32] Dekebo, A., Zewdu, M., & Dagne, E. (1999). Volatile oils of frankincense from Boswellia papyrifera. *Bulletin of the Chemical Society of Ethiopia*, *13*, 93–96. https://doi.org/10.4314/bcse.v13i1.21061

of *B. sacra* (Schmiech *et al*. 2021, Schmiech *et al*. 2019[33]), but it also includes a substantial fraction of incensole acetate (Al-Harrasi *et al*. 2019[34]). While this compound occurs in some other species of *Boswellia* (such as *B. carteri*), it is found in substantial quantities only in *B. papyrifera*, and has been suggested as a biomarker for the resin of this species (Schmiech *et al*. 2021, Paul *et al*. 2012). It may also occur in the resin of *B. elongata*, but this has only been reported once and this species is only rarely traded and in very small volumes (Mothana et al. 2011[35]). For the purposes of identifying species in trade, the presence of any significant quantity of incensole acetate is indicative of the material being *B. papyrifera*. Elemonic acid has also been reported in *B. papyrifera* but not in *B. carteri* and *B. sacra* when using a TLC method (Zhang *et al*. 2013[36]). Some samples of *B. papyrifera* also contain high levels of verticilla-4(20),7,11-triene, which doesn't seem to occur in high levels in other species.

3.2.2.7 *Boswellia rivae*

Boswellia rivae essential oil is characterized by dominance of α-pinene (5-66%), limonene (1-28%), δ-3-carene (1-17%), and sometimes β-pinene (1-11%) or *p*-cymene (3-22%) (Basar *et al*. 2003, Basar 2005, Camarda *et al.* 2007, Bekana *et al*. 2014, Schmiech *et al*. 2021, pers. comm. with supplier in Ethiopia). *Trans*-Verbenol is also noted as a minor component in some samples (Basar *et al*. 2003, Schmiech *et al*. 2021). Unique marker compounds (those seen in all or almost all *B. rivae* samples but not seen in other *Boswellia*) are not immediately apparent. Verbenol and/or myrtenal being in the top 10-15 most abundant components may be indicative of *B. rivae*. *Boswellia rivae* also does not contain incensole or incensyl acetate, which helps distinguish it from other similar species such as *B. carteri*.

Chirality may be a useful tool to differentiate *B. rivae*. Boswellia rivae contains 50-55% dextrorotary α-pinene, which is different from other α-pinene-rich *Boswellia* (compared to 79-99% in *B. sacra*, 20-59% in *B. carteri*, and 2% in *B. dalzielii*) (FairSource Botanicals 2020). There is some overlap in chirality with *B. carteri*, which can be difficult to distinguish.

However, the boswellic acid compositions are different. *Boswellia rivae* resin contains small amounts of several boswellic acids, particularly α- and β-boswellic acid (Basar 2005, Schmiech *et al*. 2019, Schmiech *et al*. 2021). The low levels of boswellic acids helps distinguish it from other species of *Boswellia*, as only *B. frereana* and *B. neglecta* are known to be likewise impoverished in these components. *Boswellia rivae* is distinguished from *B. frereana* in that the latter contains large amounts of lupeols while the former does not. It is differentiated from *B. neglecta* by the low level of terpinen-4-ol and higher levels of limonene, δ-3-carene, and/or β-pinene.

3.2.2.8 *Boswellia sacra* (Oman)

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[33] Schmiech, M., Lang, S. J., Werner, K., Rashan, L. J., Syrovets, T., & Simmet, T. (2019). Comparative Analysis of Pentacyclic Triterpenic Acid Compositions in Oleogum Resins of Different Boswellia Species and Their In Vitro Cytotoxicity against Treatment-Resistant Human Breast Cancer Cells. *Molecules*, *24*(11), 2153. https://doi.org/10.3390/molecules24112153

[34] Al-Harrasi, A., Csuk, R., Khan, A., & Hussain, J. (2019). Distribution of the anti-inflammatory and anti-depressant compounds: Incensole and incensole acetate in genus Boswellia. *Phytochemistry*, *161*, 28–40. https://doi.org/10.1016/j.phytochem.2019.01.007

[35] Mothana, R., Hasson, S., Schultze, W., Mowitz, A., & Lindequist, U. (2011). Phytochemical composition and in vitro antimicrobial and antioxidant activities of essential oils of three endemic Soqotraen Boswellia species. *Food Chemistry - FOOD CHEM*, *126*. https://doi.org/10.1016/j.foodchem.2010.11.150

[36] Zhang, Y., Ning, Z., Lu, C., Zhao, S., Wang, J., Liu, B., Xu, X., & Liu, Y. (2013). Triterpenoid resinous metabolites from the genus Boswellia: Pharmacological activities and potential species-identifying properties. *Chemistry Central Journal*, *7*(1), 153. https://doi.org/10.1186/1752-153X-7-153

Boswellia sacra is noted for the typically high level of α-pinene in the essential oils (typically 60-80%), with other individual monoterpenes (limonene, δ-3-carene, camphene, myrcene, etc.) present, often at 5% or less of the total sample. However, some samples have been reported that contained lower levels of α-pinene and higher levels of limonene and other monoterpenes, similar to *B. carteri* (Al-Saidi *et al*. 2012[37], Woolley *et al*. 2012[38], Al-Harrasi and Al-Saidi 2008[39], Di Stefano *et al*. 2020[40]). Samples taken from individual trees also indicate that while many trees produce resins in this pattern, some rare trees produce dominated by δ-3-carene or mixtures of sesquiterpenes (DeCarlo *et al*. *in preparation*). However, it is unlikely that mixed commercial lots of resin would show this chemistry.
This α-pinene dominant chemistry similar in composition to *B. dalzielii* and some samples of *B. carteri*, but is distinguished by the dominant dextrorotatory enantiomers. *Boswellia sacra* is dominant in (+)-α-pinene, 79-99%, while *B. carteri* and *B. dalzielii* are dominated by (-)-α-pinene (41-80% and ~98%, respectively) (DeCarlo *et al*. 2019b[41], Woolley *et al*. 2012).

Schmiech *et al*. 2021[42] found *B. sacra* to be characterized by a low total content of KBAs (11-keto-β-boswellic acid and 11-keto-α-boswellic acid), and a low proportion of 11-keto-α-boswellic acid. Al-Harrasi *et al*. 2018[43] also found *epi*-α-amyrin to be a marker for *B. sacra*, compared to *B. serrata* and *B. papyrifera*.

Caryophyllene oxide was identified by Paul *et al*. (2011)[44] as being a marker compound for *B. sacra* and *B. carteri* (compared to *B. serrata* and *B. papyrifera*). Likewise, Hamm *et al*. (2005)[45] and Camarda *et al*. (2007)[46] found caryophyllene oxide only in these two species when comparing them to samples of *B. papyrifera*, *B. serrata*, *B. frereana*, and *B. rivae*. However, other studies on *B. carteri* and *B. sacra* samples suggest that this compound does not occur in all resin samples tested, and it has been found in samples of *B. frereana*, *B. dalzielii*, and *B. neglecta* as well (Van Vuuren *et al*. 2010[47], DeCarlo *et al*.

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[37] Al-Saidi, S., Rameshkumar, K. B., Hisham, A., Sivakumar, N., & Al-Kindy, S. (2012). Composition and antibacterial activity of the essential oils of four commercial grades of Omani luban, the oleo-gum resin of Boswellia sacra FLUECK. *Chemistry & Biodiversity*, *9*(3), 615–624. https://doi.org/10.1002/cbdv.201100189

[38] Woolley, C. L., Suhail, M. M., Smith, B. L., Boren, K. E., Taylor, L. C., Schreuder, M. F., Chai, J. K., Casabianca, H., Haq, S., Lin, H.-K., Al-Shahri, A. A., Al-Hatmi, S., & Young, D. G. (2012). Chemical differentiation of Boswellia sacra and Boswellia carterii essential oils by gas chromatography and chiral gas chromatography–mass spectrometry. *Journal of Chromatography A*, *1261*, 158–163. https://doi.org/10.1016/j.chroma.2012.06.073

[39] Al-Harrasi, A., & Al-Saidi, S. (2008). Phytochemical Analysis of the Essential Oil from Botanically Certified Oleogum Resin of Boswellia sacra (Omani Luban). *Molecules*, *13*(9), 2181–2189. https://doi.org/10.3390/molecules13092181

[40] Di Stefano, V., Schillaci, D., Cusimano, M. G., Rishan, M., & Rashan, L. (2020). In Vitro Antimicrobial Activity of Frankincense Oils from Boswellia sacra Grown in Different Locations of the Dhofar Region (Oman). *Antibiotics*, *9*(4), 195. https://doi.org/10.3390/antibiotics9040195

[41] DeCarlo, A., Johnson, S., Okeke-Agulu, K. I., Dosoky, N. S., Wax, S. J., Owolabi, M. S., & Setzer, W. N. (2019). Compositional analysis of the essential oil of Boswellia dalzielii frankincense from West Africa reveals two major chemotypes. *Phytochemistry*, *164*, 24–32. https://doi.org/10.1016/j.phytochem.2019.04.015

[42] Schmiech, M., Ulrich, J., Lang, S. J., Büchele, B., Paetz, C., St-Gelais, A., Syrovets, T., & Simmet, T. (2021). 11-Keto-α-Boswellic Acid, a Novel Triterpenoid from Boswellia spp. With Chemotaxonomic Potential and Antitumor Activity against Triple-Negative Breast Cancer Cells. *Molecules*, *26*(2), 366. https://doi.org/10.3390/molecules26020366

[43] Al-Harrasi, A., Rehman, N. U., Khan, A. L., Al-Broumi, M., Al-Amri, I., Hussain, J., Hussain, H., & Csuk, R. (2018). Chemical, molecular and structural studies of Boswellia species: β-Boswellic Aldehyde and 3-epi-11β-Dihydroxy BA as precursors in biosynthesis of boswellic acids. *PLoS ONE*, *13*(6), e0198666. https://doi.org/10.1371/journal.pone.0198666

[44] Paul, M., Brüning, G., Bergmann, J., & Jauch, J. (2012). A Thin-layer Chromatography Method for the Identification of Three Different Olibanum Resins (Boswellia serrata, Boswellia papyrifera and Boswellia carterii, respectively, Boswellia sacra). *Phytochemical Analysis*, *23*(2), 184–189. https://doi.org/10.1002/pca.1341

[45] Hamm, S., Bleton, J., Connan, J., & Tchapla, A. (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. https://doi.org/10.1016/j.phytochem.2005.04.025

[46] Camarda, L., Dayton, T., Di Stefano, V., Pitonzo, R., & Schillaci, D. (2007). Chemical Composition and Antimicrobial Activity of Some Oleogum Resin Essential Oils from Boswellia SPP. (Burseraceae). *Annali Di Chimica*, *97*(9), 837–844. https://doi.org/10.1002/adic.200790068

[47] Van Vuuren, S. F., Kamatou, G. P. P., & Viljoen, A. M. (2010). Volatile composition and antimicrobial activity of twenty commercial frankincense essential oil samples. *South African Journal of Botany*, *76*(4), 686–691. https://doi.org/10.1016/j.sajb.2010.06.001

2019b, DeCarlo *et al*. 2018[48], Niebler *et al*. 2016[49]). As a result, its presence cannot be taken as indicative of species identity.

3.2.2.9 *Boswellia serrata*

The essential oil of *Boswellia serrata* is typically dominated by α-thujene (12-70%), although a myrcene-dominant chemotype (up to 41%) has also been reported (Basar 2005, Camarda et al. 2007, Gupta et al. 2017[50], Hamm et al. 2005, Sadhasivam et al. 2016[51], Schmiech *et al*. 2021).

The presence of serratol, without the presence of caryophyllene oxide or methoxyalkanes, could be indicative of *B. serrata* when using a thin-layer chromatography approach (Paul *et al*. 2011, Johnson *et al*. 2019[52]), but some samples of *B. carteri* and other species also show modest amounts of serratol. However, two components, methyl eugenol and methyl chavicol (estragole), seem to occur in almost all *B. serrata* samples tested. Both methyl chavicol and methyl eugenol may occur in trace quantities in *B. carteri*, but this is somewhat rare. As a result, methyl chavicol can be considered a biomarker for *B. serrata*. β-Bourbonene and kessane have been suggested as biomarkers, but the former is also found in *B. frereana*, *B. carteri*, and *B. occulta*, and the latter is found in *B. occulta*. As a result, β-Bourbonene cannot be considered a marker. Kessane can be considered a marker if it occurs without the presence of methoxyalkanes (Johnson *et al*. 2019). Z-α-*trans*-Bergamotene has been noted as a marker for *B. serrata*, but it does not occur in all samples and may also be present in other species.

Boswellia serrata differs from *B. sacra* and *B. papyrifera* in that it possesses a higher level of β-KBA (1.29% vs. 0.46% and 0.73%, respectively, per Al-Harrasi *et al*. 2018). However, Schmiech *et al*. 2019 found high levels of KBAs in both *B. serrata* and *B. dalzielii*; these two species can be differentiated by the presence of a high AKBA to β-BA ratio in *B. dalzielii*, while the opposite is true for *B. serrata*. *Boswellia serrata* also has a high proportion of deacetylated boswellic acids, which differentiates it from *B. sacra* (Schmiech et al. 2021).

3.2.2.10 Other Species

There are several other species of *Boswellia* that may appear in international trade, but the populations are generally small, making large-scale trade difficult or impossible. The majority of these species are confined to the island of Socotra (11 species), with other species such as *B. ogadensis* and *B. globosa* occupying small, insular ranges (Thulin 2020[53]). These species are not known to be in regular trade, nor

[48] DeCarlo, A., Johnson, S., Poudel, A., Satyal, P., Bangerter, L., & Setzer, W. N. (2018). Chemical Variation in Essential Oils from the Oleo-gum Resin of Boswellia carteri: A Preliminary Investigation. *Chemistry & Biodiversity*, *15*(6), e1800047. https://doi.org/10.1002/cbdv.201800047

[49] Niebler, J., Eslamieh, J., & Buettner, A. (2016). Frankincense Revisited, Part II: Volatiles in Rare Boswellia Species and Hybrids. *Chemistry & Biodiversity*, *13*(5), 630–643. https://doi.org/10.1002/cbdv.201500339

[50] Gupta, M., Rout, P. K., Misra, L. N., Gupta, P., Singh, N., Darokar, M. P., Saikia, D., Singh, S. C., & Bhakuni, R. S. (2017). Chemical composition and bioactivity of Boswellia serrata Roxb. Essential oil in relation to geographical variation. *Plant Biosystems - An International Journal Dealing with All Aspects of Plant Biology*, *151*(4), 623–629. https://doi.org/10.1080/11263504.2016.1187681

[51] Sadhasivam, S., Palanivel, S., & Ghosh, S. (2016). Synergistic antimicrobial activity of Boswellia serrata Roxb. Ex Colebr. (Burseraceae) essential oil with various azoles against pathogens associated with skin, scalp and nail infections. *Letters in Applied Microbiology*, *63*(6), 495–501. https://doi.org/10.1111/lam.12683

[52] Johnson, S., DeCarlo, A., Satyal, P., Dosoky, N. S., Sorensen, A., & Setzer, W. N. (2019). The Chemical Composition of Boswellia occulta Oleogum Resin Essential Oils. *Natural Product Communications*, *14*(7), 1934578X19866307. https://doi.org/10.1177/1934578X19866307

[53] Thulin, M. (2020). *The Genus Boswellia (Burseraceae): The Frankincense Trees*. Acta Universitatis Upsaliensis. http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-405908

are the known population sizes large enough to accommodate any significant level of commercialization. Likewise, *B. pirottae* and *B. ovalifoliolata* are not known to be in international commercial trade, and have relatively restricted ranges that would make international trade on a wide scale unlikely. However, as these species occur in range states where there are major commercial species (Ethiopia with *B. papyrifera* and India with *B. serrata*, respectively), they may be harvested to some degree and sold as the more commonly traded species or used in markets locally.

3.3. Tools and technologies

3.3.1 Organoleptic

The visual appearance and scent of an essential oil or resin can often be used to differentiate species (this can't be used for boswellic acids). This process can work well with pure (single species rather than mixed species) material and unprocessed/raw resin. This provides a good 'first pass' testing option to positively identify a large percentage of the materials in trade. For instance, a customs officer could use a small sample kit of frankincense resins and oils to identify an unknown resin or essential oil by the similarity of scent and appearance of the resin. However, organoleptic testing can be ineffective when the material is mixed (for instance, mixed *B. sacra* and *B. serrata* essential oil) or when the material has been processed (for instance, incense that includes multiple other fragrance components or supplements made from purified boswellic acids). Furthermore, while this type of testing is fairly effective to tell the difference between distinctive oils like *B. papyrifera* and *B. occulta*, it requires some practice to correctly identify samples of *B. carteri* vs. *B. sacra*, *B. rivae* vs. *B. carteri*, etc.

3.3.2 Physical Constants and Properties

Physical properties of the resins and essential oils are often used to differentiate species. The specific density, refractive index, and optical rotation are all properties of the essential oil that are commonly used as markers of authenticity. While there is a significant overlap in the values for each of these properties across species (i.e. many species have very similar densities, refractive indices, and optical rotations), they can be useful when trying to determine between just a few options.

Optical rotation is a characterization of the chirality of the molecules in the essential oil. For frankincense, many of the major molecules (such as α-pinene, limonene, α-thujene, etc.) come in two stereoisomers, dextrorotary (symbolized by (+)), and levorotary (symbolized by (-)). The ratio of dextrorotary to levorotary stereoisomers for each constituent molecules varies from species to species, and results in a sum optical rotation value that characterizes the predominance of stereoisomers in the sample. For instance, an essential oil sample with a +30 optical rotation is dominant in dextrorotary stereoisomers, while a sample with a -30 optical rotation is dominant in levorotary stereoisomers; a sample with an optical rotation of 0 is an even mixture of dextro- and levorotary stereoisomers. Many frankincense species have characteristic optical rotation ranges that can be used to differentiate two similar species (for instance, *B. dalzielii* and *B. sacra*). Optical rotation is a composite value describing the general chirality of the sampled essential oil; determining the specific enantiomeric ratios of individual components (such as a-pinene) requires the use of chiral chromatography.

Solubility is another useful property. Frankincense resin is typically a combination of fat-soluble terpenes (volatile and nonvolatile) and water-soluble carbohydrate gum. *Boswellia frereana* is a notable exception to this rule, however, as it contains no (or very little) water-soluble gum. As a result, the relative solubility of a resin in ethanol versus water can be used to distinguish a sample of *B. frereana* from a sample of other frankincense resin. *Boswellia papyrifera* can be distinguished from *B. carteri*, *B. sacra*, and *B. serrata* by the fact that a diethyl ether extract of the resin can be easily dissolved in methanol; diethyl ether extracts of the latter species produce a dim white colloidal solution when dissolved in methanol (Paul *et al*. 2012).

3.3.3 Gas Chromatography-Mass Spectrometry (GC/MS)

Gas Chromatography-Mass Spectrometry (GC/MS) is a highly accurate technique to identify the chemical composition of substances. It is the most commonly used technique to analyze essential oil compositions, and is best used for substances that volatilize reasonably easily, and for that reason is best for essential oils but may not capture larger, less volatile components such as boswellic acids as well.

It consists of two devices, a gas chromatograph and a mass spectrometer. Samples of a substance to be analyzed are dissolved in a solvent and vaporized into a gas inside the gas chromatograph. The sample gas is then carried through a column by an inert carrier gas such as helium (referred to as the mobile phase). The column is lined with a substance, the stationary phase, that interacts with the sample being analyzed. Different molecules travel through the stationary phase at different speeds; this helps to separate out the individual components of the sample, which come out of the column at different times based on their individual molecular characteristics (the retention time). The individual molecules exit the column and go into the mass spectrometer, which breaks them into ionized fragments using a high energy beam of electrons. These fragments hit a detection plate, allowing the calculation of the relative abundance of each fragment and the mass to charge ratio for each fragment. This allows the generation of a graph of the mass spectrum of the fragments for each component. Based on the retention time and mass spectrum, components can be very accurately identified. GC/MS is also used to determine the chirality of different terpenes within a sample; this is accomplished by using a column with a chiral stationary phase to cause the different enantiomers to separate and allow them to be measured and quantified.

3.3.4 High Performance Liquid Chromatography (HPLC)

High-Performance Liquid Chromatography is an analytical technique to separate and identify the constituent components of a substance. Unlike GC/MS, HPLC is able to identify components that do not readily volatilize, and for that reason, it is used to analyze resins and boswellic acids.

HPLC works by sending a liquid solvent (called the mobile phase) through a pressurized column at a constant flow rate, using a high-pressure pump. The column is packed with a substance, called the stationary phase, that interacts with the substance being analyzed. Unlike normal liquid chromatography, HPLC uses a pressurized column to effect better separate of the components. The sample being analyzed is injected into the mobile phase, which carries it through the column where it separates into its constituent components and into a detector, where the components are quantified and identified. As HPLC does not rely on the sample being vaporized into gas, it is better able to detect and quantify non-volatile components such as boswellic acids. HPLC may also be used with mass spectrometry to better identify the components.

3.3.5 Thin Layer Chromatography (TLC)

Thin-layer chromatography is a chromatography technique used to separate non-volatile substances. TLC is easy and cheap, but it does not detect/resolve components present in small quantities; for this reason, it is appropriate for analysis of resin but not essential oil. Still, the limited resolution can make it difficult to accurately read a TLC plate, especially for species that have very similar compositions.

Thin layer chromatography is performed using a thin layer of stationary phase material, such as silica gel, covering an inert substance such as a glass plate. The resin being analyzed would be dissolved in a solvent such as diethyl ether and methanol, and applied to the bottom of the plate. A solvent (the mobile phase) would then be applied and drawn up the chromatography plate via capillary action. The sample (the dissolved resin) is separated into its constituent components as it is drawn up the plate, as different components ascend the plate at different rates depending on their molecular characteristics. The separated components are then visualized using a dyeing reagent and/or UV light. The resulting chromatography plate can then be compared to the plate obtained from analysis of a known reference material to compare the compositions observed.

3.3.6 Other Techniques and Technologies

3.3.6.1 Direct Analysis in Real Time (Time of Flight) Mass Spectrometry (DART-TOFMS)

DART-TOFMS is a newer technique that shows promise. It has not been widely used to analyze frankincense resins, but will likely become more popular in the future.
DART-TOFMS requires no sample preparation and can be used on either essential oils or whole resins. The sample is exposed to a stream of heated helium atoms, which volatilizes the components on or near the surface of the sample. These components are then detected and analyzed by the mass spectrometer as previously described in 2.3.3. As a result, DART-TOFMS produces a complete or near-complete chemical profile for the sample. It has been used with great success to identify different species of timber products in trade (Paredes-Villanueva et al. 2018[54], Price et al. 2021[55], Deklerck et al. 2020[56]), and recent experiments suggest it could be used to identify different frankincense species.

3.3.6.2 Infrared Spectroscopy

Infrared spectroscopy (IR), near-infrared spectroscopy (NIR), and Fourier transform infrared absorption spectrometry are fast, non-destructive techniques that have been used in limited cases to analyze frankincense resins. In simple form, it involves passing a beam of infrared light through a sample and examining the absorbance, which allows an analyst to determine the composition of the sample. FTIR has been used to examine differences between resin samples of different geographic origins (Archier

[54] Paredes-Villanueva, K., Espinoza, E., Ottenburghs, J., Sterken, M. G., Bongers, F., & Zuidema, P. A. (2018). Chemical differentiation of Bolivian Cedrela species as a tool to trace illegal timber trade. *Forestry: An International Journal of Forest Research*, *91*(5), 603–613. https://doi.org/10.1093/forestry/cpy019
[55] Price, E. R., Miles-Bunch, I. A., Gasson, P. E., & Lancaster, C. A. (2021). Pterocarpus wood identification by independent and complementary analysis of DART-TOFMS, microscopic anatomy, and fluorescence spectrometry. *IAWA Journal*, *42*(4), 397–418. https://doi.org/10.1163/22941932-bja10064
[56] Deklerck, V., Lancaster, C. A., Van Acker, J., Espinoza, E. O., Van den Bulcke, J., & Beeckman, H. (2020). Chemical Fingerprinting of Wood Sampled along a Pith-to-Bark Gradient for Individual Comparison and Provenance Identification. *Forests*, *11*(1), 107. https://doi.org/10.3390/f11010107

and Viellescazes 2000)[57], and NIR has been used to quantify incensole and AKBA content in *B. serrata*, *B. papyrifera*, and *B. sacra* (Al-Shidhani *et al.* 2018[58], Rehman *et al.* 2020[59], Rehman *et al.* 2018[60]). The results indicate that these techniques have potential as analytical techniques, but they would have to be authenticated by a far larger number of samples than have currently been used. As a result, these techniques are not currently suggested for widespread use.

3.3.6.3 DNA-Based Species Identification

DNA-based species identification involves extracting DNA from a sample and comparing it against known sequences for target species. This requires the isolation of DNA sequences of sufficient quantity, length, and purity to allow for reliable identification. Processed materials such as essential oils and extracts may not contain sufficient material to allow for this identification; prospects are better with raw resins, but these present their own challenges. Resins are sticky and adhesive by nature, and accidental contamination from airborne plant particles, microorganisms, etc. that may stick to the resins can confound analysis. Additionally, certain components of the resin can interfere with DNA extraction and amplification (Yamamuro *et al*. 2018[61], El Alaoui *et al*. 2013[62]). As a result, this is not a recommended technique for efficient identification of material in trade.

3.4. Identification of Parts

3.4.1. *Boswellia carteri*

3.4.1.1. Essential Oils

Boswellia carteri produces a highly variable essential oil, and for that reason it can be difficult to identify all genuine samples with complete accuracy. The profile of *B. carteri* essential oil in some samples can be very similar to *B. rivae*, *B. neglecta*, *B. dalzielii*, and *B. sacra*. However, there are a variety of indications.

For the α-thujene chemotype of *B. carteri*, the composition is very similar to *B. frereana*. However, *B. carteri* ct. α-thujene has much lower levels of α-phellandrene dimers. Thus, the presence of α-thujene, sabinene, and *p*-cymene in significant quantities but without the α-phellandrene dimers is an indication of *B. carteri* ct. α-thujene.

For the α-pinene chemotype of *B. carteri*, there is some degree of crossover between *B. carteri* and *B. rivae*, *B. neglecta*, *B. dalzielii*, and *B. sacra*. *Boswellia carteri* differs from *B. rivae* in three respects. First, *B. rivae* essential oil does not contain incensole or incensyl acetate, while *B. carteri* does. Second, *B.*

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[57] Archier P, Vieillescazes C. (2000). Characterisation of various geographical origin incense based on chemical criteria. *Analusis*. *28*(3), 233-237.
[58] Al-Shidhani S, Rehman NU, Mabood F, Al-Broumi, M, Hussain, H, Hussain, J, Csuk, R, Al-Harrasi, A. (2018) Quantification of incensole in Three *Boswellia* Species by NIR spectroscopy coupled with PLSR and cross-validation by HPLC. *Phytochem Anal*. *29*(3), 300-307.
[59] Rehman NU, Al-Shidhani S, Al-Harrasi A, Al-Rawahi, A, Mabood, F, Al-Broumi, M, Al-Azri, M, Alam, T, Hussein, J. (2020). Analysis of incensole acetate in *Boswellia* species by near infrared spectroscopy coupled with partial least squares regression and cross-validation by high-performance liquid chromatography. *J Near Infrared Spec*. *28*(1), 18-24.
[60] Rehman NU, Ali L, Al-Harrasi A, Mabood, F, Al-Broumi, M, Latif Khan, A, Hussein, H, Hussein, J, Csuk, R. (2018) Quantification of AKBA in *Boswellia sacra* using NIRS coupled with PLSR as an alternative method and cross-validation by HPLC. *Phytochem Anal*. *29*(2), 137-143.
[61] Yamamuro T, Iwata YT, Segawa H, Kuwayama, K, Tsujikawa, K, Kanamori, T, Inoue, H. (2018). Development of rapid and simple method for DNA extraction from cannabis resin based on the evaluation of relative PCR amplification ability. *Forensic Sci Int*. 287, 176-182.
[62] El Alaoui MA, Melloul M, Alaoui Amine S, Stambouli, H, El-Bouri, A, Soulaymani, A, El-Fahime, E. (2013). Extraction of high quality DNA from seized Moroccan cannabis resin (Hashish). *PLOS ONE*. *8*(10), e74714.

rivae essential oil typically only has a very small percentage of sesquiterpenes (often less than 2% of the total), while *B. carteri* typically has a more developed sesquiterpene profile. Third, *B. rivae* often (though not always) has a higher level of δ-3-carene and/or *p*-cymene than *B. carteri* (over 5% in *B. rivae* and under 5% in *B. carteri*). There are samples of each species that break this rule (and some samples of *B. sacra* may have elevated levels of δ-3-carene), but a high level of either of these components is an indication that it may be *B. rivae*. *Boswellia rivae* also commonly has verbenol and/or myrtenal as one of the top 15 most abundant components, while this is very rare in *B. carteri*. On the other hand, a sample of essential oil high in α-pinene with incensole or incensyl acetate, modest levels of δ-3-carene and *p*-cymene and a variety of sesquiterpenes, which doesn't match *B. sacra*, *B. neglecta*, or *B. dalzielii*, could be *B. carteri*.

Boswellia carteri differs from *B. neglecta* in that it rarely has more than 5% terpinen-4-ol; samples with levels above this may be *B. neglecta*.

Boswellia carteri also differs from *B. dalzielii* and *B. sacra* in that it typically has a lower level of α-pinene (often 20-50% in commercial batches vs. 60% in the other species). As mentioned above, various monoterpenes and sesquiterpenes can be used to indicate *B. dalzielii* vs. *B. carteri*. Additionally, *B. carteri* has a distinct chirality, with 20-60% (+)-α-pinene while *B. dalzielii* has 2% or less (+)-α-pinene and *B. sacra* has 79% or more (+)-α-pinene. Finally, *B. sacra* essential oil often lacks viridiflorol, incensole, dimethyl ether orcinol, and cembrenol, while these components are often seen in *B. carteri*.

3.4.1.2. Resins, Extracts, Incense

Boswellia carteri can be identified by the presence of boswellic acids. The boswellic acid profile is variable, but generally is dominated by β-BA and/or β-ABA. In contrast to *B. sacra* and *B. dalzielii*, most samples of *B. carteri* have very little AKBA. The boswellic acid profile of many samples of *B. carteri* resemble the Somalia samples of *B. neglecta*, but *B. neglecta* has higher levels of lupeolic acid compared to α-BA, while the opposite is true for *B. carteri*. Individual samples may break this rule, but it is generally true. The volatile profile can be useful to differentiate material in question, as the low level of terpenin-4-ol helps exclude *B. neglecta*, while the chirality helps differentiate *B. carteri* from *B. sacra*. The Bos_i is not particularly helpful as an identifier for this species, as it overlaps a wide range of other species. However, a Bos_i over 46,000 may help indicate the specimen is *B. sacra* if the analyst is trying to differentiate between *B. carteri* and *B. sacra*.

3.4.1.3. Adulterants

Boswellia carteri resin may be mixed with *B. occulta* resin or with resins from *B. neglecta* or *B. rivae*. Likewise, *B. papyrifera* resin is often sold as *B. carteri* resin, and could be mixed into *B. carteri* resin (although this has not been clearly documented). It is conceivable that certain *Commiphora* resins could be mixed into *B. carteri*, although this has not been documented.

3.4.1.4. Look Alike Species

Boswellia carteri co-occurs with species such as *B. neglecta* and *B. rivae*, and it is frequently traded informally into the Arabian Peninsula where it could be co-distilled with *B. sacra* resin. Given the similarities between these species and the lack of unique definitive markers, it could be difficult to detect if these species are co-distilled, especially if it is done at low levels.

3.4.2. *Boswellia dalzielii*

3.4.2.1. Essential Oils

Boswellia dalzielii is typically rich in α-pinene, although the level in the essential oil seems to vary depending on its geographic origin (samples from Nigeria seem to show slightly higher levels of α-pinene on average compared to those from Burkina Faso). Its primary distinguishing characteristic is the extremely levorotary optical rotation and particularly the high percentage of (-)-α-pinene (98% or more). This distinguishes it from other α-pinene dominant *Boswellia* species. Although not definitive due to the natural variation within *B. dalzielii* and other *Boswellia* species that results in overlapping component ranges, *B. dalzielii* also tends to have a lower level of limonene than *B. carteri* and *B. rivae*, and higher levels of α-copaene, carvacrol, carvone, α-campholenal, and/or *trans*-verbenol than these species or *B. sacra*. α-terpenyl acetate can also be an indicator as it is often present greater than 1% in *B. dalzielii* but is often not present or present in low levels in other species. However, individual samples may not conform to these indications, so they should not be taken as definitive. The chirality seems to be consistent across samples, and can be a reliable indicator of *B. dalzielii*.

3.4.2.2. Resins, Extracts, Incense

Boswellia dalzielii can be identified by the presence of boswellic acids, particularly AKBA, which is consistently the most abundant boswellic acid. *Boswellia dalzielii* is unique among the *Boswellia* in that the ratio of AKBA to β-BA appears to consistently be 3 or greater. The chirality of the α-pinene in the volatile fraction can also be used to positively identify the species. It has a Bos_i over 130,000, which is overlapped only by a few samples of *B. sacra*.

3.4.2.3. Adulterants

There is little established informal trade between *B. dalzielii* Range States and Range States of other α-pinene rich species, so there is relatively little risk of mixing of species before the first stage of export. *Boswellia dalzielii* has only recently entered international trade, so there is little information about adulterants that may be added to the resin or essential oil.

3.4.2.4. Look Alike Species

Boswellia dalzielii doesn’t co-occur with other species of *Boswellia* except for *B. papyrifera*, in some areas, which is easy to identify by its high level of octyl acetate and incensole acetate (whereas *B. dalzielii* does not contain any octyl acetate and only traces in some samples of incensole acetate). Although other resins are produced in these areas, none are known to closely resemble *B. dalzielii*.

3.4.3. *Boswellia frereana*

3.4.3.1. Essential Oils

Boswellia frereana can be identified by sabinene and *p*-cymene being major components alongside α-thujene and/or α-pinene as the dominant components. Additionally, α-phellandrene dimers are characteristic of *B. frereana* and almost always occur at levels greater than 1% of the total sample.

3.4.3.2. Resins, Extracts, Incense

Boswellia frereana can be identified by the lack of boswellic acids. Instead, the triterpene profile includes high levels of lupeol, 3-*epi*-lupeol, and amyrins. These are present in other types of resins as well, but *B. frereana* can be identified if these triterpenes are also found with a volatile profile that includes α-phellandrene dimers and is rich in α-pinene, α-thujene, sabinene, and *p*-cymene. The resin looks distinctive as well, golden with white striations, which makes it a bit difficult to confuse with other species of frankincense.

3.4.3.3. Adulterants

Boswellia frereana essential oils sometimes contain small amounts of methoxyalkanes, indicating that some *B. occulta* resins have been codistilled with the *B. frereana* resin. *Boswellia frereana* may also be adulterated with *B. carteri*, especially with α-thujene type *B. carteri*. This may be difficult to distinguish in the essential oil at low levels (the reduction in α-phellandrene dimers at higher levels of adulteration may be detectable). The adulteration of *B. frereana* resin with *B. carteri* or *B. occulta* would be identifiable by the presence of boswellic acids.

3.4.3.4. Look Alike Species

There are some *Boswellia carteri* essential oils that closely resemble *B. frereana*, in that they are dominant in α-thujene with significant quantities of sabinene and *p*-cymene. However, these samples don't include α-phellandrene dimers at any significant level, so their presence is a good way to distinguish genuine *B. frereana*.

3.4.4. *Boswellia neglecta*

3.4.4.1. Essential Oils

Boswellia neglecta can be distinguished primarily by the elevated level of terpinen-4-ol, which is almost always present in levels greater than 5% of the total sample. Though some samples of *B. frereana* or *B. carteri* might overlap this range slightly, the vast majority of samples with 5% or more terpinen-4-ol will be *B. neglecta*.

3.4.4.2. Resins, Extracts, Incense

Boswellia neglecta can be identified by the dominance of β-boswellic acid in the boswellic acid profile. It is consistently at least twice as abundant as any other type of boswellic acid. Samples from Kenya show very low levels of boswellic acids, while samples from Somalia show levels comparable to other *Boswellia* species, but in all of the samples, it is β-BA is consistently the most abundant type of boswellic acid. Samples from Kenya resemble some samples of *B. rivae*, while samples from Somalia resemble some samples of *B. carteri*, but *B. neglecta* can be distinguished from both of these by the relatively high level of terpinen-4-ol in the volatile profile. This resin is typically clumped and black, often with dirt in the resin (as much of it is collected from the ground under the trees), which helps distinguish it from other species such as *B. papyrifera*. It has a typically low Bos_i of 0-1,000, although this range is overlapped by *B. rivae* and *B. carteri*.

3.4.4.3. Adulterants

The presence of *C. confusa* in the essential oil may be difficult or impossible to detect. The compositions are extremely similar; the level of terpenin-4-ol seems to be lower in *C. confusa* (often below 5%), but this would only be noticeable in essential oil that is almost exclusively *C. confusa*. There may be other species of *Commiphora*, such as *C. tenuis*, which are monoterpene dominant and resemble *B. neglecta*. Low levels of adulteration may be difficult to detect, but any significant inclusion of *Commiphora* resin would be noticeable by the reduction in the terpenin-4-ol level in the essential oil/volatile profile.

3.4.4.4. Look Alike Species

Commiphora confusa resin closely resembles *B. neglecta* resin in color and chemical composition. However, it is distinguished by the lack of boswellic acids in the resin and the lower level of terpenin-4-ol in the volatile profile. *Boswellia microphylla* co-occurs with *B. neglecta* and looks very similar. There are no studies on the resin, so it is difficult to say how to detect it. The same is true for *B. globosa* and *B. ogadensis*, but these are narrow endemics and unlikely to be in trade at all. Likewise, other species of *Boswellia*, such as *B. rivae* and *B. carteri*, also occur with *B. neglecta*. These can be distinguished from *B. neglecta* by the low levels of terpenin-4-ol.

3.4.5. *Boswellia occulta*

3.4.5.1. Essential Oils

Boswellia occulta can be easily identified by the presence of methoxyalkanes, particularly 1-methoxydecane (decyl methyl ether) and methoxyoctane (octyl methyl ether) in the essential oil.

3.4.5.2. Resins, Extracts, Incense

Boswellia occulta can be identified by the presence of boswellic acids and dominance of methoxyalkanes in the volatile profile (as well as serratol and 4,10-di-*epi*-guaiol in some samples). The presence of methoxyalkanes at low levels may indicate mixing of *B. occulta* resin with other species. Similarly, an elevated level of α-pinene or α-thujene (above 5-10%) may indicate adulteration of *B. occulta* resins with other species, such as *B. carteri*, *B. frereana*, etc. There is not enough data to reliably use the Bos_i to identify this species yet.

3.4.5.3. Adulterants

It is important to note that *B. occulta* resins are sometimes mixed and codistilled with resins of *B. carteri* (or other species) (Johnson et al. 2019b[63]). If methoxyalkanes, serratol, and 4,10-di-*epi*-guaiol are the

[63] Johnson, S., DeCarlo, A., Satyal, P., Dosoky, N. S., Sorensen, A., & Setzer, W. N. (2019). Organic Certification is Not Enough: The Case of the Methoxydecane Frankincense. *Plants*, *8*(4). https://doi.org/10.3390/plants8040088

major components in the oil, it is pure (or mostly pure) *B. occulta*; if methoxydecane is identified only in small amounts with a sample in which the dominant component is α-pinene or α-thujene, it is likely a small amount of *B. occulta* in *B. carteri*, *B. sacra*, *B. frereana*, etc. essential oil.

3.4.5.4. Look Alike Species

The resin of *B. occulta* resembles that of *B. carteri*, and the two both occur in Somalia (Somaliland). Indeed, the resin of *B. occulta* was for many years sold as *B. carteri* before being differentiated as a separate species. However, it can be clearly differentiated by the presence of methoxyalkanes; for this reason, the scent profile of the resin and oil are also very distinct, and can often be determined simply by the organoleptic qualities.

3.4.6. *Boswellia papyrifera*

3.4.6.1. Essential Oils

Boswellia papyrifera can be identified if octyl acetate is the major constituent in the essential oil and/or if incensole acetate is present in amounts greater than 1% of the total constituents.

3.4.6.2. Resins, Extracts, Incense

Boswellia papyrifera can be identified by the presence of boswellic acids, dominance of octyl acetate or verticilla-4(20),7,11-triene in the volatile profile, and more than trace amounts of incensole acetate. It has a Bos_i of 13,000 to 35,000, which is overlapped by *B. carteri*, *B. occulta*, and *B. sacra*.

3.4.6.3. Adulterants

There are no known adulterants of B. papyrifera. It is possible the resin or oil could be mixed with that of other Boswellia species, but this would be revealed by corresponding spikes of α-pinene, verbenol, etc.

3.4.6.4. Look Alike Species

Boswellia papyrifera resin has a unique scent, due to the volatile profile, which by itself makes it difficult to confuse *B. papyrifera* resin with other species of *Boswellia* co-occurring in its range states (*B. rivae*, *B. neglecta*, *B. dalzielii, etc*). If there is any confusion, the high level of octyl acetate and incensole acetate are clear markers. There are no other resins in *B. papyrifera* range states that are known to have a similar composition.

3.4.7. *Boswellia rivae*

3.4.7.1. Essential Oils

Boswellia rivae often looks similar to *B. carteri*, in that it has abundant α-pinene and often abundant limonene. However, it is distinguished by three characteristics. First, it does not contain incensole or incensyl acetate. Second, it has a relatively impoverished sesquiterpene profile, often less than 2% of the total sample, and it typically includes levels of δ-3-carene, *p*-cymene, and/or *trans*-verbenol and verbenone combined greater than 5% (and often far higher), levels not normally seen in *B. carteri*. Finally, verbenol and/or myrtenal are almost always in the top 15 most abundant components in the oil.

3.4.7.2. Resins, Extracts, Incense

Boswellia rivae can be identified by the presence of boswellic acids, but these are present at much lower levels than other α-pinene rich species (with the exception of some samples of *B. neglecta*). *Boswellia rivae* is unique in that it contains more α-KBA than β-KBA, providing a good point for differentiation. Low levels of boswellic acids and lack of significant terpenin-4-ol in the volatile profile (differentiating it from *B. neglecta*) is also a telltale sign of *B. rivae*. *Boswellia rivae* resin is almost always clumped together with a fair amount of dirt, because it is most often collected from the ground under trees. This helps distinguish it from other species of *Boswellia* such as *B. papyrifera*.

3.4.7.3. Adulterants

It is likely that *B. rivae* resin may sometimes be mixed with small amounts of *B. neglecta*, *B. microphylla*, and various *Commiphora* species, as these resins are harvested from self-exudations in mixed species woodland. It is difficult to say whether existing studies have been carried out on pure *B. rivae* or on mixed samples, making identification difficult. Very low levels of adulteration may be difficult to detect, especially for *Commiphora* species producing monoterpene-dominant profiles. However, most *Commiphora* species seem to include furanosesquiterpenes, which are useful markers to identify adulteration. *Boswellia rivae* resin has also been adulterated with gum Arabic, which is easy to identify by its glassy, orange appearance, solubility in water, and lack of boswellic acids or essential oils.

3.4.7.4. Look Alike Species

Boswellia rivae co-occurs with multiple species of other *Boswellia*, such as *B. neglecta*, *B. carteri*, *B. papyrifera*, *B. occulta*, and *B. frereana*, but can be differentiated from them as outlined above. It also occurs with *B. microphylla*, *B. globosa*, and *B. ogadensis*, which have not been studied; of these, only *B. microphylla* is likely to be harvested to any degree. Various *Commiphora* resins may resemble *B. rivae*, but can be differentiated by the lack of boswellic acids and (normally) presence of furanosesquiterpenoids.

3.4.8. *Boswellia sacra*

3.4.8.1. Essential Oils

Boswellia sacra can often be identified by its high level of α-pinene (typically above 60% in commercial batches), which is rare in other frankincense species other than *B. dalzielii*. *Boswellia carteri* may sometimes overlap this range slightly, but commercial batches with levels higher than 60% α-pinene are rare. Additionally, most *B. carteri* samples include incensole, dimethyl ether orcinol, cembrenol, and/or viridifloral, while most *B. sacra* samples do not. To distinguish a high α-pinene *B. sacra* sample from *B. dalzielii*, officers can look at several characteristics. First, *B. dalzielii* is often impoverished of sesquiterpenes (whereas *B. sacra* tends to have a wider sesquiterpene profile), and the most abundant minor components are components like α-terpenyl acetate, α-copaene, carvacrol, carvone, α-campholenal, and *trans*-verbenol (sometimes α-thujene also appears), which are not often the dominant minor components in *B. sacra*. Additionally, *B. sacra* is predominantly dextrorotary, so either polarimetry (optical rotation) or chiral GC/MS should reveal a very dextrorotary optical rotation (at least +15 or higher) and at least 79% (+)-α-pinene. The opposite is true for *B. dalzielii*; although the optical rotation range has not been defined for this species as it is just starting to enter the market, it is dominated by (-)-α-pinene and other levorotary enantiomers, and will therefore have a very levorotary optical rotation (probably at least -15 or lower). Optical rotation can also be used to differentiate *B. sacra* from *B. carteri*, as *B. carteri* mostly has levorotary optical rotations that don't overlap with *B. sacra*'s optical rotation range. As a result, if the optical rotation is +15 or higher, it can be identified as *B. sacra*.

3.4.8.2. Resins, Extracts, Incense

Boswellia sacra can be identified by the presence of boswellic acids, and particularly by the fact that AKBA and β-ABA tend to be the most abundant of the boswellic acids. It also has a low total content of KBAs, a low proportion of α-KBA, and a low proportion of α-AKBA despite the abundance of AKBA in general.

The abundance of AKBA distinguishes *B. sacra* from other α-pinene rich species such as *B. carteri*, *B. neglecta*, and *B. rivae*. The fact that β-ABA levels tend to be about the same as, or higher than, the level of AKBA distinguishes *B. sacra* from *B. dalzielii*, in which AKBA is consistently the most abundant component.

Mixing of *B. carteri* with *B. sacra* resin would be difficult to detect at low levels, but any significant amount of *B. carteri* would be noticeable by the fact that it would reduce the level of AKBA and increase the level of β-BA. AKBA is almost always more abundant in *B. sacra* than β-BA; the opposite is true in *B. carteri*. The Bos_i is not particularly helpful as it overlaps many other species, such as *B. carteri*, *B. papyrifera*, *B. dalzielii*, and *B. occulta*.

3.4.8.3. Adulterants

Mixing of *B. carteri* with *B. sacra* resin would be difficult to detect at low levels, but any significant amount of *B. carteri* would be noticeable by the fact that it would reduce the level of AKBA and increase the level of β-BA. AKBA is almost always more abundant in *B. sacra* than β-BA; the opposite is true in *B. carteri*. There is significant cross-border trade from Somalia to Oman, so *Boswellia carteri* resin may be codistilled with *B. sacra* resin, resulting in a mixed essential oil. It may be difficult to detect this kind of mixing, especially if it is a relatively small percentage of *B. carteri* in the mixture, because its addition would not move the components significantly out of range.

3.4.8.4. Look Alike Species

There are no other species that closely resemble *B. sacra* in Oman or Yemen. However, there is significant informal trade of *B. carteri* and *B. frereana* from Somalia and Somaliland, so *B. carteri* could be confused for *B. sacra*. The difference would be revealed by the chirality of the α-pinene and potentially by the higher level of AKBA.

3.4.9. *Boswellia serrata*

3.4.9.1. Essential Oils

Boswellia serrata can be identified by the presence of methyl chavicol and/or methyl eugenol, which are clear marker compounds for this species. Although there is a myrcene-dominant chemotype, *Boswellia serrata* essential oil in trade is virtually always dominated by α-thujene, making this species easy to identify.

3.4.9.2. Resins, Extracts, Incense

Boswellia serrata can be identified by the presence of boswellic acids and the presence of methyl chavicol and/or methyl eugenol in the volatile profile. It can also be identified by the high percentage of deacetylated boswellic acids, relatively high level of β-KBA, and low AKBA to β-BA ratio. The Bos_i is characteristically low, -22,000 to -2,000; this is overlapped only by occasional samples of *B. carteri*.

3.4.9.3. Adulterants

Boswellia serrata resin may be adulterated with other species of *Boswellia*, such as *B. ovalifoliolata*, which could possibly be identified by the high level of β-caryophyllene present in the volatile profile of *B. ovalifoliolata*. *Boswellia serrata* resin may also occasionally be adulterated with Pinaceae resin, which can be identified by the presence of longifolene- and longipinene-type sesquiterpenes such as α-longipinene, longicyclene, longicamphylenone, longiborneol, and longiborneol acetate (McCutcheon 2018[64]). It is also reported that *Garuga pinnata* resin may be used as an adulterant; there is very little information about the composition of *G. pinnata* resin, but butyrospermol, 3a-epimer, and dammaradienol have been detected (Bhat and Joshi 1985[65]). A low level of boswellic acids would likely be an indicator of adulteration with foreign material (McCutcheon 2018).

The presence of methyl chavicol and/or methyl eugenol in essential oil dominant in α-pinene or components other than α-thujene or myrcene could indicate that *B. serrata* has been added to another oil, for instance to a *B. carteri* essential oil, or that artificial α-pinene was added to *B. serrata* to improve the scent profile. *Boswellia carteri* may contain traces of these components naturally, but only in rare cases. *Boswellia ovalifoliolata* is also present in India and is a possible source of adulteration of *B. serrata* essential oil. While little work has been done on *B. ovalifoliolata* essential oils, they appear to contain large amounts of β-caryophyllene (10-30%) (Reddy et al. 2015[66], Benelli et al. 2017[67], Geetha and Chakravarthula 2018[68]); this is notable because *B. serrata* appears to contain very little to no β-

[64] McCutcheon, A. (2018). *Boswellia serrata Adulteration* (Botanical Adulterants Bulletin). Botanical Adulterants Prevention Program.

[65] Bhat V, Joshi V. (1985). The constituents of the exudate of *Garuga pinnata*. *Curr Sci*. *54*(13), 631-632.

[66] Reddy, P. A., Reddy B, N., Ratnam K, V., MD L, B., & Reddy, L. (2015). Chemical Profile, Antioxidant and Antimicrobial Activity of Essential Oils From Boswellia ovalifoliolata Bal. Et Henry. *International Journal of Pharmaceutical and Clinical Research*, *7*, 96–101.

[67] Benelli, G., Rajeswary, M., Vijayan, P., Senthilmurugan, S., Alharbi, N. S., Kadaikunnan, S., Khaled, J. M., & Govindarajan, M. (2017). Boswellia ovalifoliolata (Burseraceae) essential oil as an eco-friendly larvicide? Toxicity against six mosquito vectors of public health importance, non-target mosquito fishes, backswimmers, and water bugs. *Environmental Science and Pollution Research*, 1–8. https://doi.org/10.1007/s11356-017-8820-0

[68] Geetha, V., & Chakravarthula, S. N. (2018). Chemical composition and anti-inflammatory activity of Boswellia ovalifoliolata essential oils from leaf and bark. *Journal of Forestry Research*, *29*(2), 373–381. https://doi.org/10.1007/s11676-017-0457-9

caryophyllene. Consequently, the presence of more than 0.05% β-caryophyllene in the essential oil is an indication that adulteration may have occurred.

3.4.9.4. Look Alike Species

The resins of Pinaceae and *Garuga pinnata* may to some degree visually resemble *B. serrata* resin, leading to their use as adulterants. Pinaceae resin can be identified by the presence of longifolene- and longipinene-type sesquiterpenes, while there is no research on the composition of *G. pinnata* resin. *Boswellia ovalifoliolata* is the only other species of *Boswellia* occurring with *B. serrata*; it can be distinguished by the high level of β-caryophyllene present and significantly lower level of boswellic acids (Laila Nutraceuticals 2022).

3.4.10 Interchangeability of Species

Some species are similar enough in chemical composition and scent profile to be interchangeable for industrial purposes. In other words, some species are sufficiently similar that if one of the species were listed or trade was otherwise reduced, another species could be used in its place. This is only true for some species, and differs for the essential oil versus the resins.

The essential oils of *B. papyrifera* and *B. occulta* are sufficiently unique that no other species could be substituted for them. Likewise, while several species have an α-thujene chemotype, *Boswellia serrata* is sufficiently different in its scent profile that it is unlikely other species could be substituted for it. Many of the α-pinene dominant species could be interchanged; the preferred species for essential oils are *B. carteri*, *B. sacra*, and *B. frereana*, but these could be replaced by *B. dalzielii*, *B. neglecta*, or *B. rivae*. Although there are some differences in scent profile and composition, they are similar enough to be considered interchangeable.

By contrast, the resins show a different pattern of interchangeability. *Boswellia serrata*, *B. papyrifera*, *B. sacra*, and *B. dalzielii* all have relatively high levels of boswellic acids and show a diversity of boswellic acids (although the specific levels of each acid vary, they can generally be considered interchangeable). *Boswellia carteri* may also be considered a source of boswellic acids, but it is often impoverished of AKBA, which is one of the most desirable boswellic acids and therefore it is less likely to be a substitute for *B. serrata* and *B. papyrifera* than the others. *Boswellia frereana*, *B. neglecta*, and *B. rivae* show insufficient levels of boswellic acids to be of interest, although *B. neglecta* or *B. rivae* might be used as low-quality incense.

Chapter Four

Required Capacity and Resources for Species Identification

Authors: Anjanette DeCarlo and Stephen Johnson

4.0 Summary

A sample set of frankincense resins and essential oils can be used for first-pass organoleptic testing to help identify shipments for further testing. This will cost around $250 USD annually per lab. Thin-Layer Chromatography is a good second-pass option that is still low-cost and easy, and can provide additional insight into possible species identification, albeit not with the same accuracy or selectivity as more sophisticated techniques. GC-MS and HPLC testing are the best detailed testing options to resolve species identity definitively. HPLC can identify the presence of boswellic acids or other heavy components like lupeol, to determine if a sample contains frankincense and to give an indication of the species. A new HPLC unit will cost around $40,000 to $50,000 with a sample cost of $2-$5 per sample and modest ancillary costs. A GC-MS unit can be used to positively identify species from either resins or essential oils. A unit will cost approximately $30,000 to $65,000, with a sample cost of $2.50 to $3.00 for essential oils and $4.00 to $5.00 for resins, with modest ancillary costs. A chiral column can be used for further aid in identifying individual species. Other techniques such as infrared spectroscopy or DART-TOFMS are not currently recommended as there is not enough data currently to support their widespread use. The information contained in this chapter is summarized in tabular form in table 4.1.

Table 4.1 Analytical approaches and costs to differentiate *Boswellia* essential oils, resins, and extracts in trade.

	Organoleptic	**GC-MS**	**Chiral GC-MS**	**HPLC**	**TLC**	**DART-(TOF)MS**
New Unit Cost	$250 Annually	$30-$65,000	--	$40-$50,000	--	?
Reference Standards	--	--	--	$2,000-$4,000	--	$2,000-$4,000
Sample time	Minutes	1-2 hours	1-2 hours	1-2 hours	5-30 minutes	?
Maintenance	--	$2,500 Annually	--	$2,500 Annually	--	?
Cost per sample (Consumables)	--	$2.50-$4.80	$2.50-$4.80	$2-$5	<$1	?
Personnel time	Minutes	1-2 hours	1-2 hours	1-2 hours	5-30 minutes	?

4.1. Organoleptic Kits

A reference sample set of frankincense resins and essential oils would be a useful tool to initially identify if a shipment is likely frankincense or not, and which species it might be. This is not a perfect identification protocol, but would be useful to identify samples for further in-depth testing. A complete sample set of both resins and essential oils could be procured for approximately $500 USD. Sample sets should be replaced every two years in order to ensure the freshness of the samples. However, this is only a “first pass” tool as some species can be difficult to identify definitively for non-experts, and organoleptic methods are less useful for highly processed materials such as boswellic acid extracts.

4.2. Gas Chromatography-Mass Spectrometry

Gas-Chromatography-Mass Spectrometry (GC-MS), as the name implies, uses a dual process to identify compounds. As the process relies on volatility, it is often used to analyze essential oils but is not very effective at detecting boswellic acids. A sample is dissolved in a solvent, such as dichloromethane, and injected into the GC-MS. It is vaporized, separated into constituent parts by passing it through a gas chromatographic column, and then each component is identified by both the time it takes to pass through the column and the mass spectrum it produces when it hits the detector plate in the mass spectrometer. Both these systems (the gas chromatograph and the mass spectrometer) are self-contained within a single unit. A GC-MS unit is small enough to be placed on a counter top workstation, often not exceeding 150 x 60 x 60 centimeters.

The initial cost of a GC-MS depends heavily on the specific accessories and features desired. Although they can cost upwards of several hundred thousand dollars, a high-quality GC-MS capable of detecting the necessary components would typically cost between $30,000 to $65,000. It is possible that a good quality used GC-MS may be slightly cheaper. More sophisticated GC-MS equipment such as GC-triple quad-MS or GC-qToF can be substantially more expensive (up to $400,000). However, these are not necessary to determine the volatile profile. It takes approximately one hour to analyze a sample by GC-MS, so a single unit can analyze approximately 24 samples in a single day. Fast GC-MS, which uses smaller diameter columns, can be used to reduce the analysis time if required.

In addition to the initial unit cost, maintenance and consumables are required. Service agreements are often offered by the manufacturer of the GC-MS unit; a typical agreement would be $7,500 for 3 years of maintenance. Consumables include supplies such as carrier gas (helium or hydrogen), GC columns, solvents, vials, orifice tips, etc. Although prices have been volatile recently due to COVID-related supply chain disruptions, the approximate cost should be around $2.50-$3.00 per sample. This does not include sample preparation time (laboratory personnel salaries), which will be variable depending on the country.

GC-MS can also be used to analyze the volatile components derived from a sample of resin. To do this, the components would need to be extracted either by distillation or by using a solvent such as hexane, petroleum ether, or dichloromethane. Both of these approaches have advantages and disadvantages. A laboratory distillation kit is very inexpensive (no more than a few hundred dollars), but the process of distillation takes between 3-8 hours to obtain a complete essential oil profile for a single sample, and thus is extremely time-consuming. The advantage of using a solvent extraction is that it can be done quickly. However, injecting an extract directly into a GC-MS will drastically reduce the useable life of the column (to around 10% of its lifetime if used exclusively with essential oils); as a result, the cost per sample of running extracts would rise to $4.30-$4.80 per sample.

4.2.1. Chiral GS-MS

Chiral GC-MS uses the same unit as a standard GC-MS. The only difference is that it uses a chiral column, in order to separate the enantiomers and determine the chiral composition of the sample. To run a chiral GC-MS analysis, the analyst only needs to switch out the standard GC column, replace it with a chiral column, and recalibrate the unit. However, this process takes approximately half a day, so if a large number of chiral samples are being run, it may be most efficient to dedicate a separate GC-MS unit to this task. Chiral columns are slightly less expensive than a standard GC column ($600-$700 versus $800 for a standard column).

4.3. High Performance Liquid Chromatography

High-Performance Liquid Chromatography uses a pressurized chromatographic column to separate and identify components. It does not rely on volatilization, unlike GC-MS, so it is an effective technique to identify and analyze heavy triterpenoid components like boswellic acids. A sample is dissolved in a solvent such as dichloromethane, injected into the HPLC unit, and sent through a pressurized column at a constant rate using a high-pressure pump. Based on the interaction of the sample components with the column substrate, components exit the column at different times, and can be identified. In order to identify the components, the analyst must compare the results of the sample run with a standard for the array of components being screened for. In other words, the analyst will run the known analytical standard component to determine the exact runtime and detection for that component; the different results for each type of boswellic acid, then, can be used to determine the composition of boswellic acids in a sample of unknown frankincense. An HPLC unit is not large, typically only 40cm x 60cm x 50cm, able to fit on a workspace or counter top.

The initial cost of an HPLC unit is comparable to that of a GC-MS; a new unit will cost approximately $40,000 to $60,000 USD. These often contain autosamplers, so that multiple samples can be run consecutively without the analyst having to inject each new sample; it typically takes about an hour to process a sample. An HPLC can also be combined with a mass spectrometer to enhance the identification of compounds. However, this approach (Liquid Chromatography-Mass Spectrometry, or LC-MS) is much costlier, with a new LC-MS until costing between $150,000 to $500,000. As an HPLC unit will successfully detect different boswellic acids with strong quantification, an LC-MS is unnecessary for the purposes of identifying different *Boswellia* species. A separate mass spectrometer could be attached to an HPLC unit for around $50,000, but this is probably unnecessary for identification of *Boswellia* species.

The cost of maintenance and consumables are comparable to those of GC-MS. HPLC columns cost between $500-$1,000 depending on the specifications, and the same types of solvents are used. As a result, the per-sample cost of analysis is similar, $2-$5 USD per sample. Analytical reference standard boswellic acids can be purchased for $2,000 to $4,000 for all needed references.

4.4. Thin Layer Chromatography

Thin-Layer Chromatography is a simple process that involves dissolving a sample in a solvent and passing it through a TLC plate via capillary action in order to separate out components. This can be done on a counter top and is very inexpensive; it is less than $1.00 and sometimes as little as $0.10 to run a sample. This does not include sample preparation time (laboratory personnel salaries), which will be variable depending on the country. High Performance Thin Layer Chromatography (HPTLC) is a way of improving the resolution to make it easier to distinguish and identify different components. However, this incurs additional cost as an HPTLC system costs around $60,000 USD per unit.

TLC is not a recommended approach for detailed examination of an unknown resin, as the process is qualitative rather than quantitative, the resolution is limited (meaning it can be difficult to distinguish between many components and to distinguish components present at low levels), and has only been tested in a few *Boswellia* species with a small number of samples. Further testing with additional species and more samples, especially from notoriously variable species such as *B. sacra*, will be needed to ensure it can be used effectively. It does appear to effectively distinguish between resins from *Boswellia* and potential look alike resins (*Commiphora*, *Pistacia*, *Canarium*, etc.) (Hairfield et al. 1989[1])

However, it is far cheaper to deploy than other technologies such as HPLC or GC-MS, and does not require the same level of maintenance or training. This makes it a more viable technology for use in range states—such as Somalia, Sudan, Ethiopia, etc.—where funding and access to more complex analytic tools is limited. Consequently, TLC can be used alongside organoleptic testing as a first pass test to identify some samples, while other technologies such as HPLC and GC-MS can be used for more in-depth testing if there is uncertainty after TLC and organoleptic analysis. Furthermore, research and development are underway by major industry actors to create more accurate TLC profiles of *Boswellia* species in trade, using multiple vouchered resin specimens for each species. As a result, this method will likely become more and more viable for detailed species differentiation (pers. comm. with Bhaumik Darji, January 2022).

4.5. Other Technologies and Approaches

4.5.1 Direct Analysis in Real Time (Time of Flight) Mass Spectrometry

DART-TOFMS is a fairly new process, with limited information available. A DART-TOFMS unit should cost around $400,000. DART-TOFMS works by shooting heated helium ions at a sample (such as a piece of resin) in order to volatilize components on or near the surface, which are then detected and characterized. A similar approach using a GC-MS can also be used to directly analyze resin, by using a headspace analyzer with solid phase microextraction (SPME) to extract components, which are heated up to volatilize them. These volatiles are then captured, injected into the GC-MS, and identified. A triple quadrupole GC-MS costs approximately $300,000 USD. As this technology is not widespread currently, unlike GC-MS and HPLC, it would likely require installation of new units at most customs labs. It is also likely poor at differentiating boswellic acids. For this reason, it is not recommended for primary use in distinguishing *Boswellia* components.

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[1] Hairfield E, Hairfield H, McNair H. (1989). GC, GC/MS, and TLC of *β*-boswellic acid and *O*-acetyl-*β*-boswellic acid from *B. serrata*, *B. carteii*, and *B. papyrifera*. *J Chromatogr Sci*. 27(3), 127-133

4.5.2 Infrared Spectroscopy

Infrared spectroscopy (IR), near-infrared spectroscopy (NIR), and Fourier transform infrared absorption spectrometry are fast, non-destructive techniques that have been used in limited cases to analyze frankincense resins. In simple form, it involves passing a beam of infrared light through a sample and examining the absorbance, which allows an analyst to determine the composition of the sample. FTIR has been used to examine differences between resin samples of different geographic origins[2], and NIR has been used to quantify incensole and AKBA content in *B. serrata*, *B. papyrifera*, and *B. sacra*[3,4,5]. The results indicate that these techniques have potential as analytical techniques, but they would have to be authenticated by a far larger number of samples than have currently been used. As a result, these techniques are not currently suggested for widespread use.

4.5.3 DNA-Based Species Identification

DNA-based species identification involves extracting DNA from a sample and comparing it against known sequences for target species. This requires the isolation of DNA sequences of sufficient quantity, length, and purity to allow for reliable identification. Processed materials such as essential oils and extracts may not contain sufficient material to allow for this identification; prospects are better with raw resins, but these present their own challenges. Resins are sticky and adhesive by nature, and accidental contamination from airborne plant particles, microorganisms, etc. that may stick to the resins can confound analysis. Additionally, certain components of the resin can interfere with DNA extraction and amplification[6,7]. As a result, this is not a recommended technique for efficient identification of material in trade.

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[2] Archier P, Vieillescazes C. (2000). Characterisation of various geographical origin incense based on chemical criteria. *Analusis*. *28*(3), 233-237.

[3] Al-Shidhani S, Rehman NU, Mabood F, Al-Broumi, M, Hussain, H, Hussain, J, Csuk, R, Al-Harrasi, A. (2018) Quantification of incensole in Three *Boswellia* Species by NIR spectroscopy coupled with PLSR and cross-validation by HPLC. *Phytochem Anal*. *29*(3), 300-307.

[4] Rehman NU, Al-Shidhani S, Al-Harrasi A, Al-Rawahi, A, Mabood, F, Al-Broumi, M, Al-Azri, M, Alam, T, Hussein, J. (2020). Analysis of incensole acetate in *Boswellia* species by near infrared spectroscopy coupled with partial least squares regression and cross-validation by high-performance liquid chromatography. *J Near Infrared Spec*. *28*(1), 18-24.

[5] Rehman NU, Ali L, Al-Harrasi A, Mabood, F, Al-Broumi, M, Latif Khan, A, Hussein, H, Hussein, J, Csuk, R. (2018) Quantification of AKBA in *Boswellia sacra* using NIRS coupled with PLSR as an alternative method and cross-validation by HPLC. *Phytochem Anal*. *29*(2), 137-143.

[6] Yamamuro T, Iwata YT, Segawa H, Kuwayama, K, Tsujikawa, K, Kanamori, T, Inoue, H. (2018). Development of rapid and simple method for DNA extraction from cannabis resin based on the evaluation of relative PCR amplification ability. *Forensic Sci Int*. 287, 176-182.

[7] El Alaoui MA, Melloul M, Alaoui Amine S, Stambouli, H, El-Bouri, A, Soulaymani, A, El-Fahime, E. (2013). Extraction of high quality DNA from seized Moroccan cannabis resin (Hashish). *PLOS ONE*. *8*(10), e74714.

Chapter Five. Frankincense production and trade

J. Brinckmann, A.B. Cunningham, A. DeCarlo and S. Johnson

5.0 Introduction

This chapter provides an analysis of the production and trade scenarios for selected *Boswellia* species, with a focus on international or regional cross-border trade. This includes information on the grade, quality and trade classifications of different raw or processed forms, country-specific production and customs data, where available, and *Boswellia*-specific import trade data of selected countries. The latter was possible in cases where data for frankincense or olibanum are published in import statistics bulletins (e.g., Saudi Arabia) or in governmental export/import trade databases (e.g., India), or retrievable through searchable customs shipment bill of lading databases (e.g., USA). Several frankincense range states have not made their export trade data available through the United Nations Statistics Division databases in many years (e.g., Somalia and Yemen). However, looking in reverse, by analysing the import data of UN reporting countries, estimations of the export trade value and volume of non-reporting countries can be ascertained, albeit using general 6-digit HS Codes for the most part. The retrieved data were analysed alongside other estimates obtained from governmental and non-governmental organisation sector development project reports, assessments from published papers, regional news reports, and statements made by representatives of individual companies or trade associations.

5.0.1 Trade classifications

International trade values and volumes can be estimated, in part, by utilizing harmonized system (HS) tariff codes in trade databases. The known HS codes that may be used for *Boswellia* articles of commerce are shown in Table 5.1. Most of these, however, are general codes, inclusive of lac and all natural gums and resins of the *Boswellia* and *Commiphora* genera (excluding Gum Arabic from *Acacia*), with the exception of the Gulf Cooperation Council (GCC) States,[1] which have specific separate tariff codes for "frankincense" (لبان بخور) HS 1301907000 and "olibanum" (لبان ذكــر) HS 1301906000. The fact that different tariff codes are used by the six GCC Member States to distinguish between "olibanum" and "frankincense" is noteworthy, given that on a global scale, the trade names "olibanum" and "frankincense" are synonymous. During preparation of this trade analysis, Josef Brinckmann contacted the GCC for clarification on the issue, but received no response. Furthermore, it appears that Saudi Arabian imports of olibanum only originate from Sudan, which would imply that it is *B. papyrifera*. By contrast, Saudi Arabian imports of frankincense are mainly from Somalia, which imply that it is *B. carteri* and other species.

If in the future, there were scope to bring "olibanum" and "frankincense" under one GCC Member States tariff code, this could avoid confusion. This would then conform the GCC system to the Customs Tariff of India definitions wherein the India Trade Classification (ITC) HS 13019032 definition is inclusive of both terms 'olibanum or frankincense'.[2] However, in the Import and Export Tariff of the People's Republic of China, the 8-digit HS 13019020 is defined broadly as inclusive of "frankincense, myrrh, and dragon's blood".[3] These are not species-specific codes, which would be necessary in order to differentiate the trade of the various *Boswellia* species traded as frankincense (or olibanum). Furthermore, it is also known that incorrect HS codes are used by some exporting companies for some shipments, which is a limiting factor that skews trade data.

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[1] The Unified Customs Tariff for Gulf Cooperation Council (GCC) States: https://fca.gov.ae/En/HomeRightMenu/Documents/HSCodes_2021.pdf

[2] Customs Tariff of India 2022: https://www.cbic.gov.in/resources//htdocs-cbec/customs/cst2022-010122/chap-1-98.pdf

[3] Customs Import and Export Tariff of the Peoples Republic of China 2021: http://gss.mof.gov.cn/gzdt/zhengcefabu/202012/P020210122622147687825.pdf

Table 5.1. HS tariff codes used for export trade of substances or products containing *Boswellia* species

Traded form	BTI	CCC	CCCCS + CIQ	HTSUS	ITC	GCC	SMOTI
Frankincense	1301900000	1301902200	1301902000102	1301909190	13019032	1301907000	13019032
Olibanum	1301900000	1301902200		1301909190	13019032	1301906000	
Essential oil	3301294100		1301902000105	3301295150		33012900	
Extracted oleoresin				3301901000			
Incense sticks	3307410000			3307410000			
Resinoids				3301300000			

Legend:

BTI: Binding Tariff Information rulings of the European Commission Taxation and Customs Union

CCC: Standard Classification of Commodities of the Republic of China (Chinese Taipei)

CCCCS: Commodity Classification for China Customs Statistics (PR China)

CIQ: China and Inspection Quarantine

GCC: Gulf Cooperation Council (GCC) States (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, UAE) Unified Customs Tariff

HTSUS: Harmonized Tariff Schedule of the United States

ITC: India Trade Classification, Department of Commerce

SMOTI: Somaliland Ministry of Trade and Investment

5.0.2 *Frankincense sector development*

Organizations and governmental entities in multiple Range States have acknowledged the need to upgrade frankincense supply chains. As Bongers et al (2019) point out, this has started in Ethiopia. In the Puntland region of Somalia, the **Puntland Development and Research Center** made recommendations in 2021 including (1) regulation of the sector (e.g., governmental oversight, creation of a public-private-partnership, have the entire frankincense sector fair trade certified and protection of the growing areas from exploitation by money lenders); (2) establish a frankincense cooperative society (e.g., create investment funds for lending to members, increase productivity and improve the frankincense business ecosystem); (3) establish a Puntland Frankincense Association (e.g., organize skills training programmes, disseminate market information, ensure well-being and safety of workers, create new value-chain, protection of labor rights).[4]

One prioritized project outlined in the **Somaliland Ministry of Trade, Industry and Tourism** 2020 Annual Strategic Plan Report is “Improving the Gums and Resins Sector”,[5] which establishes a Gums and Resins Department, aiming to develop an annual business survey, establish a Gums and Resins Association, increase in-country value addition, and improve data management systems for production and standardization of statistics reports.[6] Within the Department of Industrial Development, there are three divisions, one of which is the Gums and Resins Section, charged with promoting the use of gums and resins locally and internationally, and developing a gums and resins marketing strategy and plan.

While the gums and resins sector projects outlined for both Puntland and Somaliland would be helpful to implement, it is not clear whether the internal resources exist to carry these out without external funding support. One option may be private sector involvement, particularly through the Somali diaspora, which is one of the largest diasporas in the world, estimated at 1.2 million people living in the United Arab Emirates, United Kingdom, United States, Canada and Kenya (Hammond et al. 2011)[7]. Somali emigrants living in North America and Europe send back US$1.6 billion/year in remittances according to the United Nations Development Programme (UNDP) in 2012 (Africa Renewal, 2013[8]).

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[4] Puntland Development and Research Center (PDRC), 2021. Assessment Report: Community Dialogue on Market Needs, Jobs and Skills in Puntland State of Somalia. Garowe, Puntland: PDRC.

[5] Somaliland MOTT (Ministry of Trade and Tourism), 2021. Department Of Industrial Development: Gums and Resins Section. Somaliland MOTT, Hargeisa, Somaliland. https://mott.govsomaliland.org/article/department-industries

[6] Somaliland MOTT (Ministry of Trade and Tourism), 2020. 2020 Annual Strategic Plan Report. Somaliland MOTT, Hargeisa, Somaliland. https://mott.govsomaliland.org/article/2020-annual-strategic-plan-report?category=strategic-plan-2

[7] Hammond, L., Awad, M., Dagane, A.I., Hansen, P., Horst, C., Menkhaus, K. and Obare, L., 2011. Cash and compassion: The role of the Somali diaspora in relief, development and peace-building. *Nairobi: UNDP Somalia*.

[8] African Renewal. 2013. Somali diaspora’s remittances cast a lifeline. https://www.un.org/africarenewal/magazine/may-2013/somali-diaspora%E2%80%99s-remittances-cast-lifeline

5.0.3 *Mixing of species in products and traceability*

Some frankincense traders and product companies list gum resins of *B. carteri* and *B. sacra* as separate articles of commerce while others lump them together as synonyms. The world's largest production areas of *beeyo* frankincense obtained from *B. carteri* trees are the Somaliland and Puntland regions of Somalia.[9] Other Somali frankincense gum resins that are harvested and exported include *maydi* obtained from *B. frereana* trees and *qadhoon* obtained from *B. rivae* trees,[10,11] as well as *mirafur* gum resin of *B. neglecta* trees.[12]

In any case, mixing of *Boswellia* species of different geographic origins, species and/or types is not uncommon in marketed finished products. For example, a major U.S.-based brand (dōTERRA) advertises their frankincense essential oil as a "proprietary blend" of the resins of four species, namely *B. carteri*, *B. frereana*, *B. papyrifera*, and *B. sacra*.[13] In the destination markets, geographical distinctions are made between *B. carteri* and *B. sacra*, whereby *B. carteri* is generally labelled as Somali origin[14,15] and *B. sacra* as Omani origin.[16] Products of *B. papyrifera* are generally designated or labelled Ethiopian or Tigray frankincense[17,18] or as Sudanese frankincense.[19.20]

Frankincense traceability can be complex because middlemen and traders may aggregate batches of resin from different sources into larger single lots.[21] However, implementation of a systematic method of traceability that clearly identifies all links of a frankincense trees' supply chain should be possible.[22] From 2015 to 2020, USAID funded a program in Somalia that featured frankincense as a high potential value chain. In 2019, the frankincense sector was dropped, reportedly because key players were uncooperative.[23] There are, however, some Somali companies, such as those listed in Table 5.2, implementing voluntary sustainability standards, such as the FairWild Standard,[24] and the organic wild-crop harvesting practice standard, which require mapping of collection areas, resource assessment and management, audits by accredited independent third-party inspection and certification control bodies. However, organic certification has been shown in Somalia to be ineffective at differentiating between species (large areas containing *B. occulta* were certified as organic *B. carteri* before the species was "discovered" and described as clearly distinct), raising serious questions as to

[9] Aden, A.M., 2013a. *Report. Stocktaking of Exporters and Traders in the Gums & Resins value chain in Somaliland*. SOFRECO, Hargeisa, Somaliland.

[10] Canney Davidson, S., Bongers, F., Phillips, D., November 2021. *HerbalEGram*, Issue 11.

[11] Osman, Z., 2020. Annex 16: Neo Botanika (Somalia): Questionnaire Notification 2020/010. In: Convention on International Trade in Endangered Species of Wild Fauna and Flora, Twenty-fifth meeting of the Plants Committee Geneva (Switzerland), 17 and 20-23 July 2020. Boswellia Trees (*Boswellia* spp.). CITES Secretariat, Geneva, Switzerland.

[12] Schmiech et al. 2019, comm. with traders in Puntland and Kenya.

[13] dōTERRA, 2019a. dōTERRA Frankincense, a Co-impact Sourcing Story. dōTERRA Holdings, LLC, Pleasant Grove, Utah. https://media.doterra.com/us/en/brochures/co-impact-brochure-frankincense.pdf

[14] William Bernstein Company, Inc. Gum Olibanum (Frankincense) Somalian: https://www.wbernsteinco.com/portfolio/gum-olibanum-somalian/

[15] Albert Vieille – Givaudan. FRANKINCENSE SOMALIA Essential oil *Boswellia carterii*: https://www.albertvieille.com/en/product/frankincense-somalia/

[16] Walmart. Superior Hojari Frankincense - *Boswellia sacra*: https://www.walmart.com/ip/Superior-Hojari-Frankincense-Boswellia-Sacra/699301386

[17] GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH), 2020. Global Business Network Programme. Partnership Ready Ethiopia: Gums and Resins. GIZ, Eschborn, Germany. https://www.giz.de/en/downloads/GBN_Sector%20Brief_Aethiopien_Gums_Resins_E_Web.pdf

[18] Amazon. 1 oz. Boswellia Papyrifera "Tigray" Frankincense -Imported directly from Ethiopia: https://www.amazon.ca/Boswellia-Papyrifera-Frankincense-directly-Ethiopia/dp/B00VXPTEUI

[19] Walmart. Frankincense Resin, Sudanese (*papyrifera*), Wild Crafted: https://www.walmart.com/ip/Frankincense-Resin-Sudanese-papyrifera-Wild-Crafted/252641930

[20] The Fragrance Shop. https://thefragranceshop.com/sudanese-frankincense/

[21] Canney Davidson, S., Bongers, F., Phillips, D., November 2021. *HerbalEGram*, Issue 11.

[22] Hassan, K.A., 2020. *Boswellia* in Somaliland: An Overview. In: Convention on International Trade in Endangered Species of Wild Fauna and Flora, Twenty-fifth meeting of the Plants Committee Geneva (Switzerland), 17 and 20-23 July 2020. Boswellia Trees (*Boswellia* spp.). CITES Secretariat, Geneva, Switzerland.

[23] BIFAD, 2019. Board for International Food and Agricultural Development 180th Public Meeting. Meeting Minutes, Des Moines Downtown Marriott, Des Moines, Iowa, Tuesday, October 15, 2019. USAID, Washington, D.C.

[24] FairWild Foundation, 2022. Neo botanika. FairWild Foundation Secretariat, Cambridge, UK. https://www.fairwild.org/all-fairwild-participants/neo-botanika

whether it can guarantee sustainable harvesting practices.[25] FairWild certification is carried out by the same auditors and does not publicly release audit reports, raising the question of whether this standard will run into similar problems with on-ground verification of practices.

Figure 5.1. Bags of organic certified frankincense oleo-resin in a warehouse in the Somaliland Region of Somalia, certified by Ecocert. Photo: Ulrich Feiter.

Table 5.2 shows the total hectares of land in Somalia that are certified organic for wild collection of gums and resins[26]. It must be noted that no correlation can be made between the increasing number of certified organic hectares and the decreasing export quantity. This has mostly to do with the COVID-19 production and trade interruptions of 2020 and 2021 resulting in fewer purchase orders. It is very interesting to note, however, that these numbers imply only 0.08kg to 0.034kg of resin per hectare of certified land (far less than expected potential production) is being exported to the EU and the US in official trade data.

Table 5.2. Somalia hectares of certified organic land for wild collection of gums & resins, export qty. to EU & US, 2017-2021

Year	Organic hectares	Companies	Qty (MT) exported to EU and US
2017[27]	849,482 ha	Five processors including Alla Magan Gums and Resins Processing Center, and four exporters including Kobac General Trading,[28] Nagaad Trading Company,[29] and Neo Botanika.[30]	Not reported
2018[31]	807,300 ha		Not reported
2019[32]	826,400 ha		66 MT
2020[33]	822,300 ha		50 MT
2021[34]	940,034 ha		32 MT

Because of the absence of species-level HS Codes, teasing out the actual proportions of the different *Boswellia* (and *Commiphora*) species that are included under a general 6-digit HS Code, is not possible. When analysing country-specific trade data, what can be ascertained are the species that are most likely to originate from each country. These data may also be confounded by the fact that there is

[25] Johnson, S., DeCarlo, A., Satyal, P., Dosoky, N., Sorensen, A., Setzer, W.N.S. 2019. Organic certification is not enough: the case of the methoxydecane frankincense. *Plants, 8*(4), https://doi.org/10.3390/plants8040088.
[26] Note that the referenced IFOAM annual reports are inclusive of EU and US organic certification. Due to the USDA NOP equivalence arrangement with the EU, goods do not need to hold both (EU and NOP) to be imported into the US as organic. Not all organic goods are found in the USDA organic integrity database, only those with NOP certificates.
[27] Willer, H., Lernoud, J. (eds.). 2018. The World of Organic Agriculture. Statistics and Emerging Trends 2018. Research Institute of Organic Agriculture FiBL, Frick, and IFOAM – Organics International, Bonn.
[28] EcoCert SA. Certificat. Kobac General Trading: http://certificat.ecocert.com/client.php?source=recherche&id=A6AE2228-41D0-49B3-B5AC-12258CF93061
[29] EcoCert SA. Certificat. Nagaad Trading Company: http://certificat.ecocert.com/client.php?source=recherche&id=9D15885E-00CF-41A4-95AA-B3DD2F30C97E
[30] EcoCert SA. Certificat. Neo Botanika: http://certificat.ecocert.com/client.php?source=recherche&id=B6E00BBE-ED8E-4E34-A4D0-3CE7E7BE12B2
[31] Willer, H., Lernoud, J. (eds.). 2019. The World of Organic Agriculture. Statistics and Emerging Trends 2019.
[32] Willer, H., Schlatter, B., Trávníček, J., Kemper L., Lernoud, J. (eds.). 2020. The World of Organic Agriculture. Statistics and Emerging Trends 2020. Research Institute of Organic Agriculture (FiBL), Frick & IFOAM – Organics International, Bonn.
[33] Willer, H., Trávníček, J., Meier, C., Schlatter, B. (eds.). 2022. The World of Organic Agriculture. Statistics and Emerging Trends 2022. Research Institute of Organic Agriculture (FiBL), Frick, and IFOAM – Organics International, Bonn.
[34] Willer, H., Trávníček, J., Meier, C., Schlatter, B. (eds.). 2021. The World of Organic Agriculture. Statistics and Emerging Trends 2021. Research Institute of Organic Agriculture (FiBL), Frick, and IFOAM – Organics International, Bonn.

unreported cross-border trade where the second country re-exports raw materials of the neighbouring country. Table 5.3 summarises the main countries that are included in the subsequent trade data in this chapter, noting which species are likely to be included in the 6-digit HS 130190 total for each country.

Table 5.3. Countries and likely species included in exports of HS 130190: Lac; natural gums, resins, gum-resins and oleoresins – Other: includes gum resins of all *Boswellia* and *Commiphora* species but excludes *Acacia* species.

Country	Species likely included in HS 130190 exports
Burkina Faso	*B. dalzielii*[35]
Djibouti	*B. papyrifera*, *Commiphora africana*;[36] and re-exports of Somali *B. carteri* and *B. frereana*
Eritrea	*B. papyrifera*,[37] *Commiphora spp.*
Ethiopia	mainly *B. papyrifera* but also *B. microphylla*, *B. neglecta*, *B. pirrotae*, *B. rivae*; and *Commiphora* spp.;[38] and re-exports of Somali *B. carteri* and *B. frereana*
Kenya	*B. microphylla*, *B. neglecta*, *B. rivae*;[39] and *Commiphora* spp. and re-exports of *B. carteri* and *B. frereana*
Mali	*B. dalzielii*[40]
Nigeria	*B. dalzielii*,[41] and possibly *B. papyrifera*,[42] *Commiphora spp.*
Oman	*B. sacra*;[43] *Commiphora* spp. and probably *B. carteri* (entering Salalah by sea from Somalia).
Somalia	*B. carteri*, *B. frereana*, *B. rivae, B. neglecta*[43]; and *Commiphora* spp.
South Sudan	*B. papyrifera*[44]
Sudan	*B. papyrifera*, *Commiphora africana*[45]
Yemen	*B sacra*[43]*;* and possibly re-exports of Somali *B. carteri* and *B. frereana*[46]

5.0.4 *National demand and trade*

As the supply chain diagrams in this chapter show, frankincense is used domestically for medicinal, cultural and religious purposes in all of the range States. In Ethiopia, for example, the Ethiopian Orthodox Church uses an estimated 2,050 tons of *B. papyrifera* frankincense/year, with an additional 440 tons/year used for cultural purposes at homes in Addis Ababa (Gebremedhin, 1997[47]). Similarly, in Oman, daily domestic use of *B. sacra* frankincense is high due to the cultural and religious importance of the oleo-resins as well as for medicinal purposes (such as frankincense water). Quantities of *B. sacra* sold for domestic use have not been assessed, but the large quantities of *B.*

[35] Thiombiano, A., Kampmann, D. (eds). 2010: *Biodiversity Atlas of West Africa*, Volume II: Burkina Faso. Ouagadougou & Frankfurt/Main.
[36] Munyua, S.J.M., Mbiru, S. (eds). 2011: Report on Formulating a Strategy for Production, Value Addition and Marketing of Products from Arid and Semi-arid (ASAL) in the IGAD Region – **Case of Djibouti**. Nairobi, Kenya: IGAD Centre for Pastoral Areas and Livestock Development (ICPALD).
[37] Vasisht, K., Kumar, V. 2004. Compendium of Medicinal and Aromatic Plants AFRICA, Volume I. Trieste, Italy: United Nations Industrial Development Organization and the International Centre for Science and High Technology (ICS-UNIDO).
[38] Munyua, S.J.M., Mbiru, S. (eds). 2011: Report on Formulating a Strategy for Production, Value Addition and Marketing of Products from Arid and Semi-arid (IGAD) in **Ethiopia**. Nairobi, Kenya: IGAD Centre for Pastoral Areas and Livestock Development (ICPALD).
[39] Munyua, S.J.M., Mbiru, S. (eds). 2011: Report on Formulating a Strategy for Production, Value Addition and Marketing of Products from Arid and Semi-arid (ASAL) in the IGAD Region – **Case of Kenya**. Nairobi, Kenya: IGAD Centre for Pastoral Areas and Livestock Development (ICPALD).
[40] Schmiech, M. et al. 2021. 11-Keto-α-Boswellic Acid, a Novel Triterpenoid from *Boswellia* spp. with Chemotaxonomic Potential and Antitumor Activity against Triple-Negative Breast Cancer Cells. *Molecules*, 26, 366. https://doi.org/10.3390/molecules26020366
[41] Owolabi, M.S. et al. 2020. Essential oil compositions, antibacterial and antifungal activities of Nigerian members of the Burseraceae: *Boswellia dalzielii* and *Canarium schweinfurthii*. *Natural Product Communications*. 15(8):1–9, doi: 10.1177/1934578X20946940.
[42] Motuma Tolera, M. et al. 2013. Resin secretory structures of *Boswellia papyrifera* and implications for frankincense yield, *Annals of Botany*, 111(1):61–68, https://doi.org/10.1093/aob/mcs236
[43] Schmiech, M., Ulrich, J., Lang, S. J., Büchele, B., Paetz, C., St-Gelais, A., Syrovets, T., & Simmet, T. (2021). 11-Keto-α-Boswellic Acid, a Novel Triterpenoid from *Boswellia* spp. With Chemotaxonomic Potential and Antitumor Activity against Triple-Negative Breast Cancer Cells. *Molecules*, *26*(2), 366. https://doi.org/10.3390/molecules26020366
[44] Canney Davidson, S., Bongers, F., Phillips, D., November 2021. *HerbalEGram*, Issue 11.
[45] Munyua, S.J.M., Mbiru, S. (eds). 2011: Report on Formulating a Strategy for Production, Value Addition and Marketing of Products from Arid and Semi-arid (IGAD) in **Sudan**. Nairobi, Kenya: IGAD Centre for Pastoral Areas and Livestock Development (ICPALD).
[46] Aden, A.M., 2014. Value Chain Development Project – Somaliland Gums & Resins Markets in Yemen. SOFRECO, Hargeisa, Somaliland.
[47] Gebremedhin, T., 1997. *Boswellia papyrifera from the Western Tigray. Opportunities, Constraints, and Seed Germination Responses,* Skinnskattebergy: s.n.

sacra frankincense and traditional censers (frankincense burners) available in souks in Muscat and Salalah are an indication of domestic demand (Figure 5.2).

Figure 5.2. Bags of frankincense from Somalia (probably *B. carteri*) and Oman (*B. sacra*) for sale in a market in Muscat, Oman, along with traditional censers (frankincense burners) of different sizes to the right. Large censers are for use at weddings in in mosques. Smaller censers are for domestic use (and for sale to tourists). Photo: A.B. Cunningham.

5.0.5 *Informal sector and cross border trade*

The informal sector trade in frankincense does not appear in official statistics. Despite this, it is very important to consider in the Horn of Africa, where cross-border trade thrives under conditions of poor governance and corruption, and where borders are highly porous (Figure 5.3). As Little (2005) points out: "*Trans-border trade in the Horn of Africa represents a particularly important and challenging unofficial, informal sector activity. On the one hand, it epitomizes the essence of informal or 'shadow' trade, operating along remote borders in a vast region where government presence is particularly weak or, in some cases (Somalia), absent. In many instances it represents the only type of exchange in the area, since extremely poor regional infrastructure and communications impede official trade between neighbouring states……For some commodities, like livestock and grain,* ***unofficial exports to neighbouring countries can exceed officially licensed trade by a factor of 30 or more****."*[48].

With Kenya, India and Oman as notable exceptions, *Boswellia* range States are characterised by poor governance, conflict, porous borders and some of the highest Corruption Perceptions Indices (CPI) in the world (Chapter 6), with limited capacity to implement international trade regulations. In Kenya, forthcoming legislation ("The Forest Gums and Resins Rules" (2021) (under the Forest Conservation and Management Act, 2016) state that "*No person shall import gums and resins from any country into the Republic of Kenya, or export gums and resins from the Republic of Kenya to any other country, unless such person is in possession of a valid gums and resins import or export permit issued by the Service under these Regulations*". Whether this is enforceable in sparsely populated and thinly policed border areas remains to be seen.

[48] Little, P., 2005. *Unofficial trade when states are weak: The case of cross-border commerce in the Horn of Africa*. United Nations University (UNU).

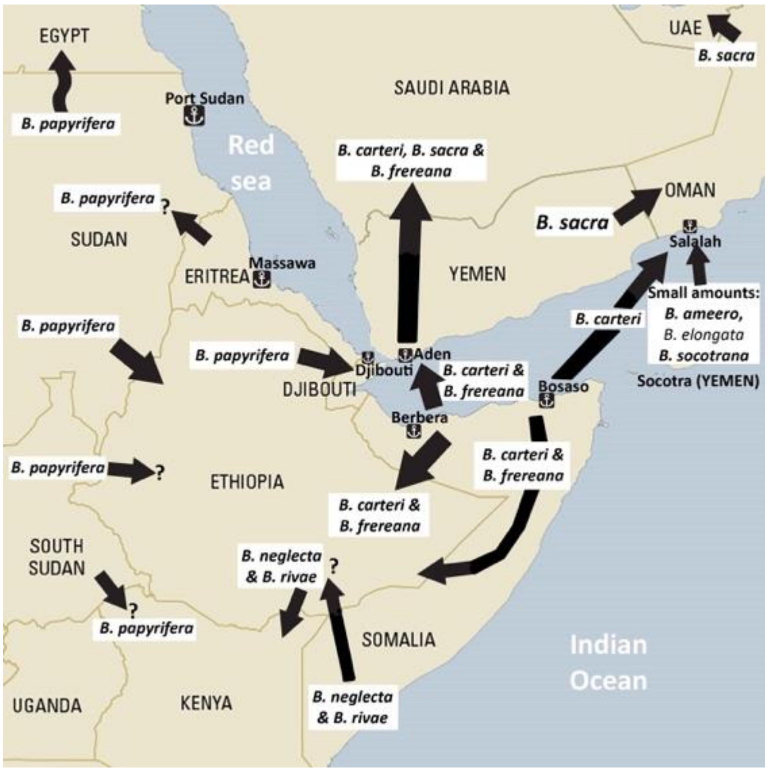

Figure 5.3. North-eastern Africa is characterised by highly porous borders. And as shown in this map, which is based on field knowledge, a significant cross-border trade in *Boswellia* oleo-resins already exists.

Little (2005) also gives the example of the livestock trade, pointing out how "stateless Somalia" has become "*one of the largest exporters of live animals in the world, and much of this came from informal cross-border trade*", with over half of all livestock traded coming from across the border in Somali areas of eastern Ethiopia. And in the Horn of Africa, there has long been a close association between the livestock trade and the trade in frankincense. For example, *B. frereana* oleo-resins are commonly exported together with livestock from Somalia directly to the Arabian peninsula (Osman, Z., pers comm. to ABC, 2022; ITC - Eastern Africa 2006)[49]. This occurs through the ports of Berbera and Bosaso respectively in Somaliland and Puntland Autonomous Regions of Somalia. Cross-border trade is generally more widespread than previously recognised.

The implications of a CITES-imposed "trade suspension" on exports from Ethiopia (through Djibouti or through any ports in Somalia, including the port of Berbera, under the de facto agreement that Ethiopia has with the Somaliland Region of Somalia) that would be stimulated if *B. papyrifera* was CITES Appendix II listed are discussed in Chapter 6. The same may apply to the "invisible" cross-border trade in *B. papyrifera, B. neglecta* and *B. rivae* oleo-resins from Ethiopia into Sudan, and possibly through Eritrea to Port Sudan and Massawa, as alternatives to exporting from Djibouti, or into Kenya (to Mombasa port), following existing cross-border trade routes.

5.0.6 *Undocumented workers*

Since the 1970's, most Omanis have been able to find better-paying employment with the government or oil industry, and thus there has been a steady decline in the number of Omani harvesters. Over a decade ago, (Farah 2008[50]) noted that almost all frankincense harvesting was done by undocumented immigrants, primarily Somalis from the Puntland region of Somalia. Today, the vast majority of commercial harvesting in Oman is conducted by Somalis, who are perceived to be good tappers due to their cultural background of frankincense harvesting (Figure 5.4). Yemeni immigrants may also be

[49] ITC - Eastern Africa, 2006. *Review and Synthesis of Local Economic Development (LED) Materials: Puntland,* s.l.: The European Union's 5th Rehabilitation Programme for Somalia/Somaliland.
[50] Farah, M., 2008. Non-Timber Forest Product (NTFP) Extraction In Arid Environments: Land-Use Change, Frankincense Production And The Sustainability Of *Boswellia sacra* In Dhofar (Oman), s.l.: University of Arizona.

involved in harvesting activity, although this is not as well documented. As a result of their undocumented status, the harvesters shun contact with the public, operating in as remote areas as possible. They typically only have contact with the traders that purchase the resin from them, and in turn provide them with food, water, and other supplies. Harvesters are periodically arrested by security forces, who may also confiscate the resin they have harvested.

The undocumented status of the harvesters is both a social and a sustainability challenge. Their need to remain in remote areas means they must rely on a small group of allies—particularly the traders they sell to—for support. This makes them vulnerable to exploitation by these traders, who can negotiate from a position of strength to keep prices down. While there is limited evidence about whether this is happening or not, the conditions for significant exploitation are certainly present. Furthermore, this vulnerable position degrades the long-term stability and tenure needed to promote sustainable harvesting.

Figure 5.4. Somali frankincense tappers in Oman. Photo: A. DeCarlo.

If harvesters know they can continue to manage and benefit from a given set of trees long-term, they have an incentive to manage them sustainably; on the other hand, when they are likely to lose their access to the resource (and possibly the resin they've already harvested) at any given time, with no guarantee of being able to return to work again, there is less incentive to harvest sustainably and more incentive to harvest as much resin as possible now.

It is also important to note that the majority of frankincense supply chains are socially high risk, especially for women (Schindler et al. 2022[51]). Many harvesters, in multiple species/range States, are poor, rural, with few other livelihood options and limited knowledge of the overall market (Figure 5.5). This is particularly the case Ethiopia, Eritrea, Somalia and Sudan, where frankincense tappers and graders at the start of supply chains are vulnerable to manipulation and exploitation by more powerful traders. In Oman, where since the 1970's, there has been a huge national investment in education and development, there are positive exceptions, including cases where Omani women of Somali descent employ Bangladeshi men as frankincense graders (Figure 5.5 E).

[51] Schindler, C., Heral, E., Drinkwater, E., Timoshyna, A., Muir, G., Walter, S., Leaman, D.J., Schippman, U. (2022). Wild Check—Assessing Risks and Opportunities of Trade in Wild Plant Ingredients. Rome, FAO. https://doi.org/10.4060/cb9267en

Figure 5.5. Women predominate frankincense sorting and grading. A. Woman grading of *B. papyrifera* in a large warehouse in Ethiopia. **B.** Grading frankincense (from *B. carteri*) in the Somaliland Autonomous Region of Somalia. **C.** Grading of *B. papyrifera* oleo-resin in Sudan. **D.** Close up of *B. sacra* oleo-resin before grading in Salalah, Oman. The challenge is to break open larger masses of oleo-resin to separate bits of bark or grit from frankincense, which is then sorted into grades for national or international use. **E.** A male guest-worker from Bangladesh employed by a female Omani-Somali frankincense trader sorts and sieves *B. sacra* oleo-resin in the Salalah *souk*, Oman. Photos: S. Johnson (A, B), S. Agieb (C), and A.B. Cunningham (D, E).

Furthermore, women are particularly vulnerable in these systems to gender discrimination and sexual exploitation (although this may not be related to the frankincense trade, *per se*, but exist as a general vulnerability in supply chains with limited governance and high levels of opacity). It has also proven difficult to verify what women resin sorters are paid due to lack of recognized legitimacy and transparent payment systems.

5.1 Estimated formal export trade

Table 5.4 looks at five (pre-COVID) years (2015-2019) of export values and volumes for the general category of HS 130190 gums and resins from ten selected African *Boswellia*-exporting countries (Burkina Faso, Djibouti, Eritrea, Ethiopia, Kenya, Mali, Nigeria, Somalia, South Sudan, and Sudan) and two selected countries in the Arabian peninsula (Oman and Yemen). These data are not obtained from export trade data but rather, in reverse, they are based on import trade data of countries that report into the UN system. Several of the listed countries have not routinely reported export trade data in recent years. The included countries are selected based on production and trade of *Boswellia* species prioritized in this report, *B. carteri*, *B. dalzielii*, *B. frereana*, *B. papyrifera*, and *B. sacra*. For that reason, India and *B. serrata* are not included. Two of the world's top exporters of HS 130190, Indonesia and Brazil, are not relevant to the trade of *Boswellia* species.

Table 5.4. Value and volume of exports / Selected countries / 2015-2019 / Value: US$ millions (M) / Volume: metric tonnes (MT) / HS 130190: Lac; natural gums, resins, gum-resins and oleoresins – Other: includes gum resins of all *Boswellia* and *Commiphora* species but excludes *Acacia* species.

	2015		2016		2017		2018		2019	
	US$ M	MT	US$ M	MT	US$ M	MT	US$ M	MT	US$ M	MT
BurkinaFaso	0.000906	0.21	0	0	0.000986	1.2	0.092768	36.01	0	0
S Sudan	0.123897	21.11	0.045358	11.60	0	0	0.54064	510.00	1.194325	0.93
Yemen	0.405140	64.78	0.008901	1.41	0.001232	1.80	0.073778	25.59	0.007646	2.22
Eritrea	0.016294	17.01	0.000105	0.01	0.010781	2.41	0.050975	58.47	0.016767	3.93
Oman	0.10529	12.65	0.57622	8.75	0.33507	103.26	1.28403	34.79	0.38753	19.58
Djibouti	0.439386	176.22	0.301123	121.64	0.076251	46.40	0.161589	91.55	0.344038	80.13
Nigeria	0.165632	63.84	0.319796	83.19	0.383532	135.11	0.381661	192.70	0.407606	203.66
Ethiopia	6.4090	1,862.74	4.099981	913.73	7.472259	1,907.68	5.983025	1,277.49	5.740827	1,472.18
Mali	3.644389	1,509.10	3.052808	1,246.49	4.426521	2,268.95	4.960715	1,839.58	3.717909	2,275.19
Kenya	1.128296	417.05	1.494926	343.85	1.593769	387.43	1.550042	283.39	21.115409	2,433.24
Somalia	11.730403	2,392.26	17.535932	3,295.09	27.074835	4,237.40	36.899495	4,165.10	36.136206	3,634.69
Sudan	2.838973	1,004.51	4.548963	1,524.90	5.274689	1,916.28	8.337904	3,923.49	8.965713	4,500.61
TOTAL	27.007606	7,541.48	31.984113	7,550.66	46.649925	11,007.92	60.316622	12,438.16	78.033976	14,626.36

Source: UN COMTRADE data based on imports of reporting countries due to nonreporting of exports of some countries.

In terms of volume, based on HS code data, Somalia has generally been the largest exporter (of these 12 selected countries), although in 2019 Sudan was the largest, exporting 4,500.61 MT of HS 130190, presumably from *B. papyrifera*. Interestingly, although this is not reflected by HS code data in Table 5.4, Ethiopia is widely recognised to be the major exporter of frankincense (from *B. papyrifera*). For example, based on data from Ethiopia's Central Statistics Bureau, Ethiopia exported 4533 tonnes of frankincense in 2007 to 27 different countries (with China, United Arab Emirates, Germany, France and Greece importing 64% of the total) (Gelaye, 2012).[52] By 2014, Ethiopia exported 7900 tonnes of *B. papyrifera* oleo-resin (Gidey et al., 2020).[53] It is difficult to know for sure whether Sudan or Ethiopia is actually the largest exporter of resin—in no small part because of the large amount of cross-border trade in resin—but the current trade data certainly represent a reversal in dominance of Ethiopia as traditionally reported. It is also likely that the conflict in Tigray, which heavily affects *Boswellia* harvesting areas, coupled with the removal of Sudan from the State Sponsors of Terror list, is pushing buyers to purchase from Sudan rather than Ethiopia. However, the coup in Sudan and ongoing instability in both major exporting states means that exports are likely in flux. *Boswellia papyrifera* is likely to represent the major component of the growing export from Sudan, due to the relatively low price and high boswellic acid content of the oleo-resin from this species. The next largest exporter in 2019 is Somalia at 3,634.69 MT (inclusive of *B. carteri*, *B. frereana*, *B. rivae*, *B. neglecta,* and *Commiphora* spp.), Kenya at 2,433.24 MT (likely *B. microphylla*, *B. neglecta*, *B. rivae*, and *Commiphora* spp.), Mali at 2,275.19 MT (uncertain but likely including some *B. dalzielii*), and Ethiopia at 1,472.18 MT (mainly *B. papyrifera* but possibly also *B. microphylla*, *B. neglecta*, *B. pirrotae*, *B. rivae*, and *Commiphora* spp.)[54] It is not known what proportions of these volumes constitute which *Boswellia* species nor what proportion is *Commiphora* species. The volume exported from Kenya (Table 5.4) was larger than expected, but this may reflect the quantities of oleo-resin going to China and India for incense. It may also include *B. papyrifera* oleo-resin shipped out of Mombasa, Kenya that originated in Ethiopia or Sudan and has entered Kenya through cross-border trade.

For Somalia's HS 130190 exports, the main destinations, in terms of exported volume in recent years, have been the EU (Bulgaria, France, Spain, Italy, and Germany), UK, China, Saudi Arabia, UAE, Egypt, Turkey, and Morocco. The UAE, Saudi Arabia, and Germany are the main destinations for Omani gum resin exports, and Saudi Arabia, UAE and Germany are the main destinations for Yemeni exports.

[52] Gelaye M.T. 2012. Restoration and sustainable management of frankincense forests in Ethiopia: a bio-economic analysis. PhD thesis KU Leuven.

[53] Gidey, T., Hagos, D., Juhar, H.M., Solomon, N., Negussie, A., Crous-Duran, J., Oliveira, T.S., Abiyu, A. and Palma, J.H., 2020. Population status of *Boswellia papyrifera* woodland and prioritizing its conservation interventions using multi-criteria decision model in northern Ethiopia. *Heliyon*, *6*(10), p.e05139.

[54] United Nations Statistics Division, 2021. UN Comtrade Database. United Nations, New York, NY. https://comtrade.un.org/data/

Germany remains an important destination for Omani, Somali, and Yemeni exports, but Bulgaria has become the front runner for Somali frankincense. While Table 5.3 shows a US$ 36.1 million 2019 export value for Somalia, another source, Observatory of Economic Complexity,[55] came up with a US$ 35.7 million estimate for same period. Similarly, while UN COMTRADE showed a 2018 Somalia export value of US$ 36.9 million, a World Bank analysis arrived at US$ 37.2 million. In any case, for Somalia, these values are inclusive of the gum resins of several species, *B. carteri*, *B. frereana*, *B. rivae*, and *Commiphora* species. World Bank staff calculations for 2018 ranked Somalia as the fourth largest exporter of gums and resins (all species globally) in terms of the import values reported by the destination countries; of which about 45% was exported to Bulgaria, 20% to France, 6.5% to China, 3.2% to Spain, and 2.7% to India. Neither Oman or Yemen were included in the World Bank dataset of the top 26 exporters of gums and resins.[56] Furthermore, the World Bank report estimated an average annual value for exported Somali gums and resins of US$ 30.4 million with an estimated additional untapped potential of US$ 15.8 million/year. Markets with the most potential for importing more Somali gums and resins were identified as India, China, Saudi Arabia, Japan, Pakistan, and UAE.[57]

5.2 Production and Trade by Species

5.2.1 *Boswellia carteri*

The oleoresin of *B. carteri* is harvested in Somalia, inclusive of the Puntland and Somaliland regions of Somalia, and is also re-exported from second countries, Djibouti, Ethiopia, Saudi Arabia, UAE, and Yemen (see Figure 5.2 below).

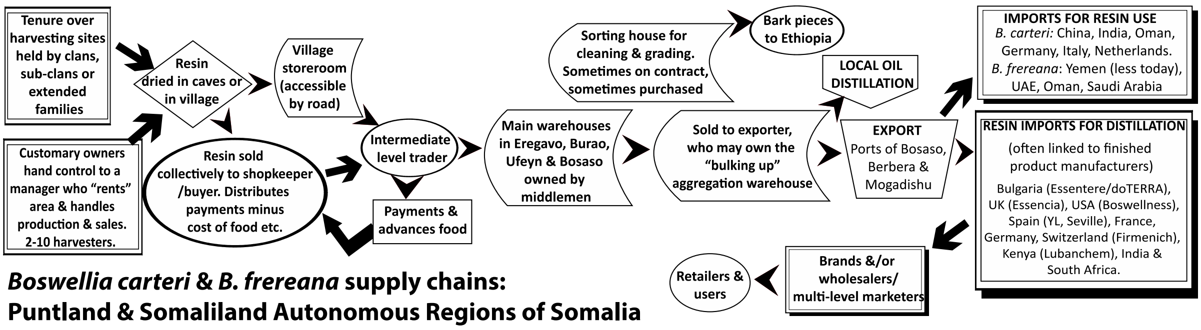

Figure 5.2. Supply chain diagram for *B. carteri* and *B. frereana* from the Puntland and Somaliland Autonomous Regions of Somalia.

In the early 2010's there were about 100 gum and resin traders operating within the Sanaag region districts of Erigavo and El-Afwein, of which about 30 traders were based in the city of Erigavo.[58] The Burao district of the Togdheer region is also a main market and base for exporters. Somali frankincense is exported through the ports of Berbera (Somaliland region of Somalia), Bossaso and Qandala ports (Puntland region of Somalia), and Mogadishu, and through land routes into Djibouti and Ethiopia. Some the main producers and/or exporters, by region, in 2010 included:

- **Mogadishu:** Hassan Kobac General Trading Company, which operates from Mogadishu but with branches in Djibouti and Dubai,[59] and Nagaad Trading Company, which also operates from Mogadishu,[60] but with headquarters and offices in Nairobi, Kenya and in the UK.[61]

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[55] OEC (Observatory of Economic Complexity), 2021. Natural gum, resin, gum-resin, balsam, not gum arabic. HS 130190. Online only, https://oec.world/en/profile/hs92/natural-gum-resin-gum-resin-balsam-not-gum-arabic
[56] World Bank, May 2021. Trade as an Engine of Growth in Somalia: Constraints and Opportunities. © World Bank, Washington DC
[57] World Bank, May 2021.
[58] Aden, A.M., 2013a. Report. Stocktaking of Exporters and Traders in the Gums & Resins value chain in Somaliland. SOFRECO, Hargeisa, Somaliland.
[59] Hassan Kobac General Trading Company, Who We Are: https://kobacgt.so/who-we-are/
[60] EcoCert. Certificat. Nagaad Trading Company: http://certificat.ecocert.com/client.php?source=recherche&id=9D15885E-00CF-41A4-95AA-B3DD2F30C97E
[61] Nagaad Resins and Gums Company Ltd. https://nagaadgums.com/business-background/

- **Puntland region of Somalia** Horn Incense, Inc., Horn Resin, Ltd., Rahan Trading LLC, Somali Frankincense Alliance (SOMFAL), and Younis Aroma.
- **Somaliland region of Somalia**: Asli Maydi Exports and Imports Co., Neo botanika, Alla Magan Gums and Resins Processing Center, Salaama Trading, Rahiiq Ltd., Riyaad Trading Company, and Abdullahi Yusuf Suleiman Trading Company.[62] Chinese buyers are also reportedly operating in the region.[63]

5.2.1.1 *Commercial grades and quality*

In Somaliland, a traditional quality grading system, based mainly on size and colour of gum resins, is used for trade in the Arabian Peninsula. Table 5.5 shows six different cleaned and sorted grades of *beeyo* frankincense obtained from *B. carteri* trees. The raw unsorted product is called *marbuush*.[64] Grade 4, called *foox*, is also referred to as *xashish* (rubbish) by Somalis in the region, and *foox* may also be used as a general term inclusive of *beeyo* (*B. carteri*), *maydi* (*B. frereana*) and *malmal* (*C. myrrha*).[65] Somaliland governmental trade statistics publications appear to also use the term *foox* as a catch-all.[66] Many other grading systems exist as well, based on the specific needs of different companies or markets. While the specific parameters of each grade vary from system to system, the resin is generally graded based on the size and colour of the resin pieces, with larger, lighter coloured pieces being considered higher grade and smaller, darker pieces being considered lower grade. Resin that includes bark, dust, and other debris is consistently considered to be in the lowest grades.

Table 5.5. Somaliland grades of "*beeyo*" frankincense (*B. carteri*)

Grade Serial Number	Grade Name	Description
1	*Fusuus caddaan*	White pieces (2mm-12mm)
2	*Fusuus cassaan*	Red-brown pieces (2mm-12mm)
3	*Jidhiidh*	Mixture of gum and bark
4	*Foox*	Bark with little gum
5	*Budo*	Powder (<2mm)
6	*Qolof*	Bark

Source: Somaliland Ministry of Trade and Investment[67,68]

5.2.1.2 *Estimating the production and trade of B. carteri*

Table 5.4 showed that Somalia's total exports of gums and resins under HS 130190 average about 3,545 MT annually (based on five years 2015-2019), which is inclusive of several *Boswellia* and *Commiphora* species and excludes *Acacia* spp. Table 5.6 summarises estimated quantities of *B. carteri* production and trade, stated by Somali companies and by governmental statistics reports of both Puntland and Somaliland regions of Somalia.

The annual trade estimates for *B. carteri* vary widely, but likely amount to more than 1,000 MT and less than 2,000 MT total. A confounding factor is that Somali exports of frankincense through the land

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[62] Osman, Z., 2020. Annex 16: Neo Botanika (Somalia).
[63] Owuor, V.O., 2017. Firm Behavior in Fragile States. The Cases of Somaliland, South Sudan, and Eastern Democratic Republic of Congo. One Earth Future Foundation, Broomfield, CO. http://dx.doi.org/10.18289/OEF.2017.013
[64] Soloviev, P., Abdi, A., 2013. Directory for Somaliland Gums, Resins and Essential Oils. Somaliland Ministry of Trade & Investment, Hargeisa, Somaliland.
[65] Hassan, K.A., 2020. Boswellia in Somaliland.
[66] MOFD (Ministry of Finance Development) Macroeconomics & Statistics Department, 2021. Trade Statistical Bulletin 2020. Ministry of Finance Development, Hargeisa, Somaliland. https://slmof.org/reports/
[67] Soloviev, P., Abdi, A., 2013.
[68] Aden, A.M., 2013b. Grading and Classification System used for Export of Gums and Resins in Somaliland. SOFRECO, Hargeisa, Somaliland.

borders to Djibouti and Ethiopia are usually not recorded.[69] Hassan (2020) also reported that no regional trade data exists, i.e., within Somalia, and to Djibouti and Ethiopia. The unreported regional trade is believed to be more significant than what ships through the ports due to large scale local use by Christians and Muslims for religious ceremonies, social gatherings, and other rituals, as well as for medicinal use.[70] For example, in neighbouring Ethiopia, frankincense (all species combined) is burned in about 15,000 churches, at a rate of about 150 kg/church annually or about 2,250 MT per annum. Domestic consumption of frankincense in Ethiopia is estimated at about 10,000 MT, of which about 25% is utilized in churches.[71]

Due to the COVID-19 pandemic there was significantly decreased production during 2020 and 2021. The export trade of Puntland frankincense to Saudi Arabia and UAE came to a near halt by mid-2020 due to the closing of markets in those countries. According to one online news source, most of the families that made their livelihood from the frankincense trade in Qandala port were reportedly out of business by mid-2021.[72] Frankincense production is a primary economic activity for households in the East Golis Frankincense zone,[73] where frankincense harvest and sales account for 54 - 72% of poor households' annual income.[74] In 2020, Puntland frankincense demand from buyers in the Arabian Gulf, Yemen, and Egypt significantly dropped, not only negatively impacting household income but also negatively impacting average market prices for export quality *beeyo* frankincense of the Bari region, which dropped down to US$ 5.40/kg in the 2020 *gu* (heavy rainfall season from April to June) compared to an average of US$ 10.25/kg in the 2019 *gu* and US$ 8.00/kg in the 2019 *deyr* (secondary rainfall season from October to December).[75]

Table 5.6 summarizes Somali frankincense production and trade estimates made by companies, by government, and by independent researchers. Because many of the "total" estimates are inclusive of several species, mentioning of species other than *B. carteri* in Table 5.6 is necessary. Estimates provided by exporters and processors should be considered with caution in that it is not unusual for companies to inflate actual production and trade in their public statements.

Table 5.6. Estimates of Somali *B. carteri* production and trade

Source	Location	Estimate
Alla Magan Gums and Resins Processing Center	Somaliland (Togdheer)	With an annual production of about 550 MT (*B. carteri*, *B. frereana*, *B. rivae*, *Commiphora* spp.), Alla Magan states that they are the sole supplier of processed and graded frankincense and myrrh to a large export trading company *neo botanika*.[76] European countries (France and Germany) and the USA are the main export destinations for its *beeyo* grades 1 to 3 whilst Djibouti, Ethiopia, and Eritrea are the main export destinations for *beeyo* grades 4 and 5.[77]

[69] FSNAU (Food Security and Nutrition Analysis Unit – Somalia), 2010. Technical Series, Report No VI. 33, September 27, 2010: 2010 Post Gu Analysis. Food Security and Nutrition Analysis Unit – Somalia, Nairobi, Kenya. http://www.fsnau.org/downloads/FSNAU-Post-Gu-2010-Technical-Report.pdf
[70] Hassan, K.A., 2020. Boswellia in Somaliland.
[71] GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH), 2020. Global Business Network Programme. Partnership Ready Ethiopia: Gums and Resins. GIZ, Eschborn, Germany. https://www.giz.de/en/downloads/GBN_Sector%20Brief_Aethiopien_Gums_Resins_E_Web.pdf
[72] Hiiraan Online, 2021. Somali frankincense traders in Puntland turn to other livelihoods. Hiiraan Online. June 9, 2021. https://www.hiiraan.com/news4/2021/Jun/182860/somali_frankincense_traders_in_puntland_turn_to_other_livelihoods.aspx
[73] Chapman, C., Kusters, C.S.L., Boerema, E., 2021. FNS-REPRO Somaliland Key Findings Report; Key findings emerging from the FNS-REPRO generated studies and other sources as input for the sensemaking events and adaptive programming. Wageningen Centre for Development Innovation, Wageningen University & Research. Report WCDI-21-174. Wageningen. https://doi.org/10.18174/551849
[74] FSNAU (Food Security and Nutrition Analysis Unit – Somalia), 2016. East Golis Frankincense, Goats and Fishing Livelihood Zone Baseline Report. Technical Series Report No VI. United Nations Somalia, Nairobi, Kenya. https://www.fsnau.org/downloads/East-Golis-Frankincens-Goat-and-Fishing-Livelihood-Zone-Baseline-Report_0.pdf
[75] FSNAU (Food Security and Nutrition Analysis Unit – Somalia), 2020. SOMALIA Food Security Outlook October 2020 to May 2021. Famine Early Warning Systems Network (FEWS-NET) and Food Security and Nutrition Analysis Unit (FSNAU), United Nations Somalia, Nairobi, Kenya. https://fews.net/east-africa/somalia/food-security-outlook/october-2020
[76] Shuraako, 2021. Allamagan Gums and Resins Processing Center. One Earth Future Foundation, Broomfield, CO. http://shuraako.org/portfolio/allamagan-gums-and-resins-processing
[77] Aden, A.M., 2013b. Grading and Classification System used for Export of Gums and Resins in Somaliland. SOFRECO, Hargeisa, Somaliland.

Source	Location	Estimate
Asli Maydi Exports and Imports Co.	Somaliland	In 2020, Barkhad Hassan, director at Asli Maydi, estimated Somaliland's annual frankincense export volume at 3,000 MT (inclusive of *B. frereana* & *B. carteri*), of which his company accounts for over 2,000 MT.[78] Hassan asserts that his family has been harvesting and selling frankincense resin for over 600 years, contracts with a distillery in the UK,[79,80] and claims to rank as Somaliland's largest exporter of frankincense.[81]
DeCarlo et al. (2020)	Somaliland	"Changes in the Somaliland frankincense market from 2010 to 2016/17. Estimate of 1400–2000 tonnes of *B. carteri*; *B. frereana* market is greatly reduced." [82]
Hassan Kobac General Trading Company	Mogadishu	Registered in Somalia, Djibouti and UK with 150 workers; specializes in frankincense (*B. carteri*) from Puntland,[83] gum arabic (*Acacia* spp.), myrrh and opoponax (*Commiphora* spp.) Own collection, sorting, weighing and distribution centers across Somalia and Ogaden region. Own and operate on large asset base.[84] 500-600 tonnes of frankincense is FairWild certified through Ecocert.[85]
Horn Incense, Inc.	Puntland (Bari, Karkaar, Nugaal, Mudug), Somaliland (Sanaag)	An association of ten frankincense & myrrh cooperatives claims an average annual production capacity of about 930 MT, of which >95% is comprised of both *B. carteri* & *B. frereana* and 5% *Commiphora* spp. They list a trade volume of about 700 MT, of which about 70% is traded locally.[86,87]
Horn Resin, Ltd.	Puntland (Bari)	Describes itself as a network of growers and traders but also planning to establish a distillation plant in Bosaso.[88] No estimate was obtained.
Muse Ibrahim Yusuf, Deputy Minister of Ministry of Trade and Tourism	Somaliland	In a BBC News Somalia report of 24 Jan 2022, Muse Ibrahim Yusuf, Deputy Minister of Ministry of Trade and Tourism, and Cabdiraxmaan Xuseen Digaale of the company Asli Maydi, were interviewed, suggesting that in 2021 Somaliland exported a total of 1,800 MT combined of *beeyo*, *malmal*, *foox* and oil.[89] Individual quantities were not broken out.
Nagaad Trading Company	Mogadishu	Exports organic-wild certified *Boswellia spp.* frankincense in three grades depending on the size of the blocks or tears that come from the tree.[90] Also exports *B. frereana, Acacia* spp., and three species of *Commiphora* from Mogadishu. Operates one processing facility in Kenya (essential oils, filtrates, hydrosols) and is building a second facility in Somalia. Other *Boswellia* species are marketed through Nagaad's headquarters and offices in Nairobi, Kenya and in the UK.[91]

[78] Rybak, A., 2020. Der Duft für Götter. *Terra Mater*. 1, 25-38. https://magazin.terramatermagazin.com/wp-content/uploads/2020/03/TerraMater_weihrauch_1_20.pdf
[79] Asli Maydi Exports and Imports Company, 2021. Facebook page. https://www.facebook.com/nuurcali06
[80] Hassan, B. 2021. LinkedIn page: Barkhad Hassan, Director/Harvester at Asli Maydi, West Midlands, UK. https://www.linkedin.com/in/barkhad-hassan-a8803a62/
[81] Somaliland Central, 2019. Beeyadii Ugu Badnayd Oo Dekeda Berbera Shirkada Asli Maydi Ka Dhoofisay. Somaliland Economic @Somalilandbiz. https://twitter.com/search?q=100%20tonnes%20frankincense&src=typed_query
[82] DeCarlo, A., Ali, S. and Ceroni, M., 2020. Ecological and economic sustainability of non-timber forest products in post-conflict recovery: A case study of the frankincense (*Boswellia* spp.) resin harvesting in Somaliland (Somalia). *Sustainability*. 12(9): 3578. https://doi.org/10.3390/su12093578
[83] Kobac General Trading: https://sommyrrh.com/
[84] Hassan Kobac General Trading Company. Who We Are: https://kobacgt.so/who-we-are/
[85] FW 2.0 Audit Report for Wild Collection Operation of Kobac General Trading. 2021.
[86] Horn Incense, Inc., 2021. Cooperative Network. Horn Incense, Inc., Bosaso, Puntland, Somalia. https://hornincense.com/cooperative-network/
[87] Abdirisak Ibrahim pers. comm. 2021.
[88] Horn Resin, Ltd., 2017. About us. Background. Bosaso, Puntland, Somalia. https://www.hornresin.com/about-us/
[89] BBC News Somalia. 24 January 2022. *Ganacsiga iyo dhoofinta beeyada Somaliland*. Elsar Media Productions: https://www.youtube.com/watch?v=7r07qe4t_BI
[90] EcoCert. Certificat. Nagaad Trading Company: http://certificat.ecocert.com/client.php?source=recherche&id=9D15885E-00CF-41A4-95AA-B3DD2F30C97E
[91] Nagaad Resins and Gums Company Ltd. https://nagaadgums.com/business-background/

Source	Location	Estimate
Neo Botanika	Maroodi Jeex, Somaliland	The company owner estimated that in Somaliland about 500 MT of *beeyo* frankincense is harvested annually, another 500 MT of *maydi* frankincense, and about 50 MT of *qadhoon* frankincense. They have also established an essential oil distillation facility.[92] *Neo botanika* exports FairWild® certified *B. carteri* and *C. myrrha* gum resins as well as their essential oil and hydrosol,[93] and Organic wild certified *B. carteri*, *B. frereana*, *B. rivae*, and *Commiphora* spp.[94]
Puntland Ministry of Commerce	Puntland	Estimates that about 40% of the annual theoretical yield of frankincense in Puntland is harvested, amounting to about 500 MT, of which about 400 MT (ca. 75% or 300 MT of *B. frereana* and 25% or 100 MT of *B. carteri*) are exported through Bosaso and other northeast Somalian ports.[95,96] However, these estimates appear low. Some individual Puntland companies publicly report that they each produce more than the government estimates for all of Puntland.
Rahan Trading, LLC	Puntland (Bari)	A Somali-UK company reports that it supplies about 200 MT of frankincense (inclusive of *B. carteri* & *B. frereana*) annually, all of which is exported to buyers in the UAE.[97]
Rahiiq Gums and Resins Ltd.	Somaliland (Sanaag)	In 2017, the diaspora returnee owners of this Somali-UK company estimated their company's annual orders at between 700 to 800 MT, inclusive of *B. carteri*, *B. frereana*, and *Commiphora* spp., with their main markets being Europe and America, and to a lesser extent, countries of the Middle East.[98] Based on other conversations with this company, their statement from 2017 may be significantly overestimated.
Somali Frankincense Alliance (Somfal)	Puntland (Bari)	SOMFAL reports an annual production capacity of 540 MT inclusive of *B. carteri*, *B. frereana*, and *Commiphora* spp.[99]
Somaliland Ministry of Finance Development (MOFD)	Somaliland	Annual Statistical Reports show that 1,047.7 tonnes of *foox* were exported in 2018 through Berbera port,[100] 1,301.07 tonnes of *foox* in 2019, and 1,250.16 tonnes in 2020.[101,102,103] These data suggest that exports listed as *foox* were inclusive of gum resins of all *Boswellia* spp. for two reasons (1) exports of *malmal* (*Commiphora* spp.) were quantified separately; and (2) some prior year statistics were more granular, i.e., reporting separate quantities for *beeyo*, *foox*, *maydi*,

[92] Osman, Z., 2020. Annex 16: Neo Botanika (Somalia).
[93] FairWild Foundation, 2021. neo botanika. FairWild Foundation Secretariat, Cambridge, UK. https://www.fairwild.org/all-fairwild-participants/neo-botanika
[94] EcoCert SA. Certificat. Neo Botanika: http://certificat.ecocert.com/client.php?source=recherche&id=B6E00BBE-ED8E-4E34-A4D0-3CE7E7BE12B2
[95] Puntland Ministry of Commerce, 2019. Puntland Investment Forum, 15-17 September 2019. Somalispot. https://www.somalispot.com/threads/puntland-investment-forums.64815/
[96] Puntland Statistics Department, 2018. Puntland Facts And Figures 2012-2017. Ministry of Planning and International Cooperation (MOPIC), Garoowe, Puntland, Somalia. https://pl.statistics.so/wp-content/uploads/2019/04/Puntland-Facts-and-Figures-2017-Year-book-2018-1.pdf
[97] Muse, O.A., 2018. Market Potential of Frankincense Gum for Rahan Trading L.L.C. Bachelor's Thesis. Haaga-Helia University of Applied Sciences, Helsinki, Finland. https://www.theseus.fi/handle/10024/159514
[98] Owuor, V.O., 2017. Firm Behavior in Fragile States.
[99] Somfal, 2021. Why choose Somfal. Somfal, Bosaso, Somalia. https://www.somfal.com/
[100] Somaliland Central Statistics Department (CST), 2019. Somaliland in Figures 2018, Somaliland CST, Hargeisa, Somaliland. https://somalilandcsd.org/wp-content/uploads/2021/08/Somaliland-Infigures-2018.pdf
[101] MOFD (Ministry of Finance Development) Macroeconomics & Statistics Department, 2020. Trade Statistical Bulletin Jan-Dec 2019. Ministry of Finance Development, Hargeisa, Somaliland. https://slmof.org/reports/
[102] MOFD (Ministry of Finance Development) Macroeconomics & Statistics Department, 2021. Trade Statistical Bulletin 2020. Ministry of Finance Development, Hargeisa, Somaliland. https://slmof.org/reports/
[103] Somaliland Central Statistics Department (CST), 2020. Somaliland in Figures 2019, Somaliland CST, Hargeisa, Somaliland. https://bankofsomaliland.net/wp-content/uploads/2021/08/Somaliland-Infigures-2019-1.pdf

Source	Location	Estimate
		and *qadhoon* frankincense, that, in total, roughly equate the annual quantities more recently attributed solely to *foox*.[104,105,106]
Somaliland Ministry of Trade and Investment	Somaliland	In 2012, Somaliland's annual production capacity was estimated at about 800 MT inclusive of *B. carteri*, *B. frereana*, & *Commiphora* spp., with a "potential" annual capacity of 2,800 MT, of which 1,000 MT could be *B. carteri,* 300 MT *B. frereana,* 1,500 MT *Commiphora spp.*[107]
Younis Aroma	Puntland	A Somali-Latvian company that claims to own the majority of frankincense trees in the Puntland region of Somalia. *Younis Aroma* reported a record shortage of *B. carteri* resin in 2021 due to harvesters intentionally harvesting from only half of the trees during the previous harvesting season. Tribal elders and landowners were reportedly persuaded to give certain trees a rest as part of a sustainable management plan.[108,109] No estimates were obtained.

Table 5.7 attempts to assemble exported volumes of *B. carteri* frankincense that are formally reported in governmental reports and illustrate the many gaps in reporting. Because different local names are used in different statistics bulletins and because gums and resins are lumped together in some years whilst in other years they are broken out, Table 5.7 necessarily includes the other related gum resins for completeness. By cross referencing different published sources of export trade data, a correlation was found between the Somaliland export quantities of frankincense and the reported Somaliland export quantities of *foox* reported in 2019 and 2020. This fact supports the suggestion that the term *foox* can be meant to be inclusive of *Boswellia* spp. of frankincense but excludes *Commiphora* spp., which were quantified separately in 2019 and 2020 customs statistics. There remain gaps in information on informal or unreported trade through land borders as well as through some ports. This fact is acknowledged in Table 5.7 by stating Not known in such cases.

Table 5.7. 2016-2020 Estimated annual volume (MT) of exports of gums and resins from Somalia

		Annual Volume (MT)				
Exporter	**Item**	**2016**	**2017**	**2018**	**2019**	**2020**
Puntland Bosaso port and other customs	*B. carteri* gum resin	Not known	Not known	Not known	**100 MT**	Not known
	B. frereana gum resin	Not known	Not known	Not known	300 MT	Not known
Somalia Mogadishu port	*B. carteri* gum resin	Not known	Not known	Not known	Not known	Not known
Somalia / Somaliland land route to Ethiopia	*B. carteri* gum resin	Not known	Not known	Not known	Not known	Not known
Somaliland land route to Djibouti	*B. carteri* gum resin	Not known	Not known	Not known	Not known	Not known
Somaliland Berbera port and other customs	*Beeyo* (*B. carteri*)	13.08 MT	Lumped in with *foox?*	Lumped in with *foox?*	Lumped in with *foox?*	Lumped in with *foox?*
	Fas saqir (grade 4 *maydi: B. frereana*)	2.5 MT	Lumped in with *foox?*	Lumped in with *foox?*	Lumped in with *foox?*	Lumped in with *foox?*
	Foox	**948.62 MT**	**1,253.99 MT**	**1,047.7 MT**	**1,301.07 MT**	**1,250.16 MT**

[104] Somaliland Dept. of Customs, 2017. Annual Statistical Report 2016. Statistics Section, Department of Customs, Ministry of Finance Development, Hargeisa, Somaliland. https://slmof.org/wp-content/uploads/2019/02/Annual-Statistical-Report-2016.pdf
[105] Somaliland Dept. of Customs, 2018. Annual Statistical Report 2017. Statistics Section, Department of Customs, Ministry of Finance Development, Hargeisa, Somaliland. https://slmof.org/wp-content/uploads/2019/02/Annual-Statistical-Report-2017.pdf
[106] Somaliland Dept. of Customs, 2019. Annual Statistical Report 2018. Statistics Section, Department of Customs, Ministry of Finance Development, Hargeisa, Somaliland. https://slmof.org/wp-content/uploads/2019/05/Annual-Statistical-Report-2018.pdf
[107] Soloviev, P., Abdi, A., 2013.
[108] Younis Aroma, 2021. About us. Younis Aroma, Bosaso, Puntland State of Somalia. http://www.younisaroma.com/
[109] Abdullahi Said pers. comm. 2021.

Foox oil	Not known	170 L	1428 L	Not known	Not known
Malmal (myrrh)	33.87 MT	100.96 MT	171.7 MT	95.85 MT	41.06 MT
Qadhoon (*B. rivae*).	Not known	Not known	2.75 MT	Lumped in with *foox?*	Lumped in with *foox?*
Xabag (all)	18.53 MT	Not known	Not known	Not known	Not known
Xabag cadaad (gum arabic)	Not known	Not known	12.93 MT	Not known	Not known
Xabag god	Not known	Not known	15.21 MT	Not known	Not known
Xabag hadi (opoponax)	Not known	Not known	14.4 MT	Not known	Not known

Sources of data: Republic of Somaliland Annual Statistical Reports (Somaliland Dept. of Customs, 2017, 2018, 2019); Berbera Port 2013-2016 and Ministry of Finance Development (MOFD) 2017-2018 (Somaliland Central Statistics Department, 2019; 2020); Somaliland Trade Statistics Bulletins (MOFD, 2020; MOFD, 2021)

5.2.2 Boswellia dalzielii

Boswellia dalzielii occurs in several African countries including Benin, Burkina Faso, Cameroon, Chad, Côte d'Ivoire, Ghana, Mali, Niger, and Nigeria. While there are data on food and medicinal uses of its gum resin and preparations of other plant parts, centralised data on the production and trade scenarios are lacking, possibly because *B. dalzielii* oleo-resin exports are a relatively new component of the supply chain (Figure 5.3).

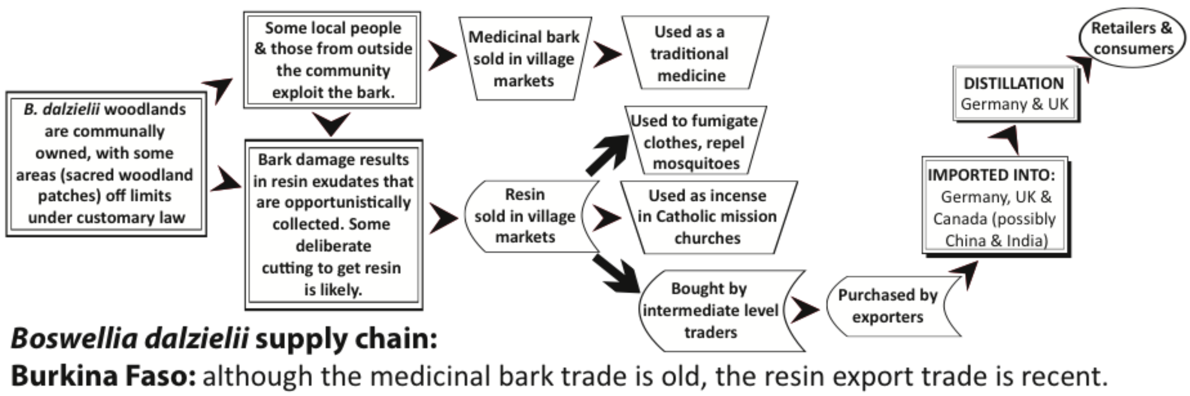

Figure 5.3. In comparison to the *B. dalzielii* medicinal bark trade, which is widespread across West Africa and the local incense trade (recorded in the 1950's) (Burkhill, 1985[110]), the export of *B. dalzielii* oleo-resin is recent. With a poorly known supply chain.

While most *B. dalzielii* products claim a geographic origin of Burkina Faso or Nigeria, a Ghanaian trading company formerly included *B. dalzielii* in its catalogue indicating an ability to supply up to 250 MT of the resin annually.[111] Harrabi Frankincense from Nigeria is marketed on the ALIBABA platform by a small German retailer Mothers Goods (Georg Huber).[112] The Mothers Goods website[113] markets *B. dalziellii* sourced from Nigeria, Burkina Faso, and Senegal. Huber states that this species "is not harvested commercially on a significant and systematic scale" in any of the three countries but sources mainly from Nigeria. Mothers Goods also markets *B. occulta* from Somalia, stating "this species is usually harvested together with *B. carterii*." Huber also markets *B. dalzielii* under a different company name (Jeomra's Räucherwelt) via AMAZON,[114] and via his own website.[115] The Burkina Faso company Afrikor Naturals[116] states that it procures raw *B. dalzielii* resin from several cooperatives, which it cleans, sorts, and analyses before exporting, and has developed facilities for distillation of *B. dalzielii*

[110] Burkhill, H.M., 1985. The Useful Plants of West Tropical Africa 2nd ed. Vol 1. Royal Botanic Gardens, Kew.
[111] Tek-Spec. Co. Ltd., Accra, Ghana. 2003 Catalogue.
[112] ALIBABA. Harrabi Frankincense from Nigeria - *Boswellia dalzielii*: https://www.alibaba.com/product-detail/Harrabi-Frankincense-from-Nigeria-Boswellia-dalzielii_62018255026.html?spm=a2700.searchcustom.0.0.65a83e34idEByZ
[113] Mothers Goods, Georg Huber. Our Frankincense Varieties: https://mothersgoods.com/frankincense
[114] AMAZON. *Boswellia dalzielii*: https://www.amazon.de/-/en/Harrabi-Incense-Nigeria-Boswellia-Dalzielii/dp/B07TKY396L
[115] Jeomra's Räucherwelt: https://raeucherwelt.de/collections/weihrauch-boswellia-dalzielii
[116] Afrikor Naturals. Products – Frankincense - *Boswellia dalzielii*: https://www.afrikornaturals.com/products

oils for export. The company has a research and conservation partnership with the University of Ouagadougou, the Aromatic Plant Research Center (APRC) in the United States, and the Burkina Faso Ministry of Environment. Many other small online retailers market the gum resin and essential oil. For example, in the ETSY platform,[117] *B. dalzielii* is marketed with various descriptors such as "Dalzielii Frankincense Resin from Nigeria," Frankincense Boswellia dalzielii 5ml RARE Nigeria Distilled in Israel from Holy Land Charged®™ Resins," "Frankincense Dalzielii – Janawhi, Cricognimu-Nigeria," Frankincense from Burkina Faso – Premium quality (Big grains) – resin," "Frankincense Oleo extract – Boswellic acids- Boswellia dalzielii – Nigeria," "Frankincense Tincture-Boswellia Dalzielii-Nigeria-Boswellic acids," "Rare Harrabi Frankincense – Top Grade West African Incense Resin," and "Resin of Janawi from Burkina Faso."

5.2.3 *Boswellia frereana*

5.2.3.1 *Commercial grades and quality*

The Somaliland Ministry of Trade and Investment states "*The main quality aspects of gums and resins in Somaliland are measured according to traditional grading systems used in trade with the Arabic peninsula. These classifications depend on the size and colour of the gum resin. In some cases certain customers, mainly from European markets, who are buying gums and resins, demand certain grades and provide the specifications for these grades.*"[118] Table 5.8 shows seven different cleaned and sorted grades of *maydi* frankincense used in Somaliland. The raw product unsorted is called *marbuush*. Grades 1-4 of maydi are exported mainly to Yemen and UAE with possible re-export to Saudi Arabia by intermediary dealers. Grades 5-6 are exported mainly to Ethiopia, Yemen, Eritrea and Egypt.[119] However, a report for the EU rehabilitation programme for Somalia/Somaliland states that "Saudi Arabia was and remains the largest importer of Grades 1-4 of *maydi* (*B. frereana*) frankincense, which is a prestigious chewing product consumed by Saudi middle-upper class households peaking during religious festivals, especially the Hajj. There was direct exporting of *maydi* frankincense from Somaliland to Saudi Arabia with livestock shipments prior to the livestock ban."[120]

Table 5.8. Somaliland grades of maydi frankincense (*B. frereana*)

Grade Number	Grade Name	Description
1	Mushaad	Large white pieces >20 mm
2	Mujarwal	Medium to large white pieces 12-20 mm
3	Fas kabiir	Medium round pieces 6-12 mm
4	Fas saqiir	Small to medium round pieces 4-6 mm
5	Jidhiidh	Mixture of gum and bark
6	Budo	Powder
7	Kasaar	Bark

Source: Republic of Somaliland Ministry of Trade and Investment

5.2.3.2 *Estimating the production and trade of B. frereana*

Although Coulter (1987)[121] estimated an annual production in Somalia of 1,000 MT of *B. frereana* frankincense and Coppen (1995)[122] suggested 800 MT were used annually, this had halved to 500 metric tons by 2004. For 2012, the Somaliland Ministry of Trade and Investment suggested an annual

[117] ETSY. *Boswellia dalzielli*: https://www.etsy.com/market/boswellia_dalzielii
[118] Soloviev, P., Abdi, A., 2013. Directory for Somaliland Gums, Resins and Essential Oils.
[119] Aden, A.M., 2013a, 2013b.
[120] ITC - Eastern Africa, 2006. Review and Synthesis of Local Economic Development (LED) Materials: Puntland, s.l.: The European Union's 5th Rehabilitation Programme for Somalia/Somaliland.
[121] Coulter, J., 1987. Market Study for Frankincense and Myrrh from Somalia, Chatham: Natural Resources Institute.
[122] Coppen, J., 1995. Flavours and fragrances of plant origin. In: Non-wood forest products 1. Rome: Food and Agriculture Organization of the United Nations, pp. x, 101p.

capacity of 300 MT of *B. frereana*.[123] DeCarlo et al (2020) reported that by 2016-2017 production and export levels for *B. frereana* were greatly reduced in the meantime since the Coppen (1995) estimate of 800 MT.[124] Osman (2020) stated that about 500 MT of *B. frereana* were produced annually in Somaliland.[125] For 2018, the Puntland Ministry of Commerce estimated that about 40% of the annual theoretical yield of frankincense in Puntland is harvested, amounting to about 500 MT, of which about 400 MT (ca. 75% or 300 MT of *B. frereana* and 25% or 100 MT of *B. carteri*) are exported through Bossaso and other northeast Somalian ports.[126,127] Taking the estimates for the Puntland and Somaliland regions of Somalia together, there may be 600 to 800 MT of *B. frereana* harvested and traded annually. As is also the case with Somali *B. carteri*, there may be significant unreported cross border trade of *B. frereana*.[128] See also the section on estimating the production and trade of *B. carteri* because most Somali companies are trading both *B. carteri* and *B. frereana*.

5.2.4 Boswellia neglecta and B. rivae

Both *B. neglecta* and *B. rivae* oleo-resins are collected by hand from natural exudates. As we discuss in Chapter 5, this is a sustainable trade. *B. neglecta*, has a huge extent of occurrence in eastern Ethiopia, Kenya, north-eastern Tanzania and Uganda, and *B. rivae* occurs in eastern Ethiopia, north-eastern Kenya and Somalia. In northern Kenya, women from pastoralist communities harvest both *Commiphora confusa* and *B. neglecta* oleo-resins by hand, where exudates have been stimulated by wood-boring beetles (Sommerlatte and van Wyk, 2022).[129]

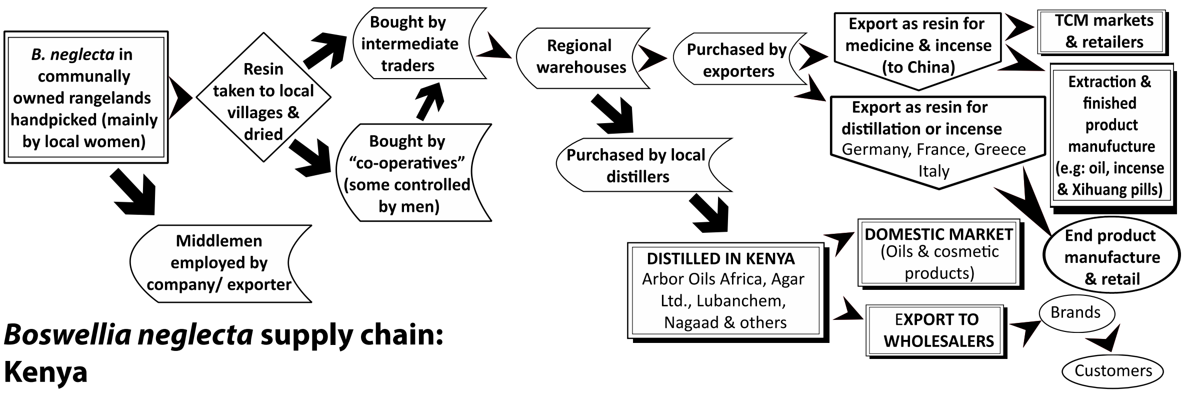

Figure 5.4. The supply chain for *B. neglecta* oleo-resins in Kenya.

[123] Soloviev, P., Abdi, A., 2013.
[124] DeCarlo, A., Ali, S. and Ceroni, M., 2020.
[125] Osman, Z., 2020. Annex 16: Neo Botanika (Somalia).
[126] Puntland Ministry of Commerce, 2019. Puntland Investment Forum, 15-17 September 2019. Somalispot. https://www.somalispot.com/threads/puntland-investment-forums.64815/
[127] Puntland Statistics Department, 2018. Puntland Facts And Figures 2012-2017. Ministry of Planning and International Cooperation (MOPIC), Garoowe, Puntland, Somalia. https://pl.statistics.so/wp-content/uploads/2019/04/Puntland-Facts-and-Figures-2017-Year-book-2018-1.pdf
[128] Hall, A., 2005. Viability of a Sustainable Frankincense Market in Somaliland: A Historical and Economical Analysis., s.l.: Somaliland Cyberspace.
[129] Sommerlatte, H. and Wyk, B.E.V., 2022. Observations on the Association between Some Buprestid and Cerambycid Beetles and Black Frankincense Resin Inducement. *Diversity*, *14*(1), p.58.

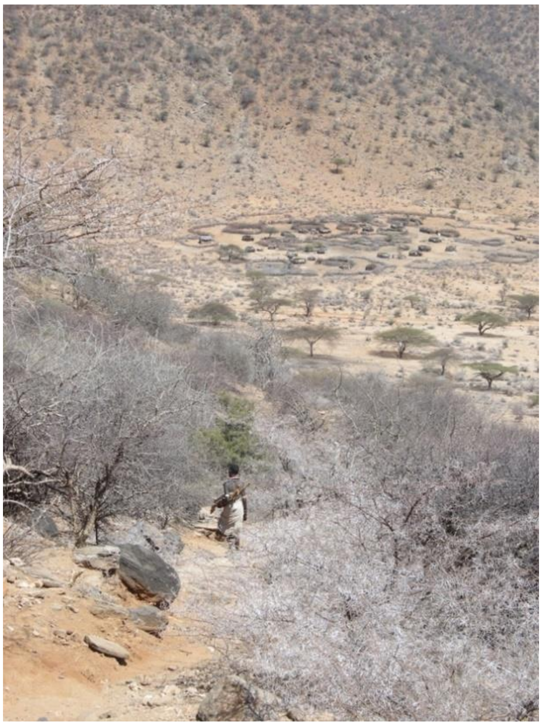

Figure 5.5. A Samburu woman from a pastoralist community (with the traditional homestead (*manyatta*) in the background descends a hill after hand collecting *B. neglecta* oleo-resins at the beginning of the supply chain for in Kenya. This landscape also gives an important perspective on why the fuelwood harvest "threat" to *B. neglecta* (see Bongers et al., 2019[130]) is overstated. The main fuelwood around *manyattas* is *Acacia tortilis* (seen in the valley below). Not *B. neglecta,* which is a less dense, less preferred fuelwood that often occurs in hill woodlands where it is less easily available (H. Sommerlatte, pers. comm, 2022). Photo: H. Sommerlatte.

Boswellia rivae and *B. neglecta* are collected similarly in Ethiopia and Somalia primarily by women from pastoralist families. As the trees are not tapped, and indeed do not necessarily respond to tapping, international trade in the resin is not a major threat factor, and trade can be considered sustainable.

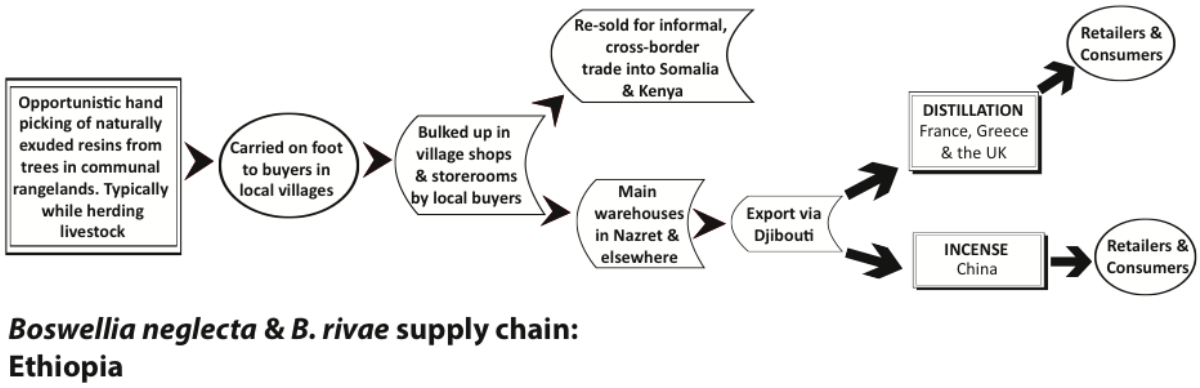

Figure 5.6. The supply chain for *B. neglecta* and *B. rivae* oleo-resins collected by pastoralists in eastern Ethiopia.

[130] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610

5.2.5 *Boswellia papyrifera*

5.2.5.1 Commercial grades and quality

The gum resin and products of this species are harvested in and exported mainly by Sudan and Ethiopia (see Figures 5.7 and 5.8), but also Eritrea, South Sudan and Djibouti. Tigray type frankincense/olibanum (*B. papyrifera*) is sorted into various different quality grades.

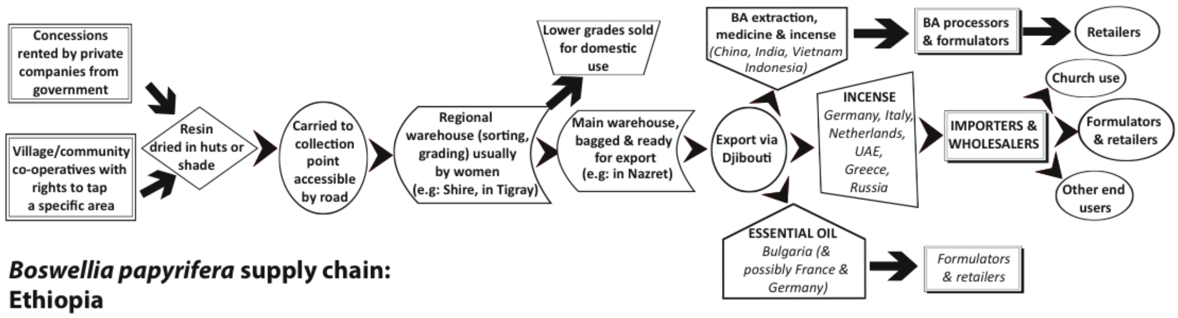

Figure 5.7. The supply chain for *B. papyrifera* oleo-resins in Ethiopia. This supply chain has been disrupted by the current conflict in Tigray. Consequently, the retail price of frankincense in the local market in Addis Ababa rose to 1000 birr/kg (almost US$20/kg) in 2021 (H. Kassa, pers. comm., 2021).

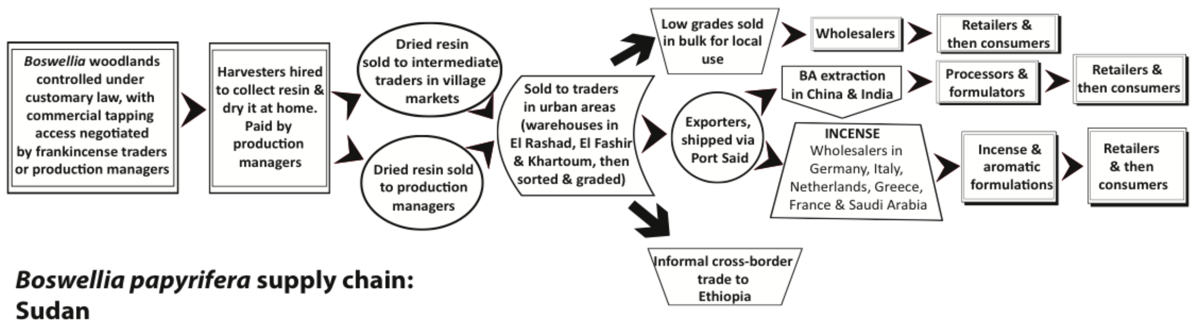

Figure 5.8. The supply chain for *B. papyrifera* oleo-resins from Sudan. It is possible that a cross-border trade in *B. papyrifera* oleo-resins occurs from Eritrea into Ethiopia and through South Sudan to Kenya.

In Ethiopia, no grading is done for the Ogaden (*B. rivae*) and Borena (*B. neglecta*) types.[131] There are no formal Ethiopian standards for *B. papyrifera*. The grading system initially introduced by the state-owned Natural Gums Processing and Marketing Enterprise (NGPME) is still used as a commonly accepted standard. Table 5.9 summarises the NGPME grading criteria. The 5th through 7th grades are traded mainly in domestic markets.[132] Sudan has a technical standard for quality grade of olibanum, which are summarised in Table 5.10.[133]

Table 5.9. NGPME Quality Grades of *B. papyrifera* olibanum

Grade name	Description	Ratio (%)
1A	Size: > 6 mm, white	22
1B	Size: > 6 mm, creamy white	9
2	Size: 4-6 mm	11
3	Size: 2-4 mm	9
4A	Any size, brown ('special')	19

[131] Chikamai, B. & Casadei, E. eds., 2005. Production and Marketing of Gum Resins: Frankincense, Myrrh and Opoponax. Nairobi: Network for Natural Gums and Resins in Africa.
[132] GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH), 2020. Global Business Network Programme. Partnership Ready Ethiopia: Gums and Resins. GIZ, Eschborn, Germany. https://www.giz.de/en/downloads/GBN_Sector%20Brief_Aethiopien_Gums_Resins_E_Web.pdf
[133] Abnaa Sayed Elobied Agro Export: https://arabicgum.sd/product/olibanum-frankincense/

Grade name	Description	Ratio (%)
4B	Any size, black ('normal')	17
5	No size limit, powder and bark	14

Table 5.10. Sudanese Quality Grades of *B. papyrifera* olibanum

Grade name	Particle size
Nagawa	> 10 mm (free of bark)
Grade (1)	10 – 5 mm (free of bark)
Grade (2)	5 – 2.5 mm (free of bark)
Grade (3)	< 2.5 mm (free of bark)
Grade (4)	Particles of different sizes stuck to tree bark

5.2.5.1 *Estimating the production and trade of B. papyrifera*

The two main producers and exporters of *B. papyrifera* are Sudan and Ethiopia. Table 5.4 in this chapter showed that in 2019 Sudan was the largest exporter of HS 130190 (*B. papyrifera*, *Commiphora* and *Sterculia* spp. combined) at 4,500.61 MT and Ethiopia exported 1,472.18 MT (mainly *B. papyrifera* but possibly also *B. microphylla*, *B. neglecta*, *B. pirrotae*, *B. rivae*, and *Commiphora* spp.).[134] Table 5.11, using NGPME data, provides Ethiopia exports of frankincense/olibanum (all species) 2009 to 2018. Based on *B. papyrifera* trade data cited by both Gelaye (2012)[135] (4533 tonnes in 2007) and Gidey et al (2020)[136] (7900 tonnes exported from Ethiopia in 2014), the NGPME data appears to reflect significant under-reporting.

Eritrea: Annual production of olibanum from *B. papyrifera* in 2005 was estimated at 450 MT.[137]

Ethiopia: A 2021 study on the Ethiopian frankincense sector makes this relevant point "*No data were available for the total volume of frankincense production at national level, because of the inaccessibility of data from a number of private enterprises and the paucity of data on cross border trading. The annual volume of frankincense production was obtained from the state company that was actively involved over the three frankincense governance eras*."[138] The former NGPME (now dissolved) was the main exporter of frankincense. Because NGPME handled not only *B. papyrifera* but also other *Boswellia* spp., species-specific quantification is not possible. Of the three main Ethiopian species [Tigray type (*B. papyrifera*), Ogaden type (*B. rivae*), and Borena type (*B. neglecta*)], Tigray type is the most widely traded both domestically and internationally, and reportedly accounts for 91% of frankincense/olibanum export value and 93% of export quantity.[139] Domestic consumption of frankincense/olibanum in Ethiopia is estimated at about 10,000 MT, of which about 25% is utilized in churches.[140] Ethiopia's frankincense/olibanum (all *Boswellia* spp.) exports from July 2009 to June 2018 are shown in Table 5.11.

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[134] United Nations Statistics Division, 2021. UN Comtrade Database. United Nations, New York, NY. https://comtrade.un.org/data/
[135] Gelaye M.T. 2012. Restoration and sustainable management of frankincense forests in Ethiopia: a bio-economic analysis. PhD thesis KU Leuven.
[136] Gidey, T., Hagos, D., Juhar, H.M., Solomon, N., Negussie, A., Crous-Duran, J., Oliveira, T.S., Abiyu, A. and Palma, J.H., 2020. Population status of Boswellia papyrifera woodland and prioritizing its conservation interventions using multi-criteria decision model in northern Ethiopia. *Heliyon*, *6*(10), p.e05139.
[137] Chikamai, B. & Casadei, E. eds., 2005. Production and Marketing of Gum Resins
[138] Eshete A, Kassa H, Livingstone J. 2021. Inclusive frankincense value chain development in Ethiopia. A historical perspective on forest governance and reforms for better livelihoods and conservation outcomes. PENHA, Addis Ababa, Ethiopia and Tropenbos International, Ede, the Netherlands
[139] Millenium Cities Initiative (MCI) Mikelle Investment Team, 2013. Investment opportunity in Mekelle, Regional State of Tigray, Ethiopia. Production of Essential Oils and Extracts from Aromatic Gums, New York: Earth Institute at Columbia University.
[140] GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH), 2020.

Table 5.11. Export market volumes Frankincense/Olibanum NGPME from July 2009 to June 2018 (Source: NGMPE)[141]

Year	Exported tonnes
2009/2010	1,124
2010/2011	1,082
2011/2012	810
2012/2013	1,027
2013/2014	712
2014/2015	825
2015/2016	533
2016/2017	552
2017/2018	805

Sudan: Most Sudanese olibanum from *B. papyrifera* is reportedly consumed internally and only a limited amount is exported. Main importers of Sudanese frankincense include UAE, Saudi Arabia, China, France, Germany, and Italy.[142] A 2009 study prepared for the Ministry of Foreign Trade, Government of Sudan and the European Commission reported a steep decline of Sudan's olibanum exports from 1,726 MT in 2001, to 112 MT (2002), 865 MT (2003), 375 MT (2004), 358 MT (2005), 169 MT (2006), and down to 76 MT in 2007.[143]

5.2.6 *Boswellia sacra*

B. sacra oleo-resin is harvested in Oman and Yemen. According to "The Sultanate of Oman's Manufacturing Strategy 2040," the Omani frankincense industry today involves large international companies and many small family businesses that distil essential oil, from which they also produce cosmetics, incenses, and perfumes in an artisanal manner in their own homes. These artisanal products are sold mainly in Omani markets and not exported (see Figure 5.6).[144] However, in 2010, the large Utah company, Young Living was granted permission from Omani authorities to plant trees, distil *B. sacra* essential oil in partnership with the Arabian Frankincense Distillery, and export large quantities of oils and extracts.[145,146] A smaller scale example is the New York company Enfleurage, which, in 2011, established an artisanal distillery, Enfleurage Middle East, LLC, initially in Salalah, Dhofar region, but moved to Muscat in 2017, where it doubled production capacity.[147] The Natural Frankincense Products Company (Salalah, Dhofar), distils essential oil in Oman and exports *B. sacra* oleo-resins to Turkey where they produce natural frankincense soaps. They state that they planted 500 *B. sacra* seedlings in 2021, plan to plant another 1,000 seedlings in 2022, and commit to planting 25,000 trees by 2025.[148] Oman's Ministry of Agriculture, Fisheries and Water Resources imposes import prohibitions on frankincense (HS 13019070), while frankincense essential oil (HS 330129) is subject to import restrictions and shipments must be accompanied by a certificate issued by the Ministry of Heritage and Tourism (WTO Secretariat, 2021).[149]

[141] GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH), 2020.
[142] Abtew, A., Pretzsch, J., Mohmoud, T. & Adam, Y., 2012. Commodity chain of Frankincense from the dry woodlands of Nuba Mountains, South Kordofan State, Sudan. Small-scale Forestry, 11(3), pp. 365-388.
[143] Konandreas, P., 2009. Final Study: Assessing Sudan's Export Diversification Potential in Agricultural Products, London: Maxwell Stamp PLC.
[144] MOCI (Ministry of Commerce and Industry, the Sultanate of Oman) and UNIDO (United Nations Industrial Development Organization), 2019. 'Manufacturing for Wellbeing': The Sultanate of Oman's Manufacturing Strategy 2040 (First Edition). MOCI, Muscat, Oman. https://open.unido.org/api/documents/15446402/download/UNIDO-Publication-2019-15446402
[145] Young Living Oman, 2021. Sacred Frankincense, Young Living Oman, Muscat, Oman. https://www.younglivingoman.com/sacred-frankincense
[146] Young Living USA, 2021. A Look at our Farms. Arabian Frankincense Distillery. Young Living Essential Oils, Lehi, UT. https://www.youngliving.com/us/en/company/our-farms
[147] Enfleurage Middle East, 2021. Our Story. Enfleurage Middle East, LLC, Muscat, Oman. https://enfleurage.me/our-story
[148] Natural Frankincense Products Company, 2021. Sustainability. Natural Frankincense Products Company, Salalah, Oman. https://www.nfproducts.com/sustainability
[149] WTO (World Trade Organization) Secretariat, 2021. Oman - Trade Policy Review Report Prepared by the Secretariat. World Trade Organization, Geneva, Switzerland. https://www.wto.org/english/tratop_e/tpr_e/s418_e.pdf

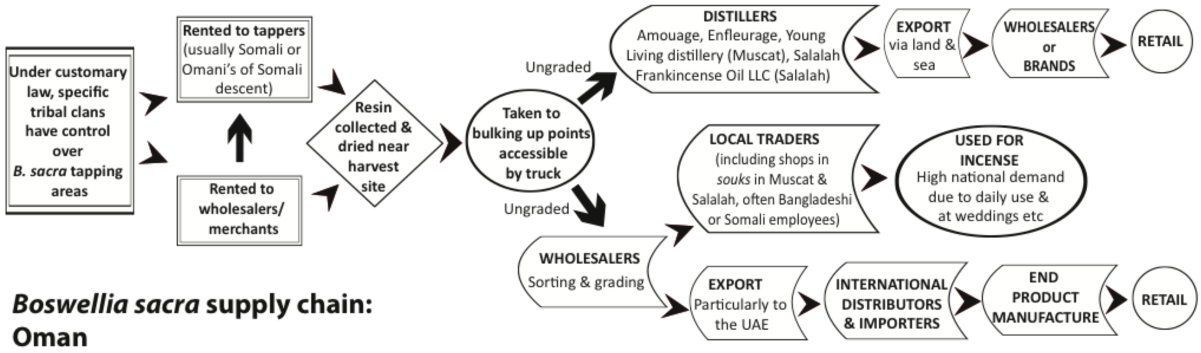

Figure 5.8. The supply chain for *B. sacra* oleo-resins from Oman.

5.2.6.1 *Commercial grades and quality*

Oman has four main *B. sacra* quality grades, differentiated by the geographic locations in Dhofar where harvested. Grade 1, called *Houjri*, has the lightest colour and a larger clump size. The second quality is called *Najdi*, which has a pale, yellow colour. The third and fourth grades, *Sahli/Shazri*, comes from the western mountains and valleys, and Sha'abi comes from the coastal cliffs and wadis.[150] In Dhofar province, another source describes five main grades of frankincense sold locally; super *hougari* green, *hougari* regular, royal *hougari* white, *hougari* yellow, and *shabi*.[151] *Houjri* grades of resin is collected north of the Samhan mountains. *Najdi* resin is collected from the plateau behind the Dhofar mountains and *Sahli/Shazri* is harvested from *B. sacra* trees in the western valleys.[152]

5.2.6.2 *Estimating the production and trade of Boswellia sacra*

According to market information of the Dutch Centre for the Promotion of Imports from developing countries (CBI), the global market for the essential oil of *B. sacra* is estimated at 30 to 40 tonnes, of which about one-third is used in aromatherapy.[153] The yield of essential oil distilled from *B. sacra* gum resin ranges between 4 and 8% according to Canney Davidson et al (2021), but other sources state a range of 6 to 10%.[154] Correspondingly, the company dōTERRA states that it takes approximately 0.5 lb. (226.8 g) of resin to produce one 15 mL bottle of their frankincense essential oil. As 1mL of oil equals roughly 1g, then 15 ÷ 226.8 = about 6.6% yield.[155] However, unpublished data from dōTERRA's main supplier shows yields between 11-12%. Table 5.12 attempts to assemble exported volumes of exports of materials that could be composed of *B. sacra* gum resin, essential oil, extract, or resinoid. While Oman customs utilises the Gulf Cooperation Council (GCC) tariff codes for 'frankincense' HS 1301907000 and 'olibanum' HS 1301906000, we were unable to access Omani export trade data. Therefore Table 5.12 lumps myrrh, frankincense, and olibanum together under the WCO 6-digit code HS 130190.

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[150] Di Stefano, V., Schillaci, D., Cusimano, M.G., Rishan, M., Rashan, L., 2020. In vitro antimicrobial activity of frankincense oils from Boswellia sacra grown in different locations of the Dhofar region (Oman). Antibiotics. 9(4): 195. https://doi.org/10.3390/antibiotics9040195

[151] Al-Harrasi, A. Ali, L., Ceniviva , E., Al-Rawahi, A., Hussain, J., Hussain, H., Rehman, N.U., Abbas, G., Al-Harrasi, R., 2013. Antiglycation and antioxidant activities and HPTLC analysis of Boswellia sacra oleogum resin: The sacred frankincense. Trop. J. Pharm. Res. 12(4), 597-602. https://doi.org/10.4314/tjpr.v12i4.23

[152] Di Stefano, V., Schillaci, D., Cusimano, M.G., Rishan, M., Rashan, L., 2020.

[153] CBI (Centre for the Promotion of Imports from developing countries), 2018. Exporting frankincense to Europe. CBI, The Hague, The Netherlands. https://www.cbi.eu/market-information/natural-ingredients-health-products/frankincense

[154] Canney Davidson, S., Bongers, F., Phillips, D., November 2021. *HerbalEGram*, Issue 11.

[155] dōTERRA, 2019b. dōTERRA Frankincense Infographic. dōTERRA Holdings, LLC, Pleasant Grove, Utah. https://media.doterra.com/us/en/flyers/infographics/frankincense-infographic.pdf

Table 5.12. 2016-2020 Estimated annual volume (MT) of exports of gums and resins from Oman and Yemen

Exporter	Item	Annual Volume (MT) 2016	2017	2018	2019	2020
Oman	HS 130190: Natural gums, resins, gum-resins, balsams, n.e.s. in heading no. 1301	9.16 MT	47.71 MT	35.98 MT	19.58 MT	39.55 MT
	Myrrh HS 13019050	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190
	Olibanum HS 13019060	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190
	Frankincense HS 13019070	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190	Lumped in HS 130190
	Essential oils excluding those of citrus fruit, n.e.s. HS 33012900	16.79 MT	12.02 MT	50.95 MT	23.49 MT	14.98 MT
	Extracted Oleoresins HS 33019090	144.31 MT	270.47 MT	182.84 MT	83.26 MT	13.15 MT
	Resinoids, n.e.s. HS 33013090	0.7 MT	0.2 MT	4.8 MT	1.34 MT	3.83 MT
Yemen	HS 130190: Natural gums, resins, gum-resins, balsams, n.e.s. in heading no. 1301	1.41 MT	1.08 MT	25.59 MT	2.22 MT	30.33 MT

Sources of data:
Oman: 2016-2018: Customs statistics (Royal Oman Police, Directorate General of Customs, 2021).[156] 2019-2020: UN COMTRADE Database (United Nations Statistics Division, 2021).[157]
Yemen: UN COMTRADE database, based on reporting countries imports.

5.3 Import Trade Data of Selected Countries

To illustrate trade flows and origins of frankincense or olibanum shipments, it is useful to evaluate the available import trade data of countries that make such data publicly available, such as India and Saudi Arabia. In the case of the United States, it is possible to obtain customs bill of lading data and extract relevant shipment descriptions and quantities of *Boswellia* import trade.

5.3.1 India

Table 5.13 shows India's imports of HS 13019032 (Olibanum or Frankincense), the country of origin, value in US$ Million and volume in metric tons (MT) 2017-18 (Apr-Mar) through 2020-21 (Apr-Mar).[158] India trade data are not reported by calendar year but rather by India's agricultural year (April through March). The India import-data show that during the COVID-19 years (2019-20 and 2020-21), imports from Somalia decreased significantly while imports from second re-exporting countries (e.g., Egypt and UAE) increased, as well as significant new import trade from Kenya. However, not shown in the table, are new changes seen thus far in the first nine months of India's agricultural year (Apr-Dec 2021), which show significantly increased quantities from Somalia (74 MT), Cameroon (45.8 MT), Chad (18.8 MT), and Nigeria (15.76 MT) and significantly decreased quantities from Egypt (47.82 MT), UAE (17.24 MT), and Kenya (0.30 MT).

[156] Royal Oman Police, Directorate General of Customs, 2021. Customs statistics: Exports. https://www.customs.gov.om/dgcportal/web/dgc/reports
[157] United Nations Statistics Division, 2021. UN Comtrade Database. United Nations, New York, NY. https://comtrade.un.org/data/
[158] Government of India, Ministry of Commerce and Industry, Department of Commerce, EXPORT-IMPORT DATA BANK Version 7.1 – TRADESTAT: https://tradestat.commerce.gov.in/eidb/default.asp

Table 5.13. India imports of HS 13019032 (Olibanum or Frankincense), 2017-18 (Apr-Mar) - 2020-21 (Apr Mar), Value (US$ Millions), Volume (MT), Exporting countries.

Exporter	Value (US$ Million)				Volume (MT)			
	2017-18	2018-19	2019-20	2020-21	2017-18	2018-19	2019-20	2020-21
Ethiopia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oman	0.0	0.0	?	0.0	0.0	0.0	1.35	0.0
Benin	0.03	0.0	0.0	0.0	16.00	0.0	0.0	0.0
Thailand	0.0	?	0.0	0.0	0.0	0.50	0.0	0.0
Nigeria	0.0	0.01	0.0	0.0	0.0	4.18	0.0	0.0
Italy	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.08
Somalia	0.46	0.62	0.19	0.10	52.63	68.70	25.20	10.80
Sudan	0.0	0.08	0.0	0.02	0.0	32.00	0.0	15.00
Chad	0.0	0.0	0.0	0.01	0.0	0.0	0.0	15.00
Cameroon	0.0	0.0	0.01	0.03	0.0	0.0	6.00	16.00
UAE	0.19	0.0	0.0	0.03	19.35	0.0	0.0	33.33
Kenya	0.05	0.0	0.14	0.18	52.00	0.0	140.00	140.00
Egypt	0.0	0.0	0.0	0.90	0.0	0.0	0.0	388.08
TOTAL	0.73	0.71	0.34	1.27	139.98	105.38	172.55	618.29

5.3.2 Saudi Arabia

Table 5.14 shows Saudi Arabia imports of HS 13019060 (Olibanum) and HS 13019070 (Frankincense). For the five-years 2015-2019,[159,160,161,162,163] on average Saudi Arabia imported about 421.6 MT per year, frankincense from both Somalia and Sudan, but olibanum from Sudan only.

Table 5.14. Saudi Arabia imports of HS 13019060 (Olibanum) and HS 13019070 (Frankincense), 2015-2019, Value SAR (Saudi Arabian Riyal), Volume (MT), Exporting Country

Description	Exporter	Value (SAR)					Volume (MT)				
		2015	2016	2017	2018	2019	2015	2016	2017	2018	2019
Frankincense	Sudan	0	0	0	2,000	2,000	0	0	0	175	176
	Somalia	910	1,000	756	1,000	1,000	306	210	290	343	284
Olibanum	Sudan	0	0	0	2,000	2,000	0	0	0	173	151
TOTAL		910	1,000	756	5,000	5,000	306	210	290	691	611

5.3.3 United States of America

Sorting out the origins, trade routes, value-adding points and reexporting points in the global frankincense supply chain can be illuminated by examination of bill of lading data that in the United States can be procured from private data mining firms who obtain the data through Freedom of Information requests for customs data.

In this section there are three tables built for three forms, essential oil, extracts and resinoids, and gum resin, respectively. Due to the large size of the tables, these data are provided in Annex 3. Import trade data for 2020 and 2021 were obtained from two different private companies ImportKey and Zauba for cross referencing and filling in gaps. These data enabled learning the identity of the exporter (for example a European based essential oil distillation company or extraction house) and the US importer. The cargo descriptions can provide details on the species of *Boswellia* or the geographic origin of the starting material as well as shipment weights (gross and net).

159 Kingdom of Saudi Arabia General Authority for Statistics, Foreign Trade Statistics. Import Statistics 2015
160 Kingdom of Saudi Arabia General Authority for Statistics, Foreign Trade Statistics. Import Statistics 2016
161 Kingdom of Saudi Arabia General Authority for Statistics, Foreign Trade Statistics. Import Statistics 2017
162 Kingdom of Saudi Arabia General Authority for Statistics, Foreign Trade Statistics. Import Statistics 2018
163 Kingdom of Saudi Arabia General Authority for Statistics, Foreign Trade Statistics. Import Statistics 2019

By learning the names of the foreign exporter and domestic importer companies, their respective websites, product labels or lists, and quality specification documents, can be examined. These extra steps can help to verify which *Boswellia* species each company is trading in and what frankincense geographic origins are promoted in their marketing materials.

Furthermore, the Annex 3 Table aims to estimate, where possible, the raw material equivalents for value-added ingredients such as essential oils, extracts and resinoids.

In most cases, it was not possible to quantify import volumes at a species-specific level. That is because shipment descriptions often used common names only such as frankincense or olibanum. Furthermore, many shipments included several different items in the same container, without providing separate weights for each.

5.3.3.1 Essential oils

Annex 3 Table shows that essential oils of *B. carteri*, that are imported into the USA, are, for the most part, distilled in European countries, including **Bulgaria** for distillation at Esseterre Bulgaria Ltd. (for dōTERRA USA), **France** for distillation at either Bontoux SAS (for Bontoux, Inc. USA), HELPAC (for NOW Foods), or at H. Reynaud & Fils (for H. Reynaud & Fils USA), **Italy** for distillation at Europiemont, division of Matières Premières Essentielles, **France** (for John D. Walsh Co., Inc.), and **Spain** for distillation at either Aromasur S.L. (for Young Living Essential Oils) or at Vida de Seville Distillery (for Young Living Essential Oils).

Essential oils of *B. frereana* and of *B. papyrifera* were found to be produced at Esseterre Bulgaria Ltd. (for dōTERRA).

Essential oils of *B. sacra*, are, for the most part, distilled in Oman, exported from Salalah, and imported by a freight forwarding service company, namely Omni Logistics, (Salt Lake City, Utah), obscuring the names of the Omani exporting company and the actual company that Omni Logistics is working for. We found one exception, where the name of an Omani company, Wilhelmsen Towell Co., LLC, was listed as the exporter and dōTERRA was listed as the buyer of the shipment.

5.3.3.2 Extracts and resinoids

In most cases, it was not possible to ascertain the species of *Boswellia* used in the manufacture of the extracts and resinoids that are exported to the USA, with the exception of extracts of *B. serrata* from Indian companies. Extracts and resinoids obtained from African *Boswellia* species are processed and exported mainly by European companies, including Firmenich **France** (for Firmenich, Inc. USA), IFF Benicarló, S.L. **Spain** (for John D. Walsh Co., Inc.), Matières Premières Essentielles **France** (for John D. Walsh Co., Inc.), Symrise AG **Germany** (for Symrise, Inc., USA). A large number of shipments from Spain listed only freight forwarding companies, e.g., exporter DHL Freight **Spain** and importer DHL Freight Forwarding **USA**.

5.3.3.3 Oleo-gum resins

US import shipment data showed that many companies in Latin America use a US port for customs clearance before onward re-export. Thus, the evaluated data includes imports by not only USA companies, but also some companies situated in Brazil, Colombia, Guatemala, Mexico, and Trinidad & Tobago. Most shipment descriptions utilized common names frankincense or olibanum making a species-specific analysis not possible, with a few exceptions.

Shipments that specifically listed *B. carteri* included Herb Land A.R.E. **Egypt** (for Whole Herb Co., California), Ismael Imports LLC **Somalia** (for Ismael Import LLC, Vermont), and Rosaroma **Egypt** (for Connplants S.A.S., Colombia).

Shipments that specifically listed *B. papyrifera* came from Habab Shamsa Import and Export **Sudan** (for Green Distribuição, Importação e Exportação Ltda, Brazil). Shipments that specifically listed *B. frereana* came from Ismael Imports LLC **Somalia** (for Ismael Import LLC, Vermont).

Other exporters of *Boswellia* spp. gum resin from origin countries include Africorp International, Ltd **Sudan** (for Casa Abascal S.A., Mexico, and for Mercantil Villacarriedo SA de C.V., Mexico), Alrasheed International for Export Import **Yemen** (for Alsaeedah Grocery & Spices LLC - Samir Abdulmalak), AZ Church Supply, LLC **Djibouti** (for Sinoceras S.A. de C.V., Guatemala), and Neo Botanika **Somaliland** exported various species (for Neo Gr. Ltd.).

European re-exporters of *Boswellia* spp. gum resin include Ernst H. Singelmann GmbH & Co.KG **Germany** (for Max Van Pels, Inc. USA).

5.4 Conclusions

There are significant differences in species volumes, supply chains and in the *Boswellia* final product markets. In China, *Boswellia* oleo-resins are used for incense and as an ingredient in Chinese traditional medicine (*ru xiang*). In Europe and North America, demand is from the fragrance market (for essential oils and aromatherapy), cosmetics, and for boswellic acids. The significance of the flavour and fragrance market is illustrated by the fact that just seven large companies have a combined annual revenue in excess of US$15.5 billion per year. These range from relatively new companies in the USA (such as dōTERRA (established in 2008) and Young Living (established in 1993) that use a larger quantity of *Boswellia* oleo-resins compared to long established European companies established over 126 years ago (such as the Swiss companies Givaudan and Firmenich (both established in 1895). In Europe, large gum and resin import-export traders in Hamburg have historically played a role in the *B. carteri* and *B. sacra* trade. However, there have been significant recent changes in trade routes due to distillation units set up in Bulgaria, Oman, Spain, and the UAE. This appears to be particularly closely associated with the product supply chains of companies based in Utah, United States (dōTERRA and Young Living Essential Oils). For example, exports from the self-declared state of Somaliland to Bulgaria have increased rapidly since 2017, with value-added distillation of frankincense oils in Bulgaria for export to the USA. The major frankincense oleo-resin suppliers in Somaliland include Asli Maydi Exports and Imports Company, Kobac General Trading, and NeoBotanika. The main frankincense oil production appears to be by Esseterre Bulgaria EOOD (Dobrich, Bulgaria), which is owned by an American company dōTERRA (Pleasant Grove, Utah). And there are also important frankincense oil production units in Seville, Spain (e.g: owned by Young Living), the United Kingdom, and France. This change is evident from trade data, showing that Bulgaria has become the largest importer of HS 130190 frankincense from Somalia. In 2019, Bulgaria imported 1,395.37 MT of HS 130190 gums and resins, of which 1,020.48 MT (73.1%) were exported from Somalia and 135 MT (9.7%) from Ethiopia. In 2020, Bulgaria imported 804.06 MT of HS 130190, of which 649.56 MT (80.1%) were from Somalia and 90 MT (11.2%) were exported from Djibouti. This drop is likely related to COVID-19-based disruptions.

Chapter six: Species management in Range States

A.B. Cunningham

6.0 Introduction

In the *Boswellia* case, the policy theory vs. the practice of species management is complex. This is due to wide variation in governance across *Boswellia* Range States and the diversity of factors affecting populations of different *Boswellia* species. In countries such as the United States, a linear approach where a species is listed purely on the basis of scientific data (such as the US Endangered Species Act) is possible and ensuing conflicts between conservation and people (land or water use, species use) are able to be resolved later. For several reasons, *Boswellia* requires a systems approach. Firstly, because while tapping oleo-resins can be damaging to trees if not done correctly, the economic value derived from the frankincense trade also provides an incentive to conserve *Boswellia* trees and their dry forest and woodland habitats. Moreover, these forest and woodland habitats are important for carbon sequestration and a range of non-timber forest products. As *Boswellia* resin are traditionally non-fatally harvested, the forests and woodlands are impacted by much more destructive uses (such as conversion to farmland, unmanaged livestock, lopping for fodder, firewood or charcoal production). Secondly, CITES is a "non-self-executing convention", requiring range States to implement CITES requirements. This is challenging in several *Boswellia* range States. Not only because parts of Ethiopia, Eritrea, Sudan, Somalia and Yemen are affected by conflict and porous borders, but also because Somalia, the second largest frankincense exporter has been sanctioned by CITES for "non-compliance" since 2004 (Notification No. 2019/35). CITES also has imposed trade suspensions on Djibouti (since 2004, Notification No. 2011/010, Notification No. 2018/015). The port of Djibouti handles 95% of Ethiopia's maritime trade)[1], including exports of frankincense from *Boswellia papyrifera*. If CITES Appendix II listings trigger "trade suspensions" for Somalia and Djibouti, this would result in *de facto* bans on legal exports from the two biggest frankincense exporting countries (Ethiopia and Somalia). This in turn could stimulate vulnerable communities to find other, more destructive uses for the Boswellia populations and the dry forests and woodlands where they occur. Thirdly, objective, systems-based approaches are crucial. Over-simplification and mischaracterization of the challenges facing species or group of species is widespread, misinforming policy processes to the detriment of species conservation and for people along supply chains (Challender et. al., 2022[2]). *Boswellia* and the frankincense trade are no exception.

6.1 The critical need for an impartial evaluation of the frankincense trade

For reasons given above, it is critical for the CITES Secretariat to have an independent evaluation of the frankincense trade and the multiple factors (both "trade" and "non-trade") affecting different traded *Boswellia* populations in different contexts. An impartial, unbiased evaluation can inform local, national and international policy responses to the frankincense trade. The need for an impartial assessment was made to CITES (2021)[3], at the time they were deciding on the contract for this report, with NeoBotanika requesting for good reasons that "*If a decision was made to carry out a comprehensive and comparative multi-disciplinary, non-partisan and unbiased study in order to fill the information gaps, it would need to be given ample time to achieve its objectives".* An impartial assessment has been extremely challenging in the *Boswellia* case. Long before the invention of social media such as Facebook, a former Secretary-General of CITES recognised the pressure that different interest groups ("*from private conservation groups and from economic*

[1] https://issafrica.org/iss-today/djibouti-looks-to-ethiopia-to-gauge-its-economic-future

[2] Challender, D.W., Brockington, D., Hinsley, A., Hoffmann, M., Kolby, J.E., Massé, F., Natusch, D.J., Oldfield, T.E., Outhwaite, W., 't Sas-Rolfes, M. and Milner-Gulland, E.J., 2022. Mischaracterizing wildlife trade and its impacts may mislead policy processes. *Conservation Letters*, *15*(1), p.e12832.

[3] CITES. 2021. Addendum to Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Online, 2-4, 21 and 23 June 2021. https://cites.org/sites/default/files/eng/com/pc/25/Documents/E-PC25-25-Add.pdf

lobby groups ranging from the luxury fur and leather industries to pet dealers, safari parks and biomedical research establishments") place on CITES policy processes (Sands, 1979)[4]. "*Plant blindness*"[5] often keeps lobby groups and Facebook "influencers" focused on trade in animals, rather than plants, with the exceptions of the illegal timber trade and orchids (Margulies et al., 2019)[6]. The frankincense trade is another exception to "plant blindness". A real risk is that mischaracterization of the *Boswellia* situation by lobbyists, commercial companies and vested interest groups misinforms policy processes to the detriment of *Boswellia* species, their dry forest and woodland habitats and people's livelihoods. Being in trade does not equate to risk of extinction from trade. This chapter therefore starts by placing commercially traded *Boswellia* species in an bio-geographic and ecological context (Section 6.2). It then deals with several important questions before discussing species management or the ability to implement international trade regulations, with a particular focus on the Horn of Africa[7]. These questions are: (1) what factors have had negative (or positive) effects on populations of different commercially traded *Boswellia* species? (Section 6.3); (2) what role can plantations or enrichment planting play to supplement frankincense supplies from wild stocks? (Section 6.4) and then (3) where, and under what conditions does *Boswellia* species management occur to sustain wild populations? (Section 6.5).

6.2 Meeting remarkable trees: *Boswellia* and the Burseraceae

The *Burseraceae* are a remarkable, terpenoid rich tree family. Often forming dominant (or even mono-dominant) components of tropical forests and woodlands. In the neotropics, for example, *Bursera*, *Protium* and occasionally some *Dacroydes* species are the dominant forest trees (Daly et al., 2012[8]; Gámez et al., 2014[9]; Vieira et al., 2010[10]). In Africa, the Arabian peninsula and Asia, *Boswellia* species can also be a dominant component of seasonally dry forests and woodlands (Figures 6.1), including along maritime escarpments in otherwise arid systems (that get moisture from the seasonal monsoon) (Figures 6.1 C).

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[4] Sand, P.H., 1979. Combating the trade in endangered species through CITES. *Unasylva (FAO)*.

[5] first described by Wandersee and Schussler (1999 as "*the misguided anthropocentric ranking of plants as inferior to animals*" (cited in Margulies et al., 2019)

[6] Margulies, J.D., Bullough, L.A., Hinsley, A., Ingram, D.J., Cowell, C., Goettsch, B., Klitgård, B.B., Lavorgna, A., Sinovas, P. and Phelps, J., 2019. Illegal wildlife trade and the persistence of "plant blindness". *Plants, People, Planet*, *1*(3), pp.173-182.

[7] **Note:** The Horn of Africa region approximates to the region covered by the Intergovernmental Authority for Development (IGAD), with the Member States of Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan and Uganda (www.igad.int). The focus of this report is on frankincense exporting countries within the Horn of Africa, with additional attention to *B. serrata* and *B. ovalifoliolata* in India.

[8] Daly, D.C., Neill, D. and Martínez-Habibe, M.C., 2012. An ecologically significant new species of *Dacryodes* from the northern Andes. Studies in neotropical Burseraceae XV. *Brittonia*, *64*(1): 49-56.

[9] Gámez, N., Escalante, T., Espinosa, D., Eguiarte, L.E. and Morrone, J.J., 2014. Temporal dynamics of areas of endemism under climate change: a case study of Mexican Bursera (Burseraceae). *Journal of Biogeography*, *41*(5): 871-881.

[10] Vieira, F.D.A., Appolinário, V., Fajardo, C.G. and Carvalho, D.D., 2010. Reproductive biology of Protium spruceanum (Burseraceae), a dominant dioecious tree in vegetation corridors in Southeastern Brazil. *Brazilian Journal of Botany 33*: 711-715.

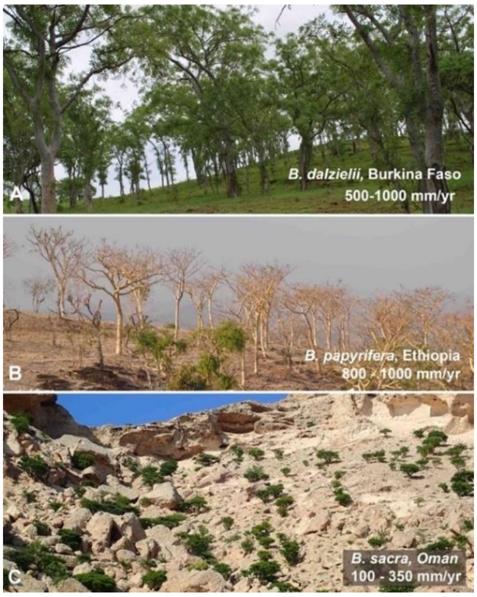

Figure 6.1. Across a range of ecological conditions, *Boswellia* can be the dominant tree species**. A.** A mono-dominant stand of *B. dalzielii* in Burkina Faso (>60 adult trees/ha). **B.** *B. papyrifera*, which has a huge geographic range and can occurs at densities >200 trees/ha and **C.** *B. sacra* can dominate limestone slopes in Dhofar, Oman. Photos: A. Ouédraogo (A), B-E van Wyk (B) and A.B. Cunningham (C).

Even the newly described species *B. occulta*, which has a very restricted distribution (an AOO of <500km^2), is a locally common, dominant tree species where it occurs along west-facing limestone hillslopes (Thulin, 2020)[11]. The same applies at the centre of *Boswellia* diversity and endemism on Socotra, where *Boswellia* species such as *B. ameero* are locally common dominant on Socotra (Yemen). For narrowly distributed species, however, high density within a tiny range poses a risk for species that are accessible, palatable to livestock and in the case of *B. occulta*, are tapped and commercially traded for frankincense.

For geographically widespread species, the conservation risk is reduced. In comparison to the neotropical genus *Bursera*, which have a limited distribution (with geographic ranges <50 000km^2) (Becerra et al., 2009)[12] , most of the African and Asian *Boswellia* species that are tapped for frankincense have massive geographic ranges. Particularly *Boswellia serrata* (Figure 6.2A), *B. papyrifera* (Figure 6.3A), *B. dalzielii* (Figure 6.4A), *B. sacra* (Figure 6.5A) and *B. neglecta* (Figure 6.8A). *B. serrata* is the most widely distributed of all *Boswellia* species (Figure 6.2; Thulin, 2020), followed by *B. papyrifera*, which is distributed from Ethiopia to Nigeria (with an EOO of c. 1.2 million km^2. With 1.7 million ha of woodlands where *B. papyrifera* is a dominant species in just three administrative regions of Ethiopia (MAPROW, 2019)[13] and a total of 2.9 million ha of *B. papyrifera* woodlands in Ethiopia (Eshete et al., 2005)[14]. What is urgently needed, and is currently in progress (Bongers, F., pers. comm., 2022) is the use of GBIF data to assess the Extent of Occurrence (EOO) and Area of Occupancy (AOO) for all commercially traded *Boswellia* species. This follows the methods that calculated EOO's and AOO's for fish species using the GBIF database (Smith et al., 2020)[15].

In addition to distribution over large geographic areas, the biomass per hectare and densities of these widely distributed *Boswellia* species can be high. In the Shivpuri division, Madhya Pradesh, India, *Boswellia serrata* forms the largest portion (7.943 tonnes/ha) of the total biomass in dry forest (of 34.72 ± 0.41 tonnes/ha) (Figure 6.2; Bung et al., 2021[16]). Occurring across 16 States in

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[11] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.
[12] Becerra, J.X., Noge, K. and Venable, D.L., 2009. Macroevolutionary chemical escalation in an ancient plant–herbivore arms race. *Proceedings of the National Academy of Sciences 106*(43): 18062-18066.
[13] MAPROW. 2019. Species Data Fact Sheet: Medicinal and Aromatic Plant Resources of the World. Cited in CITES (2020). Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Geneva (Switzerland), 17 and 20-23 July 2020
[14] Eshete, A., Teketay, D. and Hulten, H., 2005. The socio-economic importance and status of populations of *Boswellia papyrifera* (Del.) Hochst. in northern Ethiopia: The case of North Gonder Zone. *Forests, trees and livelihoods*, *15*(1): 55-74.
[15] Smith, J.A., Benson, A.L., Chen, Y., Yamada, S.A. and Mims, M.C., 2020. The power, potential, and pitfalls of open access biodiversity data in range size assessments: Lessons from the fishes. *Ecological Indicators*, *110*, p.105896.
[16] Bung, S., Rajmohan, S., Bhutia, S., Pandey, H. and Mitra, M., 2021. Estimation of Biomass and Carbon Sequestration by Non-Destructive Method in Dry Deciduous Forest of Shivpuri, Madhya Pradesh, India. In *IOP Conference Series: Earth and Environmental Science* (Vol. 943, No. 1, p. 012020). IOP Publishing.

India, there are an estimated 15-20 million *B. serrata* trees and the species is not considered a conservation priority (Dubey, 2021)[17].

B. papyrifera also occurs at high densities (Figure 6.3) in the three (of 10) Range States that have been studied. In Sudan, for example, Abtew et. al., (2011)[18] recorded *B. papyrifera* densities of 81 ± 79 trees/ha and 52 ± 50 trees/ha in Kajinat reserved forest and Tajmala unreserved forest, while in the Jebel Marra, Sudan, for example, Khamis (2001)[19] recorded 114 trees/ha. In Ethiopia and Eritrea, *B. papyrifera* densities could be even higher, with 80-270 trees ha-1 in Eritrea (Ogbazghi et al. 2006)[20] and 64-225 trees/ha in Ethiopia (Lemenih et al, 2007)[21]. And in Burkina Faso, West Africa, the density of adult *B. dalzielii* trees was 82.37 ± 6.57 trees/ha in intact woodlands, 62.00 ± 3.98 trees/ha in fallow systems and 30.02 ± 1.63 trees/ha in farmland (Prospère et al., 2021; Figure 6.4)[22]. These densities make the Burseraceae important in terms of ecological values, carbon sequestration and as a commercial source of aromatic resins.

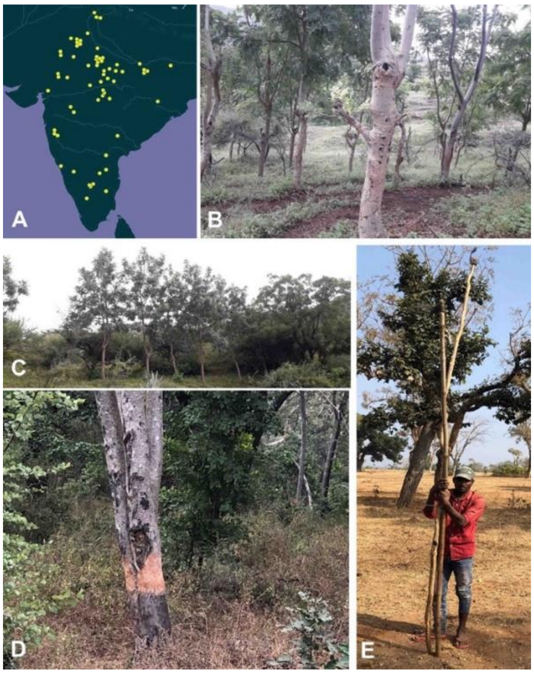

Figure 6.2. ***Boswellia serrata***. **A.** Geographic distribution, redrawn to combine data from GBIF (2021a)[23] and Rajpoot et al (2020)[24], showing the vast Extent of Occurrence (EOO) across India. **B**. Recruitment of young and medium sized *B. serrata* (Madyha Pradesh, India). **C.** Planted *B. serrata* along a roadside. **D.** Tapped tree showing tapping impacts in vegetation where fire can be a factor. **E.** *B. serrata* tapper in a heavily grazed, low fire risk, but low seedling recruitment landscape (Madyha Pradesh, India). Showing the different type of tapping tool used in comparison to the Horn of Africa, or Yemen and Oman: a hand-forged curved blade that can be fitted to the long handle to tap large (up to 15m tall) *B. serrata* trees. Photos: P. Flowerman.

With their wide geographic range, wide habitat specificity and large population sizes of commercially traded *Boswellia* species, such as *B. serrata* and *B. papyrifera*, it is not surprising that a potential CITES Appendix II listing of these *Boswellia* species is controversial. Nevertheless, it is crucial to understand that factors have negative (or positive) effects on populations of different commercially traded *Boswellia* species. This is covered in the following section (Section 6.3).

[17] Estimate given in a questionnaire prepared during a sustainability assessment for PLT Sustainability. Cited with permission from P. Flowerman (pers. comm., 2022)

[18] Abtew, A., Pretzsch, J., Mohamoud, T. & Adam, Y., 2011. *Population structure, density and natural regeneration of Boswellia papyrifera (Del.) Hochst in Dry woodlands of Nuba Mountains, South Kordofan State, Sudan.* Bonn, DITSL GmbH, p. 245.

[19] Khamis, M. A. 2001. Management of *Boswellia papyrifera* stands for resin production in Jebel Marra Area, Western Sudan. present situation and future prospects. MSc thesis, Technische Universität Dresden. Germany

[20] Ogbazghi W, Bongers F, Rijkere T, Wessel M (2006) Population structure and morphology of the frankincense tree *Boswellia papyrifera* along an altitude gradient in Eritrea. Journal of the Drylands 1(1): 85-94.

[21] Lemeneh M, Feleke S, and Tadesse W (2007) Constraints to small-holder production of frankincense in Metema district, North-western Ethiopia. Journal of Arid Environments (71) 393–403

[22] Prospère, S.A.B.O., Ouédraogo, A., Gbemavo, D.C., Salako, K.V. and KAKA, R.G., 2021. Land use impacts on Boswellia dalzielii Hutch. an African frankincense tree in Burkina Faso. *BOIS & FORETS DES TROPIQUES*, *349*, pp.53-65.

[23] *Boswellia serrata* Roxb. ex Colebr. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org. accessed 10 February 2022.

[24] Rajpoot, R., Adhikari, D., Verma, S., Saikia, P., Kumar, A., Grant, K.R., Dayanandan, A., Kumar, A., Khare, P.K. and Khan, M.L., 2020. Climate models predict a divergent future for the medicinal tree Boswellia serrata Roxb. in India. *Global Ecology and Conservation*, *23*, p.e01040.

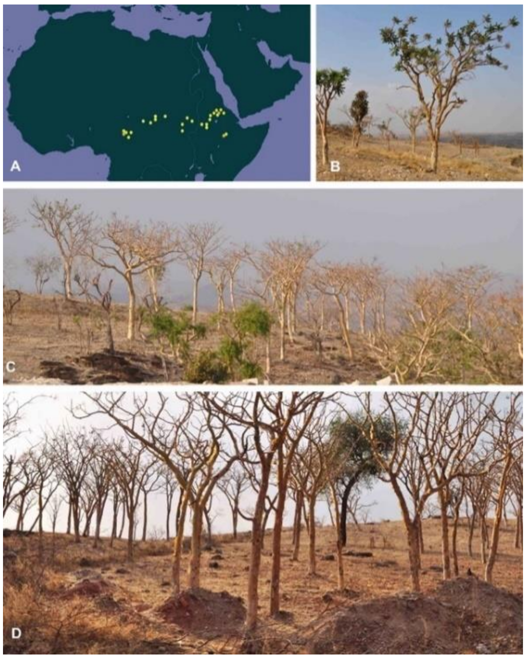

Figure 6.3. ***Boswellia papyrifera.*** **A.** Geographic distribution, redrawn from GBIF (2021b)[25] and Thulin (2020), showing the vast Extent of Occurrence (EOO) across Africa. **B.** Trees before leaves are shed. **C.** Trees on a hilltop on the Humera to Gondar road, Ethiopia, showing monodominance and deciduous habit. **D.** Clearing under *B. papyrifera* and poor recruitment. Photos: B-E van Wyk.

Figure 6.4. ***Boswellia dalzielii.*** **A.** Geographic distribution, combining data from GBIF (2021c)[26] and Thulin (2020), showing the large Extent of Occurrence (EOO) of the only West African *Boswellia* species. **B.** *Boswellia dalzielii* detail showing pale trunk bark on a rocky slope (where fire frequencies are presumably lower). **C.** Monodominant stand of *Boswellia dalzielii* on a sacred hill. **D.** *Boswellia dalzielii* bark for sale in a market in Burkina Faso. Photos: S. Johnson.

[25] *Boswellia papyrifera* (Delile) Hochst. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-02-09.

[26] *Boswellia dalzielii* Hutch. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-02-09

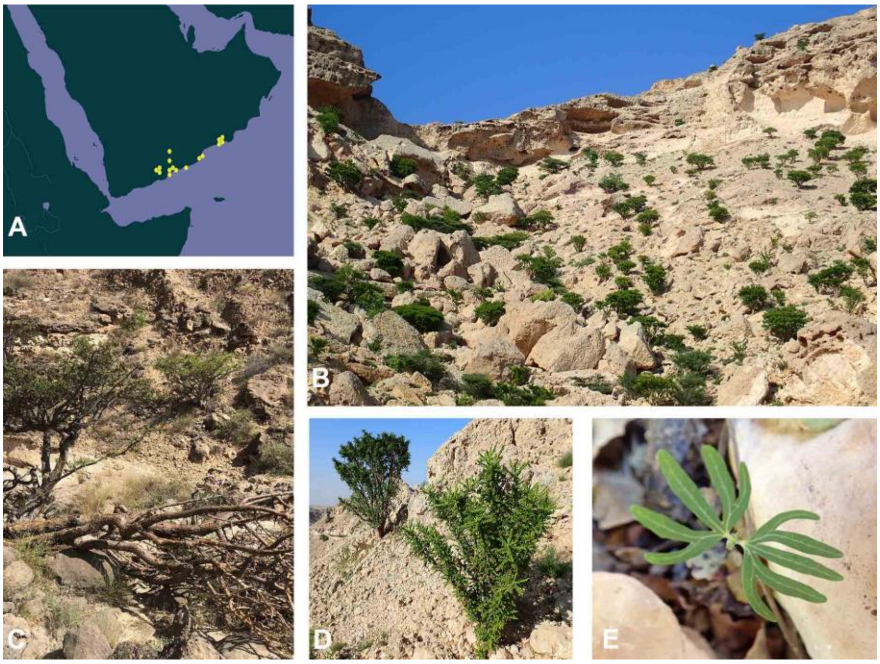

Figure 6.5. ***Boswellia sacra.*** **A.** Geographic distribution, combining data from GBIF (2021d)[27] and Thulin (2020) showing geographic distribution in southern Oman and western Yemen. **B.** *B. sacra* as the dominant tree on a maritime escarpment in Dhofar, southern Oman, where the seasonal monsoon brings moisture. **C.** Dead *B. sacra* pushed down by an episodic flood along a wadi in Dhofar. **D.** Healthy *B. sacra* in an area inaccessible to camels. **E.** *B. sacra* seedling. Photos: A.B. Cunningham.

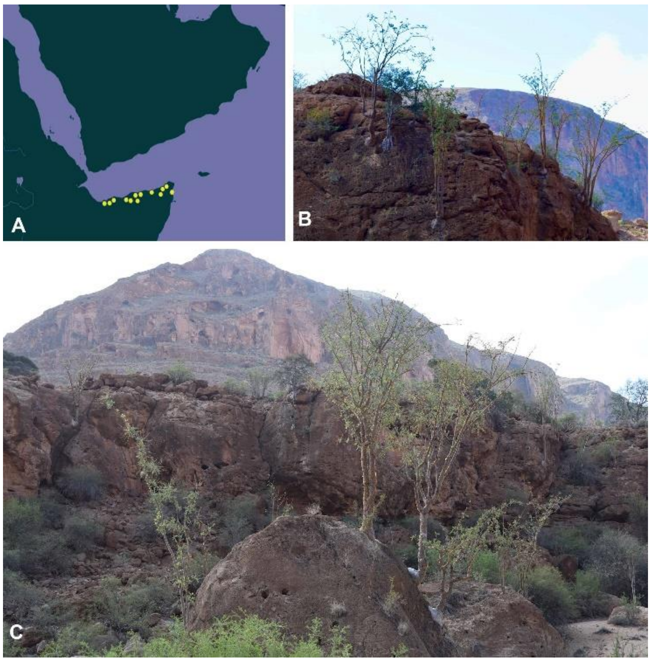

Figure 6.6. ***Boswellia frereana,*** **a species endemic to northern Somalia that split from *B. sacra* in the early Pliocene (c. 5 million years ago). A.** Geographic distribution, combining data from GBIF (2021f)[28] and Thulin (2020). **B.** *B. frereana*, on a rock away from browsing livestock, showing the characteristic "hold-fast" bases to the trunks. **C.** Typical *B. frereana* habitat: rocky gullies, limestone rocks and cliff faces. Photos: S. Johnson (B, C).

[27] *Boswellia sacra* Flück. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-02-09.
[28] *Boswellia frereana* Birdw. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-02-10.

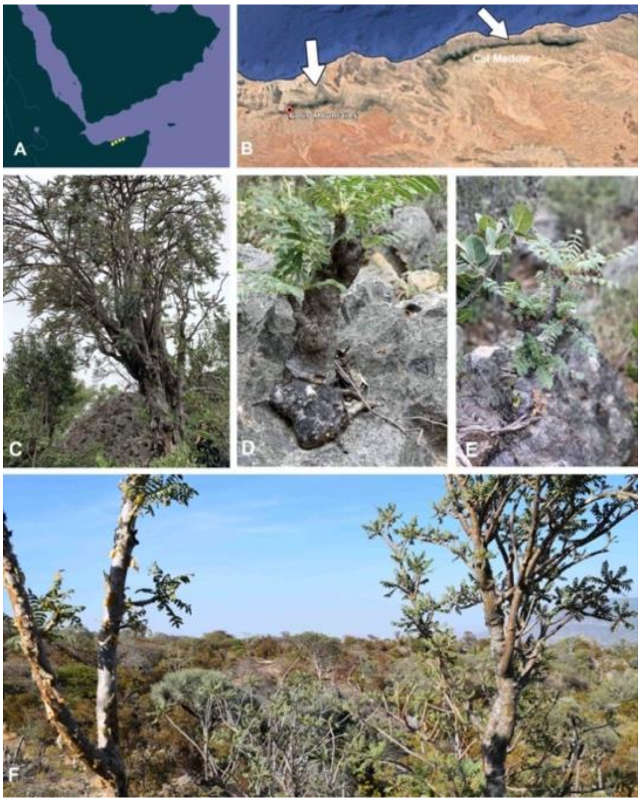

Figure 6.7. ***Boswellia carteri.*** **A.** Geographic distribution, combining data from GBIF (2021e)[29] and the distribution data for what is currently considered *B. sacra* in Somalia[30]. **B.** Google Earth image showing the location of two important maritime escarpments (the Golis mountains and the Cal Madow mountains) where *B. carteri* is commercially tapped. **C.** A fine, tall *B. carteri* in the East Golis mountains. **D & E.** Short *B. carteri* growing on limestone rock in the Golis mountains. **F.** *B. carteri* in the Cal Madow mountains, a biodiversity rich forest area with forested plateaus and upper slopes, with its highest point at Mount Shimbiris, (2460 m asl). Photos: Z. Ousman (C, D & E) and S. Johnson (F).

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[29] *Boswellia carteri* Birdw. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-02-09.
[30] *Boswellia sacra* Flück. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-02-10.

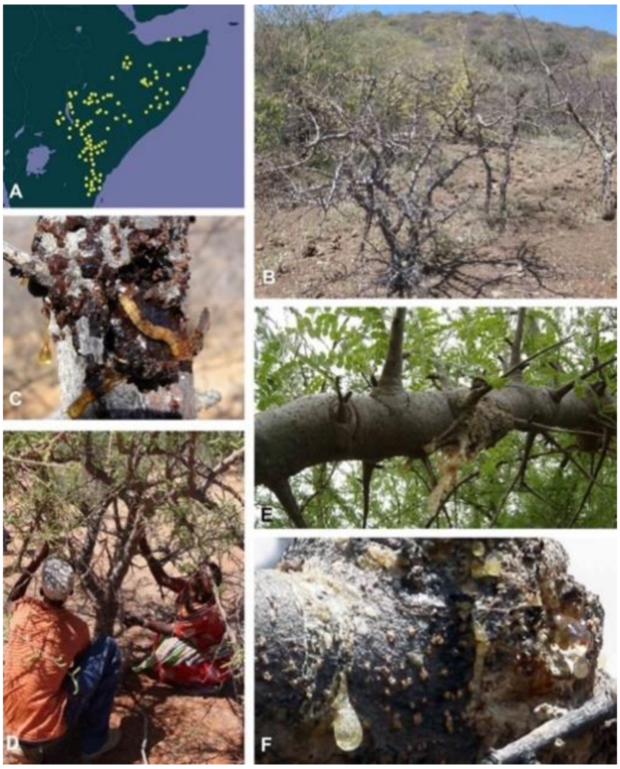

Figure 6.8. ***Boswellia neglecta,* whose oleo-resin is sustainably harvested by pastoralists in north-eastern Kenya, south-eastern Ethiopia and Somalia. A.** Geographic distribution, combining data from GBIF (2021g)[31] and Thulin (2020), showing the huge EOO of this species. **B.** *B. neglecta* is relatively fast growing (mean annual radial growth, 2.5mm, with an average age of trees 22 years, Mokria et al., 2017)[32]. **C.** Oleo-resin exudation is stimulated by beetle larvae (Buprestidae and Cerambycidae), which do not appear to have long-term detrimental effect on the trees (Sommerlatte & van Wyk, 2022)[33]. **D.** Hand-picking naturally exuded black *B. neglecta* oleo-resin. **E.** Naturally exuded oleo-resin. **F.** White oleo-resin on *B. neglecta*. Photos: H. Sommerlatte.

6.3 What factors (both "trade" and "non-trade" negatively (or positively)) affect populations of *Boswellia* species tapped for frankincense across their geographic range?

In this review, it is necessary to consider what Bongers et al (2019)[34] termed "cryptic" impacts as well as the more obvious impacts on different *Boswellia* species populations. Many of the impacts on *Boswellia* populations (such as conversion of woodlands to farmland, fire, lopping of *Boswellia* trees for fodder and impacts of unmanaged livestock (goats, camels, cattle, sheep) are not directly related to the frankincense trade (Figure 6.9). The future of frankincense depends, however, on all of the factors in Figure 6.9 being addressed[35], including climate change. Which clearly is an issue of global concern that has to be tackled at a global scale. In the case of *Boswellia*, the effects of climate change have been modelled for *Boswellia serrata* (Rajpoot et. al., 2020[36]). For *B. neglecta*, rainfall is the primary factor influencing growth (Mokria et al., 2017)[37]. There is concern for arid zone *Boswellia* species as well (e.g: Attore et al., 2007[38]). The East African–Asian monsoon, for example, is one of the world's main weather systems and is critical to *Boswellia* populations along the maritime escarpments of northern Somalia and the "fog oases" of Dhofar (Oman) and the Hawf region (Yemen). In addition to climate change, there are multiple drivers impacting *Boswellia*

[31] *Boswellia neglecta* S.Moore in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-03-10.
[32] Mokria, M., Tolera, M., Sterck, F.J., Gebrekirstos, A., Bongers, F., Decuyper, M. and Sass-Klaassen, U., 2017. The frankincense tree *Boswellia neglecta* reveals high potential for restoration of woodlands in the Horn of Africa. *Forest Ecology and Management*, *385*: 16-24.
[33] Sommerlatte, H. and Wyk, B.E.V., 2022. Observations on the Association between Some Buprestid and Cerambycid Beetles and Black Frankincense Resin Inducement. *Diversity*, *14*(1).
[34] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.
[35] as pointed out by Germany at the on-line meeting of Twenty-fifth meeting of the Plants Committee 2-4, 21 and 23 June 2021.
[36] Rajpoot, R., Adhikari, D., Verma, S., Saikia, P., Kumar, A., Grant, K.R., Dayanandan, A., Kumar, A., Khare, P.K. and Khan, M.L., 2020. Climate models predict a divergent future for the medicinal tree Boswellia serrata Roxb. in India. *Global Ecology and Conservation*, *23*, p.e01040.
[37] Mokria, M., Tolera, M., Sterck, F.J., Gebrekirstos, A., Bongers, F., Decuyper, M. and Sass-Klaassen, U., 2017. The frankincense tree *Boswellia neglecta* reveals high potential for restoration of woodlands in the Horn of Africa. *Forest Ecology and Management*, *385*: 16-24.
[38] Attorre, F., Francesconi, F., Taleb, N., Scholte, P., Saed, A., Alfo, M. and Bruno, F., 2007. Will dragonblood survive the next period of climate change? Current and future potential distribution of *Dracaena cinnabari* (Socotra, Yemen). *Biological conservation*, *138*(3-4), pp.430-439.

populations (both "non-trade" and "trade") that need to be dealt with, ideally through development and implementation of appropriate management plans by range States. In many cases, local community involvement is essential for management plan implementation. Focusing solely on the frankincense trade will not solve the problem.

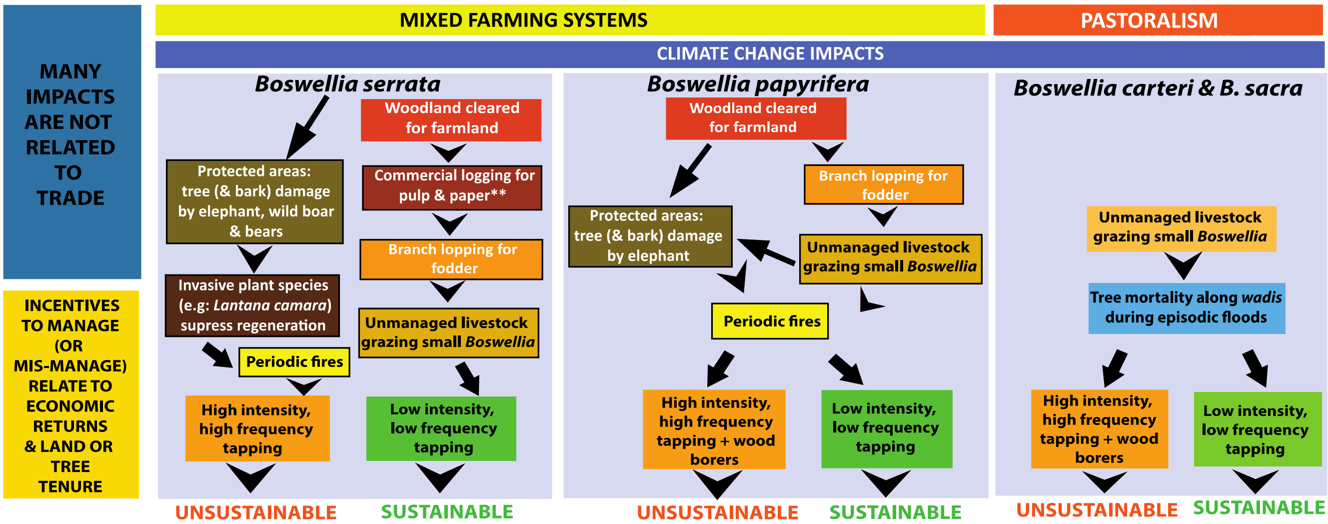

Figure 6.9. A systems approach is essential, as both the obvious impacts (such as conversion of dry forests and woodlands to farmland) and "cryptic" effects of *Boswellia* populations vary with bio-climatic conditions and land-uses as well as according to social, cultural and economic factors. The climate change and the impacts of unmanaged livestock on *Boswellia* populations apply across all land-use types. Even elephant impacts on Burseraceae occur in protected areas in both Africa and Asia. In contrast, large scale commercial logging applied only to the largest species (*B. serrata*) in Madyha Pradesh, c.20 000 tonnes of *B. serrata* was felled annually for over 40 years to supply a major pulp and paper mill.

A de facto ban on trade from Somalia and Ethiopia would also undermine proposed changes to the frankincense supply chain (Bongers et al., 2019)[39], further reducing the incentive to maintain the frankincense resource (Gelaye, 2012)[40].

6.3.1 Dry forest and woodland conversion to farmland.

Dry forest and woodland loss, a factor of major concern in higher rainfall *Boswellia* Range States with mixed farming systems, can be clearly detected through remote sensing. Several studies in Ethiopia record the extensive conversion of *Boswellia* woodlands to other land uses. In Metema area of Ethiopia, for example, even if the conservative official land allocation of 2 ha per household was taken into account then at least 37,172 ha of woodland in the district was lost to farmland in just 4 years (Lemenih & Kassa (2011b)[41]. In the same area, over a 30-35 year period, almost 303,180 ha of woodland was cleared for farmland and in Tigray Regional State of Ethiopia, over 177,000 ha of *B. papyrifera* woodland was converted to farmland over a 20 year period (Gebrehiwot, 2003). The main drivers of this land conversion are firstly, that it is allowed (often encouraged by government) and secondly, that farmers anticipate higher financial returns from crop production than from frankincense and gum-resins tapped in intact woodlands. However, Dejene et al (2013)[42] compared financial returns for two crop production options (sesame and cotton) and woodland use, in an area of northern Ethiopia (Metema district) well known for frankincense production. While net income was highest for sesame, it was lowest for cotton

[39] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.
[40] Gelaye, M.T., 2012. Restoration and sustainable management of frankincense forests in Ethiopia: a bio-economic analysis.
[41] Lemenih, M. & Kassa, H. eds., 2011b. *Management guide for sustainable production of frankincense.* Bogor: CIFOR.
[42] Dejene, T., Lemenih, M. and Bongers, F., 2013. Manage or convert *Boswellia* woodlands? Can frankincense production payoff?. *Journal of arid environments*, *89*: 77-83.

production. Income from frankincense was intermediate, but more consistent. Expectations of consistently higher returns from crop production were incorrect.

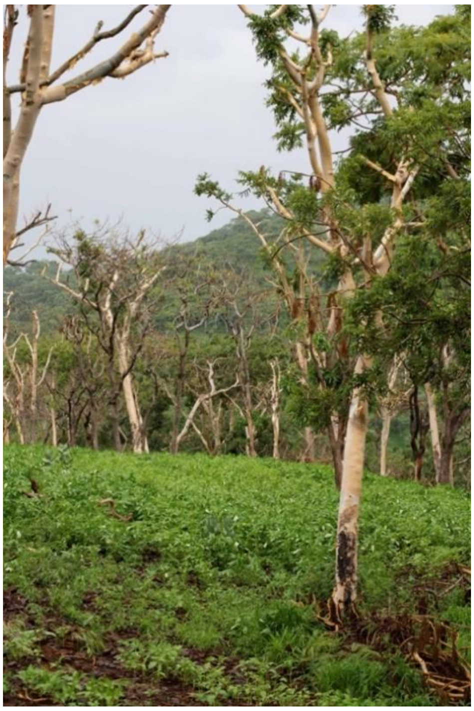

Figure 6.10. Sesame production in Metema, Ethiopia, with some *B. papyrifera* remaining in the field that formerly was intact woodland. This major driver of dry forest and woodland loss in arable areas. Although Dejene et al (2017) showed that forest based revenues are lower from sesame, income from frankincense was more reliable in the long-term (and higher than from cotton). Yet conversion of these dry forests and woodlands continues. Photo: P. Groenendijk.

In comparison to loss of dry forests and woodlands due to farming, changes to *Boswellia* populations that happen "under the canopy" are less obvious. For this reason, Bongers et al (2019)[43], in their synthesis paper of studies of 23 *B. papyrifera* populations in three (of 9-10) Range States over a 25-year period focused on "cryptic changes" within *Boswellia* woodlands. Herbivory of *Boswellia* seedlings and saplings, for example is a widespread "non-trade" concern for all *Boswellia* species, with poor recruitment of *Boswellia* saplings in areas grazed by livestock. Added to this is the "trade" related consequence of herbivory by wood-boring beetle attack of several *Boswellia* species. This occurs when the wood is exposed by high frequency, over-intensive tapping by untrained or careless tappers who do not follow traditional tapping methods.

Although the Köppen climate classification maps are basic, they are useful in illustrating *Boswellia* species distributions in relation to land-use potential. In warm desert systems (BWh) pastoralism is the main form of land-use, with unmanaged livestock found to be the most significant threat to survival and recruitment of *Boswellia* trees. For example on Socotra (Yemen) (Miller and Morris, 2004[44]) and in Oman (Figure 6.11C). Land-use options are fewer in these arid landscapes, with pastoralism and frankincense harvesting the historically important sources of income. Only 3% of the total land area of Yemen, for example, is suitable for agriculture, particularly along the course of ephemeral rivers (*wadis*) on the coastal plain or on agricultural terraces on inland hill slopes (CEOBS, 2021)[45]. In contrast, *B. dalzielii* and *B. papyrifera* in Africa (Figure 6.11B) and *Boswellia serrata* woodlands in India (Figure 6.12) occur in higher rainfall, seasonally dry areas with mixed farming (agro-pastoral) systems. Consequently, there are more diverse "non-trade" threats to *Boswellia* populations in higher rainfall systems.

[43] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.
[44] Miller, A.G. and Morris, M., 2004. *Ethnoflora of the Soqotra Archipelago*. Royal Botanic Garden Edinburgh.
[45] CEOBS. 2021. Report: Protected area conservation in Yemen's conflict. https://ceobs.org/protected-area-conservation-in-yemens-conflict/

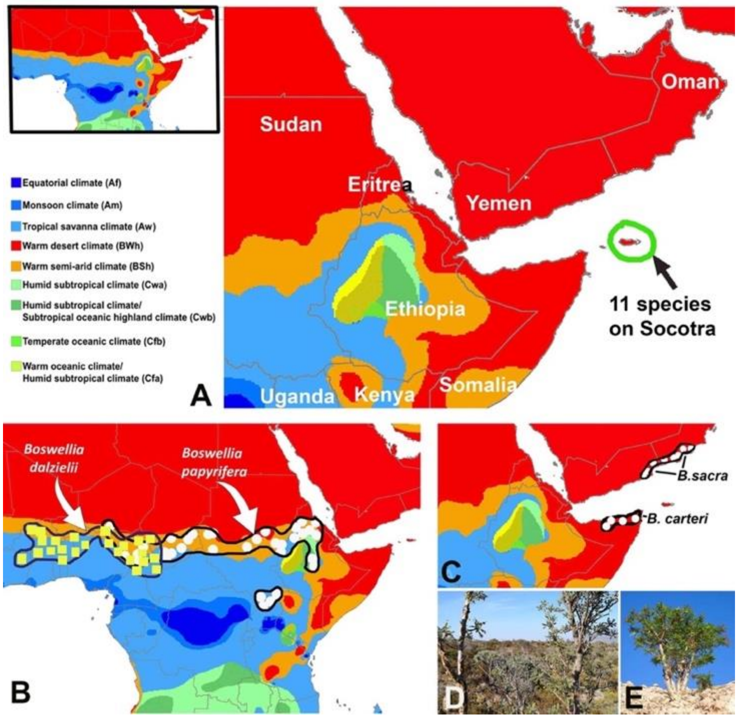

Figure 6.11. A. The Köppen climate map showing important *Boswellia* Range States in the Horn of Africa and Arabian peninsula, showing the Socotra archipelago (Yemen), the global centre of *Boswellia* diversity for *Boswellia*. **B.** The distribution of *B. papyrifera* and *B. dalzielii*, showing the occurrence of these two species in warm semi-arid areas and into warm tropical savanna. **C.** Both *Boswellia carteri* (northern Somalia) and *B. sacra* (Oman, Yemen) occur in hotter, drier landscapes than *B. dalzielii* or *B. papyrifera*, where their occurrence is due to moisture brought in by seasonal monsoons. Photo credits: S. Johnson (B) and A.B. Cunningham (C).

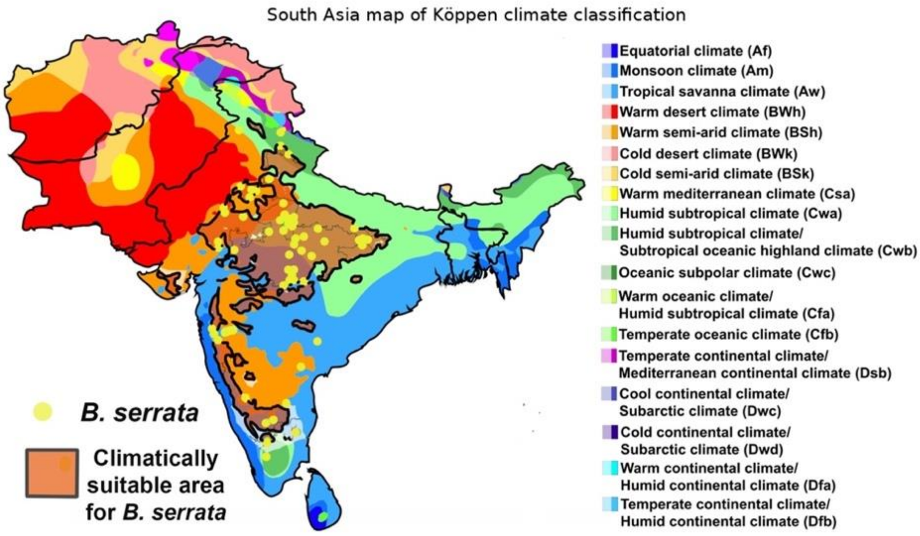

Figure 6.12. The distribution of *B. serrata* across India (and the climatically suitable area, which takes climate change into account, based on Rajpoot et. al., (2020)[46]) against the background of the Köppen climate map.

6.3.2 Unmanaged livestock and branch lopping for fodder.

As mentioned above; unmanaged livestock management is a major threat to accessible *Boswellia* populations. Grazing animals, particularly goats and camels consume *Boswellia* leaves and bark and can inflict considerable damage on adult trees and kill seedlings and immature trees. *Boswellia* leaves and bark are palatable. While *Boswellia* species can resprout vigorously after browsing, this cannot be sustained indefinitely. This big threat to recruitment of all *Boswellia* species by unmanaged livestock (goats, camels and in some cases, cattle), becomes the primary threat in arid and semi-arid landscapes when limited fodder is available. Grazing as one of the primary causes of the blocked regeneration is seen in many *B. papyrifera* populations (Bongers et al. 2019; Table 6.2). This "non-trade" impact applies to many species of *Boswellia* (e.g. *B. papyrifera, B. dalzielii, B. sacra*, etc.) with unmanaged goat grazing being of great concern for 11 restricted range *Boswellia*

[46] Rajpoot, R., Adhikari, D., Verma, S., Saikia, P., Kumar, A., Grant, K.R., Dayanandan, A., Kumar, A., Khare, P.K. and Khan, M.L., 2020. Climate models predict a divergent future for the medicinal tree *Boswellia serrata* Roxb. in India. *Global Ecology and Conservation*, *23*, p.e01040.

species on Socotra (Yemen), the global centre for *Boswellia* diversity (*B. "hesperia"* sp. prov. and *B. samahaensis* and *B. scopulorum* (rare and all Critically Endangered), *Boswellia ameero, B. asplenifolia*, *B. bullata* and *B. elongata* (all Endangered) and *B. dioscoridis, B. nana, B. popoviana* and *B. socotrana* (all Vulnerable) (Miller and Morris, 2004)[47]. In Oman, grazing and bark browsing by camels is an issue of concern in some parts of Dhofar (Figure 6.13; Farah, 2008[48]). Where camel owners say that the main reason that camels eat *B. sacra* bark is to ease the sores in their mouths that develop from eating dry camel fodder that is widely sold in Oman today (S. Al-Hatmi pers. comm., 2021). This is a good explanation, given the well-known anti-inflammatory and analgesic properties of *Boswellia* (see Su et al., 2012[49] and al-Harrasi et. al., 2019[50]). Livestock management is needed within all *Boswellia* range States, due to changes in grazing dynamics and increased livestock numbers (Scholte et. al., 2011[51]; Bongers et al., 2019). However, even on a single archipelago (Socotra), different conservation strategies are needed for different *Boswellia* species (Attore et. al., 2011)[52].

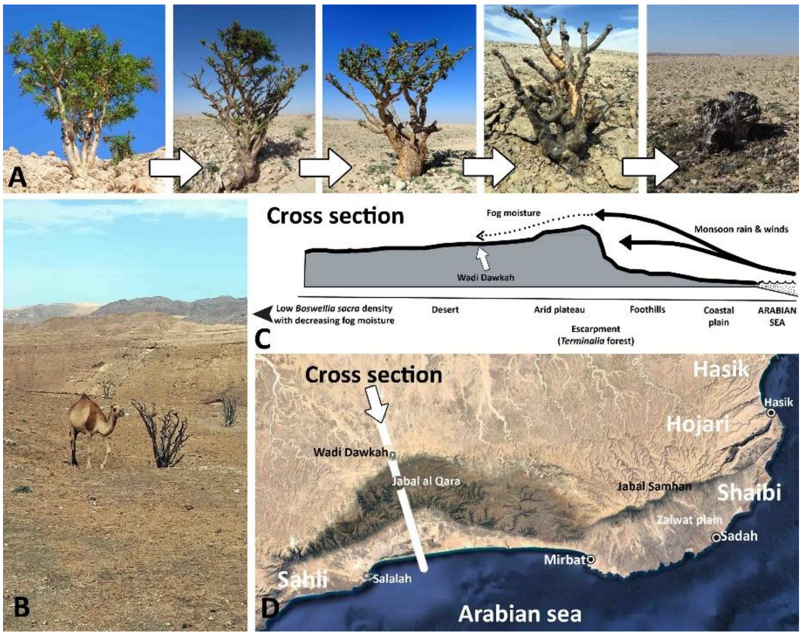

Figure 6.13. While CITES is focused on negative effects of trade on species populations, the biggest concern for many *Boswellia* species is poor livestock management. In Oman, *Boswellia sacra* populations in several areas are healthy, with good recruitment and no camel browsing or tapping. But in the landscape type north-west of the Jabal al Qara (C, D), at the margins of monsoon driven fog moisture, excessive browsing by camels is a major issue (A, B)[53]. Photo credits: A.B. Cunningham (A, (i)-(iii); Abdullah al Najar (A (iv, v) & B); D. Google Earth, with additions.

On the positive side, while livestock management is decoupled from international trade (in the sense that the frankincense trade is not a driver of poor livestock management practices), there are cases where trade can help mitigate livestock damage or incentivize improved livestock management. In Somalia for instance, livestock are often partially or fully excluded from harvesting areas, and cutting of branches for livestock is prohibited. Although harvesting sites right near human settlements experience some grazing, especially during times of drought, the economic value of the frankincense resin means that the majority of trees and seedlings are shielded from intensive grazing.

Lopping branches for fodder to feed livestock is recorded for *B. papyrifera* (Gelaye, 2012), *B. sacra*

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[47] Miller, A.G. and Morris, M., 2004. *Ethnoflora of the Soqotra Archipelago*. Royal Botanic Garden Edinburgh.
[48] Farah, M., 2008. Non-Timber Forest Product (NTFP) Extraction In Arid Environments: Land-Use Change, Frankincense Production And The Sustainability Of Boswellia Sacra In Dhofar (Oman), s.l.: University of Arizona.
[49] Su, S., Hua, Y., Wang, Y., Gu, W., Zhou, W., Duan, J.A., Jiang, H., Chen, T. and Tang, Y., 2012. Evaluation of the anti-inflammatory and analgesic properties of individual and combined extracts from *Commiphora myrrha*, and *Boswellia carterii. Journal of ethnopharmacology*, *139*(2), pp.649-656.
[50] Al-Harrasi, A., Csuk, R., Khan, A. and Hussain, J., 2019. Distribution of the anti-inflammatory and anti-depressant compounds: Incensole and incensole acetate in genus Boswellia. *Phytochemistry*, *161*, pp.28-40.
[51] Scholte, P., Al-Okaishi, A. and Suleyman, A.S., 2011. When conservation precedes development: a case study of the opening up of the Socotra archipelago, Yemen. *Oryx*, *45*(3): 401-410.
[52] Attorre, F., Taleb, N., De Sanctis, M., Farcomeni, A., Guillet, A. and Vitale, M., 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.
[53] Figure 6.1 from Cunningham, A.B, Brinckmann, J and al Hatmi, S. in prep. Scents and sensibility: a review of *Boswellia sacra* Flueck. resin harvest and trade.

(Miller and Morris, 1988)[54] and *B. serrata* (Figure 6.14). However, research on the impacts of lopping for fodder was neglected until Gelaye (2012) carried out his study and showed that the effect of lopping of trees for fodder was much worse than tapping, as this not only decreased frankincense resin yields, but also reduced flowering and fruiting of *B. papyrifera* (Gelaye, 2012)[55]. The combination of intensive lopping, plus high frequency, high intensity tapping in Tigray, Ethiopia, where demobilised soldiers were supplied with tapping tools (but no training) (Figure 6.15 C-F) is of real concern. As is the recent case of the supply of metal tools by a private company in Kenya to women who traditionally collected naturally exuded gums and resins[56]. Yet, as Muys (2019)[57] points out, the significant role of lopping *Boswellia* for fodder was overlooked by Bongers et al., (2019)[58].

Figure 6.14. *Boswellia serrata* in Madyha Pradesh, India. **A.** A lopped and tapped tree. **B.** *B. serrata* tapper, showing the heavily grazed landscape in the background. Photos: P. Flowerman.

[54] Miller, A.G. and Morris, M., 1988. *Plants of Dhofar, the southern region of Oman: traditional, economic, and medicinal uses*. Prepared and published by the Office of the Adviser for Conservation of the Environment, Diwan of Royal Court, Sultanate of Oman.

[55] Gelaye, M.T., 2012. Restoration and sustainable management of frankincense forests in Ethiopia: a bio-economic analysis. PhD thesis, Katholieke Universiteit Leuven, Belgium.

[56] See: https://www.youtube.com/watch?v=c27vvudaMGM

[57] Muys, B., 2019. Frankincense facing extinction. Nature Sustainability, 2(8), 665-666

[58] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.

Figure 6.15. The well intended supply of tapping tools can lead to disastrous outcomes for *Boswellia* trees. A. & B. Metal tools supplied to women from pastoralist communities in Kenya who formerly collected natural exudates by hand. **C.** Lopped, chopped and intensively tapped *B. papyrifera* in an the area of Tigray, Ethiopia harvested by a cooperative of former soldiers, who did not receive the same training or support. **D, E & F.** *B. papyrifera* in this area showed a much higher intensity tapping as well as damaging practices such as cutting all the way to the wood of the trees. Photos: Screenshots from: https://www.youtube.com/watch?v=c27vvudaMGM **(A, B) and S. Johnson (C-F).**

6.3.3 Commercial logging

In terms of past exploitation, the focus of commercial logging in the genus *Boswellia* has been on *B. serrata,* due to the large size of this species (up to 15 m high) and its suitability for pulp for papermaking (Mahesh et al., 2015)[59]. Commercial logging of *B. serrata* supplied India's first Indian owned newspaper factory. Started as a private enterprise in 1947, the mill was taken over by the State Government of Madhya Pradesh in 1949 and by the Government of India in 1959. *B. serrata* trees were logged to supply 60-65% of the mechanical pulp used to make newspaper, with 35-40% from bamboo and other chemical pulp (Figure 6.16; Dorset, 1970[60]). Situated adjacent to a forest reserve in Nepanagar, Madyha Pradesh, the mill had a capacity of processing 30,000 tonnes of pulp/year in 1956, with expansions in 1967, 1978 and 1989 to increase this capacity to 88,000 tonnes of pulp/year. Due to electrical supply issues and an "*acute shortage of forest based raw material*" around Nepanagar (Shah, 2021)[61]as well as the over-exploitation issue being re-iterated by Vaishnav et al (2019)[62]; Nepa mill changed to making pulp from recycled paper in 1996. However, without the de-inking plant needed for processing waste paper, the company ran into financial problems.

[59] Mahesh, S., Kumar, P. and Ansari, S.A., 2015. A rapid and economical method for the maceration of wood fibers in *Boswellia serrata* Roxb. *Tropical Plant Research*, *2*(2), pp.108-111.

[60] Dorset, T.H. 1970. Raw materials for pulp and paper in tropical countries. Pulp, Paper, and Board; Quarterly Industry Report, 41:11-15.

[61] Shah, A. 2021. Nepa mills: waiting to live life again! Can the government revive the Nepa Mills and the old vibrant city and expedite its Rehabilitation process on fast track. 25 January 2021. http://samanvaya.org.in/nepa-mills-waiting-to-live-life-again-can-the-government-revive-the-nepa-mills-and-the-old-vibrant-city-and-expedite-its-rehabilitation-process-on-fast-track/

[62] Vaishnav, V., Mahesh, S. and Kumar, P., 2019. Assessment of genetic structure of the endangered forest species *Boswellia serrata* population in Central India. *Journal of Tropical Forest Science*, *31*(2): 200-210.

Figure 6.16. An historical photograph of the Nepa mill, showing the bamboo that supplied part of the pulp for making newspaper, with *Boswellia serrata* supply 60-65% of the mechanical pulp at the time (Dorset, 1970).

There are three reasons to raise this case here. Firstly, understanding the impact of commercial logging on *B. serrata* populations is a gap in previous studies (e.g: Brendler et al., 2018). Yet it is possible than 40 years of processing c.20 000 tonnes of *B. serrata* logs per year would have a local impact on *B. serrata* populations that is detectable in the logged area today. Secondly, on the positive side, there are interesting links to Ethiopia during the early history of trying to deal with wood shortages through plantation production of *B. serrata* in India, where "*all attempts to regenerate stands of this species so far failed"* (Khan, 1972) [63], leading Indian forests to follow the method used to propagate *B. papyrifera* in Ethiopia. Thirdly, because the mill received a financial package (Rs. 4.69 billion Indian rupees) from the Government of India in 2018 "to ensure development in the tribal area" (Prasad, 2018)[64].

6.3.4 Bark damage to *Boswellia*: from incense to elephants.

There is huge variation in bark damage to commercially traded *Boswellia* trees from global to local scales (Figures 6.17 and 5.18 and Section 6.3.4.1). In West Africa, for example, the main source of bark damage is local trade in *B. dalzielii* bark for sale in local market-places for medicinal purposes. In Cameroon, for example, 86% of trees observed were affected by bark harvest (Betti, 2020)[65], raising concerns that need to be managed if oleo-resin tapping of *B. dalzielii* populations for new export markets increases. Furthermore, protected area status does not mean that *Boswellia* species are safe within conservation areas. One threat in conservation areas is the impact of unmanaged invasive species (such as *Lantana camara*) (Soumya et al., 2019a)[66]. Another threat is debarking of *Boswellia* trees by wild herbivores, particularly during droughts. In Gir Lion Sanctuary and National Park (Gujarat, India), for example, debarking of *B. serrata* trees by sambar deer killed 2.8% of the *B. serrata* population during a drought (Khan et al., 1994)[67]. The impacts of high elephant populations on both *Boswellia* and *Commiphora* are well documented in both Africa and Asia. In the Mudumalai Wildlife Sanctuary (Nilgiri Hills, India), for example, elephants have eliminated *Boswellia serrata*, with the exception of remnant *B. serrata* populations on inaccessible

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[63] Khan, M.A.W. 1972. Propagation of *Boswellia papyrifera* through branch-cuttings. *Indian Forester* 98(7): 437–440

[64] Prasad, R.S. 2018. Govt approves Rs 4.69-bn package to revive NEPA Mills' closed MP unit. https://www.business-standard.com/article/current-affairs/govt-approves-rs-4-69-bn-package-to-revive-nepa-mills-closed-mp-unit-118100300937_1.html

[65] Betti, J-L. 2020. Etat des lieux sur la biologie, l'exploitation et le commerce des especes du genre Boswellia (Burseraceae) au Cameroun. Addendum to CITES (2020). Boswellia trees (*Boswellia* spp.) Twenty-fifth meeting of the Plants Committee Geneva (Switzerland), 17 and 20-23 July 2020.

[66] Soumya, K.V., Shackleton, C.M. and Setty, S.R., 2019a. Impacts of gum-resin harvest and Lantana camara invasion on the population structure and dynamics of *Boswellia serrata* in the Western Ghats, India. *Forest Ecology and Management*, *453*, 117618.

[67] Khan, J.A., Rodgers, W.A., Johnsingh, A.J.T. and Mathur, P.K., 1994. Tree and shrub mortality and debarking by sambar *Cervus unicolor* (Kerr) in Gir after a drought in Gujarat, India. *Biological Conservation*, *68*(2): 149-154.

hilly areas (Sivaganesan & Sathyanarayana 1995[68], cited in Manakadan et al., 2010[69]). In Tamil Nadu, elephants are debarking *B. serrata* (Soumya et al., 2019b)[70] in three protected areas in the western Ghats, India (Figure 6.15A).

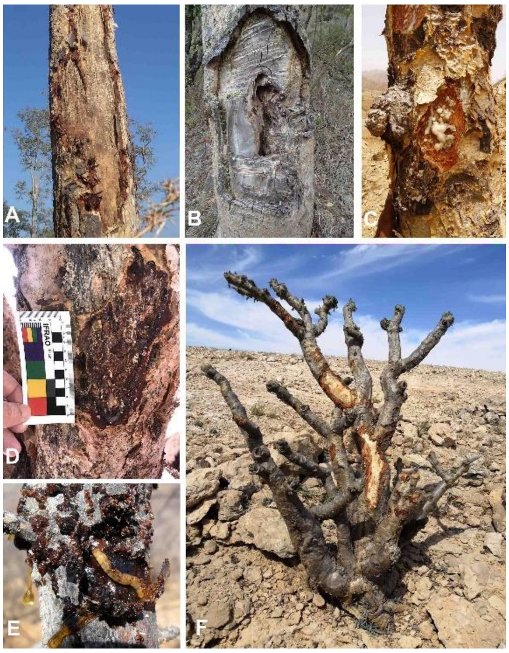

Figure 6.17. Diversity of damage to *Boswellia* bark. A. Elephant damage to *B. serrata* in a conservation area in the western Ghats. **B.** Damage from chopping the trunk to access honey from a stingless bee nest (*B. serrata*). **C.** High intensity tapping of *B. papyrifera* (Ethiopia). **D.** Bark recovery from damage by stones during an episodic flood down a wadi (*B. sacra*). **E**. A wood-boring beetle larva that induces naturally exuded resin from *B. neglecta* without long-term effects (Kenya). **F.** Bark damage and intensive browsing of *B. sacra* (Oman). Photos: K. V. Soumya (A, B); F. Bongers (C); A.B. Cunningham (D); H. Sommerlatte (E) and A. al Najar (F).

This is not an unusual or unexpected outcome for populations of non-toxic tree species in protected areas with significant elephant numbers (Wilkinson et. al., 2022)[71]. In fact, *Boswellia papyrifera* is called the “elephant tree” because of its use by elephants (Langenheim, 2003)[72]. Elephants are well known to be attracted to Volatile Olfactory Compounds (VOC’s) from both *Boswellia* and *Commiphora* species (Figure 6.18), often targeting terpenoid rich Burseraceae to the point that populations of *Boswellia* and *Commiphora* can be wiped out. Examples of this occurring across Africa are summarised in O’Connor et al (2007)[73] of cases where high elephant numbers have resulted in the disappearance or decimation of *Burseraceae*.

[68] Sivaganesan, N. & Sathyanarayana, M.C. (1995) Tree mortality caused by elephants in Mudumalai Wildlife Sanctuary, Tamil Nadu, south India. In: A Week with Elephants. Daniel, J.C. & Datye, H. (eds.) Bombay Nat. Hist. Society. pp 314-330.

[69] Manakadan, R., Swaminathan, S., Daniel, J.C. and Desai, A.A., 2010. A Case History of Colonization in the Asian Elephant: Koundinya Wildlife Sanctuary (Andhra Pradesh, India). *Gajah*, *33*(01): 17-25.

[70] Soumya, K.V., M Shackleton, C. and R Setty, S., 2019b. Harvesting and Local Knowledge of a Cultural Non-Timber Forest Product (NTFP): Gum-Resin from *Boswellia serrata* Roxb. in Three Protected Areas of the Western Ghats, India. *Forests*, *10*(10), p.907.

[71] Wilkinson, D.M., Midgley, J.J & Cunningham, A.B. 2022. Constraints, crashes and conservation: were historical African savanna elephants *Loxodonta africana* densities relatively high or lower than those seen in protected areas today?, Plant Ecology & Diversity, DOI: 10.1080/17550874.2022.2078244

[72] Langenheim, J.H., 2003. *Plant resins: chemistry, evolution, ecology, and ethnobotany* (No. 620.1924 L275p). Oregon, US: Timber Press.

[73] O’Connor, T.G., Goodman, P.S. and Clegg, B., 2007. A functional hypothesis of the threat of local extirpation of woody plant species by elephant in Africa. *Biological Conservation*, *136*(3): 329-345.

Figure 6.18. An elephant breaking branches from an endemic *Commiphora* in Namibia. Although the Burseraceae have developed chemical defences against herbivory, both *Boswellia* and *Commiphora* trees are targeted by elephant to the point that local populations of Burseraceae can be wiped out within protected areas. Photo: A.B. Cunningham.

In Tsavo East National Park, Kenya, for example, populations of *Boswellia neglecta* disappeared from monitored plots, with populations of *Commiphora* species also severely impacted (Laws, 1970[74]; Leuthold, 1977[75]; van Wijngaarden, 1985[76]). The same occurred in Ruaha National Park, Tanzania (on *Commiphora ugongensis* populations) (Barnes, 1983[77]; 1985[78]) and more recently, in the Tuli Game Reserve, Botswana where formerly common *Commiphora* species (*Commiphora merkerii, C. mollis, C. glandulosa and C. tenuipetiolata*) were all wiped out by elephant within the conservation area.

6.3.4.1 Diversity across sites: tapping and oleo-resin collection methods

In March 2021, a key question was posed at the GFA international workshop on "The Future of Frankincense": "*Where, and under what circumstances, is there successful, sustainable harvest occurring*?" (Annex 4). Under the right circumstances, sustainable commercial harvests certainly are possible. Just as there is regional variation in tapping techniques for other Burseraceae (such as *Canarium strictum*)[79], so frankincense collection and tapping techniques also vary, from hand picking of naturally exuded oleo-resins from *B. neglecta* in Kenya to skilled use of purpose-made tapping tools (Figure 6.19).

[74] Laws, R.M., 1970. Elephants as agents of habitat and landscape change in East Africa. Oikos 21: 1–15

[75] Leuthold, W., 1977. Changes in tree populations of Tsavo East National Park, Kenya. East African Wildlife Journal 15: 61–69.

[76] Van Wijngaarden, W., 1985. Elephants–trees–grass–grazers. Relationships between climate, soils, vegetation and large herbivores in a semi-arid savanna ecosystem (Tsavo, Kenya). ITC Publication Number 4. Ph.D. thesis, Wageningen University, Wageningen.

[77] Barnes, R.F.W., 1983b. The elephant problem in Ruaha National Park, Tanzania. Biological Conservation 26: 127–148.

[78] Barnes, R.F.W., 1985. Woodland changes in Ruaha National Park (Tanzania) between 1976 and 1982. African Journal of Ecology 23: 214–221.

[79] Varghese, A. and Ticktin, T., 2008. Regional variation in non-timber forest product harvest strategies, trade, and ecological impacts: the case of black dammar (*Canarium strictum* roxb.) use and conservation in the Nilgiri Biosphere Reserve, India. *Ecology and Society*, *13*(2).

Figure 6.19. Diversity of resin collection and tapping tools and techniques. A. A Samburu woman hand-picking naturally exudated resin from *B. neglecta* (north-eastern Kenya). **B.** Two types of single bladed *mengaaf* used for tapping *B. sacra* in Oman. **C.** Prizing off oleo-resin exuded around elephant damage (*B. serrata*). **D.** One of many types of tapping tools used in Somalia. **E.** A long handled tapping tool with a curved, hand-forged blade used in Madyha Pradesh (*B. serrata*). Photos: H. Sommerlatte (A); A. B Cunningham (B); K.V. Soumya (C); U. Feiter (D) and P. Flowerman (E).

Oleo-resin harvests from African and Asian *Burseraceae* could be divided into five categories, from highly sustainable to completely unsustainable. In conservancies in northern Kenya and north-west Namibia, for example, Samburu and Himba women respectively harvest oleo-resins without the use of metal tapping tools (widely known both Arabic and Somali as *mingaaf*). Instead, Himba women harvest *Commiphora wildii* oleo-resins that are naturally exuded (Figure 6.19A). With *C. wildii* resource inventories and management planning done prior to entering a commercial market[80]. This is a sustainable trade, with no need for CITES involvement. In northern Kenya, Samburu women harvest both *Commiphora confusa* and *Boswellia neglecta* (Figure 6.8D, 6.19A) oleo-resins by hand, where exudates have been stimulated by wood-boring beetles (Sommerlatte and van Wyk, 2022)[81]. *Boswellia rivae* and *B. neglecta* are collected similarly in Ethiopia and Somalia primarily by pastoral Somali and Oromo families. As the trees are not tapped, and indeed do not necessarily respond to tapping, international trade in the resin is not a major threat factor, and trade can be considered sustainable. Although growing international demand for *B. rivae* oils by small and large companies in the USA and Europe may change this situation.

The commercially traded untapped *Boswellia* resins, (such a *B. neglecta* and *B. rivae*) represent niche markets. The major internationally-trade species such as *B. papyrifera*, *B. carteri*, *B. sacra*, *B. frereana*, and *B. serrata*—are actively tapped by harvesters making incisions into the trees' bark. Tapping has taken place for thousands of years, and there are sophisticated bodies of traditional knowledge around many of these species that provide the basis for sustainable tapping and management. Sustainable resin harvest is often seasonal, with mild to moderate intensity tapping, in areas with strong land tenure (either tapping or oversight by land owners). By contrast, unsustainable, destructive harvest is often characterized by high intensity and frequency of exploitation, weakened land tenure, and resin being a primary source of income for harvesters.

[80] Galloway, F.B., Wynberg, R.P. and Nott, K., 2016. Commercialising a perfume plant, *Commiphora wildii*: livelihood implications for indigenous Himba in north-west Namibia. *International Forestry Review*, *18*(4), pp.429-443.
[81] Sommerlatte, H. and Wyk, B.E.V., 2022. Observations on the Association between Some Buprestid and Cerambycid Beetles and Black Frankincense Resin Inducement. *Diversity*, *14*(1), p.58.

6.3.5 Compounding effects: invasive species, fire and bark damage.

Bongers et al (2019) discuss the impact of fire on *Boswellia* species in seasonally high rainfall areas. Fire is rarely an issue for arid zone *Boswellia* species, however. Invasive species, such as *Parthenium hyterophorus* may affect both higher rainfall and more arid *Boswellia* Range States (e.g: Al Ruheili et al., 2022[82]). While *Chromolaena odorata* and *Lantana camara* are limited to *Boswellia* areas with seasonally high rainfall (Figure 6.20). The influence of an invasive species on *Boswellia* population biology has been best studied in India (Soumya et al., 2019a)[83], where in addition to invading forest and fallow areas, *L. camara*, for example, has invaded most Indian pasture lands (13.2 million ha) (Negi et al., 2019[84]; Figure 6.20A).

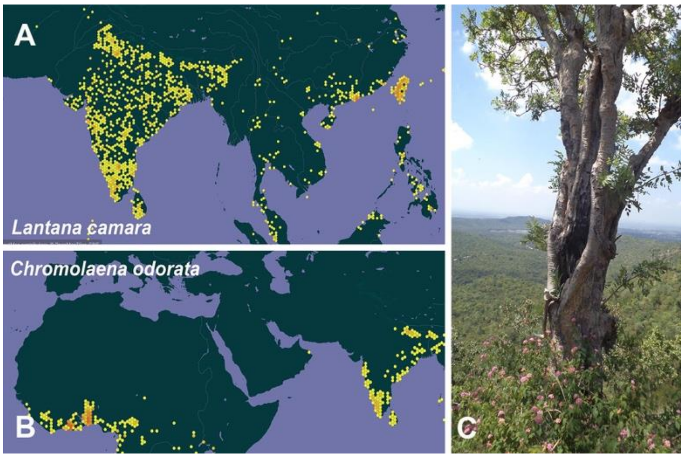

Figure 6.20. In addition to allelopathic effects on the soil that can suppress seedling germination, invasive species alter the fire ecology of *Boswellia* woodlands and dry forests in seasonally high rainfall areas. A. *L. camara* has invaded forests and fallow areas across South Asia. Including 13.2 million hectares of grazing areas. **B.** *Chromolaeana odorata* is a widespread invasive species that changes woodland fire ecology in West Africa and South Asia, but its effects on *Boswellia* populations are unknown. C. A *Boswellia serrata* tree surrounded by *L. camara* in a conservation area in the western Ghats. Photo: K V Soumya (C); Maps modified from GBIF: *L. camara*[85] and *C. odorata*[86].

Soumya et. al., (2019a) point out that in general, the effects of *L. camara* invasion in the areas they studied in the western Ghats was generally worse than frankincense tapping. Dense *L. camara* thickets can keep frankincense collectors away from *B. serrata* trees. Higher *L. camara* cover was linked to declining densities of *B. serrata* saplings and, to some extent, adult trees. What deserves further study, however, both within and outside conservation areas in Africa and South Asia are the cumulative effects of bark damage (by herbivores and people, Section 5.3.4) and fire, which is compounded by invasive species (in what Negi et al., 2019 call the "a fire-*Lantana* cycle"). In seasonally dry woodland in southern Africa, for example, bark damage by porcupines to *Burkea africana* compounded the effects of fire in *Burkea-Terminalia* woodland (Yeaton, 1988[87]). Consequently, *B. africana* represented 57% of all trees felled by fire. Resulting in successional change. Some *B. serrata* populations may face a similar risk in protected areas where bark damage due to wild herbivores is coupled to changing fire ecology due to invasive species. The same may apply to *B. ovalifoliolata*, an endemic species restricted to dry deciduous forest in Andra Pradesh, India. *B. ovalifoliolata* oleo-resins are collected for medicinal purposes (Thulin, 2020)[88]. With geospatial modelling in Andra Pradesh showing that the area worst affected by forest fire (>75% of

[82] Al Ruheili, A.M., Al Sariri, T. and Al Subhi, A.M., 2022. Predicting the potential habitat distribution of parthenium weed (*Parthenium hysterophorus*) globally and in Oman under projected climate change. *Journal of the Saudi Society of Agricultural Sciences*.
[83] Soumya, K.V., Shackleton, C.M. and Setty, S.R., 2019a. Impacts of gum-resin harvest and Lantana camara invasion on the population structure and dynamics of *Boswellia serrata* in the Western Ghats, India. *Forest Ecology and Management*, *453*, p.117618.
[84] Negi, G., Sharma, S., Vishvakarma, S.C., Samant, S.S., Maikhuri, R.K., Prasad, R.C. and Palni, L., 2019. Ecology and use of *Lantana camara* in India. *The Botanical Review*, *85*(2): 109-130.
[85] *Lantana camara* L. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-04-09.
[86] *Chromolaena odorata* (L.) R.King & H.Rob. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-05-15.
[87] Yeaton, R.I., 1988. Porcupines, fires and the dynamics of the tree layer of the Burkea africana savanna. *The Journal of Ecology*, pp.1017-1029
[88] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.

the total burnt area) was dry deciduous forest, where *B. ovalifoliolata* co-occurs with the CITES App. I listed species, red sanders (*Pterocarpus santalinus*) (Manaswini et al., 2015)[89].

6.4 What about *Boswellia* plantations?

Why, with a documented horticultural history going back almost 5000 years, are there no large-scale *Boswellia* plantations? Most famously, over 3500 years ago (in 1495 BC) Queen Hatshepsut sent an expedition sent out by to "the land of Punt" that brought back living incense trees (*Boswellia* and/or *Commiphora*) to transplant in Egypt (Hepper, 1967)[90]. With an even earlier expedition in 2800 BC sent to Punt by King Sahure and King Isesi (Groom 1981)[91].

One of the outcomes of CITES legislation at a global scale has been to stimulate horticultural production to replace wild collected plants with "*cheap, high quality, uniform and disease-free plants while taking the pressure off wild populations*" (Sajeva et al. 2007)[92]. Recognising this, the Parties have taken the decision to exempt some specific species from CITES controls. Examples are the CITES exemptions for several cultivars of cacti, Euphorbia and orchid hybrids (*Cymbidium, Dendrobium, Phalaenopsis* and *Vanda*) that are packed to specific standards. Developing separate supply chains based on cultivated medicinal plant species has been supported in previous assessments of medicinal plants Africa (e.g: *Prunus africana*[93] and *Siphonochilus aethiopicus* (both CITES App. II)[94]) and Asia (e.g: *Rhodiola rosea* (and other *Rhodiola* species))[95, 96] and *Paris polyphylla* (Cunningham et al., 2018)[97]). Is this possible through *Boswellia* planting at a large scale?

The short answer is that propagation is technically possible, whether from seed or vegetatively from cuttings (DeCarlo, 2021[98]). Even though the viability of the tiny *Boswellia* seeds is low. In *Boswellia serrata*, for example, seed germination rates are poor (10–20%), so production from branch cuttings is preferred (Vaishnav and Janghel, 2018)[99]. With local community support, enrichment planting using cuttings from local genetic stock would be possible, if young plants are protected from livestock. But "scaling-out" plantations to a significant enough scale to provide commercially viable quantities of frankincense is hugely challenging in arid and semi-arid range States. There are potential conflicts over water, land and even cultural perspectives on ownership of the cuttings taken from clan land, particularly under increasingly frequent drought conditions.

In the wet tropics, many genera and species of *Burseraceae* are traditionally cultivated for the products (such as fruits) they provide to local people. *Dacroydes edulis* is a common feature of agroforestry systems in West and Central Africa (Leakey et al., 2002)[100], as are many *Canarium*

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[89] Manaswini, G. and Sudhakar Reddy, C., 2015. Geospatial monitoring and prioritization of forest fire incidences in Andhra Pradesh, India. *Environmental monitoring and assessment*, *187*(10): 1-12.

[90] Hepper, F.N. 1967. An ancient expedition to transplant living trees. Exotic gardening by an Egyptian queen. J. Roy. Hort. Soc. 92: 435–438.

[91] Groom, N. 1981. Frankincense and myrrh. A study of the Arabian incense trade. Longman, London and New York.

[92] Sajeva, M., Carimi, F. and McGough, N., 2007. The convention on international trade in endangered species of wild fauna and flora (CITES) and its role in conservation of cacti and other succulent plants. *Functional Ecosystems and Communities*, *1*(2): 80-85.

[93] Cunningham, A B. 2005. CITES Significant Trade Review of *Prunus africana*. CITES Management Authority, Geneva, Switzerland.

[94] when South Africa is proposing the inclusion of *S. aethiopicus* on Appendix II in accordance with Article II 2 (a) of the Convention and based on criteria A and B in Annex 2 a of Resolution Conf. 9.24 (Rev. CoP16).

[95] Brinckmann, J.A., Cunningham, A. B., & Harter, D.E.V. 2021. Running out of time to smell the roseroots: reviewing threats and trade in wild *Rhodiola rosea* L. Journal of Ethnopharmacology 269: 113710 https://doi.org/10.1016/j.jep.2020.113710

[96] Cunningham, A. B., H. Li, P. Luo, W.J. Zhao, X. C. Long and J.A. Brinckmann. 2020. There "ain't no mountain high enough"?: the drivers, diversity and sustainability of China's *Rhodiola* trade. Journal of Ethnopharmacology 252, p.112379. https://doi.org/10.1016/j.jep.2019.112379

[97] Cunningham, A.B., J. Brinckmann, Y-F. Bi, S-J. PEI, U. Schippmann AND P. Luo. 2018. *Paris* in the spring: a review of trade, conservation and opportunities in the shift from wild harvest to cultivation of *Paris polyphylla* (Trilliaceae). *Journal of Ethnopharmacology* 222: 208-216.

[98] DeCarlo, A. 2021. Propagation of Boswellia In Situ. 1st Edition. Save Frankincense, Somaliland/United States. www.savefrankincese.org

[99] Vaishnav, V & Janghel, U. 2018. A note on the clonal propagation of depleted threatened species *Boswellia serrata* Roxb. through branch cuttings. *Tropical Plant Research* 5(1): 27–28

[100] Leakey, R.R., Atangana, A.R., Kengni, E., Waruhiu, A.N., Usoro, C., Anegbeh, P.O. and Tchoundjeu, Z., 2002. Domestication of *Dacryodes edulis* in West and Central Africa: Characterisation of genetic variation. *Forests, Trees and Livelihoods*, *12*(1-2), pp.57-71.

species in the Asia-Pacific region (Yen, 1996[101]; Weeks, 2009[102]). For centuries, *Commiphora* and *Boswellia* trees have been cultivated by local people across Africa as “living fences”. In northern Nigeria, for example, Dalziel (1937)[103] recorded *B. dalzielii* planted in stockades on Dimlang (Vogel peak) and as a live fence, where was considered to ward off misfortune and bring prosperity (*ba-samu* in Hausa), leading to the Hausa name for *B. dalzielii* (ba-samu). Even in semi-arid Somalia, spiny *Commiphora* (and toxic *Euphorbia*) species are grown as living fences (Leslie, 1991)[104]. Producing *Boswellia* and *Commiphora* species from cuttings is also relatively easy in nurseries. In fact, *Commiphora* species are so tough that a local name in southern Africa is “kannie-dood” (“cannot die”). But for reasons given later on in this chapter, survival rates of *Boswellia* and *Commiphora* trees that are planted out from nursery stock are poor within communal areas.

Figure 6.21. *Boswellia sacra* cultivated from seed then planted out in a plantation trial in 1998 in Dhofar, Oman. **A.** Showing location of the trees on the coastal plain. **B.** 29 year old tree showing the “micro-catchment” basin in which each tree was planted and water pipe. **C.** Salah Ajeeb, a pioneering horticulturalist (originally from Sudan) who initiated *B. sacra* trials through the Ministry of Agriculture, Oman. **D.** Fencing is essential to keep camels out of the plantation trial, but along with irrigation systems, poses a significant capital cost. Photos: A.B. Cunningham (2018).

More recently, in 1998, a *B. sacra* plantation research trial was established Oman by the Ministry of Fisheries and Agriculture (Figure 6.21). And at the World Heritage Site at Wadi Dowkah in Oman, *B. sacra* are cultivated in a fenced and watered area using seedlings from a nursery established in 1990 (Figure 6.22), with additional *Boswellia* cultivation in Djibouti, Israel and Yemen and the USA (Canney-Davison et. al., 2022[105]; Eslamieh, 2011[106]; Thulin & Warfa, 1987). In both Ethiopia and Somalia, private individuals, many of them expatriate entrepreneurs investing back in their home countries, have established cultivation trials (Figure 6.23).

[101] Yen, D.E., 1996. Melanesian arboriculture: historical perspectives with emphasis on the genus Canarium. *South Pacific indigenous nuts*, pp.36-44.
[102] Weeks, A., 2009. Evolution of the pili nut genus (Canarium L., Burseraceae) and its cultivated species. *Genetic Resources and Crop Evolution*, *56*(6), pp.765-781.
[103] Dalziel, J.M., 1937. The useful plants of west tropical Africa. *The useful plants of West Tropical Africa.*
[104] Leslie, A., 1991. Agroforestry practices in Somalia. *Forest Ecology and Management*, *45*(1-4), 293-308.
[105] Canney Davison, S., Bongers, F and Phillips, D. 2022. The future of frankincense: understanding the plant’s diversity is a key to its conservation. Herbalgram 133: 40-59.
[106] Eslamieh, J. 2011. Cultivation of *Boswellia*: Sacred trees of Frankincense. A-Z Books, Phoenix.

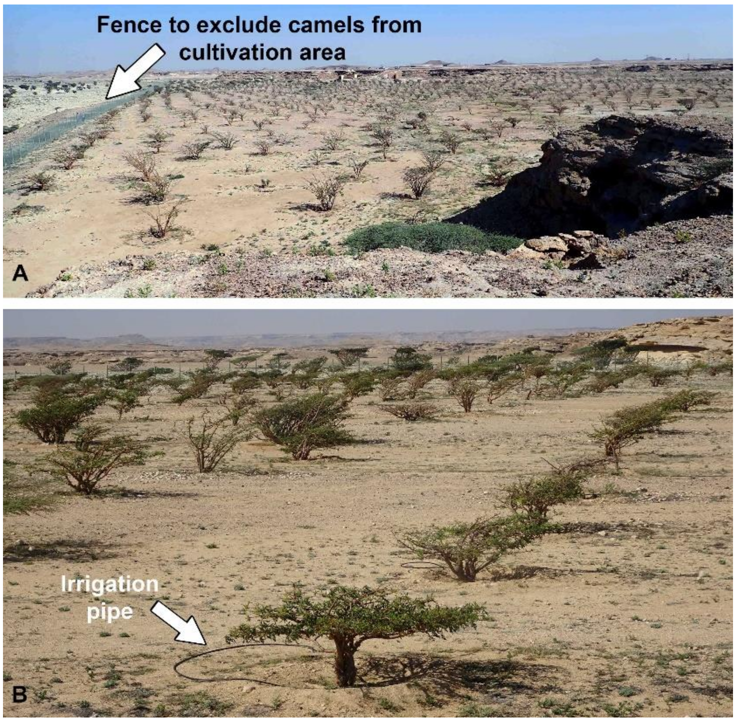

Figure 6.22. *Boswellia sacra* trees (c. 1200 trees, raised from approx.. 3000 seedings) initially grown in the Forestry nursery of the Directorate General of Agriculture in Salalah, Oman, then planted out in 1990 in a fenced and irrigated area at the Frankincense Park at the UNESCO World Heritage Centre, Wadi Dawkah, Oman. Photos: A.B. Cunningham (2018).

Plantations trials are certainly possible where government agencies have tenure over the land and where the economic costs of fencing (to keep out livestock) and water for the trees are subsidized. In the 1970's in Sudan, for example, a 10 hectare[107] *Boswellia papyrifera* plantation trial was implemented at a government research station (Nour, 2002)[108].

In 1982, during under the centrally controlled government of Mohamed Siad Barre, the then president of the Somali Democratic Republic, a plantation of *Boswellia carteri* was established by a frankincense co-operative in Somalia at Ambarsare (north-east of Gardo (or Qardho) in the Bari region of the Puntland Autonomous state of Somalia. According to Thulin and Warfa (1987)[109] there were 10,000 trees in the plantation. The fate of this plantation today is unknown.

So, what factors stand in the way of *Boswellia* plantations at large scales to produce frankincense for international trade? Firstly, under customary law across much of Africa, tree planting is associated with laying claim to land, which is a highly sensitive issue. That can lead to deliberate felling of *Boswellia* trees in plantations. *Boswellia* plantations at large scales to take pressure off wild stocks will require permanent access to very large areas with secure tenure to the land and the trees on the land for decades. For example, the only way that an expatriate entrepreneur from Somaliland (currently living in the USA) was able to plant *B. carteri* on a modest scale was to plant cuttings in black plastic nursery bags (pers. comm., to TC and ADC, 2022). Resulting in growing *Boswellia carteri* cuttings in nursery bags (as a "grey area" from a cultural perspective that they were "*not planted out on the land*").

Secondly, in Somaliland, customary rights even apply to cuttings from taken *Boswellia* trees, with clan leaders reluctant to allow the cuttings to be "taken away" without an undertaking that they would be returned. If replanted cuttings are protected by thorny brushwood "anti-browse barriers" that are maintained by community members, then this could work in favour of enrichment planting and restoration of *Boswellia* woodlands affected by poor recruitment. However, it could be a point of conflict if cuttings are taken for plantations established in other locations.

[107] Based on the area of 24 *feddans* given in Nour (2002). A *feddan* (فدّان) is an area unit used in Egypt, Oman, Sudan and Syria (equivalent to 0.42 hectares).
[108] Nour, L.A.M. 2002. Production and Productivity of *Boswellia papyrifera* in Jebel Elgarrie area (Blue Nile State). MSc degree, Faculty of Forestry, University of Khartoum.
[109] Thulin, M. and Warfa, A.M., 1987. The frankincense trees (*Boswellia* spp., Burseraceae) of northern Somalia and southern Arabia. *Kew bulletin*, pp.487-500.

Thirdly, while *Boswellia* cultivation is widely promoted, including on social media, no social or economic analyses have been done of how viable planting will be at scale. Yet the economic and social costs of providing (and maintaining) fencing and irrigation systems to *Boswellia* plantations are high, particularly in arid systems. What is needed are social and economic viability analyses similar to that done for *Prunus africana* plantations (Cunningham et. al., 2002[110]; Franzel et al., 2014[111]). So even if the hurdles of water rights and customary law (including rights to planting material from "wild" trees owned by clans or sub-clans) are negotiated, *Boswellia* tree tenure needs to be guaranteed for decades. And the question remains whether *Boswellia* cultivation is commercially viable or not?

Finally, there is the issue of water rights. *Boswellia* plantations, even on a modest scale, require access to water for years. Yet water rights (and conflicts over access to water) are particularly acute in arid landscapes where the priority is water for people and then livestock, and only then trees. Particularly during drought. Yet open ditch irrigation, the least efficient water delivery system, typifies *B. carteri* cultivation in both the Puntland and Somaliland Autonomous Regions of Somalia (Figure 6.23 and photographs supplied by a Somali expatriate who preferred to remain anonymous (pers. comm. to ABC and ADC, 2022).

Figure 6.23. *Boswellia carteri* cultivation in the Puntland Region of Somalia: showing the open ditch irrigation system that is typical of private *B. carteri* cultivation initiatives in both Puntland and the Somaliland Autonomous Regions of Somalia. Photo: A. DeCarlo.

The most efficient way of reducing water losses due to soil infiltration and water surface evaporation in open ditch systems (Figure 6.23) is to transport the water through enclosed pipelines (Figures 6.21 and 6.22), which add significantly to costs and are also subject to deliberate damage if water-use conflicts are not resolved.

In summary, *Boswellia* planting on a large scale to take pressure off wild stocks within *Boswellia* range States is hugely challenging due to social, cultural and economic factors. Catley et al (2016) point out for pastoralism in the Horn of Africa that the *"co-existence of economic growth and increasing poverty in 'high-export' areas is explained by human population growth, drought, and the private control of pastures and water by wealthier producers. <u>All of these factors combine to push poorer producers out of pastoralism</u>".* Similar concerns apply to frankincense plantations, particularly in arid and semi-arid *Boswellia* range States. Based on feedback during a field visit to Oman in 2021, fears that smaller scale producers will be pushed out of wild harvest by current cultivation initiatives in Oman are already very prevalent. So, what scale of *Boswellia* plantations would theoretically be required?

[110] Cunningham, A.B., Ayuk, E., Franzel, S., Duguma, B. and Asanga, C., 2002. An economic evaluation of medicinal tree cultivation. People and Plants Working Paper No. 10, UNESCO, Paris.
[111] Franzel, S., Ayuk, E., Cunningham, A.B., Duguma, B. and Asanga, C., 2014. Bark for sale: The adoption potential of *Prunus africana* as an agroforestry tree for small-scale farmers in Cameroon. Chapter 10, pp.189-208. in: Cunningham, A.B., B. Campbell and M. Luckert (eds) *Bark: Use, Management, and Commerce in Africa*. Advances in Economic Botany, New York Botanical Garden, New York.

As the GFA reported to CITES (2021), although "*exceptional individual trees may produce up to 2kg annually, the average frankincense yield across all trees is consistently found to be between 0.2-0.7kg per tree per year*"[112]. This equates to 1429 – 5000 trees to produce 1 tonne of frankincense. Ethiopia exports 3500 – 7900 tonnes of frankincense/yr and Somalia 1400- 3000 tonnes/year (Table 6.2). If half of the frankincense exports from Ethiopia and Somalia were to come from planted trees in these range States, this would require an estimated 3.5 million to 27.2 million *Boswellia* trees. At a tree planting density of 400 trees/hectare[113] , this would represent a vast area of land (ca. 8750 to 68000 hectares) posing huge challenges in terms of water rights (particularly during the establishment phase) and grazing rights (with fencing to keep out livestock). Risks that will apply whether there are many large plantations or thousands of individual investments in smaller scale planting.

Under these circumstances, it is not surprising that there is a widespread view in the Dhofar region of Oman that CITES Appendix II listing will favour influential *Boswellia* plantation owners at the expense of frankincense supply chains based on wild trees. This has been fuelled by popular articles and on-line films on projects such as Neal's Yard's "Project Frankincense", who have committed to support the planting of 5000 *B. sacra* trees/yr for 10 years, in the hope that commercial frankincense harvesting can start from cultivated trees (Santamaria, 2019)[114]. In theory, this may be possible, if trees survive to harvestable maturity. A total of 50 000 mature trees at 0.5 kg/tree would produce 2.5 metric tonnes of resin. In addition to conflicts over land and water, the shift to cultivation of *Boswellia* species and a move away from the wild harvest that currently provides the bulk of the world's frankincense carries many risks, however. These include drawing attention away from what is needed the most: management and implementation to deal with the diverse factors that threaten wild *Boswellia* populations (Section 6.5; Figure 6.9).

6.5 Managing wild populations: improving outcomes through social processes to identify the best combination of land-use options

With the viability of large plantation production facing major challenges, the focus of *Boswellia* needs to be on how to manage wild *Boswellia* populations: to "grow the wild". The best land-use options for this have been identified in Ethiopia where Gidey et. al., (2020)[115] worked with local stakeholders to assess the different land-use options for woodland management in Tigray (in a study area with a "low" *B. papyrifera* density of 266 trees/ha). The best option nominated to prevent poor management (due to overgrazing, agricultural expansion, over tapping and the associated wood-boring beetle attack) pests, was "Area Exclosure with Medium Tapping Resting period" (AEMTR). And the next best option was "Area Exclosure with Long Tapping Resting period" (AELTR) (Gidey et. al., 2020). Using contingent valuation methods, Gelaye et. al., (2011)[116] and Gelaye (2012)[117] showed that rural households in Ethiopia were willing to pay and contribute labour towards *B. papyrifera* woodlands. Success of both options required expanding the range of non-timber forest products harvested from these *B. papyrifera* woodlands. None of these land-use options would be favoured by a *de facto* ban on *B. papyrifera* exports from Ethiopia as a consequence of the CITES trade suspensions for Djibouti and Somalia should CITES Appendix II

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[112] citing Ali et al. 2009, Cherenet et al. 2020, Eschete et al. 2012, Al-Aamri 2014, Soumya et al. 2019, Mishra et al. 2012, Tilahun et al. 2011.

[113] Note: In Oman, *B. sacra* was planted at a 6m x 6m spacing (S. Ajeeb, pers. comm, 2022), which presents even fewer trees per hectare.

[114] Santamaria, D. 2019. Project frankincense. https://www.sublimemagazine.com/project-frankincense

[115] Gidey, T., Hagos, D., Juhar, H.M., Solomon, N., Negussie, A., Crous-Duran, J., Oliveira, T.S., Abiyu, A. and Palma, J.H., 2020. Population status of *Boswellia papyrifera* woodland and prioritizing its conservation interventions using multi-criteria decision model in northern Ethiopia. *Heliyon*, *6*(10), p.e05139.

[116] Gelaye, M, Mathijs, E., Muys, B., Vranken, L., Seppe Deckers, Kidanemariam Gebregziabher, Kindeya Gebrehiwot, and Hans Bauer. "Valuing dry land forest ecosystem services: a case of rural households' willingness to pay and contribute labor for frankincense forest conservation in Ethiopia." In *Workshop 6: Case studies on the practical use of ecosystem services in planning, management and capacity building*. Ecosystem Services Partnership, 2011.

[117] Gelaye, M.T., 2012. Restoration and sustainable management of frankincense forests in Ethiopia: a bio-economic analysis. PhD thesis, Katholieke Universiteit Leuven, Belgium.

listing of *B. papyrifera* take place. How the recommendations by Gidey et. al., (2020) are affected by the current conflict in Tigray is unknown. Nevertheless, Gidey et al (2020) demonstrated a consultative process that could be repeated across the range of contexts in other *Boswellia* range States. Including how to conserve the newly described and endangered *B. occulta* (with less than five known populations in an Area of Occupancy (AOO) of <500km^2)[118] or *B. papyrifera* (with multiple millions of trees in an EOO of c. 1.2 million km^2).

What is important is that the consultative processes and valuation methods pioneered for *B. papyrifera* woodlands, Gelaye et. al., (2011), Gidey et. al., (2020) and Dejene et. al., (2013)[119] could be repeated in other landscapes, from seasonally moist to arid, with other *Boswellia* species. In Oman, Somalia and Yemen, similar processes could be followed on land-use options that deal with a combination of frankincense production, beekeeping and improved camel management (Figure 6.24).

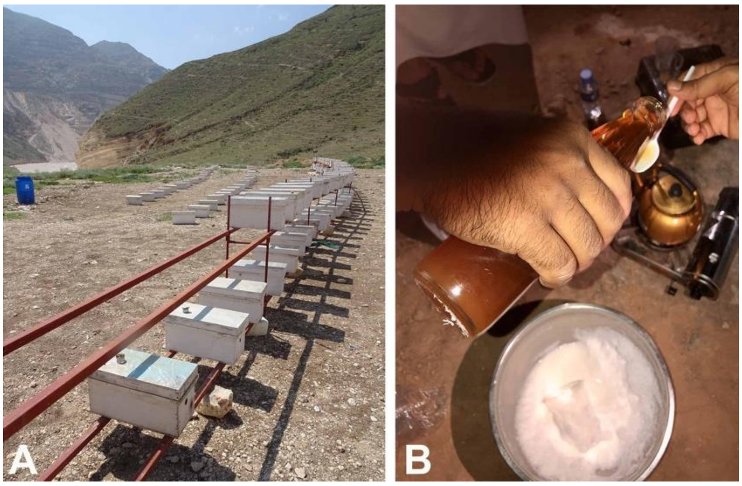

Figure 6.24. Commercial beekeeping can be a complementary form of land-use in Boswellia woodlands. A. Beehives brought into part of Dhofar, Oman during the *B. sacra* flowering season**. B.** The land of milk and honey: both honey and camels milk are highly prized. And both can be managed for improved land-use that benefits trees as well. Photos: A.B. Cunningham.

This fits with the recommendation from the GFA (2021) workshop process, which recommended the need to select areas to conserve and to prevent conversion to other land uses, where "*all those involved along the value chain need to engage in community and forest management and maintenance, not only in profiting from the resin*" (Annex 4). Range States need to develop and implement management plans for dry woodlands that deal with the diverse factors that drive *Boswellia* population loss. This applies to the development of appropriate strategies for *in situ* conservation as well. This is particularly important for narrowly endemic *Boswellia* species such as *B. occulta* (with an AOO of <500 km^2)[120] in the Somaliland Autonomous Region of Somalia and *B. ovalifoliolata* in Andra Pradesh, India (with an EOO of 5000km2 and an AOO of 2000-2200km^2)[121]. Given the risks of over-tapping from fewer than five small populations, it is worth observing that frankincense from the low oil yielding species *B. occulta*, previously mixed with *B.carteri*, is now being marketed as a unique species by small scale companies [122]. Additionally, evidence shows that the area worst affected by forest fire (>75% of the total burnt area) is the dry deciduous forest habitat of both *B. ovalifoliolata* and the CITES App. I listed species, red sanders (*Pterocarpus santalinus*) (Manaswini et al., 2015)[123]. A combination of factors, including habitat loss, fire and oleo-resin tapping, which Saha et al., (2015) suggest have caused a 30% decline over the entire range of *B. ovalifoliolata* (in Andra Pradesh) in three generations (75 yrs). In the *B. occulta* case, a CITES Appendix II listing is justified on scientific policy terms, yet is likely to worsen the situation.

[118] Thulin, 2020.
[119] Dejene, T., Lemenih, M. and Bongers, F., 2013. Manage or convert *Boswellia* woodlands? Can frankincense production payoff?. *Journal of arid environments*, *89*: 77-83.
[120] Thulin, 2020.
[121] Saha, D., Ved, D., Ravikumar, K. & Haridasan, K. 2015. *Boswellia ovalifoliolata*. *The IUCN Red List of Threatened Species* 2015: e.T50126567A50131280. https://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T50126567A50131280.en. Accessed on 25 December 2021.
[122]Mothers Goods, Georg Huber. Our Frankincense Varieties: https://mothersgoods.com/frankincense
[123] Manaswini, G. and Sudhakar Reddy, C., 2015. Geospatial monitoring and prioritization of forest fire incidences in Andhra Pradesh, India. *Environmental monitoring and assessment*, *187*(10): 1-12.

The question is what to do? At a meeting in Arusha, Tanzania in the 1960s, Sir Julian Huxley suggested that the means to justify conservation as a form of land use to local people or national governments centred upon '*pride, profit, protein and prestige'* (in Cunningham, 2001)[124]. Little attention was paid to wild plants and their importance to rural people. This is no longer the case, particularly with frankincense. Is there scope, through clans, sub-clans and the positive influence of the Somali diaspora for "pride and prestige" to play a role in *B. occulta* management and conservation? Time will tell. Perhaps more than any other *Boswellia* species, the *B. occulta* case reinforces Kingdon's (1990) point that: '*… the realities of power are exactly the opposite to those perceived by most of the participants of this struggle to conserve key areas of high endemism and biodiversity because the long-term future of Africa's Centres of Endemism lies with local peasantries rather more than with transient governments or enthusiastic conservationists; yet locals seldom receive the respect that is generally accorded to those that wield power. Meanwhile, both populations and resentments grow.… The conservationists' answers should not lie in propaganda campaigns, which are generally seen for what they are, but in a shared growth of knowledge and debate. The minimal demands of local communities will include sustained, not ephemeral, programmes of action in which their own people can find meaningful, decisive and dignified roles.'*

6.6 Should any *Boswellia* species be listed on CITES Appendices II?

[The Secretariat notes that T. Cunningham insisted on writing chapter 6 without involvement or review by consultant A. DeCarlo. As reflected in the recommendations section (chapter 2, and Annex 1), the two consultants disagree about some of the arguments made in section 6.6 with regard to the conservation status of B. papyriphera*, and as to whether the species would warrant a CITES listing.]*

As discussed above and in Chapter 5, there is great variation in the factors impacting different *Boswellia* species, the quantities in trade as well as their conservation status (Table 6.2). And based on evidence presented in Chapters 3 and 4, a genus listing is not required in order to control trade in individual species, as it would affect many species that are not negatively affected by trade, such as *B. neglecta, B. rivae* and *B. dalzielii*. This also supports the response made by India in previous feedback to the CITES Secretariat (CITES, 2021[125]). The well-established CITES policy approach on whether to list a species on CITES Appendix II (or not) depends on:

- "*Whether it is known, or can be inferred or projected, that the regulation of trade in the species is necessary to avoid it becoming eligible for inclusion in Appendix I in the near future*" or;
- whether "*it is known, or can be inferred or projected, that regulation of trade in the species is required to ensure that the harvest of specimens from the wild is not reducing the wild population to a level at which its survival may be threatened by continued harvesting or other influences"* and;
- *whether trade in specimens of certain species included in Appendix II in accordance with Article II, paragraph 2 (a), <u>may be brought under effective control"</u>.*

A useful way of thinking about the nine *Boswellia* species in international trade is to use the widely used "seven forms of rarity" matrix developed by Rabinowitz et al. (1986)[126]. That takes geographic distribution, habitat specificity and relative population size into account to rank "commonness or rarity" (Table 6.1).

[124] Cunningham, A.B. 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan, London.
[125] CITES, 2021. Addendum to Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Online, 2-4, 21 and 23 June 2021.
[126] Rabinowitz, D., Cairns, S. & Dillon, T., 1986. Seven forms of rarity and their frequency in flora of the British Isles. In: M. Soule, ed. Conservation Biology, the Science and Scarcity of Diversity. Sunderland, Massachusetts: Sinauer, p. 182–204.

Table 6.1. The Rabinowitz matrix approach can be applied at a variety of scales, from local through to national or international scales, leading to a single choice out of 8 boxes (A-H) that are then ranked (Rabinowitz, et al., 1986). In this table, commercially traded *Boswellia* species are placed in this matrix from the perspective of an international scale. Ranging from *Boswellia* species with estimated Extents of Occurrence (EOO) of >1 million km^2 (*B. serrata* and *B. papyrifera*) to *B. occulta* with an EOO of <500 km^2.

GEOGRAPHIC DISTRIBUTION		**LARGE**		**SMALL**	
HABITAT SPECIFICITY		**Wide**	**Narrow**	**Wide**	**Narrow**
POPULATION SIZE	**Large & dominant some-where**	**A.** Locally abundant in several habitats over large geographic area. ***B. dalzielii, B. neglecta, B. serrata & B. papyrifera***	**C.** Locally abundant in a specific habitat over large geographic area. ***B. sacra & B. rivae***	**E.** Locally abundant, several habitats over a small geographic area. ***B. carteri & B. frereana***	**G.** Locally abundant in a specific habitat over a small geographic area. ***B. occulta***
	Small & non-dominant	**B.** Constantly sparse in several habitats over a large geographic area	**D.** Constantly sparse in a specific habitat over a large geographic area	**F.** Constantly sparse in several habitats over a small geographic area	H. Constantly sparse in a specific habitat over a small geographic area

The newly described species *Boswellia occulta*, an endemic to northern Somalia with an AOO of <500km^2, would meet the above criteria. For practical reasons, however, we recommend against a CITES Appendix II listing for *B. occulta*, as it would likely stimulate worse damage to all or some of the four known populations of this species. This is due to effects of the CITES trade suspension that applies to Somalia and the socio-economic and cultural context of the areas where this species grows. Based on IUCN Red List Criteria and a 30% decline over 3 generations (Saha et al., 2015)[127], *Boswellia ovalifoliolata* would meet the criteria for CITES Appendix II listing. However, as this species in an adulterant (for example in the *Commiphora wightii* gum trade[128]), the recommendation is to urgently work on the chemo-taxonomy of this species and to defer CITES listing.

At the other end of the scale of geographic distribution is *B. serrata*, the most widely distributed *Boswellia* species. India has expressed concern about both a potential genus listing of *Boswellia* and considered the listing of Indian populations of *B. serrata* unjustified due to the biological data available and the protective measures in place (CITES, 2021)[129]. What would be extremely useful, however, is for the quantitative data on *B. serrata* populations (Dubbey, P.C., 2021)[130] to be published or at least made accessible.

B. dalzielii does not meet the criteria in Res. Conf. 9.24 for inclusion into CITES Appendix II due to the large populations across an extensive geographic range and the fact that international trade is at an early stage (Chapter 5). Neither *B. neglecta* nor *B. rivae* are destructively harvested (Table 6.2). In an earlier assessment, the listing of *B. frereana* in CITES Appendix II listing was also

[127] Saha, D., Ved, D., Ravikumar, K. & Haridasan, K. 2015. *Boswellia ovalifoliolata*. *The IUCN Red List of Threatened Species* 2015: e.T50126567A50131280. https://dx.doi.org/10.2305/IUCN.UK.2015-2.RLTS.T50126567A50131280.en. Accessed on 25 December 2021.
[128] Cunningham, A.B., J. Brinckmann, R. N. Kulloli AND U. Schippmann. 2018. Rising trade, declining stocks: the global gugul (*Commiphora wightii*) trade. *Journal of Ethnopharmacology* 223: 22-32
[129] CITES, 2021. Addendum to Boswellia trees (*Boswellia* spp.). Twenty-fifth meeting of the Plants Committee Online, 2-4, 21 and 23 June 2021.
[130] Responses provided in a questionnaire by Dr P C Dubey (retired PCCF, India Forestry Department) in an audit process for PLT Sustainbility, USA (cited with permission from P. Flowerman));

considered premature (Cunningham et. al., 2015b)[131]. Additional evidence gathered during this contract supports this view. And clarity is needed on the taxonomy of *B. carteri/B. sacra* before any decisions are made. In the case of *B. sacra* in Oman, as discussed earlier, the biggest threat is a unmanaged grazing/browsing by camels, not trade. Contrary to an earlier assessment in the desktop study conducted for the German Nature Conservation Agency (BfN) (Cunningham et al., 2015a)[132], which suggested that *B. papyrifera* met the criteria for inclusion in CITES Appendix II, this was premature. Careful consideration needs to be given to the preliminary IUCN Red List status of *B. papyrifera*.

There is evidence that *B. papyrifera* is in decline in Ethiopia, Eritrea and Sudan, with poor recruitment in 75% of studied populations (Bongers et al., 2019)[133], due to a combination of "non-trade" factors, combined with over-tapping for national or international trade. The statement that there is *"population collapse of B. papyrifera—now the main source of frankincense—throughout its geographic range"* overstates the situation. Rather than reflecting the situation "*through the geographic range*" of *B. papyrifera*, the admirable body of work synthesized by Bongers et al (2019) was restricted to three (of 9-10) Range States (particularly Ethiopia). The total population of *B. papyrifera* across all Range States is unknown. What we do know is that *B. papyrifera* is the most widely distributed species after *Boswellia serrata*, which like *B. dalzielii* is ranked as of Least Concern under the IUCN Red List criteria (Thulin, 2020)[134].

At a minimum, a review of the IUCN Red List status should use GBIF data (www.gbif.org) to assess the Extent of Ocurrence (EOO) and Area of Occupancy (AOO) for *B. papyrifera* and other commercially traded *Boswellia* species. This could follow the methods that calculated EOO's and AOO's for fish species using the GBIF database (Smith et al., 2020)[135]. Based on current distribution, *B. papyrifera* has an estimated EOO of c. 1.5 million km^2, with large EOO's s in southern Chad and a distribution across to Cameroon and Nigeria. These populations may not have the high tree density/hectare found in Ethiopia, Eritrea or Sudan, where *B. papyrifera* frequently occurs in high density, mono-dominant stands. But vast areas are involved. While recruitment of young trees is poor in 75% of the populations studied (Bongers et al., 2019), there is good recruitment in some sites (such as in Benishengul-Gumuz (Teshome et al., 2017[136]) and Amhara (Biresaw and Pavliš, 2010[137]). *B. papyrifera* densities can be high (175 stems/ha at Lemlem Terara (Metera district) and 87 stems/ha at Kisha (Tegede Armachiho, district). And Giday et al (2020) state that in Ethiopia *B. papyrifera* woodlands cover 1.5 million ha in Ethiopia, with potentially multiple millions of *B. papyrifera* trees across the vast geographic range of *B. papyrifera*. Under these circumstances, it is important to question whether the preliminary IUCN Red List rating of VU A2cd+3cd is really warranted for *B. papyrifera*.

The IUCN Red List Categories Listing of *Boswellia ovalifoliolata* as Vulnerable (A2cd; B1ab(i,ii,iii)) is understandable, as it only occurs in one part of India (with an AOO of 2000km^2). As are Vulnerable ratings for several *Boswellia* species on the tiny archipelago of Socotra. Other commercially tapped and internationally traded Burseraceae, such as *Canarium ovatum* (the source of Elemi resin) have an EOO (of 278,000 km^2) and an IUCN Red List rating of "Least Concern". So, a re-think may be necessary about the preliminary conservation status of VU A2cd+3cd assigned to *B. papyrifera* by Thulin (2020), which was motivated by Bongers et. al.'s, (2019) synthesis which may reflect a worst-

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131 Cunningham, A.B., Brinckmann, J., Brendler, T. 2015b. *Boswellia frereana*. Unpublished report to the German Nature Conservation Agency (BfN), Bonn.
132 Cunningham, A.B., Brinckmann, J.A and Brendler, T. 2015a. *Boswellia papyrifera*. Unpublished report to the Bundesamt fur Naturschutz, Bonn.
133 Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.
134 Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.
135 Smith, J.A., Benson, A.L., Chen, Y., Yamada, S.A. and Mims, M.C., 2020. The power, potential, and pitfalls of open access biodiversity data in range size assessments: Lessons from the fishes. *Ecological Indicators*, *110*, p.105896.
136 Teshome, M., Eshete, A. & Bongers, F. 2017. Uniquely regenerating frankincense tree populations in western Ethiopia. For. Ecol. Manage. 389, 127–135.
137 Biresaw, M.A. and Pavliš, J., 2010. Vegetation structure and density of woody plant species in two woodland areas of Amhara National Regional State, Ethiopia. *Acta Univ. Agric. Silvic. Mendelianae Brun*, *58*, pp.21-32.

case scenario in the three Range States of Ethiopia, Eritrea and Sudan. This worst-case scenario is due to the combination of exceptionally high livestock numbers, land-use developments and policy factors that together create challenges for *B. papyrifera* in Ethiopia, the best studied range State over the three generations (c.200 - 300 years) for this species.

(i) Livestock: Ethiopia has the largest livestock population in Africa (which between 1995 and 2013 increased from 54.5 million to over 103.5 million with average annual increase of 3.4 million (Leta and Mesele, 2014)[138]. A GFA Board member expressed concern that most plots where *B. papyrifera* were studied we relatively close to roads (GFA Board member, van Wyk, B-E., pers. comm., 2022).

(ii) Land-use developments: In addition, agricultural expansion will occur on a massive scale in one of the few areas in Ethiopia where there are healthy *B. papyrifera* woodlands (Benishangul Gumuz Regional State) due to irrigation schemes that result from the Grand Ethiopian Renaissance Dam (GERD), which will have a maximum reservoir area of 1904 km^2. When completed, GERD will be the largest hydropower dam in Africa and among the largest worldwide (Elagib and Basheer, 2021)[139].

(iii) National policy factors: In Ethiopia, Eritrea and Sudan, all land is owned by the State, weakening one of the key factors that underpins successful community-based resource management in communal areas (Ostrom, 1990)[140]. Furthermore, as Bongers et. al., (2019) point out, the positive development of woodland exclosure areas in Eritrea during the 1990's was forsaken as a result of the 1998–2000 border war with Ethiopia. In Sudan, the three main *B. papyrifera* production regions are reportedly at risk due to forest loss and fuel wood extraction as a result of warfare (Darfur, Kordofan) or refugee camps (Blue Nile) (Bongers et al., 2019). While in Ethiopia, radical policy changes (for example during the Derg (1975 – 1991) and EPDRF (mid-1990's to 2012) eras undermined customary tenure over woodlands and increased deforestation and *Boswellia* woodland loss (Eshete et al., 2021)[141]. Radical "top down" policies also changed traditional pasture and fire management practices, causing bush encroachment (Angassa and Oba, 2008)[142], and affected successful cases such as Farm Africa's project in Benishangul Gumuz, Ethiopia[143], where until c.2014, co-operative marketing had improved the frankincense supply chain, returns to tappers and *B. papyrifera* management.

Table 6.2. A summary of the extent of the export trade, conservation status, main threats to nine *Boswellia* species in international trade. Note that in common with the rest of this report, *B. carteri* and *B. sacra* are treated separately. **Notes:** (1) export quantities from Bongers et al (2019)[144] unless otherwise noted; (2) that based on both previous and currently unpublished chemo-taxonomic and genomic studies (Khan et al., 2017[145] and pers. comm, 2022; Woolley et al., 2012[146]; Schmiech et al., 2019[147]; Latif Khan, pers comm., 2022), *Boswellia carteri* is listed separately from *Boswellia sacra*. This conforms to Hepper's (1969)[148] taxonomic work, where he considered *B. carteri* (from Somalia/Somaliland) as a separate species from *B.*

[138] Leta, S. and Mesele, F., 2014. Spatial analysis of cattle and shoat population in Ethiopia: growth trend, distribution and market access. *SpringerPlus*, *3*(1), pp.1-10.
[139] Elagib, N.A. and Basheer, M., 2021. Would Africa's largest hydropower dam have profound environmental impacts?. *Environmental Science and Pollution Research*, *28*(7), pp.8936-8944.
[140] Ostrom, E., 1990. *Governing the commons: The evolution of institutions for collective action*. Cambridge university press.
[141] Eshete, A., Kassa, H. and Livingstone, J., 2021. Inclusive frankincense value chain development in Ethiopia. *A historical perspective on forest governance and reforms for better livelihoods and conservation outcomes. PENHA, Addis Ababa, Ethiopia and Tropenbos International, Ede, the Netherlands*.
[142] Angassa, A. and Oba, G., 2008. Herder perceptions on impacts of range enclosures, crop farming, fire ban and bush encroachment on the rangelands of Borana, Southern Ethiopia. *Human ecology*, *36*(2), pp.201-215.
[143] https://www.farmafrica.org/ethiopia/making-forests-pay-appendix
[144] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), 602-610.
[145] Khan, A.L., Al-Harrasi, A.. Asaf, S., Park, C.E., Park, G.-S, Khan, A.R., Lee, I.-J, Al-Rawahi, A. & Shin, J.-H. 2017. The first chloroplast genome sequence of *Boswellia sacra*, a resin-producing plant in Oman. PLoS ONE 12(1): e0169794.
[146] Woolley, C.L., Suhail, M.M., Smith, B.L., Boren, K.E., Taylor, L.C., Schreuder, M.F., Chai, J.K., Casabianca, H., Haq, S., Lin, H.K. and Al-Shahri, A.A., 2012. Chemical differentiation of Boswellia sacra and Boswellia carterii essential oils by gas chromatography and chiral gas chromatography–mass spectrometry. *Journal of Chromatography A*, *1261*, pp.158-163.
[147] Schmiech, M., Lang, S.J., Werner, K., Rashan, L.J., Syrovets, T. and Simmet, T., 2019. Comparative analysis of pentacyclic triterpenic acid compositions in oleogum resins of different Boswellia species and their in vitro cytotoxicity against treatment-resistant human breast cancer cells. *Molecules*, *24*(11), p.2153.
[148] Hepper, F.N., 1969. Arabian and African frankincense trees. *The Journal of Egyptian Archaeology*, *55*(1): 66-72.

sacra (Oman, Yemen). This conforms to a widely held view amongst flavour and fragrance companies, but goes against the view of Thulin (2020)[149], but makes great sense in terms of current science, trade classification and potential policy issues.

SPECIES	QUANTITY OF *BOSWELLIA* OLEO-RESIN EXPORTED (tonnes/year)	CONSERVATION STATUS	MAIN THREATS	NOTES
Boswellia papyrifera	3500-7900 (Bongers et al., 2019[150]; Gidey et al., 2020[151])	A preliminary ranking as **Vulnerable (A2cd + 3cd)** (Thulin, 2020).	Multiple factors (habitat loss, grazing / browsing (poor recruitment), high intensity and high frequency tapping). Unregulated tapping in turn reduces production of viable seed and exposes the wood to wood-boring beetle attack. In addition, after high rainfall periods, fire can be a factor in seedling mortality.	Studies in three (of 9-10) Range States show that this species is in decline: 75% of 23 studied populations (mainly Ethiopia, but also Eritrea and Sudan) lacking small trees, natural regeneration has been absent for decades, and projected frankincense production will be halved in 20 yr (Bongers et al., 2019). Quantitative studies in Ethiopia by Tolera et al. (2013)[152] showed that several *B. papyrifera* populations had been in decline for at least 50 years. Similar challenges are faced in Eritrea (Obazghi et al, 2006)[153]. Based on a detailed study of 12 *B. papyrifera* populations across northern Ethiopia, Groenendijk et. al. (2012) also concluded that if current practices continue, then there will be a 90% decline in the size of both tapped and untapped *B. papyrifera* populations within 50 years and a 50% decline in frankincense yield within 15 years. The situation in the other 6-7 Range States needs further investigation. As it is possible that *B. papyrifera* faces a worst-case situation in Ethiopia.
Boswellia carteri	1400-2000[154] up to 3000 tonnes/year[155]. According to Barkhad Hassan in an interview with Rybak (2020), his company Asli Maydi exports 2000 tonnes/yr, with a total of 3000 tonnes/yr exported from Somaliland.	**Lower risk/Near Threatened/vulnerable** as *B. carteri* was not treated as a separate species by Thulin (1998, 2020); there is little objective field data on which to base a threat category.	Traditional tapping methods, when done correctly, minimise impacts on *B. carteri* trees. The main concern with the growth in the frankincense market is unregulated (high intensity and high frequency tapping) in some areas. This in turn results in wood-boring beetles affecting damaged trees where the wood is exposed.	In contrast to *B. papyrifera* (and *B. sacra* in Oman) grazing impacts are lower. Under customary law (*xeer)*, livestock are kept away from tapping areas (Johnson, S., pers. comm. 2022). In addition, due to steep terrain, many *B. carteri* populations are less accessible to livestock. Based on a small sample size of trees in a region that supplies large quantities of frankincense, DeCarlo et al., (2020) concluded that the main issue was unregulated resin tapping. High intensity, high frequency tapping was documented during rapid surveys in important production areas near Erigaavo (DeCarlo et al., 2016[156];

[149] Thulin, M., 2020. The Genus *Boswellia* (Burseraceae): the frankincense trees. Acta Universitatis Upsaliensis.

[150] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.

[151] Gidey, T., Hagos, D., Juhar, H.M., Solomon, N., Negussie, A., Crous-Duran, J., Oliveira, T.S., Abiyu, A. and Palma, J.H., 2020. Population status of *Boswellia papyrifera* woodland and prioritizing its conservation interventions using multi-criteria decision model in northern Ethiopia. *Heliyon*, *6*(10), p.e05139.

[152] Tolera M, Sass-Klaassen U, Eshete A, Bongers F, Sterck FJ. 2013. Frankincense tree recruitment failed over the past half century. Forest Ecology and Management 304:65–72

[153] Ogbazghi, W.; Rijkers, A.J.M.; Wessel, M.; Bongers, F.J.J.M. 2006.The distribution of the frankincense tree *Boswellia papyrifera* in Eritrea: the role of environment and land use. Journal of Biogeography 33 (2006)3. - ISSN 0305-0270 - p. 524 - 535.

[154] **Note:** Bongers et al. (2019) suggested 1400-2000 tonnes/yr for a combination of *B. carteri* and *B. sacra* from all Range States. However, more recent estimates suggest that Somalia/Somaliand exports c.2000 or more tonnes/yr (S. Johnson, pers. comm, Nov 2021).

[155] Rybak, A. 2020. The incense business. https://www.terramatermagazin.com/a/w/das-geschaeft-mit-dem-weihrauch. Downloaded 28 Dec 2021.

[156] DeCarlo, A., Elmi, A.D., and Johnson, S. 2016. Frankincense in Peril: Analysis of the Resin Economy in Somaliland. Publication of A. DeCarlo, Vermont, USA.

				2017[157]). In contrast, drone footage taken in for the Swiss frankincense importer Firmenich shows large, apparently healthy *B. carteri* populations[158].
Boswellia serrata	500 – 1000 tonnes (Goraya & Ved, 2017[159]; also cited by McCutcheon, 2018); 100 (Bongers et al., 2019).	**Least Concern** (Joshi and Shringi, 2104[160]; Thulin, 2020)[161]. Widespread in India. In Madhya Pradesh and Orissa, however, *B. serrata* populations were considered Vulnerable (VU) (Biswal and Nair, 2008[162]; Chaubey et. al, 2015[163]). *B. serrata* was also ranked as a Vulnerable (VU) in Madhya Pradesh during a Conservation Assessment and Management Plan (CAMP) 2003 workshop and was given a threat status of Endangered (EN) in Rajasthan at a CAMP 2007 workshop in Jaipur[164]. *B. serrata* is listed as Critically Endangered Possibly Extinct [CR(PE)] in the National Red List of Sri Lanka.[165]	Traditional tapping methods used by tribal people, when carried out correctly do not damage mature trees. The main concerns are habitat loss through clearing *B. serrata* woodlands for farming, poor recruitment of young *B. serrata* trees into the population due to grazing and browsing by livestock. Mass felling of mature *B. serrata* trees in the 1970's for pulpwood production also had an impact. Reduced seed production due to tapping may be a factor. Even untapped *B. serrata* trees produce relatively few fruits. Open pollinated *B. serrata* only have 10% seed set (Sunnichan et al., 2005)[166].	India is the only producer of *B. serrata* oleo-resin (mainly from the states of Madhya Pradesh). Although Schultz (2022)[167] reported that a third-party audit had verified the sustainability of *B. serrata* trade to a company in the USA, the "third party audit" was based on a questionnaire sent from the USA to organisations and individuals in India, without ground-truthing. Most exported *B. serrata* oleo-resins are sourced in Madhya Pradesh, with monitoring every 5 years or so (Dubey, 2021)[168].
Boswellia sacra	100-400 (Bongers et al., 2019).	**Lower risk/Near Threatened** (Thulin, 1998)[169] and re-assessed at Vulnerable (A2cd) across the entire range (including *B.*	The major issue in Oman is not tapping. It is intensive, frequent browsing by camels. This includes camels eating the bark from *B. sacra* trees,	Although Thulin (1998) states that "*In Oman the tree is so heavily browsed that it rarely flowers or sets seed. Trees appear to be dying and regeneration is poor*", field observation in 2018 and 2021 clearly showed that while this is certainly

[157] DeCarlo, A., Elmi, A.D., and Johnson, S. 2017. Somaliland's frankincense trade: challenges, choices and sustainability. Publication of A. DeCarlo, Vermont, USA.
[158] 158 Firmenich. Ch. 15. Frankincense. https://www.youtube.com/watch?v=_dygsqQrKK8
[159] Goraya G.S & Ved D.K. 2017. Medicinal Plants in India: An Assessment of their Demand and Supply. New Delhi, India: National Medicinal Plants Board, Ministry of AYUSH, Government of India, and Dehra Dun, India: Indian Council of Forestry Research & Education.
[160] Joshi, S. & Shringi, S., 2014. Floristic Diversity with Special Reference to Rare and Threatened Plants of Jawahar Sagar Sanctuary Area near Kota Rajasthan. *Biological Forum – An International Journal,* 6(1), pp. 84-91
[161] Thulin, M., 2020. *The Genus Boswellia (Burseraceae): the frankincense trees*. Acta Universitatis Upsaliensis.
[162] Biswal, A. & Nair, M., 2008. Threatened Plants of Orissa and Priority Species for Conservation. *Special Habitats and Threatened Plants of India. ENVIS Bulletin: Wildlife and Protected Areas,* 11(1), pp. 175-86.
[163] Chaubey, O., Sharma, A. & Krishnamurthy, G., 2015. Ex-situ Conservation of Indigenous, Threatened and Ethno-Medicinal Diversity of Forest Species. *International Journal of Bio-Science and Bio-Technology,* 7(3), pp. 9-22.
[164] Ved, D. et al., 2013. Medicinal Plants Species of Conservation Concern identified for Andhra Pradesh, Arunachal Pradesh, Madhya Pradesh & Rajasthan. *ENVIS Newsletter on Medicinal Plants,* 6(1, 2, 3 & 4).
[165] MOE, 2012. *The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna and Flora,* Colombo, Sri Lanka: Ministry of Environment.
[166] Sunnichan, V., Mohan Ram, H. & Shivanna, K., 2005. Reproductive biology of *Boswellia serrata*, the source of salai guggul, an important gum-resin.. *Botanical Journal of the Linnean Society,* 147(1), pp. 73-82.
[167] Schultz, H. 2022. PLT says third-party audit verifies sustainability of its *Boswellia* sources. Nutra ingredients USA.com 28 February 2022.
[168] Responses provided in a questionnaire by Dr P C Dubey (retired PCCF, India Forestry Department) in an audit process for PLT Sustainbility, USA (cited with permission from P. Flowerman));
[169] Thulin, M. 1998. *Boswellia sacra*. *The IUCN Red List of Threatened Species* 1998:e.T34533A9874201. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T34533A9874201.en. Accessed on 12 January 2022.

		carteri) (Thulin, 2020). In Oman, Patzelt (2014)[170] considered *B. sacra* as "Near Threatened" downgrading Ghazanfar's (1998)[171] assessment of Vulnerable (A,1+cd) for Oman.	particularly during January – April in landscapes where no other fodder is available.	true in areas such as Wadi Dawkah (Figure 6.22), large healthy populations occur in steep rocky terrain and even along many wadi's are not browsed or tapped. So a re-assessment is required. This is currently being undertaken by a team from the Environmental Society of Oman. In addition, while Patzelt (2014) stating that c.70% of the world population occurred in Oman, this view may change when the size of the *B. sacra* population in Yemen is assessed. This is likely to be less dense than the *B. sacra* population in Dhofar, Oman, but occurs over a larger geographic area (for example the Hawf fog oasis in Yemen).
Boswellia neglecta	100-300 (Bongers et al., 2019).	**Least Concern** (Thulin, 2020)	None. This is a relatively fast growing species	Commercial collection of oleo-resins is not an issue of concern. Unlike the *Boswellia* species listed above, tapping does not normally take place. Instead, oleoresins are collected after Buprestid and Cerambycid beetles bore into the bark and wood. In addition, Bongers et al's (2019)[172] concern about fuelwood collection is overstated as there is an abundance of a much more favoured and more easily accessible fuelwood (from *Vachellia tortilis*) in the area.
Boswellia frereana	200 (Bongers et al., 2019).	**Vulnerable (C1)** (Thulin, 2020). This may need a re-assessment (see Notes).	The main concern with the growth in the frankincense market is unregulated (high intensity and high frequency tapping) of accessible trees. Based on interviews with frankincense harvesters in Somaliland in 2010 *B. frereana* populations were considered to be a greater concern in terms of unsustainable harvest than *B. carteri*. By 2016/17 harvester opinions had reversed and *B. carteri* was considered to be under greater pressure (DeCarlo et al., 2020).	Endemic to northern Somalia. Thulin's (2020) assessment was based on a *B. frereana* population estimate of "fewer than 10000 trees", with an expected population decline of 10% over three generations. Based on field observation, S. Johnson (pers. comm., 2021) considers that the *B. frereana* population in much larger than Thulin (2020) suggests. The trade data also suggest a far larger population, as resin production per tree rarely exceeds 0.5-1kg per tree in other *Boswellia* species studied.
Boswellia dalzielii	50?	**Least Concern** (Thulin, 2020)	Poor recruitment due to poor livestock management may be an issue. Commercial tapping for export is at an early stage and monitoring systems need to be established. Trees are debarked for the local	*Boswellia dalzielii* is the only *Boswellia* species restricted to West Africa and occurs in 9 Range States (Benin, Burkina Faso, Cameroon, Chad, Ghana, Mali, Niger, Nigeria, Togo) (Thulin, 2020).

[170] Patzelt, A. 2014. *Oman Plant Red Data Book*. Diwan of Royal Court, Oman Botanic Garden.
[171] Ghazanfar S. A. 1998. Status of the flora and plant conservation in the sultanate of Oman. *Biological Conservation* 85: 287–295.
[172] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.

			traditional medicine trade.	
Boswellia rivae	?	**Least Concern** (Alemu et al., 2021)[173] and Thulin (2020).	Grazing by livestock (camels, goats) reduces recruitment of seedlings.	This species is dominant in certain areas and easy to find. This dominance may be due to its use for resin as the species is highly valued and is therefore not removed. There are currently no major threats to this species. Resin production by the local people is sustainable and does not kill the tree but with increased demand it is not known how this species will be affected by trade. A future threat could be unsustainable harvesting of resin using non-traditional methods.
Boswellia occulta	?	**Endangered** (B2a) (Thulin, 2020).	**Unregulated** (**high intensity and high frequency tapping)** may be a concern for the restricted range species.	This Endangered status of this species is due to its small area of occupancy (<500 km^2) in possibly less than five locations. Despite the clear taxonomy by the world authority on *Boswellia* (see Thulin et al, 2019[174]; Thulin, 2020) and clear chemotaxonomic differences (Ayubova et al., 2019; Johnson et al., 2019[175]), an important trader who is FairWild and Ecocert certified disputes the scientific evidence of that this is this new species (see Ayubova et al., 2019).[176] In contrast, a German importer, Georg Huber (https://mothersgoods.com/frankincense) markets this species as *B. occulta*.

[173] Alemu, S., Alemu, S., Atnafu, H., Awas, T., Bahdon, J., Birhanu Belay, Sebsebe Demissew, Luke, W.R.Q., Efrata Mekbib, Musili, P. & Sileshi Nemomissa. 2021. *Boswellia rivae* (amended version of 2018 assessment). *The IUCN Red List of Threatened Species* 2021: e.T128044164A208229310. https://dx.doi.org/10.2305/IUCN.UK.2021-3.RLTS.T128044164A208229310.en. Accessed on 12 January 2022.
[174] Thulin, M., DeCarlo, A., Johnson, S.P.. 2019. *Boswellia occulta* (Burseraceae), a new species of frankincense tree from Somalia (Somaliland). *Phytotaxa*. 394(3), 219-224. https://doi.org/10.11646/phytotaxa.394.3.3
[175] Johnson, S., DeCarlo, A., Satyal, P., Dosoky, N.S., Sorensen, A., Setzer, W.N., 2019. Organic certification is not enough: The case of the methoxydecane frankincense. Plants. 8(4), 88. https://doi.org/10.3390/plants8040088
[176] Ayubova, M., Brevard, H., Baldovini, N., 2019. Corrigendum to “Analytical investigations on Boswellia occulta essential oils” [Phytochemistry 164 (2019) 78–85]. Phytochem. 165, 112053, https://doi.org/10.1016/j.phytochem.2019.112053

6.7 *Boswellia* range States: governance context, CITES implementation capacity and practical considerations

6.7.1 *Boswellia* range States: governance context

One measure of comparative governance across range States in the Corruption Perceptions Index (CPI) (2020). Sub-Saharan Africa is the lowest performing region on the CPI. In terms of *Boswellia* range States, Oman performs best, while Sudan and Somalia are at the bottom of this global index[177]. National capacity to implement international trade regulations such as those required under CITES is best in Oman, India, Ethiopia, Kenya and Burkina Faso, but is weakest in Eritrea, Somalia, Sudan and Yemen. Legislation applicable in the main frankincense producing countries is summarised below:

***B. sacra* and the Arabian Peninsula:** In 1982, the Sultanate of Oman became the first country in the Gulf region to pass comprehensive legislation on the environment. In 1984, Oman became the first country in the region to establish a specific Ministry for the Environment, now the Ministry for the Environment and Climate Affairs (MECA). Environmental laws in Oman are Royal (Sultani) Decrees that may be backed up by Ministerial Decisions. In Oman, as Farah (2008) points out, frankincense production occurs on "*government owned land administered by the Ministry of Municipality and Environment, the Ministry of Agriculture and the Wali of Dhofar representing His Majesty Sultan Qaboos*" and that "*although the land belongs to the government the trees that produce frankincense (B. sacra) are under the private ownership of individuals belonging to Omani tribal kinship structures*". The most relevant national legislation to *Boswellia* are the (1) Law on Nature Reserves and Wildlife Conservation (6/2003) and the (2) Amendment of some conditions of the Law of Establishment of National Parks and Natural Protected Areas (47/95). All of these are available in Arabic (see www.oman.om). For example, according to Farah (2008), the Jabal Samhan Natural Reserve (JSNR), which promulgated in 1997 under Royal Decree by Sultan Qaboos bin Said Al Said (48/97), holds "*about 60% of the two most important luban habitats (Hojari/Nejdi) but these areas lack active management plans. JSNR was set up and could prove to be instrumental in the sustainable conservation and management of B. sacra and other natural resources in the reserve*". In terms of adding value to the *B. sacra* supply chain in Oman, the request from Sultan Qaboos bin Said Al Said to Prince Sayyid Hamad bin Hamoud al bu Said to found Amouage, in 1983 as a company that maintained and built of the perfume-making traditions of Oman is also relevant. Furthermore, given Farah's (2008) observations that illegal migrants from Somalia "almost exclusively" tapped *B. sacra* at that time, Oman's legislation on forced labour and human trafficking (Royal Decree 126/2008: Promulgating the Law Combating Trafficking In Persons) is also relevant. Finally, although the Sultani Decree Number 114/2001 (the Law on the Conservation of the Environment and Prevention of Pollution (114/2001)) is considered the most powerful decree on environmental legislation in Oman, this decree relates to pollution, waste management and the oil and gas sector, with biodiversity and sustainability not yet addressed within this regulatory framework. There is scope for further developments, however as any project to be undertaken within the Sultanate of Oman that may have an environmental impact requires a permit from MECA. At present, this is focused on large projects, not the commercial harvest of frankincense. The process is an initial consultation with MECA to assess whether an environmental impact assessment (EIA) will be required, followed by an application for initial environmental approval and then the application for the environmental permit itself by the owner of a resource area. In addition, the Oman Botanic Garden, which falls under the Ministry of Heritage and Tourism, plays an important role in *ex situ* conservation, supported by scientists at the University of Nizwa and other universities. Furthermore, the Environment Society of Oman (ESO), which is a non-government organisation, promotes conservation through facilitated co-operation between the Government of Oman, NGO's and the private sector.

[177] www.transparency.org/en/news/cpi-2020-sub-saharan-africa.

In Yemen, in addition to the Basic Law in the Constitution of the Republic of Yemen, Article No. (35) states that “environment protection is the responsibility of the state and society, and it is a religious and national duty of every citizen”, there are 21 laws, Republican decrees, and Cabinet decrees that relate to biological diversity. What is also relevant to *Boswellia sacra* in Yemen is that the Hawf Area (a "fog oasis" in Al Mahrah governate, Yemen) that is ecologically similar to Dhofar in Oman) was nominated in August 2002 as a UNESCO World Heritage Site[178]. A highly relevant initiative in the Hawf Protected Area (HPA) tried to initiative livestock management based on traditional Mahjur (grazing reserve management) system as part of a ‘*Sustainable Community-Based Protected Area Management Plan*’ (Schlecht et al., 2014)[179]. However, while there has been work to identify key biodiversity areas in Yemen and strategies to promote community-based management of protected areas, the Conflict and Environment Observatory (CEOBS) considers that these "*have often been poorly designed or implemented" and that national capacity for implementation is weak*[180].

***Boswellia* and the Horn of Africa**: A high diversity of commercially traded *Boswellia* species are found in Somalia, which has been under a CITES-imposed trade suspension since 2004 specifically due to inadequate legislation. Nevertheless, there is legislation in Somalia that is followed by Young Living, a major frankincense importer, as part of their Lacey Act compliance programme (Annex 4, Text Box 7.2).

In Ethiopia, the most important legislation is the "Forest Development, Conservation and Utilization Proclamation" (2018), which recognises that the: "*forest sector also has a crucial role in balancing the demand and supply of forest products, sustain agricultural productivity and thereby ensure food security*" and that *"in addition to developing forest by state and private ownership, it is necessary to introduce community and association forest development to implement the policy and strategy*". And that: "*to enhance sustainable forest development, conservation and utilization through to recognizing community ownership and public participation"* and that: "*to ensure sustainable forest development, conservation and utilization, it is necessary to classify forest into productive, protected and exclusively protected forests based on their environmental, social and economic significance*". In recognising both the rights and responsibilities of "private forest developers" and the "*Rights and Incentives of Community Forest Developers***",** Ethiopia's 2018 "Forest Development, Conservation and Utilization Proclamation" represents an encouraging development. That legally underpins the role of the Ethiopian government in "*Expansion of the Forest Products Market*" through providing: "*the necessary support to forest developers to enable them to produce and supply quality and competitive forest products for the local and foreign markets*". The impact of a *de facto* export ban on *B. papyrifera* products through the port of Djibouti or any ports in Somalia triggered by CITES Appendix II listing of *B. papyrifera* would be devastating in terms of implementing this 2018 Proclamation.

In Eritrea, land is owned by the State (under Land Proclamation (No. 58/1994) was issued and Legal Notice (NO. 31/ 1997) on "Regulations for the Distribution and Administration of Land", whereby the State "*determines the allocation and use of land*" noting that "*Land is not transferable except when the holder dies leaving minor children*". The most relevant articles of legislation in Eritrea are the Forestry and Wildlife Conservation and Development Proclamation (No. 155/2006) and the Regulations for the issuance of forestry permits (L.N. No. 111/2006). These deal with the protection and sustainable development of forestry resources in Eritrea. Including the conservation of endangered species, afforestation and reforestation; management of protected areas and the "promotion of awareness and participation in forest and wildlife management and conservation". This proclamation is implemented through the Minister of Agriculture, who issues permits for "*the harvesting of dead wood and forest products and to process forestry products for commercial*

[178]https://whc.unesco.org/en/tentativelists/1726/

[179] Schlecht, E., Zaballos, L.G., Quiroz, D., Scholte, P. and Buerkert, A., 2014. Traditional land use and reconsideration of environmental zoning in the Hawf Protected Area, south-eastern Yemen. *Journal of arid environments*, *109*, pp.92-102.

[180] https://ceobs.org/protected-area-conservation-in-yemens-conflict/

purposes, the cutting of living trees for domestic purposes, the clearing of land for agricultural purposes and the transportation, importation or exportation of forest products", specifying that permits must "*specify conditions for a permit to clear land or to import or export forestry products*". And that export "of forestry products falling within the scope of CITES shall not permitted under these Regulations".

In Kenya, frankincense production and trade fall under the Forest Conservation and Management Act (2016), which will also cover forthcoming legislation drafted in 2021 for the Cabinet Secretary for Environment and Forestry (the Forests (Gums and Resins) Rules, 2021). This includes the rules that:

- *"No person shall import gums and resins from any country into the Republic of Kenya, or export gums and resins from the Republic of Kenya to any other country, unless such person is in possession of a valid gums and resins import or export permit issued by the Service under these Regulations";*
- *The county government may support gums and resins producer associations in the development of woodland management plans for the sustainable production of gums and resins;*
- *The Service may support the county government and the Association in developing the woodland management plans and that "The Service shall collaborate with KEFRI, other public institutions, private organizations and individuals, to "Identify gums and resins research and development needs relating to production, harvesting, utilization, quality control, product development, marketing, trade and related functions";*
- *Applied research and development on gums and resins activities may be funded by monies from the Forest Management and Conservation Fund and any other lawful sources; and that;*
- *The Service may require the Associations or individual traders and, exporters to provide information on production, harvesting, utilization, marketing and trade of gums and resins.*

In Sudan, the Forests and Renewable Natural Resources Act (Act No.11 of 2002) updated and repealed the Forests Act No. 14 of 1989, which was based on Sudan's 1932 Forest Act promulgated during the colonial period. Forests and Renewable Natural Resources Act (Act No.11 of 2002) "*promotes an intersectoral approach to natural resources management involving forests, range and pasture and agriculture"* and recognises three categories of forest ownership (private, community and institutional), with all three of these placed "*under the technical supervision*" of the Forest National Corporation (FNC). The role of the "*native administration and traditional leaders and local communities*" are recognised, as multiple use of trees and the usufruct rights of communities living around forest reserves (Forest National Corporation, 2020)[181].

***Boswellia serrata* in Asia:** As *B. serrata* is listed as Critically Endangered Possibly Extinct [CR(PE)] in the National Red List of Sri Lanka (MOE, 2012)182, the focus here is on India, which contains extensive wild populations of B. serrata. In India, the Biological Diversity Act (2002) is implemented through the National Biodiversity Authority. Providing for conservation and sustainable use of biodiversity and the fair and equitable benefit sharing from use of biological resources[183]. The Forest Rights Act (FRA) 2006 and Panchayat Extension to Scheduled Areas Act (PESA) (1996) are also highly relevant to *B. serrata* harvest and trade.

[181] Forest National Corporation (FNC). 2020. Forest Reference Level (FRL) Submission to the UNFCCC. https://redd.unfccc.int/files/sudan_frl_submission_to_unfccc_january_2020.pdf
[182] MOE, 2012. *The National Red List 2012 of Sri Lanka; Conservation Status of the Fauna and Flora,* Colombo, Sri Lanka: Ministry of Environment.
[183] https://www.indiacode.nic.in/show-data?actid=AC_CEN_16_18_000010_200318_1517807327125&sectionId=3903&sectionno=18&orderno=18

6.7.2 CITES Implementation capacity

Although slightly dated, as there now are 184 signatories to CITES, Challender et. al., (2015)[184] succinctly summarises the challenges that need to be taken into account when implementation capacity is considered in the *Boswellia* case. Citing a CITES (2013) assessment that of 180 Parties at the time: "*only 51% (88/173; excluding recent accessions and dependent territories) had legislation that met all the implementing requirements under the National Legislation Project. A further 49 Parties have legislation that is considered to meet some of these requirements, while 36 Parties have legislation which is deemed to be inadequate*". Foster and Vincent (2021)[185], in their recent review of governance, CITES and the seahorse trade point out that CITES "is unusual among global agreements because it has teeth; a process called the Review of Significant Trade (RST) allows disciplinary action in the form of trade suspensions directed at countries that do not meet their obligations". In the *Boswellia* case, however, it is worth asking: "what happens when the bites from those teeth are ignored?".

As of 17 May 2022, out of the 28 countries currently subject to CITES recommendations to suspend trade, 21 (75 %) are African countries (including Madagascar). This mainly due to significant trade in specific animal species. In the *Boswellia* case, the most immediate challenges with CITES listings are firstly, that Somalia, as the world's second largest frankincense exporting country, with a high diversity of commercially traded *Boswellia* species, has a CITES trade suspension in place for almost 20 years (No. 2004/055 of 30 July 2004). This is due to CITES concerns about national legislation in Somalia. Secondly, that Djibouti, also has a long standing CITES trade suspension due to non-submission of annual reports to CITES. Ethiopia is almost totally reliant on Djibouti's port and transport-related infrastructure (for 95% of Ethiopia's maritime trade)[186]. This would affect re-exports of *B. papyrifera* frankincense from Ethiopia through Djibouti. Another option for exports from Ethiopia is the port of Berbera in the Somaliland Autonomous Region of Somalia, of which Ethiopia is a major shareholder, through an agreement with DP World (which runs the new container terminal at Berbera port) and the Somaliland Port Authority. However, as both Djibouti and Somalia have CITES trade suspensions for all commercial trade[187] (including re-exports) of any CITES listed species (on Appendices I, II), Ethiopia's frankincense re-exports through Berbera would also effectively become a trade ban.

The attempted 2012 UN Security Council ban on charcoal trade from Somalia (UN Security Council, 2014)[188] is an excellent reality check for CITES in the *Boswellia* case. Trade in charcoal increased after the UN "ban" through "*a seamless commercial network spanning production sites and export points, often pre-financed by overseas investors and dealers*". Reliance on less conspicuous vessels (dhows) increased to transport charcoal (142 of the 161 vessels), that exported an estimated 6.57 million bags of charcoal from the ports of Kismayo and Barawe in a single year after the ban (June 2013 and May 2014). Al-Shabaab increased its share of the funds derived from the charcoal trade (Lind et al., 2015). The UN ban on the charcoal trade stimulated middlemen in the United Arab Emirates to work with shipping agents to falsify bills of lading and certificates of origin, identifying Somali charcoal imports to customs authorities in the United Arab Emirates and Kuwait as though they had been sourced primarily from Djibouti or Kenya. No response to UN Security Council requests at the time of the UN Security Council (2014) report were received from "*the Governments of the United Arab Emirates, Kuwait or Oman for access to customs documentation submitted by the captains of dozens of vessels that the Group has confirmed as transporting charcoal originating from Somalia*".

[184] Challender, D.W., Harrop, S.R. and MacMillan, D.C., 2015. Towards informed and multi-faceted wildlife trade interventions. *Global Ecology and Conservation*, *3*, pp.129-148.
[185] Foster, S.J., and Vincent, A.C.J. (2021). Holding governments accountable for their commitments: CITES Review of Significant Trade for a very high volume taxon. Glob. Ecol. Conserv. 27, e01572.
[186] https://issafrica.org/iss-today/djibouti-looks-to-ethiopia-to-gauge-its-economic-future
[187] https://cites.org/eng/resources/ref/suspend.php
[188] UN Security Council. 2014. Report of the Monitoring Group on Somalia Pursuant to Security Council Resolutions 751 (1992) and 1907 (2009), 13 October, www.un.org/ga/search/view_doc.asp?symbol=S/2014/726 (accessed 19 March 2022)

After almost 20 years of "non-compliance" by Djibouti and Somalia (both since 2004), it is naive to think that CITES listing (whether Appendices I or II) of any *Boswellia* species, will stimulate either Somalia or Djibouti to suddenly start complying with CITES. One of the effects of a CITES Appendix II listing may in fact be to similarly increase the "hidden economy" of a maritime, cross-border trade. There is a long history of exporting *B. carteri* and *B. frereana* frankincense on vessels taking livestock from Somalia directly to the Middle East from the ports of Berbera and Bosaso (ITC - Eastern Africa, 2006[189]). This is likely to increase if CITES Appendix listing of *Boswellia* species occurs, with bags of frankincense stored under the decks of vessels transporting livestock. An additional effect of CITES Appendix II trade suspensions on exports from Somalia and re-exports from Djibouti (from Ethiopia) could be to stimulate exports of high boswellic acid *Boswellia* oleo-resins from other range States. Particularly from Sudan, but also from West African Range States with *B. dalzielii* and/or *B. papyrifera*. CITES implementation will be especially challenging given that a third of the 21 African countries facing some form of CITES trade suspension are range States of *Boswellia* species in trade. Namely Benin (*B. dalzielii*); Cameroon (*B. dalzielii, B. papyrifera*); Chad (*B. dalzielii, B. papyrifera*); Ghana (*B. dalzielii*); Mali ((*B. dalzielii*); Somalia (*B. carteri, B. frereana, B. neglecta, B. occulta, B.rivae*) Togo (*B. dalzielii*) and Tanzania (*B. neglecta*).

In summary, national capacity to implement national or international trade regulations (such as CITES) varies greatly across *Boswellia* range States due to weak governance, porous borders and conflict in several of the Range States (Chapter 5, Table 6.3 and Section 6.3).

Table 6.3. Several *Boswellia* range States are characterised by poor governance, conflict, porous borders and some of the highest Corruption Perceptions Indices (CPI) in the world. Somalia, for example, has the highest CPI in the world. Ironically, the self-declared state of Somaliland (which is not internationally recognized as such since it declared independence in 1991, but is officially considered the Autonomous Region of Somaliland in Somalia) is relatively stable, with a good opportunity for community-based management of wild *Boswellia* populations under a tenure system of clans or sub-clans.

ANGE STATE & *BOSWELLIA* SPECIES (in order of scale of exports)	GOVER NANCE INDEX[190]	RANK IN CORRUPTION PERCEPTIONS INDEX[191]	NOTES ON LINKS TO *BOSWELLIA* MANAGEMENT AND TRADE
Ethiopia[192] (*B. papyrifera, B. neglecta, B. rivae*)	93/103	94/179	A significant proportion of *B. papyrifera* oleo-resins come from Tigray and Amhara, the epicentre of the Tigray War, that started on 3 November 2020. In addition, governance, resource management, livelihoods and border porosity are affected by the 2020–2021 Ethiopian–Sudanese clashes started in the Abu Tyour area along the border between Ethiopia and Sudan on 15 December 2020. Most *B. papyrifera* oleo-resin exports are through Djibouti. However, as there are CITES-imposed trade suspensions in place for Djibouti (since 2004, Notification No. 2011/010, Notification No. 2018/015) any CITES listing for *B. papyrifera* would effectively become a trade ban, impacting livelihoods and stimulating trade across porous borders.
Somalia (*B. carteri, B.*	Not assessed	179/179	Somalia is ranked as the most corrupt country in the world. Often characterized as a “failed state”, it only has a small and inexperienced police force and law and order are widely

[189] ITC - Eastern Africa, 2006. *Review and Synthesis of Local Economic Development (LED) Materials: Puntland,* s.l.: The European Union’s 5th Rehabilitation Programme for Somalia/Somaliland.

[190] https://chandlergovernmentindex.com/: this is from the 2021 version of an annual Index that measures the capabilities and effectiveness of 104 governments around the world. The worst out of the 104 countries ranked was Venezuela (with Zimbabwe at 103). The best ranked were Finland (1) and Switzerland (2).
[191] www.transparency.org/en/cpi/2020: this index ranks countries from best (New Zealand (1), Denmark (1), Finland (3) and Switzerland (3) to worst (South Sudan and Somalia (both 179), with Yemen at 176).
[192] Note: Most of Ethiopia’s exports go through Djibouti (which has a CPI of 142/180)

frereana, B. occulta)			considered to have broken down. Governance is much better in Somaliland, which declared itself independent in 1991, but is not recognised as such by the UN system. Consequently, as Somalia has been the focus of a long-standing trade suspension in all CITES-listed species since 2004 due to Somalia not national implementing legislation (Notification No. 2019/35), any CITES Appendix II listing would mean an export trade ban for the Somaliland and Puntland Autonomous Regions of Somalia as well, impacting tappers livelihoods and stimulating trade across porous borders.
Sudan (*B. papyrifera, B. neglecta, B. rivae*)	Not assessed	174/179	According to Bongers et al (2019)[193], *B. papyrifera* oleo-resins come from areas that have been affected by conflict (Darfur, South Kordofan, Blue Nile states). In addition, Sudan's political situation remains unstable since the military dissolved the transitional government on 25 October 2021.
Yemen *(B. sacra)*	Not assessed	176/179	Yemen is in the midst of the world's worst humanitarian crisis and a civil war.
Eritrea (*B. papyrifera,*	Not assessed	160/179	There is long-standing conflict between Eritrea and Ethiopia. In 2020, for example, there were reports of explosions in Asmara as a result of rockets launched from the ongoing military conflict in Tigray, Ethiopia. Military tensions also exist between Eritrea and Djibouti.
India (*B. serrata* plus *B. ovalifoliolata* (as an adulterant)	49/103	86/179	Stable, although Maoist insurgents, known as Naxalites, pose a challenge to state-based forest management in some *Boswellia serrata* areas, such as forested areas in the state of Chhattisgarh.
Oman *(B. sacra)*	Not assessed	49/179	Stable. However, the issue of a potential CITES App. II listing of B. sacra is a sensitive issue, particularly in Dhofar (southern Oman), where *B. sacra* occurs as legal controls of exports would be held by the CITES Management Authority in Muscat (northern Oman).
Kenya (*B. neglecta, B. rivae*) with *Commiphora confusa* often mixed with *B. neglecta*.	81/103	124/179	Relatively stable, although borders are porous, particularly the Somalia, Ethiopia and South Sudan border areas.
Burkina Faso (*B. dalzielii*)	96/103	86/179	A significant part of the geographic range of *B. dalzielii* is in countries experiencing armed conflicts (Nigeria, Burkina Faso, Mali, and Cameroon). Porous borders are well documented in West Africa due to concerns that range from epidemiology[194] to human trafficking.[195]

6.7.3 CITES listing and "unintended consequences"

The concerns about negative "unintended consequences" of CITES Appendix II listing of *Boswellia* are complex and very real. As Cooney et al. (2021) recently pointed out:

"CITES Parties make decisions on Appendix listings and/or amendments without any formal consideration of the consequences of those decisions. The criteria for listing species do not promote

[193] Bongers, F., Groenendijk, P., Bekele, T., Birhane, E., Damtew, A., Decuyper, M., Eshete, A., Gezahgne, A., Girma, A., Khamis, M.A. and Lemenih, M., 2019. Frankincense in peril. *Nature Sustainability*, *2*(7), pp.602-610.

[194] Petherick, A., 2015. Ebola in West Africa: learning the lessons. *The Lancet*, *385*(9968), pp.591-592.

[195] Aniche, E.T., Moyo, I. and Nshimbi, C.C., 2021. Interrogating the nexus between irregular migration and insecurity along 'ungoverned'border spaces in West Africa. *African Security Review*, pp.1-15.

or mandate consideration of such consequences. Instead, the tests for including a species in the Appendices direct Parties to consider only whether a species is in trade, and actual or potential levels of threat it faces, not the likely conservation consequences of proposed listings. The assumption is that if an internationally traded species faces a level of biological threat, its conservation will benefit from trade restriction. Yet this assumption has no systematic evidential basis [but] is frequently false…. In practice, CoP deliberations on species listings do range beyond the formal listing criteria. Parties and/or Observers regularly raise issues related to conservation impact, such as the challenges they will face in implementation, potential impacts on local livelihoods (and knock-on conservation consequences), and the "signals" that decisions could send to certain actors (e.g., poaching syndicates and other market actors). Nevertheless, such considerations are not part of the formal CITES listing process and there is no requirement for Parties to consider them".

It seems likely that a genus level CITES Appendix II listing of *Boswellia* would trigger trade bans in the two countries exporting the most frankincense (Ethiopia and Somalia). This would have negative effects on people' livelihoods in the Horn of Africa at the height of the current drought, where the region is facing the driest conditions since 1981, with 13 million people facing famine conditions[196]. The potential "unintended consequences" that could result if trade bans occurred in two of the world's poorest countries need to be carefully considered. These include:

- **Speculative buying and stockpiling** as news of an impending trade ban for *B. papyrifera* (triggered by CITES App. II listing) may well occur for *B. papyrifera* oelo-resins from Ethiopia, due to the CITES-imposed trade suspensions in place for Djibouti (since 2004, Notification No. 2011/010, Notification No. 2018/015). Speculative buying before a trade ban is not unusual. In Cameroon, for example, a partial harvest ban on *Prunus africana* bark by the government occurred in 1991. But this had the opposite effect. Twice the annual average amount of bark was exploited, much of it opportunistically and destructively, then was bought from local entrepreneurs and exported by the French subsidiary company Plantecam (Cunningham and Mbenkum, 1993)[197]. Some stockpiling due to political insecurity already occurs in Somalia, but it is likely that a listing would cause a significant increase in this activity, to the detriment of the *B. carteri* and *B. frereana* trees. Speculative buying, stockpiling and illicit cross-border trade are likely for *B. carteri* and *B. frereana* (and possibly *B. occulta*). Particularly if CITES Appendix II listings trigger *defacto* bans on exports from Somalia due to the trade suspension in all CITES-listed species since 2004 (Notification No. 2019/35) and the effects that the trade suspension for Djibouti would have on re-exports of *B. papyrifera* transported from Ethiopia to Djibouti. Frankincense stockpiling have been recommended in the past. DeCarlo and Ali (2014), for example, recommended "*quickly purchasing a large quantity of Frankincense at the current low price to build a stockpile and give a supply shock to wholesalers*" in order to "*allow sustainable businesses to revamp the market for the long run and compensate a group of harvesters (in monetary terms and/or via direct aid) to rest trees while setting up a sustainable management program*". How effective this was is uncertain.

- **Escalated cross-border trade**: A CITES-imposed trade ban stopping exports from Djibouti could stimulate escalated "invisible" cross-border trade in *B. papyrifera, B. neglecta* and *B. rivae* oleo-resins from Ethiopia into Sudan and possibly through Eritrea to Port Sudan and Massawa, as alternatives to exporting from Djibouti, or into Kenya, following existing cross-border trade routes. As Little (2005) points out: "*Trans-border trade in the Horn of Africa represents a particularly important and challenging unofficial, informal sector activity. On the one hand, it*

[196] https://www.wfp.org/news/13-million-people-facing-severe-hunger-drought-grips-horn-africa
[197] Cunningham, A.B and F.T. Mbenkum. 1993. Sustainability of harvesting *Prunus africana* bark in Cameroon: a medicinal plant in international trade. People and Plants Working Paper 2 : 1 - 28. UNESCO, Paris.

epitomizes the essence of informal or 'shadow' trade, operating along remote borders in a vast region where government presence is particularly weak or, in some cases (Somalia), absent"[198].

- **"Ripple effect" buying of oleo-resins of high boswellic acid containing species (*B. papyrifera, B. carteri* and possibly *B. dalzielii*):** This is already occurring as prices of the South Asian species *B. serrata* rise. Asian entrepreneurs, for example, are reportedly increasing their imports of *B. papyrifera* from Sudan to India and China. Furthermore, if *de facto* bans on frankincense exports from Somalia and of Ethiopian frankincense re-export through Djibouti occurred, this would affect the two largest frankincense exporters (Ethiopia and Somalia). As these countries currently collectively export between 5100 - 11100 tonnes of frankincense per year (see Table 6.2), this would create a huge ripple effect on other *B. papyrifera* populations, *B. dalzielii* and possibly *B. serrata*. This is likely to benefit companies who have pioneered commercial *B. dalzielii* supply chains, such as Afrikor Naturals (https://www.afrikornaturals.com), a joint venture in Burkina Faso with the Aromatic Plant Research Center (APRC) in the United States.

- **Higher intensity and frequency tapping**: It is worth asking whether an opportunistic rush to obtain and store as much frankincense as possible before a possible CITES Appendix II listing would increase tapping intensities and frequencies on *B. papyrifera* (in Ethiopia, Eritrea and Sudan) and *B. carteri, B. frereana* and *B. occulta* trees in Somalia/Somaliland. Overharvesting could stimulate wood borer beetle attack as the cambium of trees is damaged and Cerambycid beetles lay eggs in the exposed wood.

For these reasons, it is worth reflecting on alternative approaches to managing commercially exploited *Boswellia* populations into the future, particularly if the CITES goal of accurate monitoring of international trade is not possible, due to porous borders, corruption, weak governance and warfare. If the effects of the "unintended consequences" outlined above are likely, then what is "*the possible, the attainable — the art of the next best"* to restore, conserve and sustain harvests from *Boswellia* populations? This is discussed in the following chapter.

[198] Little, P., 2005. *Unofficial trade when states are weak: The case of cross-border commerce in the Horn of Africa*. United Nations University (UNU).

Chapter Seven: The scalpel, not the hammer: alternatives to CITES in *Boswellia* Range States.

A.B. Cunningham

"[The sustainable use]… concept is at the core of CITES, which falls in the nexus between trade, conservation, and development. Its mandate spans from conserving biodiversity, to building opportunities for resilient and sustainable livelihoods and economic opportunities for communities who most closely rely on nature" (Higuero, 2021)[1].

7.0 Introduction

The previous chapter dealt with the ecological and land-use context of *Boswellia* species management in Range States and the practical implications of potential listings of *Boswellia* species in the CITES Appendices. Chapter 5 also suggests that most of the threats that face Boswellia species are not trade related. And even where a *Boswellia* species (*B. occulta*) clearly meets the criteria for CITES Appendix II listing (Chapter 5.6), this is not recommended as this is likely to worsen the situation for this narrowly endemic species (Chapter 7). What is needed is a nuanced approach to the frankincense trade. A scalpel, not a hammer. So that economic incentives for maintaining *Boswellia* habitat and species populations are enhanced, not halted. In this chapter, several practical, alternative approaches to CITES Appendix II listing of *Boswellia* species are explored. In order to avoid the "unintended consequences" that would result from a cessation of trade triggered in the Horn of Africa's for the two major exporting countries (Somalia, Ethiopia) CITES Appendix II listing of *Boswellia* occurred.

7.1 Where, and under what conditions does *Boswellia* species management seem to sustain wild populations?

The good news for range States and commercial companies that are committed to transparent, ecologically sustainable and socially equitable supply chains is that this is not only possible, but that there are several examples of where this works in practice.

7.1.1 Sustainable harvest in conservancies coupled to local value adding and transformed supply chains: In NW Namibia and northern Kenya, sustainable, low impact harvest of *Boswellia* and/or *Commiphora* resins occurs within conservancies. In Namibia, Mane SA (France) is already involved in a transformed *Commiphora wildii* supply chain, where harvesters are getting paid 67% of the wholesale price for the resins they collect (Galloway et al., 2016)[2]. *Commiphora wildii* oil is extracted at a local factory in Opuwo, NW Namibia. Companies such as Arbor Oils of Africa extract oils in *Boswellia* and *Commiphora* oils Kenya.

7.1.2 Transparent supply chains, digital payments and incentives for sustainable harvest: In the Somaliland Autonomous Region of Somalia, a coalition of stakeholders including Lush, Pacha Soap, FairSource Botanicals, and Save Frankincense are working with the Dayaxa Frankincense Export Company to partner with harvesters and incentivize sustainable harvest methods, make traceable digital payments to harvesters to confirm fair pricing, and engage

[1] Higuera, I. 2021. Sustainable use: a powerful tool to ensure the conservation of species of wild fauna and flora. https://cites.org/eng/CITES_S-G_Presentation_ReverseTheRed_IUCN_Congress_sustainableuse_06092021
[2] Galloway, F.B., Wynberg, R.P. and Nott, K., 2016. Commercialising a perfume plant, *Commiphora wildii*: livelihood implications for indigenous Himba in north-west Namibia. *International Forestry Review*, *18*(4), pp.429-443.

with responsible buyers and importing companies. In addition, this group have pioneered a combination of harvester-friendly monitoring with new technologies, where tapped trees are photographed using mobile phones to document tapping practices, marking the GPS locations of harvested trees, so that the status of harvested *B. carteri* populations is traced through the supply chain using blockchain technology, and payments are made via a mobile banking platform for transparency.

7.1.3 Voluntary Certification Standards (VCS): Organic, FairWild and independent: Third-party certification (Fairwild) has been implemented in several Range States. In Kenya, in 2013 and 2014, Arbor Oils of Africa had FairWild certification until this became too costly for a small company. In Somalia, Ecocert, acting as third-party auditors, have awarded Organic certified Nagaad Trading[3] and completed Organic and FairWild certification to Kobac General Trading (see Text Box 1)[4]. In the Somaliland Autonomous Region of Somalia, Neobotanika has Ecocert organic certification for some of its exports[5] and FairWild certification for a smaller component. Frankincense products are also organic certified in Oman (e.g: for the Salalah Frankincense Oil company) (Chapter 5).

Text Box 7.1: CITES vs. voluntary, ethical trade: comparing outcomes in a fragile state[1].
Boswellia range states include the world's most vulnerable and fragile states (such as Somalia, Sudan and Yemen)[1]. Based on the Country Policy and Institutional Assessment (CPIA) Index, for example, Eritrea and Somalia are ranked as the weakest states in sub-Saharan Africa terms of economic management, structural policies, policies for social inclusion and equity, and public sector management and institutions[1]. These weaknesses indicate a low likelihood of implementing international policies such as CITES. In Somalia, for example, the national CITES authorities in Mogadishu have not submitted reports to the CITES Secretariat for almost 20 years, resulting in a trade suspension for all CITES-listed species for Somalia since 2004 (CITES Notification No. 2019/35). In contrast, a major frankincense exporter in Somalia (Kobac General Trading) not only records quantities of myrrh (*Commiphora myrrha*) and frankincense being exported, but works through traditional owners (the clans and sub-clans) in the remote Karkaar mountains, has Ecocert and Fairwild certification, trains frankincense tappers in sustainable tapping techniques and meets social equity criteria[1]. So at a time when CITES listing of *Boswellia* is being considered, it is worth considering the Somalia case as a "natural experiment". The very limited outcomes (a trade suspension) of CITES in this fragile state can be compared against the positive "woodland to warehouse" outcomes of Kobac General Trading due to through their voluntary approach to transparency and training (including of tappers) along the frankincense supply chain in Somalia. Which leads to "what if" questions worth asking in relation to likely outcomes if either the genus *Boswellia* or individual species (such as *B. carteri*) were listed on CITES Appendix II. Examination of this "natural experiment" highlights three important needs. Firstly, to heed Cooney et al's (2020)[1] suggestion to CITES to "*think before you act*". Secondly, to follow the recommendation made by CITES (2018)[1] that "*the complementarities, gaps and potential conflicts between the CBD provisions and CITES regulations, and between conservation, sustainable medicinal use, and impact on livelihoods warrant collaborative efforts between CITES and other pertinent national and international agencies*". Particularly when there are reports of c. 100 000 – 225 000 people earning cash income to support their livelihoods from tapping frankincense in Somalia[1]. And thirdly, to consider what the effects it would have on incentives to maintain trees when the economic value of those trees plummets due to a CITES triggered trade suspension. Fourthly, given an interest in voluntary mechanisms (such as EcoCert and FairWild)[1] and in supply chain transparency (SCT), how would the punitive outcomes of a CITES triggered trade suspension compare to the current positive actions of a major frankincense exporter based in Mogadishu (Kobac General Trading)? Not well. The short answer is that in fragile states, positive outcomes are more likely from voluntary approaches by ethical companies than by punitive trade suspensions.

[3] EcoCert SA. Certificat. Nagaad Trading Company: http://certificat.ecocert.com/client.php?source=recherche&id=9D15885E-00CF-41A4-95AA-B3DD2F30C97E

[4] EcoCert SA. Certificat. Kobac General Trading: http://certificat.ecocert.com/client.php?source=recherche&id=A6AE2228-41D0-49B3-B5AC-12258CF93061

[5] EcoCert SA. Certificat. Neo Botanika: http://certificat.ecocert.com/client.php?source=recherche&id=B6E00BBE-ED8E-4E34-A4D0-3CE7E7BE12B2

In February 2022, Schultz (2022)[6] announced that a third-party audit conducted for the US company PLT Health Solutions by botanical supply expert Trish Flaster (Botanical Liaisons, LLC) had verified that their *Boswellia serrata* supplies were sustainable. In Section 7.2, reasons are given why there is room for improvement of "third-party" audits. Voluntary Certification Schemes (VCS) are a good start. And are far better than *de facto* bans on trade than result through CITES imposed trade suspensions on "non-compliant" countries like Somalia.

Text Box 7.2: Frankincense, Somalia and Lacey Act compliance.

Whether trade is in timber or non-timber products, a key question is how to encourage companies to source responsibly? The Lacey Act Compliance Progam implemented by Young Living Essential Oils is a good example showing that in the absence of CITES regulations, some large buyers are acting responsibly with regards to traceability and natural resource conservation. Including when sourcing *Boswellia carteri* oleo-resins from Somalia. Originally enacted to protect animal species, the US Congress expanded the Lacey Act in 1981 to cover certain plants and plant parts. In 2008, the US Congress substantially expanded coverage of the Lacey Act again to include all types of plants (such as illegally harvested lumber, wood, and plant products). In relevant part, the Lacey Act today makes it a federal crime to import, export, transport, receive, buy, or sell plants or plant products—including essential oils and other natural products—taken or traded in violation of domestic or foreign laws designed to protect plants, and shipped to or within the United States. To encourage inquiry into legal harvest and sourcing of plant products, the Lacey Act creates a "*due care*" standard (defined as "*that degree of care which a prudent person would exercise under the same or similar circumstances*". Young Living's Lacey Act Compliance Program ensures that Young Living exercises due care and diligence through regular research, review, and validation of relevant information regarding plant products imported from foreign suppliers. As well as those purchased from domestic suppliers, the merchandise sold in its stores, and the individuals and organizations with which Young Living conducts business. Specifically, Young Living has developed five pertinent tasks that must be completed for all plant products and plant product suppliers: supplier education, supplier evaluation, supplier certification, risk assessment, and auditing and monitoring. For example, a supplier evaluation is performed on all new and existing plant product suppliers. This includes an evaluation for Lacey Act risk and compliance through regular research of certain product and supplier risk factors, including understanding whether a particular plant species is rare or has its harvest restricted, the corruption of the plant harvesting industry within the country of harvest, the availability of supply chain documentation and transparency in the supply chain, and legal restrictions and validation requirements for verifying legal sourcing. Given the complexity of the essential oils and natural products industry, some due care efforts may require substantial involvement from third-party auditors specializing in environmental and regulatory compliance, local counsel, and in-country contacts. Furthermore, supplier certification is a condition for all suppliers engaging in continued business with Young Living. All Young Living plant product suppliers must certify their compliance and cooperation with Young Living's Lacey Act compliance efforts, including working within their own supply chains to implement their own Lacey Act sourcing standards and practices. In addition, Young Living conducts a thorough risk assessment on all plant products and suppliers to independently assess and assign a risk category determining level of business approvals needed, and scrutiny, to engage in business with a supplier or source a plant product. Finally, regular, and ongoing auditing and monitoring is performed on all plant products and plant product suppliers and includes auditing of purchase order supply chain and legalities, auditing of legal requirements and evidence of compliance, and, as applicable, conducting in-person audits at the supplier's harvest facilities. To further support this robust and comprehensive compliance program, Young Living also provides all employees with annual Lacey Act training and offers mechanisms to report any suspected Lacey Act violation or concern either anonymously or with attribution. Together, these due care and diligence efforts give a positive example of how the Lacey Act has influenced a major US company to source responsibly.

[6] Schultz, H. 2022. PLT says third-party audit verifies sustainability of its *Boswellia* sources. https://www.nutraingredients-usa.com/Article/2022/02/28/plt-says-third-party-audit-verifies-sustainability-of-its-boswellia-sources

One option suggested by Morgan and Timoshyna (2016)[7] is to develop synergies between Voluntary Certification Standards (VCS) and national or international policy regulations. Giving examples of how this could work through the FairWild Standard (FWS) as a voluntary certification scheme (VCS). This could work in "compliant" *Boswellia* range States, but not "non-compliant" range States such as Somalia. Which makes the approach taken by Young Living, a major flavour and fragrance company in the USA, a very interesting one (Text Box 7.2), as the Lacey Act has serious legal "teeth" (Gregg and Porges, 2008)[8]. These "non-CITES" approaches to encourage improved practices and provide important lessons learned which need to be taken into account.

Firstly, there is an opportunity to raise corporate awareness about that fact that inventories, sustainable production and supply chain tracking for cultivated flavour and fragrance components (such as citrus or vanilla) is very different and much simpler to what is required for sustainably managed wild harvest of products such as frankincense. The FairWild Standard (FWS)[9] is an example of what is required.

Secondly, for small companies (and even so more for clan-based “co-operatives”), the costs of third-party certification can be prohibitive. Ideally, these costs need to be carried by larger importing companies until a sufficient scale is reached. This was the case when interested companies supported the development of sustainable wild harvesting for *Schisandra sphenanthera* and a giant panda friendly pro-conservation model that provided an incentive to maintain habitat outside formal protected areas in China (Brinckmann et al., 2018)[10], when importing companies covered the costs of sustainability standards.

Thirdly, in the *Boswellia* case, there are limits to certification, Johnson et al., (2019)[11] high-light in the case of methoxydecane adulteration (from *B. occulta*) in *B. carteri* supply chains. This highlights the need for improvements to traceability along supply chains by organic certifiers.

Fourthly, there is a need to improve existing certification processes for frankincense in the near future. Adequate mapping, field-based inventories and site ground-truthing in *Boswellia* harvest areas are needed to ensure that claims of certified sustainable wild harvest are credible. Doing a "third-party" audit of *Boswellia serrata* by questionnaire from the USA, for example, does not add credence to Schultz's (2022) claim of sustainable supplies, even if harvests are sustainable. The same applies to the FairWild certification (by Ecocert) of 500 tonnes of frankincense from Somalia, where 7 tappers were interviewed: a tiny sample size of tappers (0.7%) considering that 500 tonnes of frankincense would be collected from c. 1 million trees by around 1000 tappers (Johnson, S., pers. comm, 2022). There are betters ways of doing things, and reputational damage of certifiers may be at stake. It is appreciated that the safety of "third-party" auditors working for certification bodies is important, and may preclude them from field inventories or ground-truthing in harvest areas. But claims of "third-party" audits when there has been little or no ground-truthing need to be avoided. One way of getting around this is to use the expertise of tappers themselves, backed up by smartphone-based technology such as Cybertracker (see www.cybertracker.org, Figure 7.1)).

[7] Morgan, B. and Timoshyna, A., 2016. Creating synergies between Voluntary Certification Standards (VCS) and regulatory frameworks: Case studies from the FairWild Standard. *Policy Matters*, *21*: 111-125.

[8] Gregg, R.J. and Porges, A., 2008. *Amendment to the US Lacey Act: Implications for exporters of Indonesian forest products*. Forest Trends, Washington.

[9] https://www.fairwild.org/the-fairwild-standard

[10] Brinckmann, J. A., Wei, L., Xu, Q, He Xin, J. Wu and A. B. Cunningham. 2018. Sustainable harvest, people and pandas: Assessing a decade of managed wild harvest and trade in *Schisandra sphenanthera*. *Journal of Ethnopharmacology* 224: 522–534

[11] Johnson, S., DeCarlo, A., Satyal, P., Dosoky, N.S., Sorensen, A. and Setzer, W.N., 2019. Organic certification is not enough: The case of the methoxydecane frankincense. *Plants*, *8*(4), p.88.

7.2 Technology, management plans and monitoring in remote areas

In March 2021, the international workshop of the Global Frankincense Alliance (GFA) identified the need to: *"Promote the good examples of how to add value within countries and within regions, where more is passed back down the supply chain by ethical traders"...*pointing out that *"The industry needs to develop sustainable supply chains through a combination of technological management plans that have widespread support & combine use of technology & "on the ground monitoring" at multiple scales that gets around the challenges of working in remote &/or often unstable areas".* This is certainly do-able. There is an opportunity, for example, to improve product supply chains and *Boswellia* monitoring and mapping at the same time, through involving selected, trained local community members (such as tappers), who get to remote frankincense harvest areas that outsiders, including certifiers, would struggle to get to.

Over a decade ago, Farah (2008)[12] pointed out that in Oman (which has a single *Boswellia* species (*B. sacra*)), "*standardized resin classification and certification at the wadi of origin or "forest gate" will enable local harvesters to authenticate and enhance the grading, marketability and profitability*" along the supply chain. A decade before that, in the mid-1990's, the free-down-loadable software Cybertracker had been tested for monitoring trees in Uganda and Zimbabwe (Figure 7.1; Cunningham, 2001). The same app could be developed to help tappers in other *Boswellia* range States to identify which *Boswellia* species they are tapping, as well as map and monitor within their harvest areas. After field-based training, *Boswellia* resource monitors trained to use Cybertracker could also get paid for this service through mobile money service app's (such as Zaad (Somalia), Telebirr (Ethiopia) or the Alizz Islamic Bank's mobile money app (Oman)). These could improve field-based certification data and contributing to resource management plans at the same time.

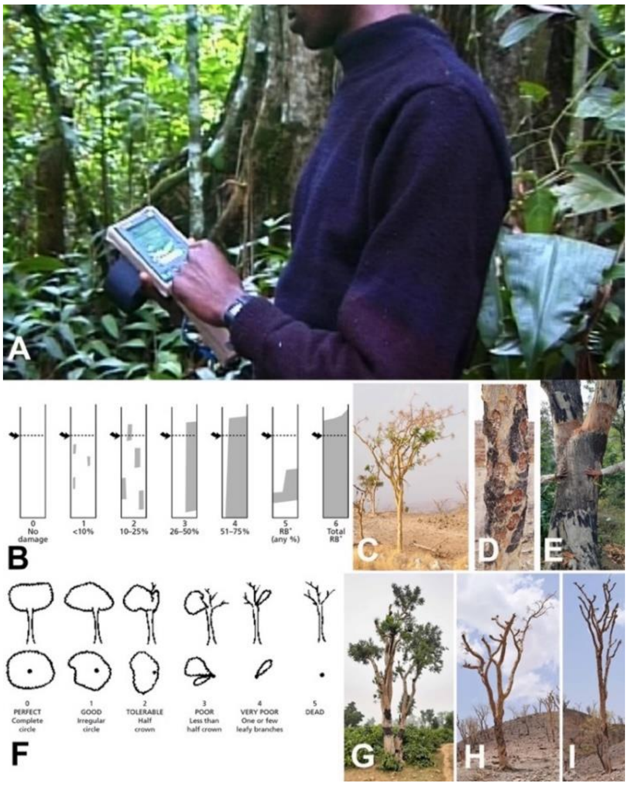

Figure 7.1. Cybertracker is a freely downloadable app. designed for use by knowledgeable local people with low (or no) numeracy or literacy. That could be used to improve *Boswellia* monitoring, management and certification, including the basic use of GPS Cybertracker technology to map harvest areas. **A.** Field testing Cybertracker in Mpanga forest, Uganda in 1996. **B - E.** Visual assessment icons to assess harvest damage (Cunningham, 2001) or **F-I** Crown damage could be purpose-made for application to *Boswellia*. photos: A.B. Cunningham (A), B-E van Wijk (C), S. Johnson (D, H, I) and P. Flowerman (E, G).

[12] Farah, M., 2008. Non-Timber Forest Product (NTFP) Extraction In Arid Environments: Land-Use Change, Frankincense Production And The Sustainability Of *Boswellia sacra* In Dhofar (Oman), s.l.: University of Arizona.

Practical approaches to establishing adaptive management plans for wild plant populations are well established, including community-based approaches (Cunningham, 2001[13]; Stockdale, 2005[14]). Supportive legislation for local community involvement in resource management plans also exists in range States (Section 6.7.1). Positive approaches are viable, and could be broadly scaled out. Encouraging sustainable use and getting “buy in” along the supply chain will enable CITES to contribute to the UN’s Millenium Development Goals (MDG’s). For example, through work with organizations such as TRAFFIC, the Union for Ethical BioTrade (UEBT) and the FairWild Foundation on links between Voluntary Certification Standards (VCS) and legal mechanisms (such as Lacey Act compliance) and with other mechanisms. Based on discussions held during this contract, a workshop with selected frankincense exporting and importing companies could be a productive way of moving things forward.

7.3 That was the good news: now how to avoid the hammer?

Enabling "non-CITES" approaches such as those outlined above would be a positive way for CITES to contribute to "*conserving biodiversity, to building opportunities for resilient and sustainable livelihoods and economic opportunities for communities who most closely rely on nature”* (Higuero, 2021)[15], while enabling CITES to contribute to the UN’s Millenium Development Goals (MDG’s) at the same time. In contrast, CITES Appendix II listings for *Boswellia* are more likely to work against achieving the above objectives that promote them. There are two reasons for this in the *Boswellia* case:

(i) The perception amongst many consumers and the general public that species listed on CITES Appendix II are endangered. Leading to cessation of trade after listing (or in the case of medicinal species on CITES Appendix II, reformulation by companies and a shift to alternative ingredients. This is a long-standing challenge that goes back to 1963, when, as former CITES Secretary-General Wim Wijnstekers (2011)[16] points out:

"In 1963, the IUCN General Assembly passed a resolution calling for “an international convention on regulations of export, transit and import of rare or threatened wildlife species or their skins and trophies”. The limited scope of this resolution may be at the origin of the later title of CITES, which gives the wrong impression that the Convention only concerns endangered species. In my opinion, this really forms a psychological barrier for industries involved in the exploitation of consumer products *derived from e.g. fish and timber. Most consumers will not understand that a species in Appendix II is not endangered when its products are covered by an international convention regulating world trade in ‘endangered’ species. To remove this obstacle, I once suggested using a working title for the convention that was much more neutral, such as CITES, the Wildlife Trade Convention".*

Re-naming of CITES did not happen despite the fact that the former CITES Secretary-General recommended that CITES change its name to avoid the word "endangered". Consequently, the public misunderstanding that species on the CITES list are endangered species, persists almost 50 years later, at a time when social media make consumer power greater than ever before. Recent examples of how this can change medicinal plant markets after CITES App. II listing are *Aloe ferox* and *Hydrastis canadensis*. The misconception that *Aloe ferox* was endangered decimated the South African export market to Japan (van Wyk, B-E., pers. comm., 2022). In 1997, after *Hydrastis*

[13] Cunningham, A.B. 2001. Applied ethnobotany: people, wild plant use and conservation. Earthscan, London.

[14] Stockdale, M., 2005. Steps to sustainable and community-based NTFP management. *Non-Timber Forest Products-Exchange Programme for South and Southeast Asia, The Philippines*.

[16] Wijnstekers, W. 2011. The evolution of CITES. 9th edition. International Council for Game and Wildlife Conservation (CIC). Budapest, Hungary.

canadensis was listed on CITES App. II, several companies reformulated their products, replacing goldenseal (*H. canadensis*) with either Oregon grape root (*Mahonia aquifolium)* or with *Coptis* rhizome (both have berberine content), while other companies took a strong stand to use only cultivated goldenseal. This stimulated the opportunity for ginseng (*Panax ginseng*) farmers in Wisconsin to grow goldenseal under shade as well (J.A. Brinckmann, pers. comm., 2022). For reasons given in Section 6.4, a shift from wild harvested *Boswellia* to plantation production faces considerable challenges.

(ii) **The effects of the CITES-imposed trade suspensions:** As discussed in Chapters 5 and 7, these are in place for both Djibouti (since 2004, Notification No. 2011/010, Notification No. 2018/015) and Somalia (Notification No. 2019/35) and would affect re-exports of Ethiopian frankincense through Djibouti.

For these reasons it is worth the CITES Secretariat considering pragmatic alternatives that reduce the chances of "unintended consequences" for both plants conservation and people.

Annex 1

Addendum to Recommendations

Author: Anjanette DeCarlo

The consultants could not agree as to whether to add an additional recommendation under Recommendation 4 (which would become Recommendation 4 (iiii)). The suggested recommendation is not currently included in the present version of Chapter 2.

<u>Tony Cunningham believes the following should be added as Recommendation 4 (iiii):</u>

"**(iiii) The preliminary IUCN Red List status of *B. papyrifera* needs to be finalized:** Without a doubt, *B. papyrifera* is the most studied of all *Boswellia* species. *Boswellia papyrifera* is also the source of most commercially traded frankincense. Threats to this species are synthesized in Bongers et al (2019), who suggested IUCN Red List category of Vulnerable (A2cd + 3cd), with Thulin (2020) "preliminarily" agreeing with that assessment. In addition, Bongers *et al.* (2019)'s research synthesis generated considerable publicity, including the suggestion by Muys (2019)[1] in the same prestigious journal (Nature Sustainability) that frankincense was "*facing extinction*", despite the fact that it is known to exist in at least six additional Range States where it was not studied. Given the emotiveness and general lack of public awareness about conservation threat terminology (such as "Extinction", "Endangered", "Vulnerable"), the CITES Secretariat needs to liaise with the IUCN Red List authorities to finalize the level of threat faced by *B. papyrifera*.

To place the preliminary threat level into context, it's worth asking, **Is a preliminary conservation status of VU A2cd+3cd a reflection of a worst-case scenario?** Global IUCN Red List rankings are very influential in the process of setting priorities for conservation action. For this reason, it is important that the preliminary rating of *B. papyrifera* as Vulnerable (**VU A2cd+3cd)** based the predicted decline of the population by 50% in 20 years is finalised. The studies predicting this population collapse were conducted in the three Range States (Ethiopia, Sudan, Eritrea) where the vast majority of resin harvesting and production takes place, with a particular focus on Ethiopia (Bongers et al. 2019). Although these three Range States contain major *B. papyrifera* populations, likely including the core populations, there are an additional six known Range States (Chad, Niger, South Sudan, Nigeria, Cameroon, Uganda) where populations have been recorded. The status of these populations is largely unknown. Based on current distribution data, *B. papyrifera* has an estimated EOO of over 3 million km^2 (3038498 km^2), as recently calculated by one of Professor F. Bongers students using GBIF data (Bongers, F. pers. comm., 2022). This includes large EOO's in southern Chad and a distribution across to Cameroon and Nigeria. The Area of Occupancy (AOO) of *B. papyrifera* is 1.8 million km^2. The populations in Chad and Cameroon are reported to be much smaller than the populations in Ethiopia and Sudan (Bongers, F., pers. comm. 2022; Betti 2020[2]); still, given the large EOO, there are potentially a billion or more *B. papyrifera* trees across their whole range.

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[1] Muys, B., 2019. Frankincense facing extinction. Nature Sustainability, 2(8): 665-666

[2] Betti, J.L. 2020. Etat des lieux sur la biologie, l'exploitation, et le commerce des especies du genre Boswellia (Burseraceae) au Cameroon. Report submitted to the twenty-fifth meeting of the CITES Plants Committee, Doc PC25 Inf. 3.

While most or all *B. papyrifera* populations likely face similar threat factors across their range (conversion of woodland to farmland, browsing by livestock, lopping for fodder, firewood collection, etc.), the impacts may be less acute in the lesser-studied Range States. The best studies Range State, Ethiopia, may represent a “worst case” scenario. As Ethiopia has the largest livestock population in Africa. Between 1995 and 2013 livestock numbers in Ethiopia increased from from 54.5 million to over 103.5 million, with average annual increase of 3.4 million (Leta and Mesele, 2014)[3]. Which must have increased vulnerable of *B. papyrifera* to grazing pressure. Radical policy changes (for example during the Derg period in Ethiopia (1974 – 1991)) and the persistent instability in frankincense production areas in Sudan, Eritrea, and Ethiopia due to warfare and refugee camps have also undermined customary tenure over woodlands and placed additional the *Boswellia* trees. Ongoing conflicts in other Range States (Chad, northern Nigeria and Uganda, etc.) have likely impacted *Boswellia* woodlands as well, although the magnitude is unknown. In any case, the large EOO of this species is encouraging, and makes imminent extinction unlikely (despite the claim of Muys 2019). The documented, ongoing population declines in Ethiopia, Sudan, and Eritrea are concerning, but information on the populations and threats across its entire range should be integrated before a final IUCN Red List status can be determined definitively.”

<u>Anjanette DeCarlo disagrees with this addition, for the following reasons:</u>

“In direct consultation with Dr. Frans Bongers:

1) The suggestion that *B. papyrifera* trends in Bongers et al. (2019) are overstated and that this may only account for Ethiopia is not correct. Eritrea is at least the same, and so are most areas in Sudan, all based on hard data.

2) The areas of Chad (and further west), South Sudan and Uganda have small areas, few locations and low density. An herbarium record from south Benin, and the EOO and AOO that are reported (these preliminary data, are still based on records that maybe doubtful). The one record in Benin and the two records in Uganda strongly expand the areas. According to the IUCN methodology this still translated into VU. Bongers has never stated that *B. papyrifera* will go extinct (but Muys 2019 did), he has said in our communications, there are many trees, if the major populations die back and disappear or turnover into a different community, then the current trade is in peril, even if the species does not go extinct. This still holds firmly.

Furthermore, the EOO and AOO are actually still being calculated and Dr. Bongers advises against using the numbers at this stage.

3) However, Dr. Bongers has expressed concern that a CITES listing could potentially be counterproductive to conservation with a trade suspension at port of Djibouti. He also supports a postponement of a CITES vote to 2025 to give exporting countries an opportunity to collect more data in other range states and improve *Boswellia* management especially now that everyone is on notice.”

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[3] Leta, S. and Mesele, F., 2014. Spatial analysis of cattle and shoat population in Ethiopia: growth trend, distribution and market access. *SpringerPlus*, *3*(1), pp.1-10.

Annex 2

Summary table for identification criteria and identification methods for oils and resins of *Boswellia* species that dominate international trade

	B. carteri	*B. sacra*	*B. papyrifera*	*B. frereana*	*B. serrata*	*B. dalzielii*	*B. neglecta*	*B. rivae*	*B. occulta*
Organoleptics									
Scent	Fresh; Rich; Floral (blossom); Sweet-resinous; Slightly citrus (lemon); Slightly coniferous	Rich; Fresh; Sweet-resinous; Slightly woody; Green-peppery; Sweet-coniferous	Slightly black licorice-sweet; Ambergris-like; Sour citrus; Leathery-terpeney	Fresh; Rich; Slightly sweet resinous; Woody; Earthy; Black peppery	Sweet-resinous; Black peppery; Earthy-resinous; Terpeney	Fresh; Earthy-resinous; Coniferous; Green-lemon like; Sweet-woody	Resinous; Sweet- woody; Balsamic; Citrus	Diffusive; Sweet-resinous; Slightly black peppery; Green lemon-like; Fresh-coniferous; Balsamic	Fresh; Ethereal green-resinous; Vanilla creme
Visual (Resin)	Translucent to opaque resin tears, multicolored but mostly yellow, pale, and white; sometimes dark colored and clumped together	Translucent to opaque resin tears, multicolored but mostly yellow, pale, and white; sometimes dark colored and clumped together	Translucent to opaque resin tears, yellow, pale, and white	Golden to yellow translucent to opaque tears, striated with white	Translucent to opaque resin tears, multicolored but mostly yellow, pale, and white; sometimes dark colored and clumped together	Translucent to opaque resin tears, multicolored but mostly yellow, pale, and white; sometimes dark colored and clumped together	Bark, clumped pieces, often with pieces of direct and wood included	Bark, clumped pieces, often with pieces of direct and wood included	Yellow to white opaque pieces of resin
Visual (Essential Oil)	Clear to yellow mobile liquid	Clear to yellow mobile liquid	Clear to yellow mobile liquid	Clear to yellow mobile liquid	Clear to yellow mobile liquid	Clear to yellow mobile liquid	Clear to yellow mobile liquid	Clear to yellow mobile liquid	Clear to yellow mobile liquid
Physical Properties									
Solubility (Resin)	Partially soluble in ethanol and water	Partially soluble in ethanol and water	Partially soluble in ethanol and water	Completely soluble in ethanol; insoluble in water	Partially soluble in ethanol and water	Partially soluble in ethanol and water	Partially soluble in ethanol and water	Partially soluble in ethanol and water	Partially soluble in ethanol and water
Solubility (Essential Oil)	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water	Soluble in ethanol, insoluble in water
Optical Rotation (essential oil)	-30° to +5°	+15° to +45°	N/A	N/A	+24° to +35°	N/A	-17° to +15°	-20° to +15°	N/A
Refractive Index (essential oil)*	1.46-1.485	1.43-1.485	1.42-1.48	1.4-1.47	1.4-1.5	N/A	1.4-1.48	1.4-1.565	N/A
Specific Density (essential oil)	0.84-0.88 g/ml	0.84-0.88 g/ml	0.84-0.88 g/ml	0.84-0.88 g/ml	0.81-0.85 g/ml	0.84-0.88 g/ml	0.84-0.88 g/ml	0.84-0.88 g/ml	0.84-0.88 g/ml
Biomarkers									
Chemical Marker Compounds	?	?	Significant portion of incensole acetate, high level of octyl acetate, sometimes a high level of verticilla-4(20),7,11-triene	Significant portion of α-phellandrene dimers, trans sabinene hydrate acetate in some samples; no boswellic acids	Methyl chavicol (estragole), Methyl eugenol	high AKBA content	Level of terpinen-4-ol >5% in the essential oil	Verbenol as one of the top 10-15 components	Methoxyalkanes, particularly 1-methoxydecane, 4,10 di-*epi*-guaiol
Characteristic Composition	20-50% α-pinene, 1-20% limonene, myrcene, viridiflorol, *p* -cymene, α-thujene; other chemotypes known similar to *B. frereana* but lacking the α-phellandrene dimers; Boswellic acids with varying composition but often low KBA and AKBA (not true for all samples)	60-80% α-pinene, various other terpenes such as δ-3-carene, camphene, myrcene, limonene; compared to B. carteri, often lack of viridifloral, incensole, dimethyl ether orcinol, and cembrenol; low total KBA content and low proportion of α-KBA	50-80% octyl acetate, 5-15% octanol, incensole, incensole acetate, boswellic acids, particularly AKBA and β-ABA,	Dominant in α-thujene and α-pinene, with smaller amounts of sabinene, *p* -cymene, and α-phellandrene dimers; no boswellic acids but large amounts of lupeol and 3-*epi* -lupeol	α-thujene dominant, although a myrcene chemotype has also been described; serratol, kessane, methyl eugenol, and methyl chavicol; boswellic acids, particularly β-BA and β-ABA; higher proportion of deacetylated boswellic acids and lower proportion of acetylated boswellic acids	α-pinene dominant, with a very rare myrcene/limonene chemotype reported as well; boswellic acids, particularly AKBA; minimum 3:1 AKBA: β-BA ratio	Dominant in α-pinene; α-thujene, *p* -cymene, and terpinen-4-ol as other major components, sometimes verbenone; low level of boswellic acids or domination of β-boswellic acids with very little AKBA	α-pinene, limonene, δ-3-carene, and sometimes β-pinene, *p* -cymene, or *trans* -verbenol; boswellic acids present but at very low levels	Methoxyalkane dominant; boswellic acids and incensole present
Known Bosi Index Range*	-5,376 to 46,026	13,137 to 307,249	7,196 to 34,172	N/A	-21,112 to -2,909	134,345 to 303,439	0 to 888	0	23,059
Chirality of Characteristic Essential Oil Components	20-59% (+)-α-pinene	79-99% (+)-α-pinene	N/A	100% (+)-α-thujene	N/A	0-2% (+)-α-pinene	N/A	50-55% (+)-α-pinene	N/A
Known Adulterants	*B. occulta, B. neglecta, B. rivae* ; possibly some types of *Commiphora* , though this seems to be rare	*B. sacra*	No known adulterants; mixture with other *Boswellia* resins would be apparent from spikes in α-pinene, verbenol, etc.	*Boswellia occulta* , possibly *B. carteri*	Other *Boswellia* ; Pinaceae, revealed by longifolene and longipinene sesquiterpenes; possibly *Garuga pinnata*	None known.	*Commiphora confusa* ; possibly other species of *Commiphora*	Various *Commiphora* resins; Gum arabic; possibly other species of *Boswellia*	Often mixed with other *Boswellia* resins
Look Alike Species/Genera	*B. occulta, B. neglecta, B. rivae, B. sacra*	*B. sacra*	None known	*Boswellia carteri* ; *B. frereana* can be distinguished by the high levels of α-phellandrene dimers	*B. ovalifoliolata* ; Pinaceae and possible *Garuga pinnata* resin	*B. papyrifera*	*Commiphora confusa* and some other *Commiphora* resins; *B. rivae, B. microphylla, B. globosa*	Various *Commiphora* species; *B. neglecta, B. microphylla, B. carteri*	*B. carteri*

Annex 3

US Imports of Frankincense/Olibanum materials 2020 and 2021 based on US Customs bills of lading

(1) Abbreviations: Bc, *B. carteri*; Bd, *B. dalzielii*; Bf, *B. frereana*; Bp, *B. papyrifera*; Bsa, *B. sacra*; Bse, *B. serrata*
(2) Gum resin equivalent for essential oil (EO) of *B. carteri* and *B. sacra* estimated at average 6% yield
(3) Gum resin equivalent for essential oil (EO) of *B. papyrifera* estimated at average 1.5%
(4) Gum resin equivalent for Olibanum Resoid 30 PCT TEC (in 30% triethyl citrate solution) not yet known
(5) Gum resin equivalent for Olibanum SFE (supercritical CO_2 soft extract) not yet known
(6) Olibanum Resinoid in 40% DPG (dipropylene glycol) made from Extraction with ethyl alcohol of gum resin of *Boswellia carterii* and related species, 1 kg is made from about 1 kg of gum
(7) Olibanum Resinoid Extra in 50% DPG (dipropylene glycol Extraction with ethyl alcohol of gum resins of *Boswellia carterii* and related species; 1 kg is made from about 1 kg of gum
(8) Olibanum Resinoid MD (molecular distillation), Extraction with ethyl alcohol followed by molecular distillation of gum resins of Boswellia carterii and related species; 1 kg is made from about 20 kg of gum
(9) Where yellow highlighted, the shipment included other materials without quantifying each separately, which makes an exact quantification not possible. Thus, in some cases, where the container contained only one or two other items, "guess-timates" of an equal proportion of items listed in the container are made. However, in cases where the container listed "many" items, estimating proportions was not done.

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
	FRANKINCENSE/OLIBANUM ESSENTIAL OILS										
2020											
2020-1-9	**Bulgaria:** Esseterre	dōTERRA	X						10 Transtore tank steel totes Frankincense oil Carterii IBC steel (31A), IMO Class 3, UN 1169, Net wt. 10911 kg Gross wt.13043 kg	10,911	181,850
2020-1-16	**Oman (Salalah):** not disclosed	Omni Logistics, Salt Lake City, Utah (actual buyer not known)					X		Chemical Boswellia sacra EO SF 122 20 steel drum 5 pallets PO 4500011855/1 UN NO 1993 // IMO Class 3 PACKING GROUP III HS CODE 33011900	3,955	65,917
2020-2-1	**France:** Bontoux SAS	Bontoux, Inc.	**X**						Olibanum EO [website claims *B. carteri*] & many other items	**?**	**?**
2020-2-22	**India:** Natures Natural India	Vital's International Group						X	*B. serrata* EO & several other items	?	?
2020-3-5	**India:** Euroasias Ingredients Pvt. Ltd.	Euroasias Organics, Inc.							Frankincense EO & several other items [10,400 kg total]	?	?

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
2020-3-16	**India**: Katyani Exports	Health and Beauty Natural Oils	X						Frankincense EO (Katyani website claims *B. carteri*) & several other items [5,355 kg total]	?	?
2020-4-10	**India:** Not disclosed	Not disclosed							Natural essential oil-herbal oils for aromatherapy purposes (Eucalyptus oil, cinnamon oil, grapefruit oil, FRANKINCENSE oil); HS code:33012990	?	?
2020-4-10	**France:** not disclosed (ECU Worldwide France)	Not disclosed (ECU Worldwide USA)							5 package(s) 1127.5 kg 2.141 MTQ (cubic metre) loaded on 2 pallets Frankincense EO UN 1169	1,127.5	?
2020-4-10	**France:** Albert Vielle, Givaudan	Young Living Essential Oils							On 2 pallets Frankincense EO Class 3 PGIII UN 1169 HS code: 3301294100	1,128	18,800
2020-4-11	**Oman** (Salalah): not disclosed	Omni Logistics, Salt Lake City, Utah (actual buyer not known)					X		Olibanum Oil, Boswellia sacra EO, stainless steel drum X (12), HDPE X (4) IMCO CL 3 / UNNO 1993	3,129	52,150
2020-4-22	**France:** H. Reynaud & Fils	H. Reynaud & Fils USA	X						Essential oils other than of citrus fruit N metal drum 50 kg Olibanum Oil RD 156665 UN 1169 extracts aromatic liquids (alpha pinene dipentene) 3 III FP 43.5 DEG. C	?	?
2020-5-4	**France:** Bontoux SAS	Bontoux, Inc.	X						Olibanum EO [website claims *B. carteri*] & many other items	**?**	**?**
2020-5-15	**China:** not disclosed (Shanghai Danube International Logistics)	Not disclosed (Danube Logistics USA)							Frankincense oil HS code: 3301299999; and many other items	**?**	**?**
2020-5-19	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Hind Aroma & Extracts, Inc.						X	8 UN GI drums of 175 kg containing: Frankincense (Olibanum)Oil HS code: 33019090	1,400	**?**
2020-5-27	**Bulgaria:** Esseterre	dōTERRA	X						5 Trans Tore Tanks Steel Totes Frankincense Oil, Carterii - IBC steel (31A), IMO CLASS 3, UN 1169, Net Wt. 5397 kg, Gross Wt. 6460 kg	5,397	89,950
2020-6-7	**Spain:** Aromasur S.L. (**France:** Albert Vielle, Givaudan)	Young Living Essential Oils	X						On 1 pallet Frankincense EO CLASS 3 PGIII UN 1169 HS code: 33012941	795	13,250

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
2020-6-29	**Spain:** Aromasur S.L. (**France:** Albert Vielle, Givaudan)	Young Living Essential Oils	X						*B. carteri* EO & clove EO [3,186 kg total] HS code: 3301294100	*1,593*	*26,550*
2020-7-6	**France:** Bontoux SAS	Bontoux, Inc.	X						Olibanum EO [website claims *B. carteri*] & many other items	***?***	***?***
2020-7-10	**Bulgaria:** Esseterre Bulgaria Ltd.	dōTERRA	X						10 Transtore tanks steel totes Frankincense oil, Carterii I BC STEEL (31A), IMO CLASS 3, UN 1169, Net Wt. 11,099 kg Gross Wt. 13,223 kg	11,099	184,983
2020-7-10	**Bulgaria:** Esseterre Bulgaria Ltd.	dōTERRA			X				3 (1H1) plastic drum Frankincense Frereana Oil IMO CLASS 3, U N 1169, Net Wt. 564 kg, Gross Wt. 612 kg	564	?
2020-7-10	**Bulgaria:** Esseterre Bulgaria Ltd.	dōTERRA				X			1 Transtore tank steel tote Frankincense Papyrifera oil IBC STEEL (31A) Net Wt. 1,077 kg and 2 (1H1) plastic drum Frankincense Papyrifera Oil Net Wt. 370 kg	1,477	96,467
2020-7-14	**Oman** (Sallalah): not disclosed	Omni Logistics, Salt Lake City, Utah (actual buyer not known)					X		Olibanum Oil Boswellia sacra EO Package 3 pallets IMCO CLASS 3 / UN NO 1993 Gross Wt. 2462.4 kg, Net Wt. 2160 kg	2,160	36,000
2020-7-21	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Phoenix Aromas & Essential Oils						X	Frankincense Oil	60	?
2020-8-2	**India:** Greenleaf Extractions Pvt. Ltd.	Prinova USA						X	10 drums Olibanum (Frankincense) Oil packed in 10X200 kg HDPE drums HS Code: 33012990 CAS NNo: 8016-36-2	2,000	?
2020-8-2	**India:** not disclosed (EMU Lines Pvt. Ltd.)	Not disclosed (The Ultimate Freight Management)							19 UN GI drums of 175 kg containing: Frankincense (Olibanum) Oil HS Code: 33019090	3,325	?
2020-8-4	**Oman** (Salalah): not disclosed	Omni Logistics, Salt Lake City, Utah (actual buyer not known)					X		Olibanum Oil *Boswellia sacra* EO, 3 pallets, Gross wt. 2462.4 kg, Net wt. 2160 kg UN number 1993, class 3	2,160	36,000
2020-8-27	**China:** not disclosed	Not disclosed							Frankincense EO, & eucalyptus EO and orange EO [1,353 kg total]	?	?

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
2020-8-30	**India:** Aromatic & Allied Chemicals Pvt Ltd	A to Z Beauty, LLC							Frankincense EO & many other items	?	?
2020-9-4	**India:** not disclosed (Strive Shipping Services)	Not disclosed (Impex GLS Inc.)							**06 UN GI drums** of 175 kg containing: Frankincense (Olibanum) Oil HS Code: 33019090; **04 UN GI drums** of 175 kg containing: BMOU5556289 001 Frankincense (Olibanum) Oil HS Code: 33019090	1,750	?
2020-9-8	**France:** Bontoux SAS	Bontoux, Inc.	X						Olibanum EO [website claims *B. carteri*] & many other items	**?**	**?**
2020-8-14	**India:** Not disclosed (VS Trans Lojistik LLP)	Not disclosed (LAM USA International)							Organic Frankincense EO and many other items	**?**	**?**
2020-9-16	**India:** Katyani Exports	Health and Beauty Natural Oils	X						Frankincense EO (Katyani website claims *B. carteri*)	7,586	126,433
2020-9-16	**India:** SOM Extracts Ltd.	Not disclosed (Swift Cargo)							Frankincense Oil Rect (Special fraction) HS code: 330119 and several other items	?	?
2020-10-1	**Bulgaria**: Esseterre	dōTERRA	X						6 Transtore tanks steel totes Frankincense Oil Carterii IB C STEEL (31A), IMO CLASS 3, UN 1169, Net Wt. 6642 kg, Gross Wt. 7918 kg	6,642	110,700
2020-10-6	**India:** Not disclosed (Dahnay Logistics Pvt. Ltd.)	Not disclosed (Dahnay Logistics USA)							Frankincense Oil and many other items	?	?
2020-10-7	**India**: Not disclosed (EMU Lines Pvt. Ltd.)	Not disclosed (Amass Intl Group)							Frankincense Oil and many other items	?	?
2020-10-16	**India:** Greenleaf Extractions Pvt. Ltd.	Lakshmi International						X	Olibanum (Frankincense) Oil HS code: 33012990 CAS NO. 8016-36-2 packed in 25 X 180 kg HDPE drums	4,500	?
2020-10-17	**Bulgaria:** Esseterre	dōTERRA	X							1,152	19,200
2020-10-18	**India:** Greenleaf Extractions Pvt. Ltd.	Lakshmi International						X		4,715	?
2020-11-8	**India:** Sri Venkatesh Aromas	Not disclosed (Swift Cargo Inc.)						X	Organic Frankincense Oil and many other items	?	?

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
2020-11-9	**Spain:** Aromasur S.L. (**France:** Albert Vielle, Givaudan)	Young Living Essential Oils	X						On 2 pallets Frankincense EO Class 3 PGIII UN 1169 Invoice 2031649 HS code: 33012941	1,147	19,117
2020-11-9	**France:** HELPAC	NOW Foods	X							463	7,717
2020-11-14	**France:** Bontoux SAS	Bontoux, Inc.	X						Olibanum EO [website claims *B. carteri*] & many other items	**?**	**?**
2020-11-25	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Hind Aroma & Extracts, Inc.						X	*B. serrata* EO, *B. serrata* extract & many other items [16,425 kg total]	**?**	**?**
2020-12-18	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Hind Aroma & Extracts, Inc.						X	4 HDPE drums of 175 kg containing: Frankincense (Olibanum-Serrata) Oil, HS code: 33019090	700	**?**
2020-12-23	**Oman** (Salalah): not disclosed	Omni Logistics, Salt Lake City, Utah (actual buyer not known)					X		Olibanum oil *Boswellia sacra* essential oil, Class 3 UN number 1993	2,466	41,100
2020-12-28	**Bulgaria:** Esseterre	dōTERRA	X							9,950	165,833
2020-12-28	**India:** not disclosed (MPRS Shipping Logistics)	Not disclosed (Air 7 Seas Transport Logistics)						X	1 drum of 180 kg each net containing Frankincense (Olibanum-Serrata) Oil HS code: 33019090	180	?
2020-12-28	**Italy**: Matières Premières Essentielles (France) but processed at Europiemont facility in Italy	John D. Walsh Co., Inc.							Steel drums of Olibanum EO & many other items (MPE uses Somalian & Kenyan *Boswellia* spp)	?	?
2021											
2021-1-8	**France:** H. Reynaud & Fils	H. Reynaud & Fils USA	X						Olibanum Oil RD & many other items	?	?
2021-01-19	**Oman** (Salalah): not disclosed	Omni Logistics, Salt Lake City, Utah (actual buyer not known)					X		Olibanum Oil 6 pallets (20 drums) Boswellia sacra essential oil / class 3 / UN Number 1993 HS code: 33012990	3,964	66,067
2021-1-31	**Bulgaria:** Esseterre	dōTERRA	X						7 Transtore tanks steel totes Frankincense Oil Carterii IBC steel (31A), IMO Class 3, UN 1169, Net Wt. 7837 kg, Gross Wt. 9328 kg	7,837	130,617

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
2021-1-31	**Bulgaria:** Esseterre	dōTERRA				X			2 (1 H1) plastic drums Frankincense Papyrifera Oil Net Wr. 370.00 kg, Gross Wt. 394 kg	370	?
2021-2-19	**India:** not disclosed (Team Global Logistics)	Not disclosed (Shipco)						X	004 HSCD 33019090 Indian Frankincense EO	2,210	?
2021-3-1	**India:** Sri Venkatesh Aromas	Health and Beauty Natural Oils						X	Organic Frankincense Oil	1,494	?
2021-3-17	**India:** not disclosed	Not disclosed						X	Frankincense (Olibanum-Serrata) oil, HS code: 33019090 and other items	?	?
2021-4-17	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Hind Aroma & Extracts, Inc.						X	*B. serrata* EO & many other items	**?**	**?**
2021-4-19	**France:** HELPAC SAS	NOW Foods	X						*B. carteri* EO & ylang ylang EO [2,027 kg total]	*1,013.5*	*16,892*
2021-5-3	**China:** dōTERRA Shanghai	dōTERRA	X						Blend (*B. carteri* EO with fractionated coconut oil) [2 pallets, 7 drums, 1,130 kg total] HS code: 3304990029	*565*	*9,416*
2021-5-14	**Bulgaria:** Esseterre	dōTERRA	X						3 Transtore steel tank totes Frankincense oil Cartierii - IBC steel (31A), IMO Class 3, UN 116 Net Wt.3345 kg Gross Wt.3984 kg	3,345	55,750
2021-5-14	**Bulgaria:** Esseterre	dōTERRA				X			4 (1H1) plastic drums Frankincense Papyrifera oil Net wt. 740. Kg Gross wt. 814 kg	740	*?*
2021-5-19	**Spain:** Vida de Seville Distillery [exported by SANTIA SARL, **Morocco**]	Young Living Essential Oils	X						*B. carteri* EO, & cedarwood EO & rosemary EO [4,909 kg total] HS Code: 3301290	*1,636.3*	*27,272*
2021-6-17	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Hind Aroma & Extracts, Inc.						X	12 HDPE drums of 175 kg each net containing: Frankincense (Olibanum-Serrata) oil: HS code: 33019090	2,100	**?**
2021-6-24	**France:** H. Reynaud & Fils	H. Reynaud & Fils USA	X						Olibanum Oil RD	50	**833**
2021-6-30	**India:** not disclosed (Allcargo Logistics Ltd.)	Not disclosed							Olibanum oil	17,823	**?**

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
2021-8-9	**Spain:** Vida de Seville Distillery [exported by SANTA SARL, **Morocco**]	Young Living Essential Oils	X						*B. carteri* EO & rosemary EO [6,664 kg total] HS Code 3301290	*3,332*	*55,533*
2021-8-14	**India:** WOW Skin Science	WOW Skin Science							WOW Skin Science Frankincense essential oil - 10mL bottles	*?*	*?*
2021-8-17	**India:** not disclosed	Not disclosed							Frankincense EO	1,676	*?*
2021-8-29	**France:** not disclosed	Bontoux Inc.	X						Olibanum EO [website claims *B. carteri*] & many other items	*?*	*?*
2021-9-3	**France:** HELPAC SAS	NOW Foods	X						*B. carteri* EO & myrrh EO [1,020 kg total]	*510*	*8,500*
2021-9-3	**Bulgaria:** Esseterre	dōTERRA	X						11 Transtore steel tank totes Frankincense oil Carterii IBC steel (31A), IMO Class 3, UN 1169, Net wt. 12253 kg,, Gross wt. 14596 kg	12,253	204,217
2021-9-3	**Bulgaria:** Esseterre	dōTERRA			X				2 (1H1) plastic drums Frankincense Frereana oil -IMO Class 3, UN 1169 , Net wt. 370 kg, Gross wt. 410 kg	370	?
2021-9-3	**Bulgaria:** Esseterre	dōTERRA				X			5 (1H1) plastic drums Frankincense Papyrifera oil, Net wt. 925 kg, Gross wt. 1025 kg	925	?
2021-09-22	**Oman** (Salalah): not disclosed	Omni Logistics, Salt Lake City, Utah (actual buyer not known)					X			5,154	85,900
2021-10-3	**Bulgaria:** Esseterre	dōTERRA	X						6 Transtore tanks steel toes Frankincense oil Carterii - IBC steel (31A), IMO Class 3, UN 1169, Net wt. 6821 kg, Gross wt.8099 kg	6,821	113,683
2021-10-11	**Oman:** Wilhelmsen Towell Co., LLC	dōTERRA					X		Olibanum oil, Boswellia sacra essential oil SFO/126ARC SF210211A SKU 3360001761 Frankincense IMO CLASS 3 / UN NO 1993	2,379	39,650
2021-10-15	**France:** H. Reynaud & Fils	H. Reynaud & Fils USA	X						Olibanum Oil, 50 kg steel drums	19,147	319,117

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Descriptions	EO qty (kg)	Gum resin equivalent (kg)
2021-20-23	**India:** Not disclosed (Greenwich Meridian Logistics)	Not disclosed (Air 7 Seas Transport]							FRANKINCENSE (SERRATA) OIL (H.S.CODE : 33019090) and many other items	?	?
2021-10-24	**China:** not disclosed	Not disclosed							Frankincense EO & several other items	?	?
2021-11-5	**France:** HELPAC SAS	NOW Foods	X						SLAC ON 1 PALLET STC Frankincense essential oil	692	11,533
2021-11-8	**China:** Not disclosed	Not disclosed							Frankincense oil Class 3,UN 1169 PK:III and many other items	?	?
2021-12-10	**Bulgaria:** Esseterre	dōTERRA	X						4 Transtore steel tank totes Frankincense oil Carterii IBC steel (31A), IMO Class 3, UN 1169 Net wt.3445.00 kg Gross wt.4185 kg	3,445	57,417
2021-12-16	**India:** SOM Extracts Ltd.	Plant Therapy, LLC						X	Frankincense EO (probably *B. serrata*)	393	?
2021-12-21	**China:** Not disclosed	Not disclosed							Frankincense oil Class 3,UN 1169 PK:III and many other items	16,010	?
2021-12-27	**France:** Bontoux SAS	Bontoux, Inc.	X						Olibanum EO [website claims *B. carteri*] & many other items	**?**	**?**

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Extract or resinoid qty (kg)	Gum resin equivalent (kg)
	EXTRACTS AND RESINOIDS										
2020											
2020-2-6	**Spain:** not disclosed (Transglory SA freight forwarders)	Not disclosed (Shipco Transport)							STC Ocimene BHT Olibanum Coeur DEP FREE 50% TEC (in 50% triethyl citrate solution)	?	?
2020-4-14	**Spain:** not disclosed (Transglory SA freight forwarders)	Not disclosed (Shipco Transport)							STC Olibanum Coeur DEP FREE 50% TEC (in 50% triethyl citrate solution)	21,621	?
2020-4-19	**Spain:** not disclosed (DHL Global Forwarding)	Not disclosed (DHL Global Forwarding)							Olibanum Resoid 40% DPG (dipropylene glycol) BLO	6,862	?
2020-5-17	**Spain:** not disclosed (Transglory SA freight forwarders)	Not disclosed (Shipco Transport)							STC Olibanum Coeur DEP FREE 50% TEC (in 50% triethyl citrate solution) HS code: 330290; and other items	?	?
2020-5-17	**Spain:** not disclosed (DHL Global Forwarding)	Not disclosed (DHL Global Forwarding)							Olibanum Resoid 30% TEC BLO (in 30% triethyl citrate solution)	6,179	?
2020-5-19	**Germany:** Symrise AG	Symrise, Inc.							Olibanum Resinoid SP 600010 - HS code: 33013000 UN 3082; and many other items	?	?
2020-6-17	**Spain:** not disclosed (Transglory SA freight forwarders)	Not disclosed (Shipco Transport)							STC Olibanum Coeur DEP FREE 50% TEC (in 50% triethyl citrate solution)	23,247	?
2020-7-12	**Spain:** not disclosed (Transglory SA freight forwarders)	Not disclosed (Shipco Transport)							STC Olibanum Coeur DEP FREE 50% TEC (in 50% triethyl citrate solution)	7,950	?
2020-7-19	**Spain:** not disclosed (Eculine Spain S.A.)	Not disclosed (ECU Worldwide USA)							Mixtures of odoriferous substances etc. NESO 1 drum Olibanum Resoid 30% TEC BLO HS (extract co-distilled with 30% triethyl citrate (TEC) solution)	?	?
2020-8-10	**Spain:** not disclosed (DHL Global Forwarding)	Not disclosed (DHL Global Forwarding)							Olibanum Resoid 30% TEC BLO	11,665	?
2020-9-6	**Spain:** not disclosed (Transglory SA freight forwarders)	Not disclosed (Shipco Transport)							4 PK 224 kg Olibanum Coeur DEP Free 50% TEC (in 50% triethyl citrate solution) HS code: 330290	224	?
2020-10-14	**India:** Not disclosed	Not disclosed						X	Boswellia serrata extract powder and many other items	?	?
2020-11-9	**Spain:** not disclosed (DHL Global Forwarding)	Not disclosed (DHL Global Forwarding)							STC Olibanum Resoid 30% TEC BLO HS COD (extract co-distilled with 30% triethyl citrate solution)	17,005	?

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Extract or resinoid qty (kg)	Gum resin equivalent (kg)
	EXTRACTS AND RESINOIDS										
2020-11-25	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Hind Aroma & Extracts, Inc.						X	Boswellia serrata extract powder: and many other items	?	?
2020-12-2	**Spain:** IFF Benicarló, S.L.	John D. Walsh Co., Inc.							Olibanum Resoid 30% triethyl citrate (TEC) solution (extract co-distilled with 30% TEC); & several other items [1,659 kg total]	?	?
2020-12-28	**Italy:** Matières Premières Essentielles (France) but processed at Europiemont facility in Italy	John D. Walsh Co., Inc.							Resinoids plastic drums Olibanum Resinoid, UN 3077 CL 9 PG III	10,457	?
2021											
2021-1-10	**Spain:** IFF Benicarló, S.L.	John D. Walsh Co., Inc.							Olibanum Resoid 30% triethyl citrate (TEC) solution (extract co-distilled with 30% TEC); and several other items [2,070 kg total]	?	?
2021-2-10	**Spain:** not disclosed (DHL Freight)	Not disclosed (DHL Freight forwarding)							Mixtures of odoriferous substances etc. and 1 drum Olibanum Resoid 40% DPG (dipropylene glycol) BLO	?	?
2021-3-2	**Spain:** not disclosed (DHL Freight)	Not disclosed (DHL Freight forwarding)							Mixtures of odoriferous substances etc. NESO 1 drum Olibanum Resoid 30% triethyl citrate (TEC) solution (extract co-distilled with 30% TEC); 1 drum Olibanum Resoid 40% DPG (dipropylene glycol) BLO	?	?
2021-3-3	**Italy:** Matières Premières Essentielles (France) but processed at Europiemont facility in Italy	John D. Walsh Co., Inc.							Olibanum Resinoid and many other items [3,382 kg total]; Boswellia resin from Somaliland, Kenya and/or India	?	?
2021-3-15	**France:** Firmenich	Firmenich USA							Olibanum SFE (supercritical CO_2 soft extract) and Siam Benzoin Resinoid [544 kg total]	?	?
2021-4-8	**Italy:** Matières Premières Essentielles (France) but processed at Europiemont facility in Italy	John D. Walsh Co., Inc.							Olibanum Resinoid and many other items; Boswellia resin from Somaliland, Kenya and/or India	?	?

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Extract or resinoid qty (kg)	Gum resin equivalent (kg)
	EXTRACTS AND RESINOIDS										
2021-6-17	**India:** Hindustan Mint & Agro Products Pvt. Ltd.	Hind Aroma & Extracts, Inc.						X	40 HDPE drums of 25 kg each net containing: Boswellia serrata extract 65 powder: HS code: 13021919	1,000	?
2021-6-18	**Spain:** not disclosed (Transglory SA freight forwarders)	Not disclosed (Shipco Transport)							STC bicyclononalactone / peomosa / olibanum co (fragrance blend)	?	?
2021-6-24	**Italy:** Matières Premières Essentielles (France) but processed at Europiemont facility in Italy	John D. Walsh Co., Inc.							Olibanum Resinoid and several other items; Boswellia resin from Somaliland, Kenya and/or India	3,260	?
2021-7-22	**Spain:** IFF Benicarló, S.L.	John D. Walsh Co., Inc.							Olibanum Resoid 30% triethyl citrate (TEC) solution (extract co-distilled with 30% TEC); and six other items [1,604 kg total]	?	?
2021-8-2	**Spain:** not disclosed	Not disclosed (DHL Global Forwarding)							STC Olibanum Resoid 30% TEC (in 30% triethyl citrate solution)	8,392	?
2021-8-10	**France:** Firmenich	Firmenich USA							Olibanum SFE (supercritical CO_2 soft extract) & Elemi Resinoid [556 kg total]	**?**	**?**
2021-8-10	**Spain:** not disclosed	Not disclosed (DHL Global Forwarding)							STC Olibanum Coeur DEP FREE 50% TEC (in 50% triethyl citrate solution)	13,719	**?**
2021-8-29	**Italy**: Matières Premières Essentielles (France) but processed at Europiemont facility in Italy	John D. Walsh Co., Inc.							Olibanum Resinoid & many other items; Boswellia resin from Somaliland, Kenya and/or India	**?**	**?**
2021-10-15	**France:** not disclosed	Not disclosed							Olibanum Resinoid and many other items	**?**	**?**
2021-11-5	**Spain**: not disclosed	Not disclosed							S.T.C. Olibanum Resoid 40% DPG (dipropylene glycol) BLO	9,619	**?**
2021-12-4	**India:** Arjuna Natural Pvt. Ltd.	Arjuna Natural LLC USA						X	*Boswellia serrata* extract (BosPure®) min. 40% total boswellic acids & min. 10% ABKA (acetyl keto β boswellic acid)	500	**?**
2021-12-7	**India**: Pharmanza Herbal Pvt. Ltd.	Verdure Sciences						X	*Boswellia serrata* extract (WokVel®) & several other items	**?**	**?**
2021-12-8	**India**: not disclosed (Magiclogisys Global Pvt Ltd.)	Not disclosed (Gateway International LLC)						X	*Boswellia serrata* extract powder 20 & several other items	**?**	**?**

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Extract or resinoid qty (kg)	Gum resin equivalent (kg)
	EXTRACTS AND RESINOIDS										
2021-12-8	India: Arjuna Natural Pvt. Ltd.	Arjuna Natural LLC USA						X	*Boswellia serrata* extract (BosPure®) min. 40% total boswellic acids & min. 10% ABKA (acetyl keto β boswellic acid)	4,205	?
2021-12-8	India: OmniActive Health Technologies Ltd.	OmniActive Health Technologies, Inc.						X	*Boswellia serrata* extract powder 20% boswellic acids	6,322	?
2021-12-13	India: Pharmanza Herbal Pvt. Ltd.	Verdure Sciences						X	*Boswellia serrata* extract (WokVel®) & several other items	**?**	**?**
2021-12-16	India: not disclosed (Montane Shipping Pvt. Ltd.)	Not disclosed (Amass Global Network US, Inc.)							Boswellia extract 95% and other items	**?**	**?**
2021-12-26	India: not disclosed	Not disclosed (Longo Aviation)						X	*Boswellia serrata* extract, gymnema extract, tulsi extract and other items	**?**	**?**
2021-12-30	Spain: IFF Benicarló, S.L.	John D. Walsh Co., Inc.	X						Olibanum Resoid 30% triethyl citrate (TEC) solution (extract co-distilled with 30% TEC); and several other items [1,133 kg total]	**?**	**?**
2021-12-31	India: Dolphin International Pvt. Ltd. (Bio Natural)	Orcas Naturals						X	Boswellia serrata extract	**2,838**	**?**

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Qty (kg)
	FRANKINCENCE/OLIBANUM GUM RESIN									
2020										
2020-1-6	**Somaliland**: Neo Botanika	Neo Gr. Ltd.							30 bags of 50 kg each Gum Olibanum Grade A certified organic	1,500
2020-1-9	**Germany**: Ernst H. Singelmann GmbH & Co.KG	Max Van Pels, Inc.							Gum Olibanum (Singelmann trades mainly in *B. carteri* und *B. papyrifera*)	8,472
2020-2-23	**Sudan:** Africorp International, Ltd.	Mercantil Villacarriedo SA de C.V. (Mexico)							1,280 bags Sudanese Gum Olibanum (Africorp trades in various *Boswellia* species)	32,000
2020-3-27	**India:** Roshan Overseas	Bobby Persad Limited (Trinidad & Tobago)							Gum Olibanum & many other items	?
2020-4-9	**Jordan:** Ard Alforat Storing & General Trade	Mr. Labeeb Alani, Ing. (Illinois)							Frankincense 25 kg bags, Gross Wt. 25,594 kg (probably includes other items in shipment)	?
2020-4-10	**Egypt:** Rosaroma	Connplants S.A.S. (Colombia)	X						Gum Olibanum (*B. carteri*) 252 bags of 25 kg net each, NW 6,300 kg	6,300
2020-4-15	**UAE:** Maydi Frankincense Natural Oil LLC	Resinolia (Burien, WA)							STC Frankincense Resin, 43 pieces, Gross Wt. 1,190 kg, HS code: 1301 9091	1,075
2020-5-9	**Yemen:** Alrasheed International For Export Import	Alsaeedah Grocery & Spices LLC - Samir Abdulmalak							Frankincense and many other products in shipment	?
2020-6-2	**Egypt:** Gs Herbs	Norberto Del Rosario Villegas (Mexico)							375 bags of Frankincense Net Wt.: 18,750 kg	18,750
2020-7-7	**Iraq:** Ard Alforat General Trading Co.	Mr. Labeeb Alani, Ing. (Illinois)							Frankincense 25 kg bags, Gross Wt. 24,704 kg (probably contains other items in shipment)	?
2020-8-12	**Germany:** not disclosed (Oceanic Container Line GmbH)	Not disclosed (Share Logistics)							50 bags Gum Olibanum 1st Grade 2,500 kg net, 40 bags Gum Olibanum pea size 2.000 kg net	4,500
2020-8-13	**India:** not disclosed	Not disclosed							Frankincense Incense	535
2020-8-23	**India:** Kanu Krishna Corporation	Casa Abascal S.A. (Mexico)						X	1 X 20 FCL = 980 bags Indian origin Gum Olibanum synthetic pea size of Gujarat origin, RI TC NO. 38062001 net wt. 24500.00 kg	24,500
2020-9-9	**Sudan:** Africorp International, Ltd.	Casa Abascal S.A. (Mexico)							Sudanese Gum Olibanum (Africorp trades in various *Boswellia* species)	16,000
2020-9-21	**India:** Regency Spices, LLP	Mercantil Villacarriedo SA de C.V. (Mexico)						X	1,000 bags of 25 kg each net Gum Olibanum (*B. serrata*)	25,000

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Qty (kg)
	FRANKINCENCE/OLIBANUM GUM RESIN									
2020-9-21	**India:** Kanu Krishna Corporation	Viveres El Triunfo S.A. de C.V. (Mexico)						X	Gum Olibanum (*B. serrata*), Gujarat origin	3,750
2020-9-25	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 24,955 kg (possibly other items in shipment?)	?
2020-10-2	**Egypt:** Rosaroma	Connplants S.A.S. (Colombia)	X						Gum Olibanum (*B. carteri*) 360 bags of 25 kg net each, NW 9,000 kg	9,000
2020-10-15	**Germany:** not disclosed (Oceanic Container Line GmbH)	Not disclosed (Share Logistics)							41 bags Gum Olibanum 1st Grade 2,016 kg net, 100 bags Gum Olibanum Peasize 5,000 kg net	7,016
2020-10-18	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 24,368 kg (possibly other items in shipment?)	?
2020-10-25	**Djibouti:** AZ Church Supply, LLC	Sinoceras S.A. de C.V. (Guatemala)							Gum Olibanum Grade 2 (8,000 kg) & Gum Olibanum Grade 3 (8,000 kg)	16,000
2020-11-1	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 26,015 kg (possibly other items in shipment?)	?
2020-11-11	**India:** Geo Fresh Organics	Starwest Botanicals Inc.						X	Organic Boswellia serrata (Frankincense) and many other items	?
2020-12-3	**Germany:** not disclosed (Oceanic Container Line GmbH)	Not disclosed (Share Logistics)							60 bags Gum Olibanum 1st Grade, 3,000 kg net	3,000
2020-12-9	**Germany**: not disclosed (Somalia origin)	Not disclosed							60 polybags with inner bag X 10 kg 600 kg net Olibanum Somalia Siftings	600
2020-12-21	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 24,660 kg (possibly other items in shipment?)	?
2020-12-26	**Djibouti:** AZ Church Supply, LLC	Sinoceras S.A. de C.V. (Guatemala)							FCL / Gum Olibanum Grade 2	16,000
2021										
2021-1-10	**Somaliland**: Neo Botanika	Neo Gr. Ltd.							64 bags of 25 kg each Gum Olibanum Grade A certified organic	1,600
2021-1-18	Undisclosed	undisclosed							Frankincense incense	711
2021-1-27	**India:** Regency Spice, LLP	Plantas Mexicanas de Exportación SA de C.V. (Mexico)						X	960 bags of Gum Olibanum (*B. serrata*)	24,000

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Qty (kg)
	FRANKINCENCE/OLIBANUM GUM RESIN									
2021-3-26	**Germany:** not disclosed (Oceanic Container Line GmbH)	Not disclosed (Share Logistics)							100 bags Gum Olibanum 1st grade 5,000 kg net	5,000
2021-4-8	**India:** Regency Spices, LLP	Mercantil Villacarriedo SA de C.V. (Mexico)						X	1,040 bags of 25 kg net: Gum Olibanum (*B. serrata*)	26,000
2021-4-19	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 23,465 kg (probably contains other items in shipment)	?
2021-4-27	**Somalia:** Ismael Imports LLC	Ismael Import LLC (Vermont)			X				Organic Boswellia frereana resin MEYDI 140 items 7000 kg	7.000
2021-4-27	**Somalia:** Ismael Imports LLC	Ismael Import LLC (Vermont)	X						Organic Boswellia carteri resin MOHOR 140 items 7000 kg	7.000
2021-5-21	**Egypt:** Rosaroma	Connplants S.A.S. (Colombia)	X						480 bags of 25 kg net: Gum Olibanum (*B. carteri*)	12,000
2021-6-14	**Germany:** not disclosed (Oceanic Container Line GmbH)	Not disclosed (Share Logistics)							80 bags Gum Olibanum 1st grade 4,000 kg net; 80 bags Gum Olibanum Pea size 4,000 kg net	8,000
2021-6-20	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 23,100 kg (possibly other items in shipment?)	?
2021-6-30	**Not disclosed**	Not disclosed (Mara Shipping Freight)							Olibanum (Frankincense)	1,572
2021-7-22	**Egypt:** Herb Land A.R.E.	Whole Herb Co.	X						*B. carteri* tears	750
2021-7-25	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 23,665 kg (possibly other items in shipment?)	?
2021-8-1	**UAE:** Halima Abdi Warfa	Saba Hailu (Georgia)							Frankincense table cover, Nigella sativa seed oil, garments, kitchenware	?
2021-8-20	**Djibouti:** AZ Church Supply, LLC	Sinoceras S.A. de C.V. (Mexico)							Gum Olibanum Grade 2 (10,000 kg) & Gum Olibanum Grade 3 (6,000 kg)	16,000
2021-9-21	**Egypt:** Elbadr Co. for Import Export	Transporte Multimodal S.A. de C.V. (Mexico)							280 bags of Olibanum big size (N.W:7000KG) & 80 bags of Olibanum medium size (N.W:2000KG) HS.CODE 13019032	9,000
2021-9-24	**Sudan:** Habab Shamsa Import and Export	Green Distribuição, Importação e Exportação Ltda (Brazil)				X			Gum Olibanum	13,000

Date	Exporter	US Importer	Bc	Bd	Bf	Bp	Bsa	Bse	Cargo Description	Qty (kg)
	FRANKINCENCE/OLIBANUM GUM RESIN									
2021-20-12	**India:** M. S. Parekh & Co.	Ramakrishnananda's Gifts (Prabhuji's Gifts) New York							Frankincense and Gum Copal [total 2948.0 kg]	?
2021-10-15	**Germany:** Ernst H. Singelmann GmbH & Co.KG	Max Van Pels, Inc.							80 bags Gum Olibanum 1st grade (2,000 kg) and 80 bags Gum Olibanum Peasize (4,000 kg) (Singelmann trades mainly in *B. carteri* und *B. papyrifera*)	6,000
2021-10-26	**Iraq:** Ard Alforat General Trading Co.	Euphrates Foods LLC (Illinois)							Frankincense 25 kg bags, Gross Wt. 24,596 kg (probably many other items in shipment)	?
2021-10-30	**Djibouti:** AZ Church Supply, LLC	Sinoceras S.A. de C.V. (Mexico)							Gum Olibanum Grade 2	13,000
2021-12-7	**India:** JABS International Pvt. Ltd.	Abastos García, S.A. de C.V. (Mexico)						X	Gum Olibanum (presumably *B. serrata*)	20,060
2021-12-23	**UAE:** Halima Abdi Warfa	Lemlem Asmara Wholesale And Retail (Seattle)							Charcoal, Frankincense, tea cups, prayer mats, kitchen ware, etc.	?

global frankincense alliance

The Main Outcomes and Road Map

The Future of Frankincense Online Workshop

March 15th, 17th, 18th 2021.
1-4 pm GMT.

Three main messages

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1 Each of the 24 species of Boswellia are different and face different current conditions and threats. Differences mentioned in the workshop include different genetic pathways, phenotypes, ranges, needs, growing habits, habitats and regeneration patterns. The resins and oils also have different constituents, medicinal and aromatic properties and end uses. Each species has different dynamics of socio-economic and environmental management, or mis-management, ownership (or not), harvesting (or not). Gathering accurate information on the current ranges, status, mortality and regeneration rates and health of the different species and populations has consistently emerged as a top research priority

2 The frankincense value chain has many steps and currently a very small percentage of the overall profits return to the harvesters. Through focal group discussions organized with local scientists, harvesters, collectors, traders and researchers in Somaliland, Ethiopia, Kenya and Oman shared their requests for access to steady fair prices and markets, regulated working conditions, safety and protective equipment, food, water, healthcare, education and adult literacy, supportive infrastructure and community development.

3 To be able to sustain the long term future of the species and their products, and the long term commitment of the communities which depend on them, accurate information on the whole value chain is required. There is variation between species in sorting and storage, trade routes, local regional, national and international trade licensing and regulations and different pressures, threats and challenges. Targeted actions towards a sustainable future is currently scattered and limited. Moving forward depends on coordinated and focused information gathering, collaboration, research and action.

“Of course we should not treat frankincense as a single monolithic entity. We need to look at the different situation and threats that each individual species faces and not extrapolate from one species to the next.”

Focusing on Frankincense trees and the communities that harvest them

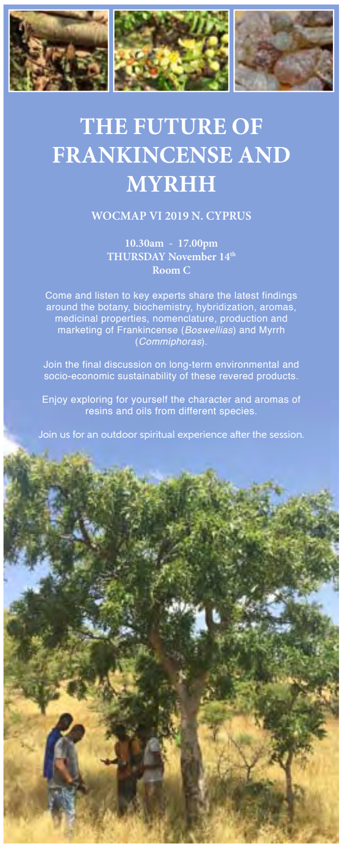
Frankincense is the resin produced in response to injury of the under bark of trees of the Boswellia species. There are currently 24 recognised species. Some species have limited geographical range. For instance, 11 species are endemic to the island of Socotra in the Red Sea between Yemen and the Horn of Africa. Yet together, Boswellia serrata, B.sacra, B.papyrifera, B.dalzielii, B.neglecta and B.rivae spread across at least 17 countries, from India, across the Arabian peninsula, the greater Horn of Africa to West Africa, with some individual species ranges spanning more than 2000kms[1]. The trees tend to grow in arid/semi-arid conditions, supported either by orographic moisture (B.sacra, B.frereana,) and/or seasonal rain (B.serrata, B.papyrifera, B.dalzielii, B.neglecta and B.rivae). Many trees grow in the relatively inaccessible areas where populations have access to limited resources. Gathering accurate information on the current ranges, status, mortality and regeneration rates and health of the different species and populations, has consistently emerged as a top research priority.

[1] E.g. *B. neglecta* spans from Northern Tanzania to Northern West Ethiopia

Frankincense is one of the oldest known globally traded products and has been a valued ingredient in Asian traditional medicine systems for millennia. Boswellia papyrifera from Ethiopia has for the last few decades been the most traded resin, both internally within Ethiopia and exported for religious and other purposes. Especially in the last decade there has been a surge in the use of the essential oils distilled from traded Boswellia resins for aromatherapy and other uses. Most frankincense commercial oil is extracted from Boswellia sacra (and B.sacra syn carteri) resin from Somalia/ Somaliland and Oman, with lesser amounts from Boswellia serrata, B. papyrifera, B. rivae, B. neglecta and B. dalzielii. So far four species, B.serrata, B. sacra, B. papyrifera and B. dalzielii, have also shown high levels of four main bioactive boswellic acids in the resin (not the essential oils or hydrosol). In vitro and in vivo research and one or two clinical trials using resin extracts of Boswellia serrata, sacra and other species have demonstrated anti-inflammatory, anti-microbial, fungal, viral and cytotoxic effects.

The current and potential increase in demand for resin has led to a growing concern about the long term viability of the trees, the well-being of the harvesters and the harvesting practices; particularly in accessible heavily harvested areas. Many species face multiple challenges including grazing from livestock, fire, land conversion (for agriculture, roads, mining etc.), lopping and felling for household needs as well as climate, and environmental stress. The challenges may differ between species and between locations within the range where a species occurs. For some species and some areas we have little factual information. There are a few reports of extensive healthy forests of B.neglecta and B.rivae across the Somali region of Ethiopia and Northern Kenya, and natural regeneration has been reported in Oman, Sudan and Western Ethiopia. At the same time, there are well-documented reports of declining populations and a lack of regeneration in Ethiopia, Eritrea, Sudan, Somaliland and reports of decline of B.serrata in India[2].

There is very little documented information on the communities and harvesters themselves. According to one study over a quarter of a million people are estimated to be dependent on Frankincense for over 50% of their income in the East Golis / Saanag region of Somaliland alone[3]. With dependent forest tribes in Madhya Pradesh in India, to extra dry season income for Samburu women, to Somali clans living deep in the bush, the exact number of those for whom the currently small extra income ensures survival and access to food, water, healthcare and education is unknown. A major focus of this workshop has been to ask 'What are the main gaps in our knowledge?' and 'What can we do?'.



Given the rising concern about the well-being of the trees and communities, a growing platform, named the Global Frankincense Alliance (GFA) was created by concerned individuals out of a special session on Frankincense and Myrrh at WOCMAP. At the same time, an informal working group on Boswellia had been initiated within the UN Convention on International Trade on Endangered Species (CITES) to gather accurate data on the range, status and health of the trees and how they may be being impacted by international trade. Due to COVID, the second International Conference on Frankincense and Medicinal Plants in Oman has been postponed until 2022. GFA decided to create an open online workshop called 'The Future of Frankincense' to gather those concerned to prioritise and coordinate current research needs, as well as to craft a roadmap of the most important and urgent activities. Over 300 people filled in the pre-workshop survey[4] and between 96 - 106 people attended each day.

[2] See Bongers et al (2019), DeCarlo et al (2020)
[3] FSNAU FAO & FEWS NET (2016)
[4] See Outcomes of the pre-workshop online survey

As mentioned above, the purpose of the on-line dialogue has been to prioritise what we need to know and do to support the long-term future of frankincense trees and the communities that harvest and depend on them. With over 100 people participating each day, it was agreed to keep a core of participants discussing in themed working groups. Each of the four themes, outlined below, had two break away groups who joined on the last day to collate their final prioritised lists. Parallel main room conversations focused first on the communities and secondly on conscious consumerism. While it was highlighted that the workshop was a great opportunity for networking, the main intended outcome of the workshop is a ROADMAP of the gaps in information, the actions we need to take and how we can take them.

The Theme and Breakout room leaders were:

1. **Theme 1: Botany identification & current status of the trees:** Professor Sebsebe Demissew, Dr Shahina Ghazanfar, Stephen Johnson.
2. **Theme 2: Communities, intentional propagation & forest management:** Professor Frans Bongers, Dr Anjanette de Carlo.
3. **Theme 3: Biochemistry and Medicinal Applications:** Professors Ahmed al-Harrasi and Abdul Latif Khan, Ahmed al-Rawahi.
4. **Theme 4: Supply chains, products, regulations and trade:** Professors Ben-Erik van Wyk and Tony Cunningham, Denzil Phillips.

“Generally speaking there is not a clear understanding between local taxonomies versus western taxonomies. So obviously the western taxonomies are pretty dynamic as they are, new species are being described at the moment and if we keep doing field work and taking herbarium specimens I am sure we will find more and more species.”

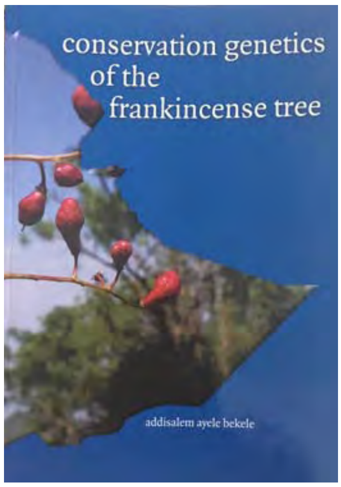
The Road Map

The most pressing gaps in knowledge and the actions identified in each theme are:

Theme 1: Botany, identification, and current status of the trees

GAP 1: How do we collectively gather adequate information on the current distribution and status of each of the Boswellia species populations?

ACTION 1: We need to fund and coordinate data collection on the current distribution and status of each of the Boswellia species population, (ages, structures and regeneration), the harvesting practices and pressures and how broader ecosystem issues of degradation, other threats and/ or climate change are affecting the status of each Boswellia species in their different populations and ranges. Multi-layered climate, soil and vegetation data can propose possible ranges of the different species. We then need to use strategic sampling and rapid qualitative and quantitative research, combining basic quantitative surveys with significant local integration/participation and focusing on local knowledge, in fully explained/consenting partnership with local communities. There is a need to develop functional tools that can be used by a combination of local university students and communities to assess the trees and yields. Range changes and shifts can be assessed from historical data, as well as a comprehensive inventory of where natural or intentional propagation and regeneration is happening.



GAP 2: How to have a central repository of information?

ACTION 2: Compile all the disparate information into an accessible location/ database so that there is a comprehensive and publicly available understanding of the current knowledge base, in order to identify what other information is urgently needed. Who can do this work? Who funds and coordinates it?

GAP 3: How to deeply understand how harvesters relate to the trees?

ACTION 3: There is an urgent importance of engaging further with the harvesting communities who actually manage the trees and understand how they perceive, engage with and manage the Boswellia trees. How do their local taxonomies, observations and cultural understandings of the trees and resins Interface with 'western' botanical taxonomies, research and understanding? How do these both, in turn, link up with the current perceived quality and value of each resin or essential oil product as it enters the current value chains? A lot of useful data by engaging with these groups as equal partners on the status and future of the different Boswellia populations.

GAP 4: How can the resin, essential oils and other products of each species be tracked back to specific species and woodlands?

ACTION 4: Understand and share how the different species, resins and essential oils are currently identified and develop tools to trace resins from their source and the specific resins and oils being harvested and traded. There is a need to develop tools to trace resins from their source into the global market. How can this be done and funded effectively? What specific markers should be looked at? What makes the most sense to be deployed? For instance, if the question is 'Can buyers or customs easily identify a resin or oil?'; What cost effective accessible tools and markers can be developed to differentiate and link resins and essential oils back to specific trees, populations and species?

> *"The other topic that came up again and again is exploring the options to add value and shortening the supply chain between communities and the market."*

Theme 2: Communities, regeneration (intentional propagation) and forest management.

COMMUNITIES

GAP 1: How we can make sure that local communities have a long-term involvement with the trees and resin and have a fair role and share in the long-term sustainable management and use?

ACTION 1a: We need to find out who are the owners and harvesters in each location? What are their harvesting practices and why? How they are currently organised and paid? How reliant are they on the resin harvest? What are their ownership and land use rights, their understanding of, connection to and long term relationship with the trees? Cooperatives are seen as the future, but beware of powerplays and rules and regulations. It may be questionable to take the past as a model for the present.

ACTION 1b: Cycle Assessments of resin. Follow the plants that produce the resins (how resin is made, how collected, how transported etc.). Evaluate ways to monitor this. Select good cases and detail what and why these are good cases (of forest management and local people involvement), across the whole range.

ACTION 1c: Education and training is needed at all levels, including at local and national government as well as company levels (e.g. Forest departments and their rules and regulations have immense impact)

ACTION 1d: Map per country the companies that get into the forest and use the forest, forest ownership, local regulations, any contestations on ownerships/use rights? Compile an overview of all the rules and regulations per species/country and the implications of these for the situation on the ground. (Forest level, species level. Regulatory taxes, concession rules and payments.

The need to develop a code of conduct for harvesters, buyers and producers (as in other value chains).

> *"Even within Ethiopia, there are 5, 6 or 7 different local forest management schemes for the same and different species; let alone the differences between range countries."*

ACTION 1e: Harvesters, cooperatives and communities need a fairer share of the overall profits. International buyers need to choose the responsible within-country companies to trade with and have checks and balances, as well as an ability to check out espoused practices. Third party voluntary certifications schemes are useful but can be expensive to maintain for small scale cooperatives and companies unless more value returns to them.

FOREST AND TREE MANAGEMENT

GAP 2: How can we maintain forest and woodland health, and improve forest management and long-term sustainability and use? And how do we translate this into guidelines specific for species, countries and regions?

ACTION 2a: Engage in care for the present forests and woodlands. Develop ways to select areas to protect and set aside for regeneration, enrichment of standing forests and trees and to prevent conversion to other land uses.

ACTION 2b: Incentivise reforestation and plantation/enrichment planting/more species at the same time; i.e.: Combine any long-term plantations with enrichment of standing forests. All those involved along the value chain need to engage in community and forest management and maintenance, not only in profiting from the resin.

GAP 3: How to overcome challenges of large scale enrichment and/or propagation?

CHALLENGES TO ACTION 3: Frankincense trees can take 5-15 years to generate revenue. There are many technical genetic, biophysical, and agronomical issues to overcome with plantations as well as concerns that ex-situ or company owned plantations will not support investment in and empowerment of indigenous communities and forests.

ACTION 3: Compile available knowledge on plantation issues. Develop new experiments based on best practices, country and species specific. Develop comparative study across species and countries, which will lead to generalization for the genus. We need to care for current forests, ensure regeneration by set aside and prevent conversion to other land uses and combine any long-term plantations with enrichment of standing forests.

(NB: There is currently a focus on and funding for tree planting in semi - arid areas, especially in Africa. Investigate including endemic Boswellia (B.papyrifera /B.dalzielii) in the Green Wall Initiative).

Theme 3: Biochemistry and Medicinal Applications

GAP 1: How do we correct the misinformation about the bioactivity and uses of Frankincense as natural medicines?

ACTION 1a: Cancer, COVID and inflammation can usefully be key targets of specific boswellic acids and derivatives in vitro and vivo trials, as well as the synergistic effects of whole resin extracts of specific species. Safety pharmacology should be the key during such trials. When used for medicinal purposes, Frankincense resin products, the essential oils or other derivatives must go through pre or clinical trials/protocols to establish the bioactive chemical constituents and CMC (chemistry-manufacturer-control). The results of these trials needs to be followed up and taken through the country-specific regulatory pathways Medicinal properties should be understood from the basic to the end use product for a specific treatment.

> *“We are now talking about massively increased production of research based products and scientists are very concerned about the sustainability issue and it has to go in both directions A massive production of frankincense products <> Issue of sustainability.”*

ACTION 1b: Correct the misinformation about the bioactivity and uses of Frankincense as natural medicines. The group suggested that a non-technical report needs to be created and disseminated and spread to the public to create awareness of what has been scientifically technically proven and what has not.

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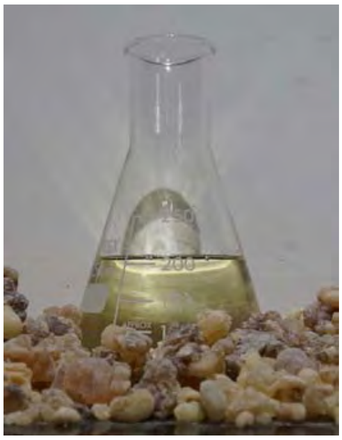
GAP 2: How can we overcome the uncertainties created in the literature by using unvouchered samples and different libraries and techniques?



ACTION 2a: We need a joint research collaboration across community, scientists, government regulatory bodies and industries to carry out the basic chemical analysis of the resins and oils of multiple specimens of accurately sourced frankincense of each species is urgently needed. We need to fully understand the origin and source, as well as the biosynthetic pathways and genes responsible for producing the resins. This is urgent because while the resins and oils of each species can demonstrate some consistent terpenoid composition, the % of each constituent can vary considerably across different populations of the same species, probably due to genetic, environmental, seasonal, extraction and testing methodologies and protocols and other unknown factors. High throughput screening technology (HTS) may really help to identify the constituents and find key species specific markers. Building on this research we need essential oils research from basic constituents and compositions, to quantification, and dermal research, and to identify the kinds of boswellic acids that remain in the residual waste product after hydro-distillation oil extraction.

GAP 3: How can genomics assist in identifying species?

ACTION 3: Create international collaboration to find ways to gather the equivalent samples to do molecular and genomics analysis of each species to develop a dataset of sequences for broader taxonomy and population diversity across populations. Carry out more research on the chemistry of ignored frankincense species and their medicinal properties through in vivo and in vitro approaches.

GAP 4: What is the impact of climate change on Frankincense?

ACTION 4: Urgent research is needed on climate change impacts on chemistry and biochemistry, tree growth, harvesting, soil biology, microbial symbiosis and pathogenesis

> *"We do not want to get to the point where pseudo-science and misinformation is used to sell the product."*

GAP 5: How do we do this?

ACTION 5: Networking, Collaboration, Consortium: Establishing a consortium or collaboration of scientists (chemists, biologists, taxonomists), who can offer resources, expertise and time. How to fund such research?

Theme 4: Supply chains, products, regulations and trade

Overarching question: How can reliable, socially beneficial, ecologically sustainable & economically viable supply chains be developed that recognize diverse source species & production regions? *NB: Recognising very diverse uses (nationally) & diverse international markets (resin, essential oils, boswellic acids, fragrances).*

GAP 1: How can transparent, traceable supply chains be developed that deal with this diversity?

ACTION 1: Explore new technologies for tracing supply chains in a transparent way, to deal with adulteration, encourage sustainable harvest & raise awareness (business & consumers). NB: Block chain technology applied for years to food markets, (Rejeb Et al 2020) more recently carbon markets & suggested for medicinal plants.... lots of hype & significant barriers. (Kouhizadeh et al., 2021) There are practical limitations in some countries. Adapt a variety of tracing systems, from pen & paper to bar codes, using smart phones. Traceability is essential to go to scale (& deal with adulteration & safety issues).

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GAP 2: Where & under what circumstances is sustainable, commercial harvest possible?

There are good examples (e.g.: collection of naturally exuded resins in Somali region of Ethiopia and Northern Kenya) as well as examples of "what not to do" (Frans Bonger's team's work highlighting Boswellia declines in areas of Ethiopia, Eritrea & Sudan (Bongers et al 2019); Somaliland (De Carlo et al 2020), and Socotra (Lvoncik et al 2020). Research in Ethiopia suggests when owners & harvesters are different, it can have a negative impact on sustainability vs. community ownership (more chance of sustainable harvest). Active research and case studies on effective cooperative structures and producer associations (e.g.: as for baobab) can be initiated, supported and shared. Participants from Somalia and Somaliland pointed out how 30 years ago there were organised cooperatives, but that these have fallen away. Challenges now arise when big buyers prepay harvesters, then pay low prices, with the value addition of grading (which needs to adapt to market needs) & processing happening later.

> *"What came out and one of the big issues is the financial issue on how local people are part of the value chain and how finances, organisation, power very much determines their relative position in the field and their relative position towards the trees and the forest. What we realised is that this is so very different from one area to another one and one species to another."*

ACTION 2: Promote the good examples of how to add value within countries and within regions, where more is passed back down the supply chain by ethical traders. Educate and engage with creating a code of ethics for buyers and traders. The industry needs to develop sustainable supply chains through a combination of technological management plans that have widespread support & combine use of technology & "on the ground monitoring" at multiple scales that gets around the challenges of working in remote &/or often unstable areas. *NB: The multi-scale approach (LANDSAT mapping, monitoring resin yields, plot based inventories combined to understand potential yields for communities and harvesting cooperatives).*

GAP 3: Where & under what circumstances is cultivation possible at sufficient scale to supplement harvest from wild stocks?

ACTION 3: Collate lessons from Oman (B. sacra) and Jason Eslamieh's work in the USA (including hybrids) with the known challenges of growing other Burseraceae. Combine seed & seedling distribution & selection of farmer entrepreneurs with secure tenure over the trees, ideally, in regions with good governance, with policy support for "scaling out" production. NB: There are a range of models for successful "scaling out", including a "decentralized, incentivized" nursery model, where local people get viable seed from known species & there is a "buy back" system. This brings local income & avoids the costs of large, state run nurseries.

- Example: Selecting elite cuttings (based on chemistry) for nursery production. Care is needed with accurate seed sourcing.

Main Room Discussion 1: Conversation with Field experts on supporting the long term sustainability of the communities and trees.

Discussants: Abeje Eshete, Abdinasir Abdikadir, Muna Ismail, Mohed Jama, Isaiah Lekisike, Dan Reigler, Ed Barrow and Soumya Kori

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GAP 1: How can we build upon local knowledge systems and local institutions to better improve land management?

ACTION 1: Listen and record how the communities manage their resources.

GAP 2: How do we get such local knowledge systems and institutional arrangements respected and recognised by government?

ACTION 2: Gather information not only on the current local, regional and national regulations but also on how they are implemented. Taxes that are raised and assess how they can in practice, best create an optimal enabling environment for value addition at source. Improve the capacities of the forest officers in frankincense areas, on the technical aspects (silviculture, production and management, marketing, etc.) of frankincense trees, for better supervision and following up.

GAP 3: How do we formalize existing local knowledge and institutions in a broad way that will improve management of frankincense trees and forests; embracing tapping, replanting, regeneration and a whole range of relevant issues?

ACTION 3: Capture, formalise and implement local knowledge in such a way that:

1. It will support livelihoods and communities are not being exploited,
2. Communities can defend their rights locally to the elders and nationally to the government.
3. There are supportive policies in place that will support sustainable frankincense harvesting and all the training needed, and equally importantly, the value chains from the farmers/ pastoralists all the way to the final retail marketer.

> *“As long as the harvesters only sell raw material and are not involved in the value-added chain, they will always make the lowest cut of the final profit.”*

GAP 4: How much can a harvester earn in a day?

ACTION 4: Determine how long it takes to sustainably collect 1 kg of resin in the different species, regions and seasons. Determine whether the focus is on quality or quantity, as well as the pricing structures and market fluctuations.

Main room Discussion 2: Conversation on being a conscious consumer:

Discussants: David Crow, Bert-Jan Ottens, Dan Reigler, Kelly Ablard and Shebhaz Khan

GAP 1: How many young people still know the ‘sourcing and inner’ aspects of these products, beyond the ingredients?

ACTION 1: Use the retail opportunity to educate and create an emotional and spiritual connection with the young consumer demanding more transparency, connection and sustainability. Use technologies to bring nature closer.

GAP 2: If we seek to deepen consumer understanding, what does consumer education mean?

ACTION 2: There are fewer suppliers that retail customers. Seek to change suppliers focus from lowest price to quality, fairly sourced value chains, species and/or batch specific purchasing and educate consumers on the long-term value of paying a slightly higher price for transparency and sustainability. Work with private companies to create a handbook and conscious consumer campaign that explains the current realities and can act as a basis for raising consumer awareness.

GAP 3: How do those taking the trouble to do it right, such as many diaspora or those working directly with the communities, get recognised, rewarded and differentiated from those who do not?

ACTION 3: Explore mechanisms to celebrate those doing it right and adding value at source and to give those looking to purchase 'ethical' frankincense the means to do so.

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Additional Actions

1. Continue with workshops/conferences as the potential exists for even more information to be collected and assimilated, so we have a better birds eye view of all the different species different issues, through more virtual conferences.

2. Use questionnaires & templates to conduct a survey (via email) to record same information as above; We can have many people contributing and it is a cost effective and efficient way to gather information on the industry. Also online workshops or conferences, with carefully selected participants from all producing regions/countries.

3. Take the 'Gaps & Actions' from this workshop forward through sub-committees with specific tasks, define the themes and see if we can generate any useful cross-regional comparisons. The results can be a Proceedings or Trade Brochure that would talk to all the different role players to disseminate information about: (a) supply chains & how they differ; (b) The different types of raw materials & products that are available; c) a survey of all potential regulations & interventions that can contribute to sustainable use & community empowerment. Currently small companies wanting to know where to buy ethical frankincense do not know how to go about selecting ethical suppliers. They want to contribute to ethical trade but do not have the necessary information.

"The group suggested that a non-technical report needs to be created and disseminated and spread to the public to create awareness of what has been scientifically technically proven and what has not."

In summary: the top actions needed are:

1. Create a consortium of local and international scientists and decide sub groups and leads to establish:-

1. The status, range, health, regeneration, challenges and threats for each species
2. The physical, chemical, specific markers and current uses of the resins and resin products of each species, matching local taxonomies with western nomenclature and internationally traded products.
3. The socio-economic realities of each of the communities that own and harvest the trees and to identify what will most incentivize their engagement in the long term sustainability of the trees.
4. The current trade volumes, patterns and how new technologies can support transparency and traceability.
5. Which trade and other certification programmes and local, national and international regulations will most support the long term health of the trees and communities that manage and harvest them.

2. Initiate, record and share the results of active 'best practice' pilot projects for both the trees and communities in key harvesting areas

3. Create an accessible handbook on the current established medicinal and aromatic properties of each species

4. Work with private companies to create a handbook and conscious consumer campaign that explains the current realities and can act as a basis for raising consumer awareness.

5. Seek out how to collaborate with existing projects and generate proposals of large scale third party funding. Short-term actions (yr1-2): Mid-term actions (yr2-5): Long-term actions (yr5-10).

Follow up actions:

- GFA will send this short report out to all participants and make all the workshop outputs available on the website www.globalfrankincensealliance.com
- GFA invite members to form collaborative working groups

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The Future of Frankincense online Workshop Proceedings

global frankincense alliance

Monday 15th March 1-4pm GMT

As described in the road map, the purpose of the workshop has been to prioritise what we need to know and do to support the long term future of frankincense trees and the communities that harvest and depend on them.

Outcomes:

Other issues included:

- A prioritized list of questions that need answering and actions that can be taken in each of the four themes
- Raised awareness about the very different context of the different species
- An awareness of who else is interested and working with frankincense and an opportunity to network during and after the workshop

While the roadmap picked out the most cogent gaps and actions, these proceedings serve to give additional detail of the discussions that took place.

After a welcome and introduction from Denzil Phillips, a GFA interim coordinator, the participants randomly met in pairs to meet and greet. Sue Canney Davison, the main facilitator, shared the purpose, processes and desired outcomes of the workshop. She emphasized the need to keep the frankincense trees and the communities who manage and harvest them at the centre of all the discussion and set principles of participation.

Anjanette deCarlo then introduced key scientists whom she had organized to conduct focal groups with communities, harvesters, traders and researchers. These included Muna Ismail and Mohed Jama representing 7 families in Somaliland, Abeje Eshete, Abdinasir Abdikadir and Yeshimebet Tegenie in different regions of Ethiopia, Isaiah Lekisike in Samburu County Kenya and Maia Willson of the Environmental Society of Oman. Dr deCarlo explained that the methodology was an open-ended narrative process where the focus group country facilitators posed open-ended questions allowing the community participants to respond freely without leading them. The two main questions posed were:

1. **What are the problems?,**
2. **What are the solutions?**

Another reason for conducting the focus groups has been to create a bridge between the people in the harvesting and sorting communities whose voice and realities are seldom represented or reported, who do not speak English, who do not have internet access, and are seldom able to join larger meetings.

The harvesters reported low unstable income, lack of regulated ownership, harvesting or working conditions, lack of safety and PPE equipment, access to food, water, healthcare, education, training or reliable secure markets. They are also clear on the solutions for which they need support from all the stakeholders .

The discussion on community owned and managed forests and harvesting continued in the main room. Key speakers were: Abeje Eshete, Solomon Mengesha, Mohed Jama, Isaiah Lekisike, Soumaya Kori, Ed Barrow, Dan Riegler. Highlights of that discussion and comments in the chat are:

COMMUNITY FOREST OWNERSHIP AND MANAGEMENT

Gaps and questions

GAP: How can we build upon local knowledge systems and local institutions to better improve land management?'

ACTION: Go, listen and record how the communities manage their resources'

'The ideas for solutions are very simple. How do we learn from and build on the indigenous knowledge base of how to manage incense trees or trees in general? I learnt a long time ago, working with pastoralists in Northern Kenya when I started talking about range management they said, '…come and listen and see how we manage our resources'. How can we build upon local knowledge systems and local institutions to better improve land management?' 'The other part of it is how do we get such knowledge systems and institutional arrangements respected and recognised by government? We heard of participatory forest management in Ethiopia, the law and policy is very supportive, as it is in Kenya. But when you come to implementation the forestry authorities can put in place so many barriers to communities being able to own and manage their own forests.' 'Can we think of forest gardens?'

'How do we learn from existing frankincense tree growing and the institutions and knowledge behind that? How do we formalise that in a strong way so that:-

1. It will support livelihoods, so that communities are not being exploited, we have had many examples of where they are being exploited and may continue to be exploited.

2. They can defend their rights locally to the elders and nationally to the government.

3. 'There are supportive policies in place that will support sustainable frankincense harvesting and all the training needed, but equally important the value chains from the farmers/ pastoralists all the way to the final retail marketer'.

'Many value chains are top heavy and they benefit the end marketer and do not benefit rural people and pastoralists. Many are talking about improving tapping as an important issue. Can we embed that in a much broader approach of 'How do we improve management of frankincense trees and forests which would embrace tapping, replanting, regeneration and a whole range of things?'.

[1] A table of the main focus group points by country can be found in Additional Information 1: at the end of this report.

‘In the Sanaag, in Somaliland, harvesting has been a man’s job, partly because the trees are tall and in remote dangerous areas. Women are vital in the industry for sorting, grading and using the resin, as well as reliable, trustworthy and dependable. Each family owns 40 km2 which is passed down through 15/20 generations in hereditary traditions in tribal areas. There are traditional ancient sorting songs and poems which tell of where people used to sell the products for big money to China, Chechnya, Russia, even Iran. Before the war (in 1993), there were basic rules and regulations from the owner, the harvester, the sorting and storage to the salesman. The Somalilanders and Somalis have thousands of years of indigenous knowledge and they have their own tools. They are well known internationally to have deep harvesting experience. The problem is when people start renting their trees’.

‘After the war, for the last 30 years there are now no rules and regulations and people with the knowledge of tree management and harvesting left the area. Whoever is staying now in the extended families, they rent it out to other people and the people harvesting do not have the traditional knowledge. A trader comes in, they take money from external finance and they go and harvest the trees. They cut the trees and collect the resin after 2/3 months. Some produce twice and some once a year. There has been a lot of demand and other Somalians are coming in acting as a middle-men, taking all the gums and mixing the different grades. They do not know how to differentiate. The trees are being destroyed and are dying. But this year they refused to rent or cut them. In terms of water for the trees, it depends on the rain. In Somaliland not a lot of animals can reach the branches and only humans can damage the trees’.

‘Only four ‘families’ own Boswellia frereana areas’. People left and they only rent it very cheaply and they do not have a market. The clan families are losing their cultural and traditional roots and knowledge of what kind of tree, how it grows, where to sell it. They just want money. It is completely different from Ethiopia, Kenya and Oman’.

The Boswellia trees are in a very beautiful forest in the Sanaag region that is very scenic and could be a very strong base for nature based eco-tourism. The infrastructure needs to be developed and the perception of insecurity needs to disappear.

‘Somalians do not need someone to come and teach them how to harvest trees, we know how to harvest and look after these trees. The different areas have different traditions. In Puntland, Somaliland, people look after the trees, it is unrealistic to say that there is over harvesting. No one will allow you to overtap the trees. If you go to the areas in Somalia where there is no control, then they may be being cut and myrrh trees in areas, like Beledwayne, may be overharvested. But even then, in the last seven years, people are waking up as a kilo of myrrh has gone from 1 -2$ Kg and to 15$. So what is the solution? We do not need people to come and tell us how to harvest, we need access to ethical and reliable international buyers and markets.

[2] It has been reported that 12 sub-clans own most of the land on which B.sacra & some say 2 clan families own B. frereana grows in the Sanaag region of Somaliland. Emphasising the need for much greater understanding of ownership, access and use rights, particularly as some ownership claims have been weakened by the fact that conflict has driven traditional owners away from the areas for up to 30 years, often as expatriates living outside the Horn of Africa.

Ethiopia

‘In Ethiopia, we have different participatory forest management systems between the highlands and lowlands, and between government owned and participatory forest management owned by community who can then benefit directly. Production of frankincense in Ethiopia starts from October and ends in June, it requires continuous tapping every one/two weeks. Many recruitments of young trees have been seen in less disturbed areas of Ethiopia.

In Metema, because the law is not allowing the agricultural farmers to hire skilled labour and it is labour intensive, the farmers are not interested or used to it. Ethiopia is now exporting very little compared to before. We need to allow skilled labour tappers under the supervision of the local community which could be a fairer system’.

THE SOMALI REGION OF ETHIOPIA

It is not known if B. neglecta and B.rivae (and B.microphylla) are usefully tapped. Currently resin is produced in response to passing camel, cattle and goat pressure and damage. Currently communities make no interventions on the trees, they wait for the tears to form and then collect them, often from the ground. They do not believe there is no tapping system, so trials and research is needed.

‘Regarding the Somali region of Ethiopia, a land/tree tenure system needs to be set up to prioritise a tenure/use rights system for the cooperatives. Currently the trees belong to all, as it is a traditional extended pastoralist ownership system. We need to have a group of cooperatives who manage the resin trees and rangeland by law. We need to control the system to prevent the destruction of the forest and additional systems; to close observation areas for regeneration; compare grazing and non-grazing areas and create a nursery with water collection to regenerate and replant. The harvesters need training on to how to collect high quality resin. They need to be connected to a laboratory to create the quality for export for pharmaceutical uses. While tapping, harvesting and selling is relatively straightforward, conservation is very complex and brings in multiple factors and has to be very intentional’.

‘There are lots of challenges to setting up cooperatives. There is a lot of very dense forest in our region and establishing a cooperative can give people a lot of opportunity to use and utilise the resins to improve their livelihood. Over the last 2 years, we have established 20 cooperatives for local harvesters and 20 cooperatives for taking the local yield and making market chain linkages; a total of 40 cooperatives for research purposes. Training was completed and a tapping and harvesting system demonstrated which is not being adopted and was discontinued because of low institutional capacity. Still, people are encouraged and eager to have licensed cooperatives in the region as importantly, local and government interventions make people aware that these tree have value for them and that over harvesting and cutting the actual trees can unsustainably reduce the forests. Establishing a cooperative is more important for making separate areas so that they can utilise’.

‘Gender. We already bridged the gap of gender inequality. There was a problem with men dominating the power of the women. We already encouraged the women in the area to participate in harvesting. We diminished the number of male cooperatives and increased the number of women involved. There is a bridge we need to solve first for women to keep the money and prioritise women’s wellness in fluctuating harsh conditions and create a stable income. We need more capacity building for them and more financial support to keep them encouraged’

TECHNICAL AND ACTIVITY RELATED COMMENTS

- Deterioration of frankincense woodlands in Sudan due to improper tapping (over tapping or too much tapping wounds), overgrazing, illicit felling and fires.
- Lack of motivation for the local people to participate in production. In many areas the local people are not involved in frankincense production, so how to encourage and motivate them to practice frankincense production is one of the important issues, especially in Sudan.
- A lot of fees and taxes charged by different governmental departments and the local leaders
- Poor intervention of the government (lack of good governance)
- Lack of awareness about the value and importance frankincense trees for most of the people in Darfur
- Absence of initiatives or organizations that can play a role in sustainable management and production of frankincense in Sudan

PROPOSED SOLUTIONS

- Improvement of the capacities of the forest officers in frankincense areas, on the technical aspects (silviculture, production and management, marketing, etc.) of frankincense trees, for better supervision and following up.
- Awareness raising, training on production and marketing for the local people living in frankincense areas, to encourage and motivate them to participate in frankincense production effectively.
- Coordination between the different government sectors or departments themselves and between the local leaders, who are charging taxes and fees, not to burden the frankincense producers
- The government of Sudan should put more effort on frankincense management, like gum arabic, so that it can contribute to the economy of the country.
- Intervention of the national and international organizations, which deal with environmental conservations and natural resources management for the livelihoods, by considering frankincense trees in their project priorities in Sudan.

India

‘Frankincense and non-timber forest products are often treated as a holy sacred item as in Somaliland. There is a lack of awareness,skills, tools and knowledge of the best harvesting practice and patterns. Harvests and quality are unpredictable with little institutional support. In Karnataka in the southern part of the Western Ghats in the southern part of India, it is harvested only for religious purposes and sold in temple markets. In this area, overharvesting is less of a problem than invasive species such as lantana. Harvesting is being regulated in other parts of India’.

WHAT A HARVESTER CAN EARN IN A DAY OR A SEASON?

A discussion arose in the chat:

- How long does it take for a harvester to collect 1 kg of frankincense?
- Responses included: It takes anywhere between 1-6 hrs. to collect 1 kg of gum depending on the concentration of the trees. It can take up to several weeks to collect 1kg, depending on the quality you target as you need to wait till it is collectable and not sticky any more. That means about 3 to 16 dollars per day.
- If it takes several weeks for 1 kg, then the people are earning far below minimum wage, even by South African standards. Maybe it will be better to pay the harvesters more money, rather than to treat them as destitute people in need of charity?
- The yield per tapping round increases as the season goes on, so it is perhaps more useful to look at total yield at the end of the season and the full length of the season to work out the dollars per hour or per day rate. Also keep in mind the answer will be different for each species and ecosystem since it depends on the density of the trees, the harvesting type (tapped or not), etc.
- What is the basis for payment for labourers? By the hour or by kg? How do they determine classification of quality? In many (most?) cases payment is per quantity (weight), combined with a small check on stones etc.

ADDING VALUE AT SOURCE

‘We could learn from the womens Argan oil cooperatives in Morocco making small independent businesses and selling the products to the tourists. We cannot introduce western culture into the different cultures. Diaspora can create cooperatives for women as they can bridge the cultures’

CLIMATE CHANGE

> ‘How do the communities and stakeholders in producing regions see the impact of climate change impact on sustainability of the supply chain from both the crucial life threatening point of view as well as frankincense subsistence farming?’

Frankincense grows in very dry areas. Dry conditions are going to be more common and more extreme, maybe more frequent. Not sure what effect that will have on the silviculture of Boswellia trees that do not need much water, but likely to have some impact.

For some concerned artists and craftsmen going to the source of the product is important, wanting to go right to the root, to create quality and in going to source in Ethiopia and Kenya it was obvious there were issues with the trees and the harvesters

Note: Reports are that some B. papyrifera trees in Sudan have regenerated in war zones, the cyclones in Oman led to greater B. sacra sapling growth and the many trees in Somaliland have been rested during COVID times and people’s attention rather turning to gold.

Wednesday March 17th 2021

Main room discussion on being a conscious consumer

This was a very general discussion sharing a lot of the speakers' experiences and approaches and has been summarised into some key points around a main question of 'How can we become more engaged and educated as consumers?"

GENERATIONAL DIFFERENCES?

'How many young people still know the 'sourcing and inner' aspects of these products, beyond the ingredients? If we seek to deepen consumer understanding, what does consumer education mean? 'Conscious capitalism is on the rise. The younger generation is increasingly demanding transparency. There is a big opportunity to educate and create an emotional connection with consumers.

Can we use technologies to bring nature closer to the consumer? Currently low-cost sourcing is part of the problem. The price should reflect the quality and may mean less supply. The shift needs to happen with retailers and consumers. Educating them and creating the emotional connection will yield the higher price that is needed. I believe the younger generation are a collective force to drive responsible consumption. As long as the harvesters only sell raw material and are not involved in the value-added chain, they will always make the lowest cut of the final profit.

FINDING THE ETHICAL BUYERS WHO BUY FROM SOURCE.

'There are two types of 'consumers' who need to be 'conscious', those that buy directly from the harvesters and the customers who buy the final retail product'. Two speakers, Shebhaz Kahn and Dan Riegler have gone to the trees in Oman, Ethiopia and Kenya respectively and buy directly from the harvesters themselves. For them, not only is it about establishing an understanding of and connection to the source, but also about establishing a fair and respectful relationship to the harvesters, and as small scale retailers and craftsmen, ensuring very high quality.

SELLING THE RESIN AND OIL AS MORE THAN JUST A COMMODITY.

'This approach not only respects the very different medicinal, aromatic and experiential properties of the resins and oils of the different Boswellia species from very different areas, but also allows a unique batch approach to the seasonal and population variances within one species. If this approach is elevated to the level of products from specific tree populations and farms with artisanal distillation, it can create and ensure a very high quality 'vintage' approach to each limited edition oil batch.

The question still remains, 'will educated consumers understand and appreciate the value of this approach?' An approach where spiritual, cultural, environmental and fair socio-economic connections are maintained, 'contained' within the product and pay the extra cost incurred? Are they willing to invest in distinguishing this approach from 100's of tons of raw resin being exported at one time through bulk traders for large scale essential oil distillation and species blending by some international companies?'

‘Until now we have been focusing on quantity, how much can I get and how little is it going to cost and so we buy things at the cheapest price to sell them at the highest price to maximize on profit. The economics has been based on profit and quantity rather than quality and I think that needs to change as well as the discussion on value added. There are far fewer suppliers than retail consumers, so we need to focus on them and how do we hold them accountable? There are really sustainable, mindful, conscious and respectful ways of doing this that comes with value added. There must be a demand for this value added which to some degree translates to higher quality. Exceedingly difficult to educate all of the consumers to ask them the many questions that we are dealing with with frankincense today; the difference species, the different eco systems, the different tapping methods, the different pressures and needs of the communities. But this is where change will come from.’

- How do those taking the trouble to do it right, such as many diaspora or those working directly with the communities, get recognised, rewarded and differentiated from those who do not?
- Can the diaspora play a much bigger role in adding value at source?

Organic has little meaning as these are almost all wild-harvested trees. Third party voluntary certifications schemes, as opposed to self-certified schemes, such as EcoCert, FairWild can assist, yet can be very expensive to implement and upkeep for the small scale producer and needs to be off set against customers willing to pay a higher price. It is not only a consumer validation that we as retailers can commercialize, but could it also be used to establish the trade requirements around equipment and wages?

Many questions were raised with limited time to generate answers and solutions.

- How can a consumer find out what is actually happening at source beyond what companies espouse and write on their websites?
- Can sustainable, ethical and transparent sourcing from the trees themselves and artisanal distilling reach as large a scale at affordable prices as any other less careful bulk harvesting and bulk distilling approaches currently employed?
- Does ‘ethical’ and ‘good’ necessarily mean smaller scale and more costly?
- Does paying $60 rather than 10$ for a 10ml bottle currently ensure sustainable harvesting and equitable share for the communities?
- How can digital technology and apps educate and engage the youth and be used to assist in making supply chains more transparent and raise awareness?
- How can conscious consumers currently best find ethically sourced resins and oils?

MANAGING THE BRIDGE BETWEEN TRADITIONAL AND SCIENTIFICALLY VERIFIED MEDICINAL PROPERTIES

‘There is the huge amount of research coming out all the time and this can be found in the scientific medical basis, specific compounds can be researched both individually and integrally. There are some human clinical trials as well as in vivo and vitro. There is a natural misconception about natural medicine being

‘ pseudo-science’ that is starting to clear up. It used to be a major argument that there was no evidence that this works, despite thousands of years and centuries at least of application of all kinds of medicinal species and case based evidence. Now modern scientific research is catching up and is confirming and proving what people have known, finding the biochemical mechanisms and making a lot of very new discoveries as well, both in terms of how botanical medicine works and new methods of administration. Frankincense is a species that is getting a lot of attention in the scientific medical research community and is being explored for its benefits against inflammation, microbes, cancer and for enhancing the immune system. It represents a tremendous medical, pharmaceutical resource in addition to the traditional way of using it’.

This discussion raised many questions, demonstrating the need to identify the impact of education and awareness campaigns on the customers willingness to demand, seek out and pay for transparent, fair and ethical sourcing. What do they need to know? What questions can they ask? What should they look for?

More detailed feedback from 8 themed breakout rooms

Theme 1 Botany identification & current status of the trees Breakout room leaders: Professor Sebsebe Demissew, Dr Shahina Ghazanfar, Stephen Johnson.

WHAT DO WE NEED TO KNOW?

- Further rapid qualitative and quantitative research, combining basic quantitative surveys with significant local integration/participation and focusing on local knowledge, in fully explained/consenting partnership with local communities. There needs to be clear communication and integration so that local communities are full partners in the research, not subjects being examined. Large, in-depth quantitative surveys, like have been done in Ethiopia are impractical on any scale, so surveys should focus on strategic sampling, integrating local ecological knowledge and protocols that local people can effectively implement.
- It would be useful to have a strong comparative study between species, to understand where commonalities or differences are, and therefore to what degree we can extrapolate from existing research
- Six Boswellia species occur in Ethiopia, with additional ones in the Horn of Africa. Taxonomy is relatively clear and B.papyrifera trees, resin and oil identification is clear cut. But in the Somali region of Ethiopia, local names are confusing, Boswellia and Commiphora resins get mixed up, (such as B.neglecta and C.confusa) are sometimes the same colour and expertise is needed to identify the trees. We need to integrate local and Western taxonomies and better understand how local ecological knowledge relates to “Western scientific” understanding. A major point in taxonomy is what we plan to use it for--whether we’re using a (fairly dynamic) Western taxonomy or a local taxonomy, how we talk about the trees depends on what questions we’re asking.

> *“ If we are talking about systematic sampling ALL Boswellia species for identification or ther research then we need to address Access & Benefit Sharing mechanisms directly. ”*

- The existing documented flora and fauna of Ethiopia, Somali and East Africa do not align, especially with regard to Commiphora and young scientists need to develop the expertise in taxonomy and identification to assure a higher quality and consistent product for the market in particular for medicinal and pharmacological authenticity. Better understanding of markers to identify 1) products like resins and match to the source trees, and 2) identify biological species to avoid hybridizing during reforestation efforts
- Along with accurate botany we need to address the socio-economic and environmental issues. We discussed the different species in Somaliland in in Oman. If we really want to have a sustainable Boswellia and Commiphora market, we need to protect trees in situ and unless we help communities to protect these trees, the trees do not have a future. The communities need to be able to conserve the woodland wherever they are. The resins are important we need to have the mother and to have the mother we need to protect the landscape so it is the vegetation and the species and that will really benefit the communities.

WHAT WE NEED TO DO?

1. Species need to be clearly identified, especially those in mixed forests like B. rivae, B. neglecta, B. microphylla. B ogandensis. Clear ID. of species, look alikes, and ability to use simple markers to distinguish between species, even for non-experts. Species need to be treated as separate entities, don't assume that they will be comparable to each other. Develop clear methods to link the product (resins) to species and taxonomies.
2. Need to map where species are and what the status is--can be fine-scale in places like Socotra, but perhaps broad-scale for species like B. dalzielii, B. sacra, etc. To do a tree population inventory (and follow it during the following years). Local surveys are difficult, as it can involve people that are not really trained for that. So why not include the students from universities. It can be part of botanical education to do local surveys; to get data on the age, habits, habitat of the trees. Involve the local harvesters to assess which trees produce more, which trees less. Can we develop some sort of scientific criteria that can be applied say 1 hour or 2 hours a one day to assess how much is actually harvested? How do we get the best results in time?
3. Significant further engagement with local communities and people who directly manage and live with the trees. Using this engagement and partnership, focus on aligning taxonomies, understanding drivers of threats (why is overharvesting occurring, further research on insects, etc), and broadly surveying the current status and range of species (particularly those in trade). Ensure that tangible benefits go to harvesters/communities/direct managers so that they see conservation-oriented actions as being the most directly beneficial course of action. Harvesters need market conditions that support them better and incentivize sustainability
4. Impact of climate change on the future of trees - scientific study

Theme 2 Communities, intentional propagation & forest management. Breakout room leaders: Professor Frans Bongers, Dr Anjanette DeCarlo

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WHAT WE NEED TO KNOW

- The habits and habitat of the trees which can grow in semi-arid areas and in some places in very dry and hot areas (e.g. Afar in Ethiopia). We need to know much better where species are growing, where they are regenerating, and where they are vanishing (e.g. by conversion).
- Distribution: The question is where, what, how much, and what are the bottlenecks?
- Identify and quantify the threats e.g. grazing, forest fire, forest conversion (populations declined in size, fragmented, over-tapping, insect attacks and pathogenesis.
- Understanding the impact that ownership, financial issues, fair sharing, stable markets and prices has on incentivizing sustainability. Can a healthy connection between the communities, harvesters and the trees solve many issues of overharvesting? Living forests need to be seen as valuable.
- Overall pricing issues and transparency issues. Find out how this is different across species and countries and even regions.
- What kind of value addition and production is commercially viable in each country?
- Forest Management: We need more data on forest density and regeneration rates. What is possible with intentional propagation which is not a solution to over harvesting.
- A technical question that arose in the chat included In the wild, do frankincense seeds germinate all at once in a group or singularly apart from each other?

WHAT WE NEED TO DO?

- Assess property and use rights (clan, private, government, communal).
- Assess local rules and laws/regulations, how they are implemented and how effective they are in specific situations (incl bottlenecks).
- Assess alternative practices. Implement best practices?
- Assess equity/fairness, alternative means of income. Implement best practices?
- Develop training and guidelines on how to improve. Engage, engage, engage.
- Co-design resource assessment schemes with locals (Kenya, and other areas)
- Forest management
- Establish forest reserve areas for conservation, in close arrangement with local people
- Establish small scale/ farm level tree preservation, planting, agroforestry
- Assess regeneration/propagation issues and bottlenecks (e.g. livestock, fire; different for species and areas) and act to solve them (enclosures, fire breaks, no free grazing, out planting with care and monitoring)
- Assess lopping/tapping interactions (which have devastating effects on yield and insect infestation)

> *“The key is to prevent the ‘cartels’ from controlling the supply chain. Harvesters can be trained not just to sort product but to create value added products from incense to medicine to oils/ hydrosols. Creating medicine that they can use in their own communities is one of the key things and that has been hugely successful in other projects.”*

- Assess effectiveness of Participatory Forest Management schemes and design more effective alternatives.
- Develop schemes with less focus on Boswellia and more on ecosystem functions and services (water catching, soil retention, diverse use and diverse products, ecotourism? And sell the broad package for forest maintenance incl. Boswellia)
- Reduce conversion to alternative land use by focus on ALL ecosystem services of a forest.
- Experiment with parklands creating more domestication then only in the wild but not full plantations and allowing further investigation on the growth and resin of intentionally planted frankincense trees, versus wild trees.

ADDITIONAL ISSUES

- Avoid middle men in order that money comes directly to the communities, increasing local upgrading.
- Improve infrastructure (as women and men have to walk a lot to collect gum from trees from remote areas)
- Increase the wellbeing of women sorting (tables, masks, gloves, ventilation)
- Provide tapping training for everyone (to get skilled collectors)
- Invest in long term connections to provide security of income.
- Ecosystem function of trees and forests. This is also important for external people. (villages, cities, country). The value of forest is much higher than only Boswellia resin (PES, resin, other things, water, soil retention). Other NTFP's such as honey
- Concentrate on some areas for better management?
- What can we learn and translate from the good examples to the less good ones?
- Need access to seeds to study regeneration. Researchers seeing low seed germination, Practitioners seeing higher germination than researchers. Study mixed plantings, not just mono cropping Boswellia.
- Need to study how to plant the seedlings back into forest with success.
- Explore options to add value and shorten the supply chain.
- Change the grading systems to match the current market demands and realities. Outdated grading is problematic.
- Education is key. Educating general public in country and internationally on the value of trees and frankincense
- Maintain the traditional lifestyle, it is not only about increased pay. Understand the local culture
- Need proper frankincense institution to centrally work on frankincense. Policy and implementation is fragmented. Production companies may not have the resources and need international support.

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> *"How can we match people who want to "help" with communities who need it to start to solve/improve some of the issues?"*

IN SUMMARY:

Develop a knowledge project

- Compile an overview of all the rules and regulations per species /country and the implications of these for the situation on the ground. (Forest level, species level. Regulatory taxes, concession rules and payments.
- Cycle assessments of resin. Follow the plants that produce the resins (how resin made, how collected, how transported etc.). Evaluate ways to monitor this.
- Select good cases and detail what and why these are good cases (of forest management and local people involvement), across the whole range.
- Map per country the companies that get into the forest and use the forest, forest ownership, local regulations, any contestations on ownerships/use rights?
- Compile available knowledge on plantation issues; Develop new experiments based on best practices, country and species specific.
- Develop comparative study across species and countries, to understand what are common issues and what are different across species.

Develop implementation projects

- Select "good" companies and support them as much as we can. Buy their products. Copy the system and implement in other areas
- Select highly producing trees for seed and cutting selection? Domestication and breeding.
- Develop seedling and cutting stocks for out planting.
- Develop larger experimental plantations with every year new experiments added, to be able to cover also for climate events
- Identify the benefits and challenges of private mono-plantations, creating nurseries and replanting in existing forests, or conserving existing woodlands without harvesting.
- Develop best practice system across cultures, but within species.
- Develop tapping/collection techniques that are suitable per species. One-time tapping for longer period instead of reopening wounds?
- Develop tapping incentives based on quality of tree treatment. Less tapping with better tree treatment will pay better than alternatives.
- Develop ways to select areas for fully setting aside for long term protection of trees/forests and genetic resource.
- Develop ways to keep product separated and location bound (tracing to farm, or tree etc).
- Calculate extra costs.

> *"Supporting the power of the dispora to create a bridge to international consumers and add value in their original communities"*

Theme 3 Biochemistry and Medicinal Applications Breakout room leaders: Professor Ahmed al Harrasi, Professor Abdul Latif Khan, Ahmed al Rawahi.

WHAT WE NEED TO KNOW

- What are gene regulatory network in frankincense production?
- How to improve healing and recovery wound process of the tree for next tapping cycle?
- Clinical process of active extract
- The importance of the other 16 species of Boswellia for chemistry
- Researches and uses with Alzheimer disease
- Environmental impact and recovery process of the trees; Cost and safety of the chemical product from frankincense ;
- There is need for more evidence based research; Total synthesis vs natural isolated compounds from Boswellia;
- Careful about claims about frankincense for its medicinal uses; Clinical studies needed
- Intellectual properties;
- DNA barcoding
- Seed banks
- Gene sequencing
- Cell culture strategies to grow in lab - frankincense tissue
- Seed banks to add up to conservation and preservation
- Hybridization through horticulture approaches could improve species fitness
- Synthetics vs non-synthetics (thinking about quality and sustainability)
- Correcting the mis-information about the bioactivity and uses of frankincense as natural medicines.
- Clinical trials need to be done to further investigate the boswellic acids as anticancer! (initiative)
- The boswellic acids have been scientifically approved as a superior anti-inflammatory drug. (clinical trials ongoing internationally)
- Nutraceuticals products are available and used to treat/prevent various diseases. (this will accelerate the process of approval)
- A massive production of frankincense products <> Issue of sustainability.

  - HTS will help in discovering more compounds with high potential.

A note on developing quality standards: The aloe industry in South Africa developed a National Standard for aloe raw materials - by not making value judgements (some people have specific uses for low quality grades) but rather by accurately describing the levels of main compounds - then the buyers can decide for themselves what to buy. What constitutes high quality may often be different for different buyers since it all depends on each buyer's/consumer's needs and uses

“Blockchain is a must when it comes to transparency in combination with geomapping... Traceability, sustainability, harvest status - all these points could be measurably included here.”

WHAT WE NEED TO DO

- Adulteration in frankincense and its oil in grades, chemical composition and cross contamination from among species. Supply of samples from all species to create a map or profile of each species. This will help in organic certification and barcode the frankincense based on localities of harvest. Quantification of key chemical constituents in the frankincense and essential oils across all species using new advanced analytical methods
- There must be more evidence based research on pharmaceutical uses of frankincense and clinical studies
- Understand how climate change is influencing frankincense production and tree growth and chemical composition. Environmental factors play a major role in deforestation of frankincense population! Acidic soil, acidic heavy rain (climate change)
- There is a need to further investigate the “overharvesting” and develop purpose target-harvesting process (more useful and less labour work and sustainable)
- Identifying biomarkers to evaluate the health status of the tree
- Investigate the chemical composition of the resin of different Boswellia species to establish the chemical profile of each Boswellia species and how that is affected by the location and the way of harvesting and other factors.

Suggestion made by Rizwan Fadiliah to contact the Government of Pakistan as they have 10 billion tree Tsunami project in regions similar to Oman, especially Balochistan province in Pakistan.

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> *“There is absolutely no research on this but disappearance of Fog in Sanaag Region and Jebel Samharan in Dhofar due to climate change is likely to have major impact on the quality end.”*

Theme 4: Supply chains, products, regulations and trade Breakout room leaders. Professors Ben-Erik van Wyk and Tony Cunningham, Denzil Phillips

WHAT WE NEED TO KNOW

- Disambiguation of species and source regions in our discussions.
- We need more information about the products of each species and what quality means in each case. In what form is frankincense exported (raw materials versus essential oils versus finished products)?
- There should be more information about traders and if they have a code of ethics that conforms with modern codes of ethics in supply chains. Support people who care to know and seek out ethically sourced products and commercial entities and avoid those who do not. There is a need to educate the younger generation on what it means and what is needed to manage and harvest the trees properly and sustainably.
- Where and under what circumstances is sustainable harvest possible? We have already heard today of the ranges of different harvesting practices. Boswellia neglecta in the dry season in Samburu where the women collect, which is similar to Commiphora wildii in NW Namibia as models of sustainable wild harvesting. We have also heard cases of destructive intensive tapping and cutting the trees for domestic and other uses. So, framing the question in a positive way. ‘Where, and under what circumstances, is there successful, sustainable harvest occurring?

- How can supply chains from different production regions and different species best be developed and communicated in relation to markets, prices and supply chains. How can transparent supply chains be developed?
- Given the incredible complexity and the difficulty of monitoring quantities and from what species that varies across the region, the overarching question of 'How can transparent supply chains from different production regions and different species best be developed and communicated and then who pays for that?' This is a real gap in knowledge. Will consumers be willing to share the costs of sustainable harvesting and supply chains and third party certification if they are educated? It will not happen on its own and suppliers cannot always just pass the costs onto the consumer. So again framing the question in a positive way. 'Where and under what circumstances are there unadulterated and high quality supply chains occurring? There is a need to involve all stakeholders, local communities, non-governmental organisations, local, regional and national governmental agencies and services, and the private sector
- How to prevent the issue of elite capture within supply chains. We talked about examples in other species. e.g. Prunus africana was CITES Appendix II listed in 1994 due to decades of mismanagement once Cameroonian entrepreneurs became involved in the trade. Today, one influential Cameroonian trader has the monopoly on all the bark exported from Cameroon, reducing the incentive for local people to cultivate and trade in Prunus africana bark. One does not want this to become a similar situation in Boswellia, especially where cultivation is starting, such as in Salalah, Oman. A counterpoint example to elite capture is the formation of producers associations, such as for the baobab export trade in southern Africa, which is a very interesting model.
- Cultivation: - where and under what circumstances can cultivation be successfully scaled out to supplement wild harvest as there are a range of circumstances. On the one hand, it is tempting to say well ' let's have restoration and enrichment planting in the wild areas', but tenure over those trees is often weak. Cultivation in plantations or agroforestry systems may have stronger tenure and management systems. So we need to understand the property rights in each case. How can the challenge of weak tenure over the trees, or the land on which the trees are growing, be overcome? We are all familiar with habitat loss with Boswellia papyrifera or grazing impacts on almost all the Boswellia species including B. serrata in India, but how can these challenges of weak tenure be overcome?
- What regulations can be used to improve the long-term survival of the trees and the harvesting communities? The main knowledge gap is what regulations can be used to improve the long term survival of the trees and the harvesting communities. There are various mechanisms in which this can be done. There is legislation, and international treaties. There are things like Fair Trade and so on and it would be nice to interrogate all the different ways and to find out which of these is most appropriate to ensure the long term survival of the trees and to improve the plight of the harvesting communities and to maybe get them better organised and improve their standard of living.
- Address any knowledge gaps between the generations and identify what education is needed.
- Create working based on each species and region.

WHAT WE NEED TO DO

- Need to identify the relationship between local and international taxonomies and products.
- Create a study to understand what drivers have weakened customary use rights, including the conflicts that drove people away.
- Establish the criteria for quality standards for each species and product.
- Set up trials with blockchain and use new technologies to raise awareness and meet the sustainability expectations of the younger generations who can then scan a QR code on a smart phone which can show photographs or data right across the supply chain from harvest to distillation to final product. Use new technologies to by-pass any large scale trader's focus on low cost and lack of interest in origins or quality.
- Implement a study on the reasons for little cultivation, including technology, incentives and policy support.
- Implement a study using workshop and questionnaires, on gathering comprehensive information on which products are being traded and demystifying current supply chains and volumes and types of trade. This information is needed to identify the problems so that effective interventions can then be designed.
- Once again, we said that there should be workshops on the different treaties. Implement a study using workshop and questionnaire on the range of possible interventions that exist and could be applied at local, regional, national and international levels. Evaluate the most effective of the many different mechanisms, including education, available to intervene to support sustainability as well as community development.
- Create sub-committees with specific tasks as a follow on from this meeting so that the momentum that has been built up and the expertise that this meeting has connected with, could really enrich and enable us to get deeper into some important questions on specific tasks that come out of this. Some supported regional groups and others adding in cross-cutting issues. 'If the cause is protecting Boswellia trees and the communities who are making a decent living out of it, educating the consumer to responsible buying, and fighting again biodiversity deterioration. It is a global cause that we embark on regardless of the region we are from. There is also the question of in what capacity we can contribute to this cause: R&D, community work initiatives, field support, marketing, processing, characterisation, social work. Should we set up groups by these main themes rather than by region?'

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"A lot of comments about block chain and similar analyses are only as good as the data you put into them - bringing us back to involving the communities and chains themselves"

A broad interpretation of sustainability

On the final morning, Professor Frans Bonger's first paid homage to four of 'the greats' of frankincense who had been unable to join for different reasons.; Dr H. P. T. Ammon, Mats Thulin, Jason Elsamieh, and Amadé Ouédraogo. He then raised the issue of engaging a broader understanding of sustainability and the unfairness in the supply chains.

He emphasized that it is important to take a very broad interpretation of the term sustainability which includes not only ecological sustainability, but also

[3] http://uu.diva-portal.org/smash/record.jsf?pid=diva2%3A1410838&dswid=9505 Link to Mats Thulin monograph.

social and economic sustainability; otherwise interventions are not going to work. Communities around the trees and forest need the power, finance and incentives to maintain the forest. The connection is between communities as well as between communities and the environment because sometimes, communities are not rooted in environment. On the right hand side of the diagram are socio-ecological systems. These are a continuous interaction between what people do in environments, how they use the trees and forest and how their interaction with the environment changes it. 'All our actions have an impact; on the environment, on people; on everything we do'.

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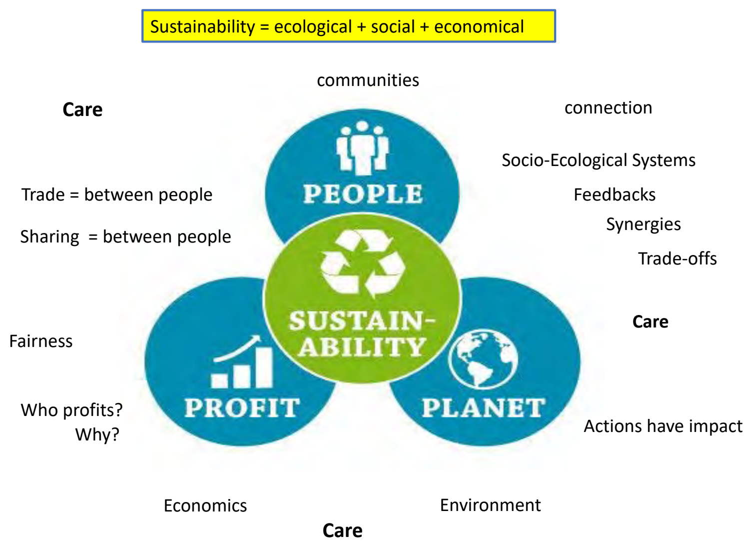
There is continuous feedback, synergy, and trade-offs between all the different aspects and some aspects can only be done at the cost of other aspects.

Trade is an integral part of the socio-ecological system, as it is the dynamic exchange of goods between people for the good of both sides. We need to understand why some profit more than others, and fairness may be connected to power, ethics, care, economic aspects, and to who profits and why so we can change it. Care is attention; it also may be love for the environment, for people.

Prof. Bongers then gave the example (loosely based on Ikg of Boswellia sacra in Somaliland) of how often only 1-2% given of the final price the consumer pays is for the harvester.

Trade	Price US$
Paid to harvester	3-6
Price paid to exporter	10-15
Wholesale price of oil from 1 kg	19.2
Range of Retail price paid for essential oil	103.5 – 476.10

Paying back 50 cents of the final retail price could double their income. Aside from India and Oman, most large scale essential oil distillation plants are not in the harvesting states and hundreds of tons



of raw resin is exported in bulk. The most profitable step is between wholesale and retail essential oil prices. What impact does more benefit accruing at the export, and international processing and retail end of the value chain have on local communities, sustainability and the long term future of the trees?

Frankincense Poem

The workshop closed with a prayer and poem from Mr Shebhaz Khan.

The Takers by Shebhaz Khan

She stands alone in arid land
Soaking up the scorching sun
Majestic as she stands
Offering her jewels to the tribal hands
Tapping and extruding all there is to offer
Until like a child abandons the mother
Returning again when she has more,
otherwise would anyone really bother?

Her secrets are kept deep in the root,
One must travel a thousand miles
A journey that takes you so within
For many they don't know where to start
Her creamy white juice excludes
for us to find our truth
and reconnect us back to our heart.

When did you stop to give thanks
or kiss the hands of the man
standing beside her,
Do they really care for her and her community?
or do the colonialist corporations still believe
deep in the DNA they can just take
What did you give back?
Not even shoes, gloves an axe or a rake
these company morals seem to be fake.

Let us not make it too late
when her guardians open their eyes
every spirit will disperse and keep you awake.

She is Boswellia ,
your lover healer and friend
These words are just to remind you
Be in Love
She is just like your Mother.

"I think we can organize country or region specific groups to continue the discussions and take the work forward and continue link up with the main groups."

A NOTE ON THE SPONSORSHIP OF THE WORKSHOP

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The Global Frankincense Alliance has been set up as a UK based not for profit company. The interim coordinators and Advisory Board members have given their time and efforts for free. Since its inception in December 2019, 20 organisations and individuals have made contributions. Contributing confers no membership rights and is only an investment in taking the collective discussion and awareness raising on the Future of Frankincense forward. Since inception these contributions have paid for registering the company and URL, building the new website, a one month business zoom license to cover the workshop and paying for non GFA professional technical and zoom facilitation support.

In just 3 words: What inspired you today?

Additional Material 1:
Table of main points from harvesters groups

#	Species	Region/ Country
1	B.sacra	Somalia/ Somaliland, Oman
2	B.papryrifera	NW and W Ethiopia
3	B.neglecta	SE Somali region of Ethiopia and Northern Kenya
4	B.rivae	SE Somali region of Ethiopia and Northern Kenya

Some of the main issues and solutions are captured in the table below:

#	Problem	Country	Comment
	Trees		
1	Trees reported in poor health. Many due to repetitive overharvesting Too many cuts, 2 times a year	Somaliland	No harvest this year due to COVID Yield diminishing
2	Insect damage	Somaliland	'Harah' Shumuxshumux
3	Clearing the trees for other purposes	N.W.Ethiopia S.E.Ethiopia	Land clearance for agricultural purposes Use of trees for construction, firewood, charcoal and other household needs
4	No replanting or frankincense nursery	Somaliland Ethiopia	
5	Fire to clear the grass	Ethiopia	Fires set to burn the grass burns saplings
6	Grazing (cattle, goats, Camels) damages saplings and smaller trees	Oman Somaliland Ethiopia	Extent of impact of grazing on B.neglecta and B.rivae unknown.
7	Natural disasters, Climate change Landslides, winds, falling rocks, drought.	Somaliland Oman	
8	Adequate tenure, ownership or demarcation of the trees and forest lands	NW Ethiopia SE Ethiopia	
9	Lack of long term rather than short term project investment	NW Ethiopia	
	Harvesters, sorters, communities		
10	Lack of secure sustainable income or low season credit facilities	Somaliland Ethiopia	
11	Lack of alternative livelihoods and income	Somaliland	
12	Lack of stable, formal, accessible, secure market or market information	Somaliland Ethiopia N. Kenya	
13	Very labour intensive, walking in remote areas	N. Kenya	

#	Problem	Country	Comment
	Trees		
14	Poor harvesting skills	Somaliland	No harvest this year due to COVID Yield diminishing
15	Lack of proper working conditions, safety, PPE equipment	Somaliland	Fatal accidents, sorters have lung, kidney and other physical conditions from dust and sitting long hours on the floor
16	Lack of water, food, emergency and other healthcare (animal attacks, malaria)	Somaliland SE Ethiopia Kenya	
17	Insecurity (kidnapping, animal attacks)	Ethiopia	
18	Lack of post-harvest collection centres and resin handling and storage	SE Ethiopia N Kenya	
19	Lack of infrastructure, roads,	Somaliland	
20	Ineffective or unclear land use rights and rural-urban drift. Owners lease land and younger generation/ hired harvesters unfamiliar with traditional harvesting practices.	Somaliland Ethiopia Oman?	
21	Lack of effective and coordinated local institutions or implementation of local, regional or national policies and regulations that organise and incentivize communities.	Ethiopia Somaliland	Some good policies exist but are not effectively implemented or supported. E.g. requiring agriculturalists to harvest their own trees without training or incentives.
22	High harvesting royalty fee	NW Ethiopia	

#	Solution	Country	Comment
	Trees		
1	Reduce the number and frequency of cuts on the trees. Harvest once a year Rest for some years	Somaliland	Healthy B.neglecta and B.rivae trees reported in Somali region of Ethiopia and Northern Kenya with natural exudate collection (no tapping)
2	Focus on species - specific quality rather than only resin quantity	Ethiopia Kenya Somaliland	
3	Insect care	Somaliland	
4	Make shallow water ways, contours to harvest annual rainfall and prevent landslides	Somaliland	
5	Forest demarcation and forest land certification. Clear tenure and ownership within extended clan-based pastoralist systems	Ethiopia	
6	Set aside exclusion zones of trees and forests to allow healthy tree regeneration	Ethiopia	
7	Construction of fire lines		
8	Production and planting of seedlings	Ethiopia	Natural regeneration reported in W Ethiopia and N. Kenya
9	Undertake quantitative surveys and survey plots to determine tree population status and threats in the wild	Oman	
10	Fair and increased pay for harvesters and sorters in contractual agreement with credit facilities to provide regular secure household income	Somaliland Ethiopia Kenya	
	Harvesters, sorters, communities		
11	Provide market information, improved regulation and linkages to ethical traders and exporters. Shorten the value chain and maintain harvested quality.	Somaliland Ethiopia Kenya	

#	Solution	Country	Comment
	Trees		
12	Create a research and training centre of excellence in the harvesting region	SE Ethiopia	Focus on local/western species taxonomies and species specific harvesting.
13	Community education and awareness programmes for benefits, conservation and sustainable harvesting and use	Somaliland Ethiopia	
14	Provide proper harvesting training and safety equipment	Somaliland Ethiopia Kenya	
15	Provide transport, food and water and emergency medical support	Somaliland Ethiopia Kenya	
16	Legalise, allow and provide skills training of hired harvesters and those new to it	Somaliland Ethiopia Kenya Oman	Research needed on B.neglecta and B.rivae sustainable tapping benefits
17	Health and education facilities	Somaliland Ethiopia	
18	Create, monitor and learn from cooperatives	SE Ethiopia	
19	Support of gender involvement on the conservation, propagation, harvesting and utilizing frankincense products to empower women to participate in all the activity of restoration and conservation strategies through training and giving practical activities and also provide education support.	S E Ethiopia N Kenya	
20	Concern that CITES listing will negatively impact the trees	Oman	
21	All stakeholders to create much stronger relationships to the harvesters and trees	All	

Contact: **info@globalfrankincensealliance.com**
Website: **www.globalfrankincensealliance.com**

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Workshop initiation and design. GFA Coordinators and Advisory Board

Process facilitation team: Dr Sue Canney Davison, Leanne Davies with Ross Henry

Focus group design and facilitation: Dr Anjanette DeCarlo

Workshop report: Dr Sue Canney Davison with GFA Advisory Board and Theme leaders.

Photos: Sue Canney Davison, except: Samburu meeting, page 9: Isaiah Lekisike, Boswellia Carteri Somaliland, page 12: Haris Hassan

Report Design: Paul Gurney (www.thegraphicdesignshop.co.uk)

28th March 2021

global frankincense alliance

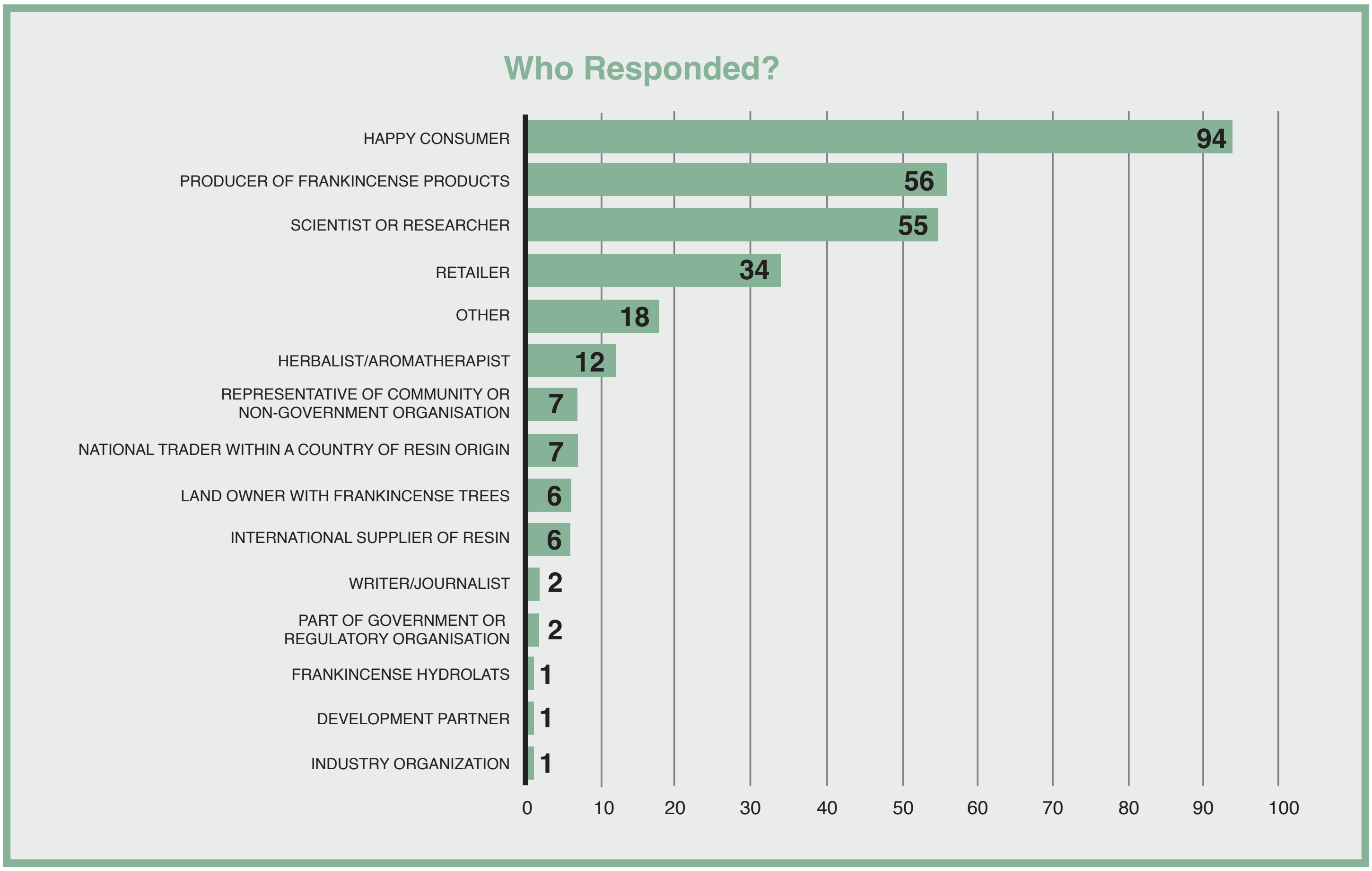
'Future of Frankincense' on-line survey

FINAL RESULTS

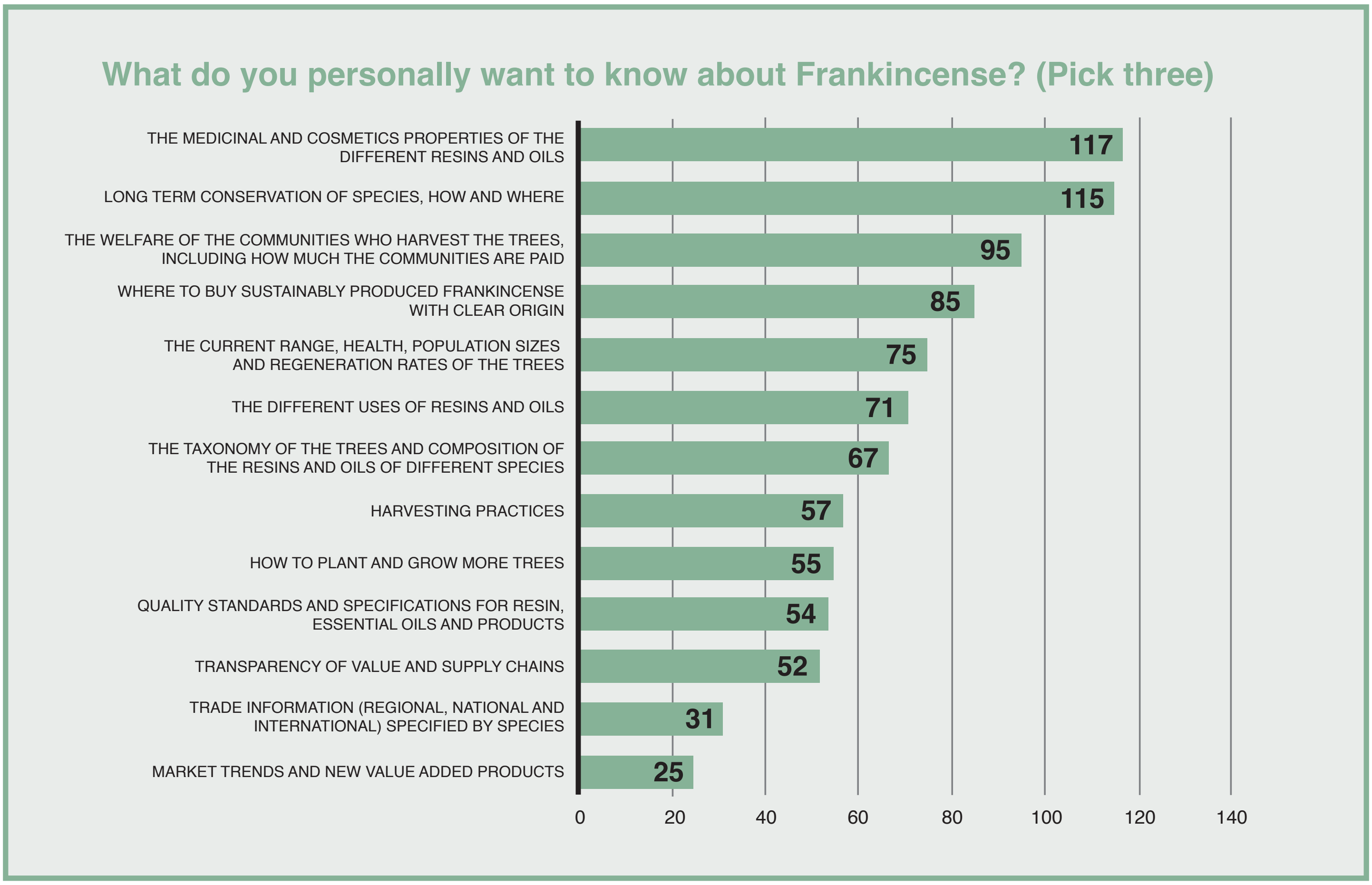
Background

An online survey was set up on Google forms to ask would-be participants what they would describe themselves as, what they most want to know, what collective information most needs to be gathered and what do we most need to do? 302 people from over 46 countries responded.

Who has responded so far?



The first question asked:

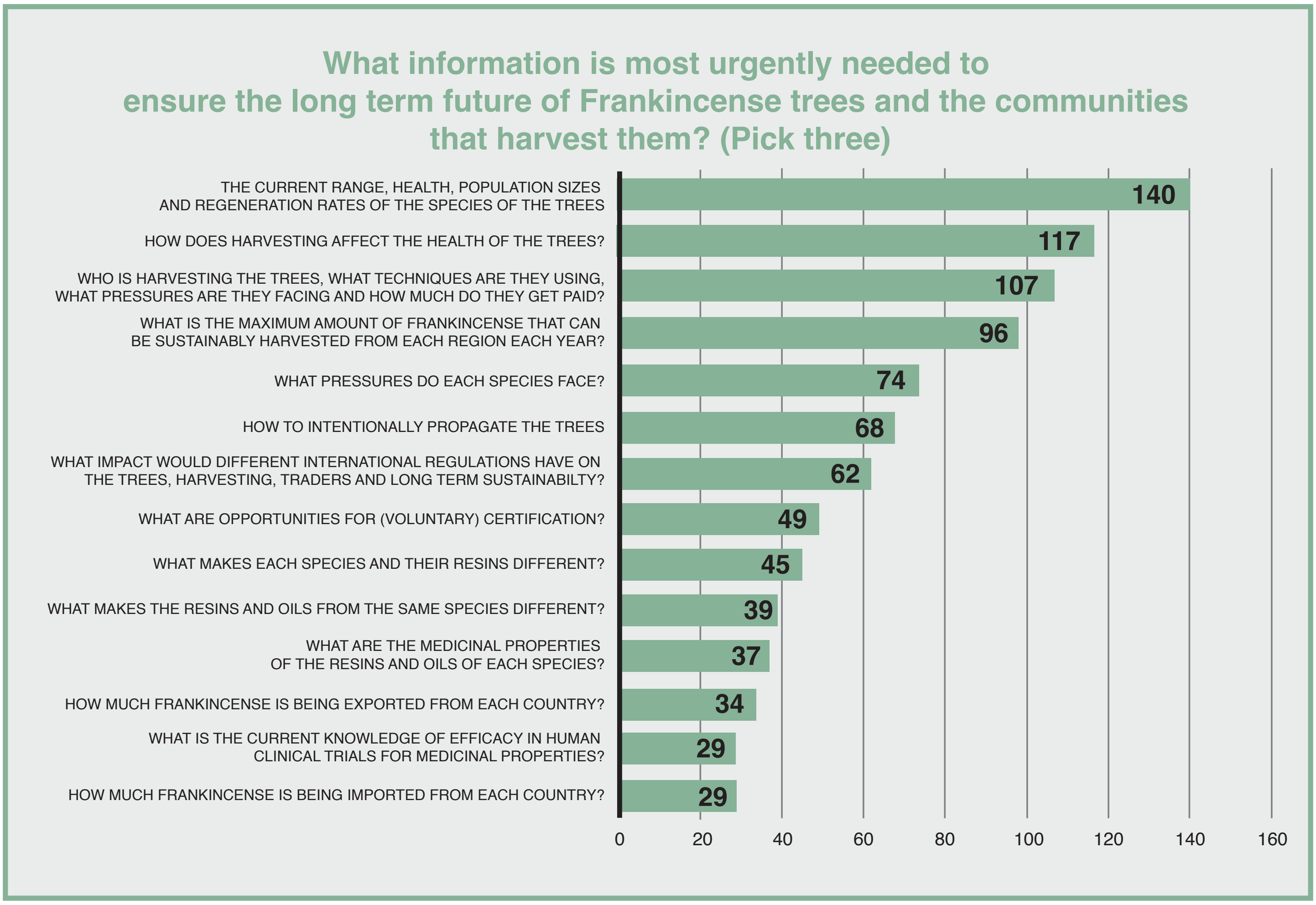


Other issues included:

- How to encourage frankincense grove production here in the United States and elsewhere.
- I'm interested in all aspects, including how can we spread these trees so they survive?
- Are there historical and technological reasons behind the frankincense that we found in our home land?
- The frankincense that we found in underground deposits in Somaliland.
- Spiritual traditional uses.
- The genetic diversity of frankincense trees and potential for adaptation.
- Where/how to grow in Southwest USA and all the above.
- More about the day to day lives and cultures of the communities that harvest as well as their well being.

Any other comments are in Annex 1

The second question asked:



Other issues included:

- Again, I think all the above are important- growers/harvesters are in a symbiotic relationship with the trees and their input matters too.
- How long does it take a tree to grow before it can be harvested?
- How can the farming community be fairly compensated and supported?
- Regenerative practices and projects along with current situation.
- How to detect adulteration?
- These are all important.

Any other comments are in Annex 2

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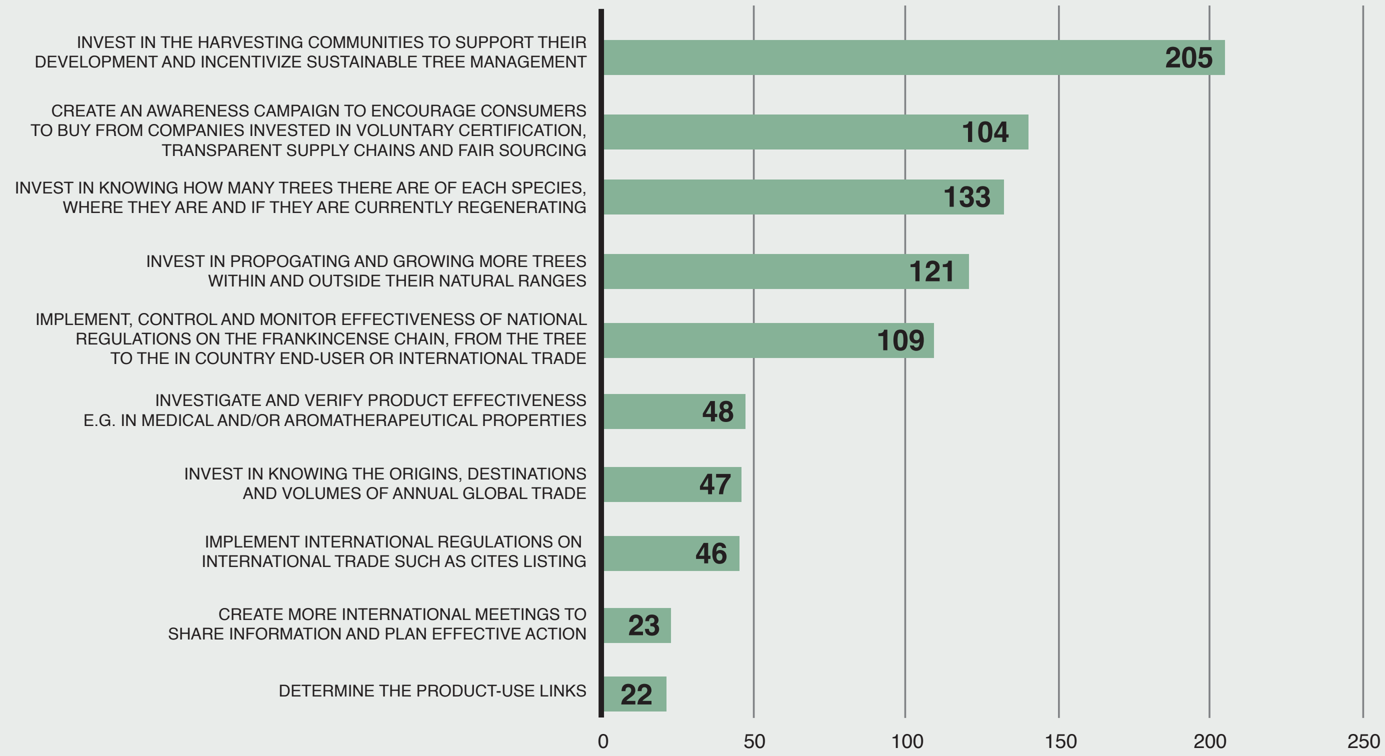
The third question asked:

What most needs to be done to ensure the long term future of the Frankincense trees and the communities that harvest them? (Pick three)



Other issues included:

- All of the above! I would like to see transparency in the end user product companies too.
- All of this and none of it because I'm ignorant :)
- All these indicate outside controls over each country, and it should be locally driven — I don't agree with any three of these but since it's mandatory to answer, but this question is incredibly slanted in favour of a few large companies and not neutral.
- Consider and manage other sources of degradation (crops, livestock).
- Explore options to link buyers to producers and to create economic incentives for producers and countries having Boswellia populations to keep them on the landscape.
- Facilitate legislation that frankincense trees can only be owned/harvested by residents of the countries in which they grow as patrimonial heritage and prohibit multi-national corporation ownership.
- How does sustainability happen?
- Integrated conservation and Protected Areas planning at the national level with appropriate implementation.

- Invest in communities of growers - encourage healthy small traders - grow from bud cuttings. Develop root stocks to take plants into other ranges, while we work on spreading their range again.
- Invest in determining what regions from other countries that frankincense is suitable to grow in, and if there are consequences to native animal and plant species.
- Legal protections for indigenous farmers and communities against corporations.
- Take adulteration out of the market.
- These are all important and inter-related. Too hard to choose without hearing discussion of each.

Any other comments are in Annex 3

Annex 1: Other comments on 'What do you personally want to know about Frankincense? '

- Frankincense, myrrh and trees are magical. We need to preserve and sustain their being.
- Life strategies of frankincense trees.
- I need more sustainability for these trees.
- Frankincense has a special place in our hearts and sustainable cultivation is important.
- Everything about frankincense is interesting!
- I also would like to know how to contribute to support frankincense trees.

Technical and activity related comments

- In Sudan and particularly in Darfur less involvement of local communities in resin production, due to lack of motivation and also the lack of good governance by the administrative authorities, are considered to be the main factors that jeopardize the sustainable production of frankincense.
- A comment regarding B.sacra in Oman there is not any proper survey taken in the dfifferent frankincense lands to determine the deteriorated frankincense lands and the conservative ones till this moment.
- Upgrade livelihood of local community and frankincense harvesters is extremely important. Otherwise no conservation efforts could be possible. As well as to improve harvester's knowledge and capacity is inevitable.
- How is climate change involved?
- Researching frankincense and other plants in ancient Egypt.
- I would like to know more about the general harvesting practices of frankincense. Also issues around overharvesting.
- Also we need to explore options (i) to improve tenure security of communities managing landscapes with gum bearing species, (ii) to create incentives for companies so that they begin at least partial processing in the producing countries, and (iii) explore and address ecological barriers hindering population establishment of Boswellia species.
- We found a frankincense in the suburb of Hargeisa, the capital of Somaliland

incidentally which is just like a mine. it has a very pleasant fragrance but we have no idea how this frankincense happened to be there? At the beginning, some members of the community who found it used to sell it but later on we thought it could have something that could lead to other useful information or findings botanically, anthropologically, or archeologically. We are seeking your expertise to assess how this barren earth frankincense occurred in this area?

- The welfare of the communities who work with these trees - the trees and their workers are inseparable x2.
- Quality standards and specifications for resin.
- How to recognize a good quality of resin.
- But in addition will be interested to know "Quality standards and specifications for resin, essential oils and products" and "Where to buy sustainably produced and frankincense with clear origin."
- What are climatic and soil conditions for frankincense trees to grow.
- I'm interested in most of the points! Overharvesting is a real thing to manage etc.
- I want to be sure that my sources are also in the best interest of the plants.

  - We cannot assume that these trees are merely a resource for our use alone, but that they have a purpose in the ecosystem of the area in which they grow. What other species rely on frankincense for their well-being? I'd like to hear more about that in the discussion.
  - The first half of that list all seems super important. I also feel like white western herbalists/enviro people neglect to even consider the humans affected by the ecocide and genocide we perpetuate and that no "eco" initiative can ever do any good while also being colonial and genocidal and racist at its core.
  - Are there historical and technological reasons behind the frankincense that we found recently in our home land. Our comment is to know why and how is it possible technically poored for centuries perhaps unknown early times
  - I have a goal of getting frankincense seeds and starting a small forest here in Hawaii. I am aware of its endangered presents and would like to start a seed bank to ensure that we support its survival.
  - The potential of other related tree species for production in Southern Africa.
  - Does frankincense and sandalwood grow in similar environmental conditions?
  - Has GFA developed any Voluntary Sustainability Standards?
  - We value the importance of traceability, sustainability and community work initiatives within the supply chain, to be correctly reflected through international standards from the CSR/ESG perspective.
  - Sustainability and fair trade.
  - How to deal with Nagoya/ABS in the context of Olibanum and Commiphora?
  - I have been working with plant extracts professionally for >25 yrs. and watch in horror as it became nothing more than a greed oriented sales channel. Many species of Boswellia have been over-harvested for more than a decade and it can't be propagated. We should ban the trade at least short term until it can be proven sustainable which it currently is not.

- I think it's time to spread harvested seed, saplings, cuttings - and work towards guaranteeing we have access to these amazing plants in the future. Information on the different varieties, their particular uses, and differences should be better promulgated. Active conservation matters.
- Especially interested in Boswellia serrata and Boswellia papyrifera.
- I would like to know more about tree replenishment and international trade of resins in regard to European countries.

GENERAL COMMENTS AND THOSE ON THE WORKSHOP PROCESS OR SURVEY

- I am interested in quite a few of the other issues as well but chose a broad range.
- I am interested in all topics but especially those that affect the future of the plant and the communities that use them.
- I would like to know as much as possible as I am struggling to find reliable information.
- I'd like to know more about all of these!
- I had the feeling I needed to tick more boxes here......
- Most of the above.
- I would choose more options above, so I add quality standards and long term conservation.
- Many of the items in question 1 appeal to me.
- All of the issues above interest me.
- Thank you. Thank you.
- This is exciting!
- Excited for this conference.
- I want to do the right thing, even if that were to provide less products

Annex 2: Other comments on "What information is most urgently needed to ensure the long term future of Frankincense trees and the communities that harvest them?

TECHNICAL AND ACTIVITY RELATED COMMENTS

- I would rather focus on the optimal amounts of resins that can be harvested rather than the maximum amounts. Harvesters should be fairly paid for their work (of course) but they must also become the primary carers of the trees they harvest to ensure not only the continued health of the trees but the well-being of the communities that rely on them.
- We need good data to begin.
- All of the above aspects and information points are important, but as to Q2, I think the focus needs to be on regenerative farming of them in a way that is sustainable and enables the stewards, harvesters and processors to thrive.
- Is there any way to support the communities currently growing and harvesting frankinsence in order to make it more sustainable for them long term?

- We may need to add aspects of trade & power balance large vs small companies?); and user group impact possibilities for increasing sustainability in the chain (e.g. churches, aromatherapy users).
- I would like to know where are the trees being propagated at present and what methods are being used?
- If there are plagues, insects or other, affecting production?
- More trees is the answer.
- People around the world are overusing.
- Knowledge of supply chain of frankincense trading and market is something essential to avoid exploiting practices by international partners and private companies.
- Also.... I believe consumers need to be educated about the uses of something so pure.
- In order to help our trees.... we need to train people to not overuse and therefore create such demand for product.
- What can we do in that region to create more space and protection for the trees? What about some reserved park spaces for preservation and research?
- By using frankincense in different ways than essential oil, it will most definitely sustain longer survival rate of frankincense species
- Medical research and use does not offer further protection just more rape and pillage of the trees.
- Various religions need to explore alternative herbs to displace frankincense use until the population rebounds by having conversations with themselves and others.
- Cosmetic properties of the plants?
- It is also important to know the scale of exportation out of our country to guess the threat faced by our indigenous species.

- A CITES listing would definitely help.
- Sustainability and fair trade.

GENERAL COMMENTS AND THOSE ON THE WORKSHOP PROCESS OR SURVEY

- A very interesting list of possible urgent issues.
- I am very interested in all of these questions.
- I would think all information will help.
- I don't understand how to choose only 3 things above.
- So much to learn.
- Thank you for doing this. It is so important. I look forward to writing on this for the publications I write for.

Annex 3: Other comments on Q3. What most needs to be done to ensure the long term future of the Frankincense trees and the communities that harvest them? (Pick three)

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TECHNICAL AND ACTIVITY RELATED COMMENTS

- The current species facing extinction are not only being overharvested but they are facing severe drought, species like Boswellia papyrifera
- According to our local communities and how carelessly it is harvested, it would be so helpful to create awareness raising campaigns.
- Creating a frankincense cooperative society and regulation acts passed by the government.
- As above, we need to concentrate on spreading the range of the trees themselves - that is the real priority.
- Biological activities of the plant.
- Research and exploration scientifically .
- We need a paradigm shift in thinking about how we use trees overall. And we need more of them.
- I think it's hard for consumers to tell when frankincense is genuinely being sustainably managed, and where companies are simply claiming that but it's not true.
- Yes, consumers need to be aware of how their choices affect the supply chain etc. but industry (the big cosmetic and perfumery companies) absolutely need to be on board and accountable.
- Creating awareness is definitely a good point, although I assume there could be a risk of fake certifications as well. Fairness and transparency besides mindful harvesting are the only solutions.
- These questions all favour regulations and control of a natural resource by companies. The surveys and "investigations".
- I'm concerned that regulating it like with organizations such as CITES often drives trade underground and into the black market. I think awareness campaigns to inform consumers, whether perfumers / cosmetic makers / the Catholic Church / small buyers, would be a better focus initially.
- Capacity building will be needed at the national level to build CITES Management Authorities and CITES Scientific Authorities.
- Qualified institutions should be established to look after this sector
- I worked very closely on the Royal Hawaiian sandalwood projects for the last eight years. I see a lot of synergies in approach and would love to be a contributor.
- I do not know exactly what would help. I would like to know.
- Unfortunately I don't know what the right things are because I don't understand the business

GENERAL COMMENTS AND THOSE ON THE WORKSHOP PROCESS OR SURVEY

- Also here, more options to be ticked? the list is nice!
- I think 3 options are too few.
- Thank you for all your leadership on this, up to now and going forward.

Photos: Dr Sue Canney Davison

Design: Paul Gurney
www.thegraphicdesignshop.co.uk

YOUNG LIVING
ESSENTIAL OILS

LACEY ACT COMPLIANCE PROGRAM

Not only is our Lacey Act Compliance program comprehensive, it's also the first in the essential oils industry that has been reviewed and accepted by the government. It is the gold standard for compliance programs, and we are proud to have gone above and beyond any of our competitors to establish it. We are engaging top legal experts around the world to keep us advised of the most current laws, as well as to inform us how to appropriately apply them to our most important business needs.

Our team has been working collaboratively with our corporate-owned farms, partner farms, Seed to Seal-certified suppliers and the government for more than a year to develop this new program.

We also continually work with environmental experts around the world to keep us advised on the protection of delicate landscapes, and plants.

The Lacey Act Compliance Program consists of five general steps that when followed will help ensure our essential oil, products and partners comply with all laws and regulations in the jurisdictions in which we do business.

These five steps are:

SUPPLIER EDUCATION

- Provide all suppliers with the basic requirements of the Lacey Act.

SUPPLIER EVALUATION

- Determine which products to source and which suppliers to partner with by evaluating "product risk" and "supplier risk" factors.

SUPPLIER CERTIFICATION

- After providing training on the Lacey Act and our Compliance Program, suppliers will be required to execute the Young Living Lacey Act Compliance Certification.

RISK ASSESSMENT

- As part of the certification, each supplier and plant product will be assigned a risk category that will determine the level of approvals needed to partner with, or source plant products for, Young Living. Both suppliers and plant products are independently assessed.

AUDITING/MONITORING

- Based on the risk factors, Young living has developed an ongoing auditing and monitoring program. The new Lacey Act Compliance Program is designed to cover all individuals and organizations in the supply chain.

This gold standard program sets the precedent for the industry and demonstrates Young Living's commitment to lead the essential oils movement by protecting delicate landscapes and plants.

Annex 6: Examples of large flavour and fragrance companies in the frankincense trade noting existing approaches to ESG (Environment, Social & Governance) and supply chain transparency. Reference is made to existing or forthcoming Due Diligence or other legislation. Given governance challenges in several *Boswellia* Range States this legislation may be relevant to *Boswellia* supply chain transparency.

COUNTRY OF HEADQUARTERS	COMPANY NAME & SIZE	EXISTING APPROACH to ESG (Environment, Social & Governance) FACTORS	RELEVANT NATIONAL OR REGIONAL POLICY INITIATIVES RELATED TO SUPPLY CHAIN TRANSPARENCY
Bulgaria	Esseterre Bulgaria EOOD (Dobrich, Bulgaria), established in 2015, is owned by the American company dōTERRA (Pleasant Grove, Utah). It's distillation facility opened in June 2016 and is a major frankincense oil importer (from Somalia) and distiller (c. 50 tonnes of oil/yr, equivalent to 800-1000 tonnes of frankincense resin/yr).	According to their website, "*All Esseterre' s employees are familiar with and committed to following the company's policy for sustainable environmental development….*" And that "*With its eco-policies and voluntary eco-initiatives, Esseterre strives to set a leading example and inspire other followers in the region in a responsible way of protecting the environment*"[1].	As Bulgaria is part of the EU, it is likely that the EU Due Diligence Act will apply to Esseterre Bulgaria, as a major frankincense importer. The aim of this Act, which was supposed to be in force by December 2021, but has been delayed, requires companies to ensure that human rights and environmental standards are maintained and protected. Following public consultation on Sustainable Corporate Governance (30 July – 8 October 2020), the European Parliament's Committee on Legal Affairs (JURI) and the Committee on International Trade and the Sub-Committee on Human Rights have developed legislation related to Sustainable Corporate Governance[2].
France	**Mane SA, founded in 1871,** €1,058 million (2016) (US$1.2 billion)	Mane SA's approach is to "*apply a responsible purchasing policy aimed at raising awareness among suppliers of the CSR policy and to assess their environmental and social performance".*[3] Mane SA have been a very supportive partner in commercialisation of *Commiphora wildii* exudates linked to conservancies in Namibia[4].	**EU Due Diligence Act** (see above) will apply in terms of supply chain transparency (SCT) when this Act comes into force.
Germany	**Symrise Gmbh,** 2003 (through a merger of Bayer subsidiary Haarmann & Reimer (H&R) (founded in 1874) & Dragoco. Revenue of €3.408 billion (2019) (US$3.84 billion)	Symrise is a member of SEDEX[5], and they follow the Sustainable Development Goals and the SDG goals 12 & 13 on sustainable sourcing is important to them.[6] They aim to have transparent, traceable supply chains,	Both the **EU Due Diligence Act** (see above) and the forthcoming German Supply Chain Due Diligence Act[7] apply**.** The **German Supply Chain Due Diligence Act** will be implemented through the Federal Office for Economic Affairs and Export Control (BAFA). From 1 January 2023, this Act will require that German companies with 3000 or more

[1] https://esseterre.bg/en/activity/#ecology
[2] See: https://www.europarl.europa.eu/legislative-train/theme-an-economy-that-works-for-people/file-corporate-due-diligence
[3] https://www.mane.com/sustainability/purchasing
[4] Galloway, F.B., Wynberg, R.P. and Nott, K., 2016. Commercialising a perfume plant, *Commiphora wildii*: livelihood implications for indigenous Himba in north-west Namibia. *International Forestry Review*, *18*(4), pp.429-443.
[5] https://www.sedex.com/
[6] https://www.symrise.com/sustainability/sourcing/#sustainability-along-the-value-chain
[7] See: https://www.taylorwessing.com/en/insights-and-events/insights/2021/07/overview-of-the-german-supply-chain-due-diligence-act

		stating that all of their suppliers have to complete a Code of Conduct. SEDEX have a "risk assessment tool" to investigate raw material supply chains and follow a SMETA (Sedex Members Ethical Trade Audit) system. There does not appear to be any information on how this applies to *Boswellia* supply chains (e.g: *Boswellia serrata* (India) and *Boswellia papyrifera* (Ethiopia))	employees will need to adapt and update their compliance, purchasing and contract drafting processes. **As of 1 January 2024, c**ompanies with at least 1,000 employees that have their head office, administrative seat or statutory seat in Germany or companies that have a branch in Germany and usually employ at least 1,000 employees in this branch. Although the focus of the German Supply Chain Due Diligence Act is on human rights, it is also relevant to corporate due diligence in relation to environmental damage. Fines for violations of due diligence will be up to EUR8 million depending on the situation.
USA	dōTERRA, 2008. US$1.83 billion, 1500 employees.[8]	USA (Utah) with offices in Australia, Europe, and East Asia. Reported as using 50 tonnes of frankincense oil/year (c. 800-1000 tonnes of frankincense/year). dōTERRA reported at WOCMAP VI that it has its own "*ethical and sustainable sourcing program known as Co-Impact Sourcing™, which creates shared value for all stakeholders in the supply chain and intentionally implements environmental stewardship and/or poverty solutions*".[9]	*B. carteri*, *B. frereana, B. papyrifera* & *B. occulta.* In the Somaliland Autonomous Region of Somalia mainly supplied to dT through the company Asli Maydi. With most exported to Bulgaria (value-added processing of frankincense oil), then re-export to the USA. See Chapter 4. The Lacey Act applies to all US companies involved in the wildlife trade, including plant materials (since 2008). Since 2012, the California Transparency in Supply Chains Act may to supply chains of both manufacturers and retailers.
	Young Living, 1993, US$2.2 billion (2020)[10]	USA (Utah). Young Living is Lacey Act compliant (see Chapter 6) and sources frankincense through a supplier in Somalia whose products are Ecocert/ FairWild certified.	*B. carteri* and *B. sacra* from Somalia & Oman respectively. In the USA, since 2012, the California Transparency in Supply Chains Act may to supply chains of manufacturers and retailers.
Switzerland	**Firmenich,** 1895, CHF 4.3 billion (2020) (US$4.65 billion). Firmenich employs 10,000 people across 46	Firemnich belong the the Union for Ethical BioTrade (UEBT) and produce regular ESG reports[11]. They use a "Path2Farm" digital traceability tool[12]. How this	On 29 November 2020, the Swiss people voted in favour of a Responsible Business Initiative ("**RBI**") by 50.7%. The RBI required human rights due diligence and civil liability where Swiss companies – or the entities they control – breached environmental and

[8] https://www.dnb.com/business-directory/company-profiles.doterra_international

[9] doTERRA Shares Vision For More Sustainable Sourcing Of Frankincense And Myrrh At 6th World Congress on Medicinal and Aromatic Plants (WOCMAP VI). Nov 26, 2019, 17:21 ET. https://www.prnewswire.com/news-releases/doterra-shares-vision-for-more-sustainable-sourcing-of-frankincense-and-myrrh-at-6th-world-congress-on-medicinal-and-aromatic-plants-wocmap-vi-300965799.html

[10] https://www.prnewswire.com/news-releases/young-living-named-to-top-10-of-direct-selling-news-global-100-list-301276114.html

[11] https://www.firmenich.com/sustainability/esg-report

[12] http://www.firmenich.com/path2farm.

	manufacturing plants and 6 R&D Centers.	applies to *B. carteri*, *B. frereana* (& possibly *B. occulta* in the mix) from Somaliland/Somalia (oleo-resins) with NeoBotanika (based in the UK, with warehouses in Somaliland) is uncertain at this stage.	human rights at home or abroad. However, this was rejected by a majority of cantons, thus failing the double majority threshold required for an initiative to become law. The Swiss government and parliament considered have now developed alternative **reporting and due diligence requirements** for Swiss companies. This will become law at the same time as the **German Supply Chain Due Diligence Act** (January 2023). The counter-proposal to the RBI, which will come into law, will require **non-financial reporting duties** from Swiss businesses on human rights, environmental, social and employment-related matters. This is similar to the European Union Directive 2014/95/EU on Disclosure of Non-Financial and Diversity Information.
	Givaudan, 1895. CHF 6.3 billion (2020) (US$6.81 billion)	Givaudan has a "Sourcing4Good" responsible sourcing programme[13]. There is no detail on how this translates into action related to their sourcing of *B. carteri*, *B. frereana* & *B. occulta*, Puntland/ Somalia & *B. sacra* from Oman.	

[13] https://www.givaudan.com/sustainability/communities/sourcing4good