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Good intentions meet complex realities: CITES listing of diverse frankincense (*Boswellia* species) might do more harm than good

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ABSTRACT

Frankincense gum resin is a globally traded forest product, likely generating more than $1 billion USD in value annually for its use in perfumery, medicines, and incense. It supports thousands of rural livelihoods in Somalia, Sudan, Ethiopia, India, and several other countries, where it is harvested from *Boswellia* trees. Recent research indicates unsustainable practices and population declines in both heavily and minimally traded species, prompting a review by the CITES Secretariat and consideration of potential listing of the genus (or species therein) in Appendix II. We argue that each of the 24 *Boswellia* species faces different circumstances and challenges with respect to trade and must be treated as an individual entity rather than being lumped together as part of a homogenous multi-species entity. The trade-conservation relationship for *Boswellia* species is not straightforward, with both positive and negative impacts of trade apparent, and interventions must account for this. CITES as a mechanism relies heavily on the infrastructure of exporting states, some of which suffer from limited resources, severe corruption, and existing trade suspensions. These limitations make CITES listing inappropriate as a conservation and regulatory tool. Tougher standards are needed, but without aiming for simple answers, we suggest that these are better implemented through importing country regulation driving private supply chain improvements rather than through exporting country-based CITES regulations. This can avoid foreseeable unintended negative consequences for both the conservation of different *Boswellia* species, populations, and the livelihoods of local communities frankincense tapping has supported for thousands of years.

1. Introduction

Frankincense is an aromatic oleogum-resin (hereafter, "resin") produced by species in the genus *Boswellia* Roxb. (Burseraceae). *Boswellia* comprises 24 species of trees, growing in arid to humid sub-tropical environments in West Africa, East Africa, southern Arabia, and the Indian subcontinent (Thulin, 2020; POWO, 2023). The resin is produced and stored in canals in the trees' cambium. It has been harvested by humans for thousands of years by scraping natural exudate or making small incisions into the bark with a knife, waiting for the resin to seep out, letting it dry, scraping off the 'tears' and then re-opening the wound to allow for another harvest cycle. Frankincense resin has been used locally and traded internationally for up to 5000 years, making it one of the oldest known traded commodities (Pickenhagen, 2017). In the modern world, frankincense is in high demand for its use in incense, perfume, aromatherapy, cosmetics, traditional medicines, and various other applications. Indeed, the international trade in frankincense resin may exceed 6000–7000 metric tonnes per annum, worth tens of millions

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of USD in its raw form, hundreds of millions of USD once processed into essential oil, resinoids, and other extracts, likely USD1 billion or more once in retail product form (Cunningham and DeCarlo, 2022). It is a major non-timber forest product (NTFP) and a primary or significant supplementary livelihood for hundreds of thousands of rural people in *Boswellia* Range States (countries in which *Boswellia* trees occur). Some small-scale propagation experiments have been undertaken, but functionally all frankincense is wild harvested today (Cunningham and DeCarlo, 2022).

In recent years, multiple studies have raised concerns about the conservation status and sustainability of harvesting of several *Boswellia* species. These studies have mainly focused on *Boswellia papyrifera* in Ethiopia, Sudan, and Eritrea (Groenendijk et al., 2012; Lemenih et al., 2014; Bongers et al., 2019), with others examining *B. serrata* in India (Soumya et al., 2019), *B. dalzielii* in Burkina Faso (Sabo et al., 2021, 2022, 2023), *B. sacra* and *B. frereana* in Somaliland and Somalia (DeCarlo et al., 2020), and the 11 species of insular *Boswellia* on Socotra island (Attorre et al., 2011; Lvončík et al., 2020). These studies have varied in methodology, sample size, and focus, and there are likely less accessible populations that are less disturbed. However, virtually all studies indicate sustainability concerns. While conditions vary between species and regions, most species studied have been found to experience one or more threat factors, such as overharvesting, clearing for land conversion, insect attacks, fire, grazing, cyclones, and invasive species. The impact of increasing climatic variability is yet to be determined but may have both positive and negative impacts on *Boswellia* (Martinez Nieto, 2022).

The socio-economic systems in which these trees are situated are also complex. There are generally limited data on the many factors driving specific threats and changes in management practices. The impact of changes in accessibility, land and tree ownership, harvesting rights, urbanization of traditional frankincense resin harvesting families, and economic pressures can all be expected to impact the management and harvesting practices of the trees and will differ in each location. From an international trade perspective, the main focus of concern has been on overharvesting of the most traded species; harvesters making too deep, too many, too frequent, incisions on any one tree. Fears have been raised that the burgeoning international market for and trade in frankincense may be driving unsustainable harvesting practices and leading to population declines in accessible harvested species (Bongers et al., 2019; DeCarlo et al., 2020; Cunningham and DeCarlo, 2022).

Consequently, the Plants Committee of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) began investigating the status of the genus *Boswellia*, and whether listing some or all of the species may be appropriate (CITES, 2020; Cunningham and DeCarlo, 2022). CITES is an international agreement between 184 Parties, in place for nearly half a century, designed to protect species that are threatened (or presumed to be threatened) from the negative effects of excessive international trade. If approved by a two-thirds majority vote of the Parties, species are listed in one of three appendices. Appendix I prevents international trade of the "most endangered species", except in exceptional circumstances. Appendix II allows for trade of threatened and non-threatened species but requires permits certifying the legality (a Legal Acquisition Finding) and sustainability of harvest (a Non-Detriment Finding, or NDF) from the Range State of export or re-export. Appendix III allows a Range State struggling to regulate trade in a species to enlist the help of other States by requiring export permits for export from that State and certificates of origin for export from any other range State (Wijnstekers, 2018).

At the eighteenth meeting of the Conference of the Parties (COP18) in 2019, the decision was made to begin compiling information on the trade in *Boswellia* and assessing whether one or more species met the criteria for listing (Cunningham and DeCarlo, 2022). Distinguishing resin at species level is complicated, provoking the suggestion that, if one of the species would meet criteria for listing, a genus-wide listing should be implemented. Subsequent analysis suggests that species can largely be distinguished based on chemical markers in the resin, but there are still some concerns about the technical sophistication of the methods necessary for these analyses (Cunningham and DeCarlo, 2022). This process is ongoing, and any listing is unlikely to take effect until at least 2026. However, while the CITES Plants Committee has been directed to identify if a listing is warranted, an additional question must be raised, namely whether CITES itself is the best mechanism to encourage conservation and sustainable use of *Boswellia* trees. If listed, *Boswellia* is most likely to be listed in Appendix II, with legal trade requiring permits from the Management Authority of the State of Export certifying that the export is legal and will not harm the species.

CITES is intended as a powerful tool to regulate legal international trade in species and is premised on two key assumptions. First, exporting Range States have the capacity to effectively implement the regulations, and second, that restricting trade will automatically have a positive effect on conservation outcomes for the species involved (Cooney et al., 2021). The reliance on Range States to implement the provisions of the Convention is a critical assumption, as many Range States exporting CITES-listed species suffer from chronically limited resources to assess and monitor the sustainability of wildlife trade. Indeed, 29 Range States are under trade suspension recommendations as of October 2023, with 7 Range States under recommendations to suspend all trade or all commercial trade; two are major frankincense-exporting countries (Somalia, and Djibouti as a transshipment point for Ethiopian frankincense).

Likewise, CITES was originally designed, and since has been implemented, with lethally harvested species in mind. These are species in which the harvesting requires killing the organism, such as rosewood (*Dalbergia* spp.); this category also covers species that could be non-lethally harvested, but are most often lethally collected, such as oud (*Aquilaria* spp.) or bois de rose (*Aniba roseadora*) oil. Many other products (e.g., fruits, leaves, resin, etc.), however, by definition require living and reasonably healthy individuals to obtain the product. Frankincense, a tree resin, is such a product. The relationship between trade and conservation in non-lethally harvested NTFPs is rarely straightforward (Belcher and Schreckenberg, 2007; Shackleton et al., 2015), and the complexity of the socio-ecological, economic, and political circumstances around the harvesting and trade of frankincense make this especially true for *Boswellia*.

The existing research clearly indicates a need for greater conservation of many *Boswellia* species and improved ecosystem and supply chain management. However, the key question is whether CITES as a mechanism—using the approaches and structures that it does—is the right tool to achieve this outcome. Caution must be used when applying regulatory powers, as even well-intentioned legislation can have unintended negative outcomes on the ground (Zhunusova et al., 2022). In this paper, we examine some of the complexities in the conservation of *Boswellia* species and urge that any potential listing (of some or all of the species) decisions be approached with significant caution and respect for these complexities, to avoid unintended negative outcomes for both the conservation of *Boswellia* species and the livelihoods of communities that traditionally rely on them. We do not seek to critique CITES itself, as there are excellent discussions on optimizing the Convention elsewhere (Lavorgna et al., 2018; Cooney et al., 2021; Fukushima et al., 2021; Challender et al., 2022; Morton et al., 2022). The aim here is to demonstrate that CITES's current mechanisms make it inappropriate as a conservation and regulatory tool given the specific context of most *Boswellia* species.

2. Different species face different challenges

First, it is important to emphasize that not all commercially traded *Boswellia* species are experiencing the same suite of threats, and that there is a significant degree of diversity in their socio-economic, political, and ecological contexts. This is critical to consider in the light of the suggested genus-level listing of all *Boswellia* species. The diversity prohibits a "one size fits all" policy tool, and successful conservation

interventions need to be driven by and tailored to the desired outcome and specific local circumstances of the species, rather than any generic intervention based on a priori assumptions (Fukushima et al., 2021). CITES is built upon the foundational premise that if a species faces any level of biological threat, regulating (which almost always means reducing) trade via a listing will be beneficial to the species (Cooney et al., 2021). Many species are listed in the CITES appendices not because they are threatened by trade, but as "look alike species" because a similar species or taxon is threatened or assumed to be threatened (Alfino and Roberts, 2019). The underlying logic is the "precautionary principle," whereby listing is assumed to have a universally net-positive impact, thereby opening the doors to listing of any species that is thought to be under threat. Additionally, the Convention utilizes the "look alike" clause, issuing blanket listings of large numbers of species in one genus if it is deemed difficult or impossible to distinguish between the species based on the parts in trade (CITES, 2016). The genus *Aloe* provides an historical example of a non-specific CITES listing having unintended negative impacts on trade and hence rural economies. Companies importing aloe raw materials from South Africa considered it impossible to overcome real or perceived negative consumer sentiments regarding the use of an "endangered species" (*Aloe ferox*) in cosmetic formulations. An industry-supported proposal by South Africa to have finished products exempted from CITES regulations under Appendix II was accepted since it is backed up by a well-organized regulatory system, including a Non-Detriment Finding (NDF) and a Biodiversity Management Plan (DFFE, 2019).

A genus-level approach is reasonable if the socio-ecological circumstances of all species are the same and if impacts of trade are uniformly negative, as has been the assumption (Cooney et al., 2021). In non-lethally harvested NTFPs such as frankincense, however, sustainability of collection is dependent on multiple factors, some of which are largely the same between *Boswellia* species (life history traits, product type), while others are profoundly different (land tenure, resource security, harvesting techniques, lopping of branches for livestock feed, animal impacts (browsing, grazing, debarking), dominant governance structures, supply chain/commercialization structures) (Shackleton et al., 2015; Cunningham and DeCarlo, 2022). A systems approach is essential to understand the management and conservation of *Boswellia* species, as they experience both obvious (e.g., conversion of woodlands to farmland) and cryptic (suppressed regeneration; slow but continuous adult mortality; decrease of tree vitality; decreased reproductive capacity) threats that vary with bio-climatic conditions, land-uses, social, cultural, and economic factors.

Consequently, although the 24 species of *Boswellia* occupy the same genus, and the term "frankincense" is used generically to refer to the resin of any of these species, they cannot be thought of as equivalent or interchangeable. Each species is subject to a unique nexus of ecological, social, political, economic, and cultural factors that affect the harvesting and management practices determining the long-term sustainability of the tree populations. The challenges and opportunities therefore cannot be readily extrapolated or generalized from one species to another, even in the same Range State. Further, demands from trade in the frankincense resin act as both a pressure on the species as well as an incentive for maintaining harvestable populations, with the balance between these demands varying from species to species and place to place (Canney Davison et al., 2022). As a result, policies that may be beneficial in one species or set of circumstances may be detrimental in another. Regulatory mechanisms and incentives will be most effective if they are crafted for and responsive to local community, regional and national level contexts, and realities (IPBES, 2022).

Here we compare, as an example, three commercially traded *Boswellia* species occurring close together in the Horn of Africa: *B. rivae* (eastern/southern Ethiopia[1]), *B. papyrifera* (northern/western Ethiopia[1]), and *B. sacra* (northern Somalia).[1] Despite their geographic proximity, the three species experience significantly different socio-ecological contexts and thus, different drivers of sustainability (Table 1, Fig. 1). Collection of resin for trade has a more or less neutral impact on *B. rivae*, as it is not actively tapped like *B. papyrifera* or *B. sacra* (Lemenih and Kassa, 2011). However, it occurs in communal/open-access rangeland, where it experiences pressure from grazing animals and occasional fires; thus, the key driver of sustainability for *B. rivae* is likely rangeland grazing management rather than trade management. On the other hand, while *B. papyrifera* and *B. sacra* are both actively tapped, they occur in very different land tenure and governance contexts (Table 1). *Boswellia papyrifera* does suffer from damage from resin tapping in a number of locations, but other key factors like grazing, fires, and land clearance for agriculture play even greater roles in the observed population declines. As a result, both pastoral management, agricultural land management, and trade management must be integrated to drive sustainability. In the case of *B. papyrifera* in Ethiopia, there is greater potential for direct government intervention and adjusting policies to ensure better management practices, training, and incentives (Lemenih and Kassa, 2011). *Boswellia sacra* in Somalia has more secure traditional land tenure, harvesting and traditional livestock practices that can be built upon to ensure greater sustainability. For this species, over-harvesting and subsequent insect damage are likely the greatest threat, requiring a focus on supply chain practices and community forest management (DeCarlo et al., 2020). These differential circumstances give the opportunity for different locally effective interventions as well as necessitate the individual evaluation of each species in each national range, to ensure conservation goals are met. Any genus or broad cross-species listing is very unlikely to provide that.

3. How does the trade in frankincense resin impact *Boswellia* trees and tree populations?

The next key consideration is whether the impact of the trade in frankincense resin has a positive or negative effect on the *Boswellia* trees, populations, and forests. While it is tempting to assign a simple "negative" or "positive" value to this impact, the reality is more complex. CITES often deals with lethally harvested species, where the trade in a species inherently requires the death of individuals of that species (Abensperg-Traun, 2009). The Convention was created with the assumption that there is a straightforward relationship between trade and conservation: high or increasing trade should mean negative conservation impacts, so regulation leading to reduction in trade should have a positive conservation impact (Hutton et al., 2000; Abensperg-Traun, 2009).

However, a species being "in trade" is not the same as being "threatened by trade", conditions that are too often conflated in the literature (Challender et al., 2019, Challender et al., 2022). Frankincense is a non-lethally harvested NTFP, which does not inherently require the harvested individuals' deaths to support ongoing trade. With this kind of product, high or increasing trade volumes may, but do not necessarily, threaten the conservation of the species. Large volumes produced using sustainable methods may have a smaller impact on the trees' conservation than a small volume produced by highly destructive tapping methods. Sustainability of harvesting of non-lethal NTFPs depends on a complex of factors including the specific type of product, species ecology, biology, harvesting method, socio-economic dynamics, cultural context, political and governance environment (Newton, 2008; Stanley et al., 2012; Shackleton et al., 2015). Given this complexity, regulation leading to a reduction in trade volumes may have either positive or negative effects on long-term conservation and species

[1] These species occur in other localities as well; we consider the land tenure regimes, threats, etc., only for the stated location.

Table 1
Summary of the different socio-ecological considerations affecting *Boswellia papyrifera*, *B. rivae*, and *B. sacra*, three commercially traded *Boswellia* species in the Horn of Africa (Cunningham and DeCarlo, 2022). VU = Vulnerable; LC = Least Concern; NT = Near Threatened; MT = metric tonne.

	Boswellia papyrifera	***Boswellia rivae***	***Boswellia sacra***
Location	Northern/Western Ethiopia	Southern/Eastern Ethiopia	Somaliland/Northern Somalia
IUCN Global Status (assessment date)	Suggested VU (2019)	LC (2018)	NT (199)
Research Status	Comprehensive	Low	Low
Resin Collection	Actively tapped	Resin collected from natural self-exudations	Actively tapped
Land Tenure	Private companies control government land concessions; local cooperatives organized and permitted by government	Open access rangeland	Traditional family-owned land parcels
Governance	National government permitting and control; management by companies and cooperatives	Limited national government involvement; management by local communities	Virtually no government involvement; management by individual families
Annual Commercialization	2000–4000 MT	<300 MT	>1500 MT
Grazing Impact	High	Moderate	Low
Harvesting Impact	Moderate	Neutral	High
Insect Attack Impact	Moderate	Low	High
Land Conversion Impact	High	Low	Low
Fire Impact	High	Low	Low

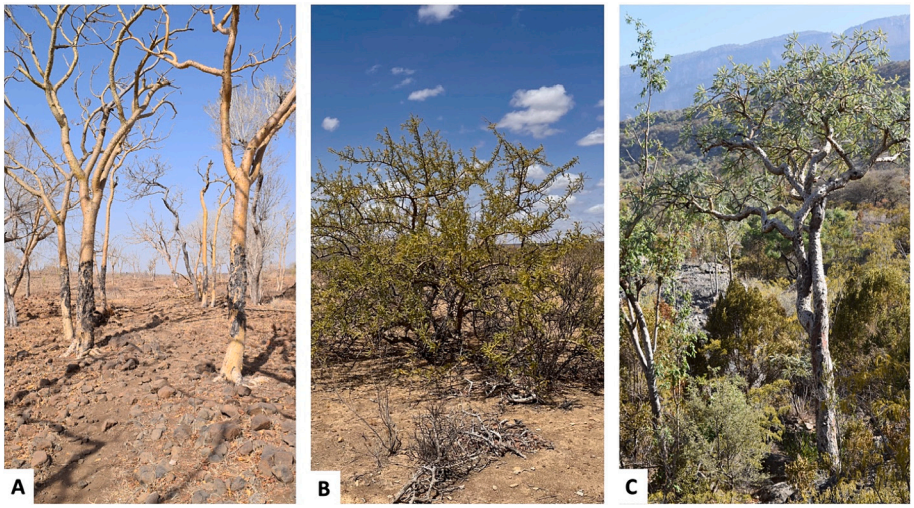

Fig. 1. *Boswellia papyrifera* in northern Ethiopia (A), *B. rivae* in southeastern Ethiopia (B), and *B. sacra* in Somaliland/northern Somalia (C).

sustainability, depending on the specific circumstances of trade.

Harvesting of frankincense resin for trade inherently takes a toll on tapped *Boswellia* trees, and the magnitude of that impact depends on the practices used. Resin harvesting acts as an often-significant carbon sink, reducing the trees' resources (Silpi et al., 2007, Mengistu et al., 2012, Mengistu et al., 2013); this in turn hampers annual growth (Silpi et al., 2006) and reduces seed set (Rijkers et al., 2006; Abad-Fitz et al., 2022). Cutting the trees' bark for resin also opens opportunities for attacks by pathogens and pests like boring beetles (Botha et al., 2004, Negussie et al., 2018). When well-managed, these impacts can be minimized, and the trees given time to sufficiently heal. However, improper and excessive tapping (such as cutting too deeply into the tree and putting too many cuts on any one tree) can severely damage the trees and cause increased mortality and long-term population decline. Improper harvesting techniques and damaged trees have been observed in all major commercial tapped species and different geographies (Bongers et al., 2019, Soumya et al., 2019, DeCarlo et al., 2020, [Author] et al. in preparation), highlighting this as a real and critical threat.

The negative effects of harvesting and trade on *Boswellia* trees are real, but so are the positives. Lower-impact, likely sustainable tapping of frankincense has also been observed across all major commercial tapped species and range states (Bongers et al., 2019, Soumya et al., 2019, DeCarlo et al., 2020). Perhaps more importantly, the economic value of frankincense resin plays a critical role in some areas in protecting the trees from land clearance or more damaging forms of use such as cutting of branches for fodder, charcoaling, firewood, or stripping of bark for low-grade incense. In Somalia, charcoal production has negatively impacted other species, but frankincense trees have been protected in part due to their economic value as well as their less desirable wood (Oduori et al., 2011); use of branches for fodder is also proscribed (PDRC, 2003). Likewise, some species of *Commiphora* in Somalia have been observed to be stripped of their bark for incense, because the resin is not valuable enough; a local harvesting cooperative leader commented of *B. occulta* trees that they would meet the same fate if there were no market for the resin, and this may occur with *B. sacra* and *B. frereana* should they face the same condition ([Author] pers. obs. and communication with cooperative leader in Hargeisa, Somaliland, 2018). Similarly, *B. papyrifera* trees face land clearance for crop production, but may be protected or left standing in otherwise cleared fields if the landowner derives income from them (Dejene et al., 2013).

We cannot say that the destructive alternative use of *Boswellia* trees in the absence of resin trade is a foregone conclusion, but it is a point of no small concern. A large number of people derive income from the harvesting of frankincense resin, which they can ill afford to lose. In Somaliland and Puntland (Somalia) alone, the UN FAO estimated that around 225,000 people derived most of their income from frankincense or related activities in 2010; the poorest families were the most reliant on the resin, receiving 72% of their income from it (FSNAU, 2016). The

number of beneficiaries is likely higher in Ethiopia and/or Sudan, where resin exports are typically higher than from Somalia (Cunningham and DeCarlo, 2022). Indeed, gum and resin production is reported to represent up to almost 40% of rural household income in southeastern and northern Ethiopia (Lemenih et al., 2003; Woldeamanuel, 2011; Worku et al., 2011). While obtaining reliable figures is notoriously difficult, especially in Somalia, this and other estimates from Somalia (Farah, 1994) indicate the magnitude of the dependence on frankincense for local livelihoods. Other major sources of income in frankincense-producing regions include crop cultivation (requiring land clearance), and, critically, livestock, which has been repeatedly devastated by drought in the recent past, a trend expected to worsen under ongoing climate change (Cook and Vizy, 2012, 2013). Indeed, gums and resins function as a critical source of emergency income during times of drought in Ethiopia (Woldeamanuel, 2011, Worku et al., 2011). As a result, local communities will be under significant pressure to extract value from both the frankincense trees and other species in any way possible.

Stripping of bark for low-grade incense that is traded informally across regional borders (and is thus difficult to regulate), which has been seen in limited areas in Somaliland, may expand (DeCarlo et al., 2020). The use of *Boswellia* foliage for fodder may become more prevalent in an attempt to reinforce the livestock trade, a process already seen in northern Ethiopia, with a significant negative impact on resin production and likely tree health (Tilahun et al., 2007; Gelaye, 2012; Muys, 2019). Furthermore, landscape-level impacts need to be considered, especially as *Boswellia* trees in Somalia grow in a critically endangered mountain forest ecosystem (Magin and Burdette, 2017); charcoal production is one of the few viable sources of alternative income in harvesting regions, other than harvesting or livestock, and while *Boswellia* trees themselves are undesirable as charcoal due to their light wood, the elimination of the resin trade may put significant pressure on many other suitable species such as those of *Vachellia* and *Senegalia* due to former resin harvesters switching to charcoal production out of necessity (Oduori et al., 2011).

It is apparent that the harvesting and international trade in frankincense resin is both protecting and damaging *Boswellia* trees (Table 2), with the exact balance between these forces differing from location to location. It is equally apparent from the existing research that the major commercial species are suffering serious conservation challenges and require interventions to protect them. Therefore, it is important to implement policies and approaches that reduce the negative impacts of trade, while maintaining the positive livelihood and conservation functions, and to evaluate potential interventions on this basis.

4. Is CITES the right mechanism to address these challenges?

The CITES Convention has the considerable advantage of being almost universally recognized, and it contains strong provisions to suspend trade if Parties fail to follow the Convention's requirements. However, both the structure of CITES itself and the specific circumstances of the major commercial species of *Boswellia* raise doubts as to whether the effect of a CITES listing would be net positive for some or all *Boswellia* species (Challender et al., 2015).

Table 2
Positive and negative impacts on *Boswellia* trees and populations of harvesting and trade in frankincense resin.

Positive Impacts	Negative Impacts
Economic value of resin incentivizes protection of trees from land clearance, grazing, limb cutting, destructive use	Harvesting reduces carbon gain, annual growth, reproduction; tapping opens opportunities for pests/pathogens
Income from resin harvesting reduces incentives for destructive use of other species (such as charcoaling)	Overharvesting or improper harvesting can lead to increased morbidity and mortality
Income from resin harvesting is a critical livelihood and source of resilience against climate impacts	Trade value can drive overharvesting in poorly organized supply chains

A critical presupposition of the CITES framework is that the original States of Export, that is, the countries in which the species were collected, have the capacity to effectively assess the legality and sustainability of the species' harvest in order to make non-detriment findings (Foster and Vincent, 2021). However, while some Range States have relatively strong governance, such as Oman or India, the majority of internationally traded frankincense originates from countries like Somalia and Sudan, which have limited resources to monitor or assess the sustainability of harvesting in the remote and often conflicted regions where the resins are sourced. In the case of a lethally harvested species, a simple export quota may be sufficient to determine sustainability if basic population data are known. However, in the case of non-lethally harvested species like *Boswellia*, where the harvesting techniques and land management approaches used to produce any individual batch of resin are the critical factors, a relatively high level of monitoring is required to ensure sustainability. This is difficult for any state, but particularly for those that are already stretched thin or for whom there are structural barriers such as large distances, poor infrastructure, widespread and remote sourcing, and political, and in many cases armed, conflict.

Another consideration is the relatively high level of corruption in frankincense-exporting states, including Yemen, South Sudan, and the major exporters Somalia and Sudan, which are ranked among the most corrupt according to Transparency International's Corruption Perceptions Index (Dumenu, 2019; Transparency International, 2023). Corruption in NTFP supply chains is relatively common, with bribery, collusion, nepotism, and favoritism representing some of the most common forms (Tieguhong et al., 2015; Timoshyna and Drinkwater, 2021). Indeed, corruption in the CITES permitting process has been reported in a variety of range states and taxa, including in Nigeria, which is a *Boswellia* exporting state, and in Cameroon, with the NTFP *Prunus africana* bark (Tieguhong et al., 2015; Cunningham et al., 2016; Outhwaite, 2020). Additionally, many importing states have strict laws against companies being involved in corrupt practices in foreign countries, such as the USA Foreign Corrupt Practices Act or the UK Bribery Act. A listing in an exporting state where corruption is, or is perceived to be, occurring, may discourage international partners from becoming more involved in the supply chains and production processes within range states. This could stymie efforts to address endemic inequalities within the value chains, which are a key driver of unsustainable practices (Farah, 1994; DeCarlo et al., 2020).

Existing trade suspensions and significant levels of informal international trade complicate matters further. There are long-standing suspensions on trade of CITES-listed species from Somalia and Djibouti, both of which are major exporters of frankincense resins (Somalia exports directly, while Djibouti is the transshipment point for resins from Ethiopia). A listing would therefore act as a trade ban from Somalia and effectively from Ethiopia, two of the top three largest frankincense exporters in the world (Cunningham and DeCarlo, 2022). Although a listing may provide further incentive to resolve the legislative and reporting issues underlying these suspensions, a quick resolution is unlikely. This is complicated additionally by the high level of informal international trade. *Boswellia papyrifera* resin is often brought into Ethiopia or Egypt from Sudan; *B. sacra* and *B. frereana* resins from Somalia are traded informally into Kenya, Ethiopia, Djibouti, Oman, and Yemen, while *B. sacra* from Oman is sent to the UAE. Similar patterns occur for almost all species (Cunningham and DeCarlo, 2022). In these cases, barriers to formal trade may expand or incentivize these informal trade networks. In Nepal, for instance, the centralized quota and royalty system for harvesting the CITES-listed *Nardostachys jatamansi* in theory supports conservation, but widespread illegal trade continues due to systemic enforcement failures (Smith-Hall et al., 2023). Informal trade is even more opaque than formal supply chains; supply chain opacity is a

key factor limiting sustainable harvesting and resource management, and stymies efforts by purchasers and users of these materials to support such efforts (Brendler et al., 2018; Johnson et al., 2019). Consequently, while listing would almost certainly reduce legal trade, it is likely that large volumes of resin would still be harvested and traded, but without the potential for improvements found in formal supply chains.

Finally, it is important to acknowledge the iconic cultural and social importance of frankincense for the traditional owners and harvesters of the resins, and to take into account how listing would be perceived by these communities and the market. The harvesting, use, and trade of frankincense resin is integral to the culture of harvesting regions such as southern Oman and northern Somalia (Farah, 1994; Farah, 2008). A non-lethally harvested NTFP comparison would be the iconic cultural importance of maple (*Acer saccharum*) syrup tapping to the communities and culture of southern Canada and the northeastern United States. Declines due to a variety of threats, including non-trade threats, have been noted in both frankincense and maple species (Bishop et al., 2015; Barstow et al., 2017) and sugar maple may well have a lower EOO and total populations size than *Boswellia papyrifera* (Farrell, 2013; Barstow et al., 2017). But, in order to support the long-term sustainable management of the tree populations such as frankincense and maple, the cultural and economic sensitivities and consequences around listing need to be taken fully into account. Indeed, there is a strong sense of anger and indignation in some frankincense harvesting areas at the idea of CITES controlling or blocking the trade ([Author] pers. comm. with harvesters, landowners, and traders in Somalia and Oman), which may not ultimately benefit the trees, especially if there is little incentive to protect them because of trade blocks or elite permit capture and important cultural and social engagement, incentives and knowledge are lost.

As with the potential for alternative destructive use of *Boswellia* trees in the absence of the resin trade, the potential for significant corruption, ineffective implementation, cultural upheaval, and effective trade bans is not an inevitable or inherent outcome of a listing. Still, the majority of the world's frankincense resin originates in range states that are impacted by extremely limited resources, severe corruption, and/or trade suspensions. As a result, the way in which CITES works, relying on exporting state infrastructure and with trade suspensions already in place, reduces the likelihood of it achieving the desired conservation effect without significant support to the exporting states.

5. Potential alternatives to a CITES listing

Given these considerations, we argue that CITES listing is likely not the best approach to protect *Boswellia* species from negative effects of international trade. Still, while it is clear that the mechanisms of CITES listing fit poorly with the circumstances of most *Boswellia* species, it is equally apparent from the existing research that interventions are needed to protect these species from ongoing or potential declines in connection with trade or other activities. Successful interventions will necessarily be multifaceted and tailored to the specifics of each species, addressing the multiple stakeholders and threat actors involved, but broadly fall into two categories: direct improvements in governance and standards of practice by supply chain actors, and importing state regulatory requirements driving the implementation of these improvements (Canney Davison et al., 2022).

Direct actions including improved supply chain and production management technologies, improved rangeland management programs, and product or supply chain certifications, have seen some use in frankincense production systems, although much greater implementation is necessary (Cunningham and DeCarlo, 2022). Certifications designed or adaptable for the collection of wild plants, like FairWild or UEBT Ingredient Certifications, often have stringent standards for sustainable collection practices and limits; either alone or in combination with social standards such as Fair Trade or Fair for Life, they have the potential to demand much higher levels of practice from supply chain actors (Yadav and Dugaya, 2013). Certifications have already seen some use in frankincense Range States: almost one million hectares of land in Somalia were certified organic for wild collection of gums and resins in 2021, while frankincense operations have also been certified in Oman, Kenya, Ethiopia, and India (Cunningham and DeCarlo, 2022). Likewise, five producers in Somalia, India, and Kenya have become FairWild certified for frankincense collection, with the majority of certifications taking place since 2020 (FairWild, 2024). While the certified quantities are not publicly disclosed, the growing number of certified producers highlights the increased interest in applying certification standards to production.

However, while the standards themselves are often comprehensive, systemic challenges to implementation exist in many NTFP systems, including frankincense (Pierce et al., 2008; Schmitt et al., 2008; Duchelle et al., 2014; Delgado et al., 2016). The remote harvesting sites, widely dispersed trees, security challenges on the ground, and traditional supply chain opacity make effective field auditing difficult. Indeed, questions have been raised about whether the standards for certifications currently in use are being met on the ground, with reports of insufficient field auditing for the amounts of resin certified and significant biological contamination in certified batches (Johnson et al., 2019; Cunningham and DeCarlo, 2022).

Pairing certifications with enhanced supply chain management tools like digital distributed documentation apps holds potential to bridge this gap. Programs such as CyberTracker (https://cybertracker.org/partner/smart-conservation/), ArcGIS Collector, and various other private and open source data collection apps have been used successfully to map environmental resources and track harvesting impacts, even in very remote areas such as those in which frankincense is harvested (Ansell and Koenig, 2011; Ens, 2012; Nowak et al., 2020). These applications allow the collection of data on harvested tree populations and supply chain operations where data can be collected with time, date, and location stamps, allowing temporal and spatial tracking of trade operations and impacts. The recently developed app SharkTrace is currently being trialed to track the sustainability of shark and ray fisheries, with initial testing in Australian fisheries (TRAFFIC, 2024). Likewise, ArcGIS Collector has been used to map *Boswellia sacra* populations and document tree health in Oman, demonstrating the applicability in frankincense supply chains (Johnson et al., n.d.).

Additional data security features such as blockchain can also help protect data integrity, as it provides an indelible ledger of data captured in real time, making it difficult to obscure or falsify supply chain data at a later date (for instance, during a certification audit) (Heinrich et al., 2019; Raterman, 2019; He and Turner, 2022). Distributed documentation also offers the potential for broader confirmed data collection even in remote areas that would be difficult to access during a standard audit, thereby improving audit strength. This approach is already being applied by at least two producers in Somalia, where blockchain-enabled mobile apps are being used to document supply chain operations and resin purchases, register harvesters, and document harvesting practices and tree health (Johnson and Thornton, 2023). The use of blockchain to track complicated supply chains involving myriad smallholders in remote areas is being expanded in other forest products as well, including coffee (*Coffea arabica*) in Colombia, Honduras, and Ethiopia (Bager et al., 2022, Trollman et al., 2022, [Author] pers. comm. with Bext360); wild-collected palm (*Elaeis guineensis*) in Liberia and Ghana; and bois de rose (*Aniba rosodora*) in Peru (Johnson and Thornton, 2023).

The existing application of these supply chain management tools demonstrates their practical potential to improve frankincense supply chains, and offers case studies of successful implementation. Still, the use of these tools will necessarily need to be dramatically scaled up to cover a significant fraction of resin harvesting, and over time we expect these approaches to become more refined and successful at capturing key data. Engaging with harvesting communities and local traders will be critical, in addition to mobilizing downstream actors like brands and fragrance houses to ensure economic incentives for traceability are

present. The lack of stability and fair prices for harvesters is a major driver of poor harvesting practices for frankincense in Somalia (DeCarlo et al., 2020). Enhanced traceability could both monitor harvesting and forest management standards and ensure harvesters are being paid fairly, providing a strong incentive for communities to engage with these systems (Watts et al., 2019). Harvesters would likely embrace improved transparency if they perceive it would improve their financial returns ([Authors] pers. comm. with harvesters in Somalia, Ethiopia, and Kenya). Stronger land tenure for harvesters may also improve land management outcomes (Kozanayi et al., 2022), but tenure devolution from central government to local control can be complicated and does not necessarily result in improved practices in the short term (Tegenie et al., n.d.; *S. Johnson* pers. comm. with land managers in Tigray and Amhara, Ethiopia). Furthermore, the threats to local land tenure include large-scale processes such as migration, armed conflict, and population increases, which are not easily solved by simple policy shifts (DeCarlo et al., 2020, Johnson and Bongers, 2024).

Despite the potential of these supply chain management tools, regulatory improvements may be necessary to see their widespread use. The key challenge with using CITES to accomplish this is that it relies on exporting state institutions to issue the key permits. This results in the onus falling on institutions that are, with a few exceptions, limited in both budget and capacity in key *Boswellia* range states and some of whom are subject to trade suspensions. Shifting the regulatory burden to importing state institutions (and importers themselves) could ameliorate these challenges. Various pieces of national or supranational legislation already in place could be applied to *Boswellia* supply chains, such as the US-based Lacey Act and California Supply Chain Transparency Act, or the EU Due Diligence legislation (Cunningham and DeCarlo, 2022). Although none are comprehensive alone in addressing all social and environmental risks, they could force improvements. Further importing state legislation implementing import, rather than export, permits as the key controls on trade could avoid the capacity challenges in Range States while still forcing trading entities to ensure their collection and trade is sustainable.

Finally, it is clear that further data collection and research are necessary to fully understand and better manage the frankincense trade. While *Boswellia papyrifera* in Ethiopia is one of the best-studied NTFPs, there are significant gaps in other *Boswellia* species (Cunningham and DeCarlo, 2022). There are still limited quantitative data on the population dynamics, regeneration, and threats impacting other commonly traded species such as *B. sacra, B. frereana,* and *B. serrata.* Likewise, the harvesting systems, resource use and tenure rights, and factors driving tree management remain poorly documented in most species. However, there are opportunities to use improving transparency and traceability in supply chains to address these gaps, using participatory research approaches that collect data in partnership with supply chain actors like harvesting communities (Palaschuk et al., 2024). This has been a historically under-utilized source of data, but as transparency efforts expand, the ability to conduct meaningful analyses of *Boswellia* populations and their harvesting systems will improve.

6. Conclusions

The well-documented conservation challenges in multiple commercially traded *Boswellia* species necessitate interventions to arrest or avoid population declines. However, the complex relationship between trade and conservation for *Boswellia* species, with both positive and negative effects, means that the chosen interventions should be designed to address the negative aspects of trade without likewise removing the positive aspects, or damaging the livelihoods of the large numbers of people dependent on the frankincense trade. While CITES has power as a broad international treaty, its reliance on exporting-state infrastructure and existing trade suspensions on key frankincense-exporting states make it inappropriate to address the challenges seen in most *Boswellia* species. Direct supply chain improvements driven by importing state regulations have some potential to toughen the standards for the ongoing trade of frankincense, while avoiding these problems. We conclude that while there are no simple solutions, the best course of action is to avoid a listing of some or all *Boswellia* species, particularly those from range states where implementation capacity is relatively low, and corruption is relatively high.

CRediT authorship contribution statement

Stephen Johnson: Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Sue Canney Davison:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **Kelly Ablard:** Writing – review & editing. **Frans Bongers:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Anthony B. Cunningham:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Anjanette DeCarlo:** Writing – review & editing, Supervision, Investigation, Conceptualization. **Ben-Erik Van Wyk:** Writing – review & editing.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

Stephen Johnson reports a relationship with FairSource Botanicals that includes: equity or stocks. Anjanette DeCarlo reports a relationship with various private-sector companies that includes: consulting or advisory. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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