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Subject strapline: Plant conservation

Title: Frankincense facing extinction

Standfirst: The conservation of *Boswellia papyrifera*, a dryland tree from the Horn of Africa and source of frankincense, conflicts with growing use. A new study finds impending collapse of this iconic tree throughout its range, prioritizing the need to restrict uncontrolled tapping and cattle herding.

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Home to some of the most iconic plant domestications, including Arabica coffee (*Coffea arabica*) and the coeliac-friendly cereal teff (*Eragrostis tef*), the Horn of Africa is a biodiversity hotspot and region of exceptional natural history and cultural value. There, the western foothills of the Abyssinian highlands capture short and erratic rains that support a treasure of world-class heritage, the frankincense tree *Boswellia papyrifera*. Frankincense, the tapped resin of the deciduous dryland tree genus *Boswellia*, is a fragrant luxury product already traded by Egyptians and Hebrews for ceremonial purposes in ancient times and used widely today in Christian churches and perfumes. For many familiar with the product but with little idea of its sourcing, a recent paper in *Nature Sustainability*, Bongers et al. (2019), brings staggering news. After previous declines of other frankincense species in Somalia and the Arabian peninsula, the authors show evidence for collapse of the current major frankincense producer, *Boswellia papyrifera*, over its entire geographic distribution.

A first encounter with a *B. papyrifera* woodland, typically on a rocky outcrop in a desertic landscape, feels like an extraterrestrial experience. With their thick, sub-vertical and

twigless branches covered in a peeling orange bark, these trees look like root systems turned upside down. The species' ecology and management has received growing attention after Gebrehiwot et al. 2003, a recent review, and aspects of its intriguing life cycle and human use have been unraveled. For instance, before becoming a tree, *B. papyrifera* goes through a so-called "suffrutex stadium", where it invests in the development of deep water-seeking roots while the above-ground parts may die back every dry season. This is a fascinating adaptation to accidental fire or browsing, but it costs the tree precious soluble carbohydrates and adds mortality risk if they are overbrowsed or if fires recur. An artificial regeneration technique inspired by indigenous knowledge opens possibilities for restoration (Negussie et al., 2009). High mortality and lack of regeneration among *B. papyrifera* has been observed and linked to unsustainable resin tapping and other human-mediated pressures (e.g. Negussie et al. 2008, Groenendijk et al. 2012, Tolera et al. 2013), but an overview of the state of the species over its full geographic range, including its more inaccessible lowland areas, was lacking.

Bongers et al. (2019) synthesize information from 21,786 trees spread over 23 populations covering *B. papyrifera*'s entire range, including its altitudinal distribution, along with four detailed tree-ring studies. The analysis relied on scientific coordination over sometimes war-torn borders between Ethiopia, Eritrea and Sudan. These inputs enabled the authors to model the tree's population dynamics for the coming decades. They found an over 50% decrease in frankincense yield in just 20 years time, a breathtaking decline of this iconic non-wood forest product. Age-class distributions further showed a huge regeneration gap, so populations are not replacing themselves.

Based on these results, the authors mount a convincing case to add *Boswellia papyrifera* to the "vulnerable" category in the IUCN Red List, the benchmark inventory of conservation status for species worldwide, which will surely be discussed at the 18th meeting of the Conference of the Parties (CoP) to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), in August 2019. In the meantime they plead for controlled resin tapping, obligatory tapping rests, establishment of firebreaks, and reduced livestock pressure by applying exclosures, areas effectively closed to cattle through by-laws and guards, which have proved extremely effective for forest restoration in northern Ethiopia. The drivers of decline are not explicitly studied in Bongers et al., but other studies (e.g. Rijkers et al. 2006; Mengistu et al. 2013) suggest tapping *B. papyrifera* harms tree vigor, seed production and seed viability. This is interesting, because studies on pine-resin tapping show contrasting and context-dependent effects of tapping on stem growth (van der Maaten et al. 2017). But while rightfully focused on tapping, Bongers et al. possibly overlooked another important cause of *Boswellia* woodland degradation, tree lopping for cattle feed. One realizes how keen herbivores are on fresh *Boswellia* leaves when observing a herd of dromedary camels eagerly foraging in the bottom of their crowns (Figure 1). Farmers cut leaved branches to feed their cattle, a practice observed especially in critical dry years. A single tree lopping reduces frankincense yield (Gelaye, 2012), and recurrent leaf lopping may, just like tapping, cause carbon starvation, mortality from depletion of soluble carbohydrates in stem and roots. Future research could therefore focus on disentangling the

multiple drivers of tree harm to inform context-specific policies. Indeed, governance studies supporting the sustainable use of *Boswellia* are still in their infancy.

As with many other commodities, consumers savor the qualities of frankincense without realizing the story behind its provision. The Bongers et al. paper has usefully traced the resin to its origins in some of the most inaccessible parts of Africa and informed us about the impending population collapse of its source trees. Now that the diagnosis has been made clear and the causes better understood, the time has come for knowledge-based action. Corporate social responsibility could play a pivotal role. By adopting rigorous eco-certification standards and creating conservation funds supporting concrete field projects, the perfume industry, the church, and individual consumers can support local communities and authorities in the rescue of this cultural and natural monument.

References

- Bongers et al. (2019). Frankincense in peril. *Nature Sustainability*. 1 July 2019. doi.org/10.1038/s41893-019-0322-2
- Gebrehiwot, K., Muys, B., Haile, M., Mitloehner, R. (2003). Introducing *Boswellia papyrifera* (Del.) Hochst and its non-timber forest product, frankincense. *International forestry review* 5(4), 348-353.
- Gelaye M.T. (2012). Restoration and sustainable management of frankincense forests in Ethiopia: a bio-economic analysis. PhD thesis KU Leuven.
- Groenendijk, P., Eshete, A., Sterck, F. J., Zuidema, P. A., Bongers, F. (2012). Limitations to sustainable frankincense production: blocked regeneration, high adult mortality and declining populations. *Journal of Applied Ecology*, 49(1), 164-173.
- Negussie, A., Aerts, R., Gebrehiwot, K., & Muys, B. (2008). Seedling mortality causes recruitment limitation of *Boswellia papyrifera* in northern Ethiopia. *Journal of Arid Environments* 72(4), 378-383.
- Negussie, A., Aerts, R., Gebrehiwot, K., Prinsen, E., Muys, B. (2009). *Euphorbia abyssinica* latex promotes rooting of *Boswellia* cuttings. *New forests* 37(1), 35.
- Mengistu, T., Sterck, F. J., Fetene, M., Bongers, F. (2013). Frankincense tapping reduces the carbohydrate storage of *Boswellia* trees. *Tree physiology*, 33(6), 601-608.
- Rijkers, T., Ogbazghi, W., Wessel, M., Bongers, F. (2006). The effect of tapping for frankincense on sexual reproduction in *Boswellia papyrifera*. *Journal of Applied Ecology*, 43(6), 1188-1195.
- Tolera, M., Sass-Klaassen, U., Eshete, A., Bongers, F., Sterck, F. J. (2013). Frankincense tree recruitment failed over the past half century. *Forest Ecology and Management*, 304, 65-72.

van der Maaten, E., Mehl, A., Wilmking, M., & van der Maaten-Theunissen, M. (2017). Tapping the tree-ring archive for studying effects of resin extraction on the growth and climate sensitivity of Scots pine. *Forest Ecosystems* 4(1), 7.

Figure 1. Dromedary camels browse and stand in the shade of *Boswellia papyrifera* trees in the lowlands of Tigray, northern Ethiopia. Photo: Eva November / Raf Aerts, Creative Commons Attribution 4.0 International License (<https://creativecommons.org/licenses/by/4.0/>).