Section SIX

Boswellia Field Surveys

Given the concept that tracking trade volumes and patterns only has limited value in either the identification of over-harvesting or any procedures to ameliorate that threat, it has become clear that monitoring trees and populations directly in the field is the only way in which *Boswellia* tree conservation can be monitored and achieved in the long term. As such, a rapid field survey protocol was developed and tested in ten localities encompassing five species (see Table 6.1).

Species	Countries surveyed				
Boswellia dalzielii	Benin	Burkina Faso	Ghana	Niger	Nigeria
Boswellia frereana	Puntland	Somaliland			
Boswellia neglecta	Kenya				
Boswellia rivae	Somalia				
Boswellia sacra	Somaliland	Yemen			

Table 6.1. Summary of locations and species surveyed.

Section 6.1

Survey design

The survey was designed with repeatability, comparability and the potential for expansion in mind. Further, it was designed to be relatively straightforward to accomplish in the field by a variety of stakeholders, focusing entirely on local actors. It was NOT designed as a one-off, stand-alone scientific study during which detailed field assessments and subsequent analyses would be undertaken but rather as a survey that gathered data relevant to assessing levels of harvesting and damage on individual trees and across populations that could demonstrate sustainable levels of harvesting in the short, medium and long term. Comparability was considered so that the same methods could be used in different areas, States and cultural backgrounds to enable judgements as to the levels of sustainability could be made across the range of each species.

Surveys were designed so that critical factors were measured directly as opposed to being estimated on a scale or grade of intensity as the latter would be susceptible to differences in interpretation which would make the data and surveys as a whole incomparable with each other spatially and across different time intervals. Direct measurements also give greater statistical power for meta-analyses in the future should this be desirable.

While the survey protocol was the same in all areas studied, it was also a deliberate attempt to ascertain which aspects of the survey protocol were easy to undertake, and also whether the protocol would require modification in any way prior to presentation as a long-term monitoring tool that can be implemented by a range of actors in different geographical and cultural settings.

The survey protocol and instructions is presented in Appendix 6.1.

Those undertaking surveys included individuals, from local universities, forestry services, Government environmental authorities, NGOs and harvesting communities.

Section 6.2

Methodology

The suggested methodology for in-country survey teams was to use 50 m x 50 m plots where possible, and to record data for up to 50 trees per plot. A standardised set of observations was recorded for each tree. Observations included diameter at breast height (measured at 1.3 m above the ground) for all stems, and tree height and crown spread estimates (measurements where possible). To allow for a comparison of harvesting intensity at different sites, survey teams were asked to record the number of cuts on each stem. Information was also gathered on presence/absence of flowers and fruits, damage from insects or animals, fire damage, and whether trees had been cut for wood. Local communities were asked a series of questions relating to use (of resin and any other tree parts) trade, and threats.

All incoming data were checked for errors and omissions and adjusted as necessary following discussion with survey teams. Where site descriptions were not provided, photographs and satellite images (Google Earth) were examined. Where sufficient data were provided, population structure was examined based on DBH size class (increments of 10 cm). For trees with multiple stems, the measurement of the main/largest stem was used. Where DBH measurements were not provided, tree height and/or crown spread measurements were used.

For species that require cuts for resin tapping, the intensity of tapping was assessed by examining the percentage of trees with cuts, stems with cuts (i.e. where trees had multiple stems), size classes of stems with cuts, and number of cuts on individual stems. Information on the frequency of resin harvesting was also taken into consideration, alongside any use of other parts of *Boswellia* trees, to provide a preliminary assessment of the status of each species in each range state.

Exchange rates for resin selling prices were converted from local currency to USD in January 2025 via https://www.xe.com/.

The data received from survey teams (tree data, voucher specimens, resin samples, and information from community interviews) were variable in content and quality, and there were a number of recurring issues, largely brought about by differing interpretations of survey protocols. These are discussed in section 6.4 together with recommendations for future work.

Section 6.3

Survey results

Surveys were carried out in 2023 and 2024 by local teams in the following ten range states: Benin, Burkina Faso, Ghana, Kenya, Niger, Nigeria, Puntland, Somalia, Somaliland and Yemen. A total of 879 trees were surveyed. Data for *B. dalzielii* were collected in Benin, Burkina Faso, Ghana, Niger and Nigeria. Data for *B. frereana* were collected in Puntland and Somalia. Data for *B. neglecta* were collected in Kenya. Data for *B. rivae* were collected in Somalia. Data for *B. sacra* were collected in Somaliland and Yemen.

Boswellia dalzielii

A total of 470 *B. dalzielii* trees (595 stems) were measured across five range states (Benin, Burkina Faso, Ghana, Niger and Nigeria).

Benin

Surveys were carried out in September 2023. A total of 22 trees (27 stems) were recorded across 12 plots in Benin. The full extent of the search area is not known but the sample data indicate a very patchy distribution of relatively small trees (see Figure 6.1), often isolated individuals, or occurring together in very low numbers (the minimum number of trees recorded in a plot was 1, mean was 2, maximum was 6). Examination of site photos and satellite imagery indicates that all but one of the survey locations were on land where the ground layer has been cleared for agriculture (see Figures 6.2a and 6.2b).

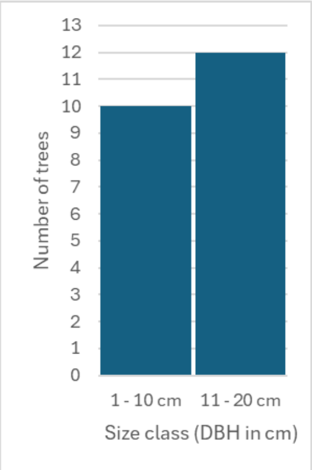

Figure 6.1. Number of trees in each size class (based on DBH measurement of main stem) for 22 *B. dalzielii* trees in Benin. Minimum DBH 2.3 cm, mean 10.3 cm, maximum 19.6 cm.

Figure 6.2a. *B. dalzielii* on land where ground layer has been cleared for agriculture in Benin.

Figure 6.2b. *B. dalzielii* on a hill overlooking the town of city of Savè, Benin.

64% of trees (59% of stems) had cuts for resin harvesting (see Table 1). The size class (DBH in cm) that had the most stems with cuts was 11 – 20 cm. No information was provided on resin trade, or local use of other parts of the tree.

Although the frequency of resin harvesting is not known, the relatively high percentage of trees and stems with cuts in combination with stems as small as 5.9 cm DBH having multiple recent cuts (see Table 6.2) suggest that current levels of resin harvesting are unlikely to be sustainable. Clearing of ground layer for planting crops would likely result in removal of seedlings, therefore hampering regeneration. Although no evidence was recorded of *Boswellia* trees having been cut for wood, there are dead trees, stumps, and dead wood in several of the site photos. No trees over 19.6 cm DBH were recorded and so the question remains as to why there are no large trees. It is possible that smaller trees are not reaching maturity due to overharvesting of resin, or other threats. This is a very small sample size and further field surveys are required.

Burkina Faso

Data were recorded for a total of 324 trees (442 stems) across 21 plots in Burkina Faso in August 2023. All plots were located away from urban and/or agricultural areas and settlement, and none were recorded as being threatened by development or other anthropogenic landscape modifications (e.g. well, damns, etc). Twelve plots were located in areas that have been previously identified as 'natural ecosystems of *B. dalziellii*' (Imasgo, Niou and Zitenga -see Sabo *et al.*, 2023). The full extent of the search area is not known but data suggest a scattered distribution, with considerable variation in population size (the minimum number of trees in a plot was 2, the mean was 15 and the maximum was 115). Across all plots, the DBH size class with the highest number of trees was 11 – 20 cm (see Figure 6.3).

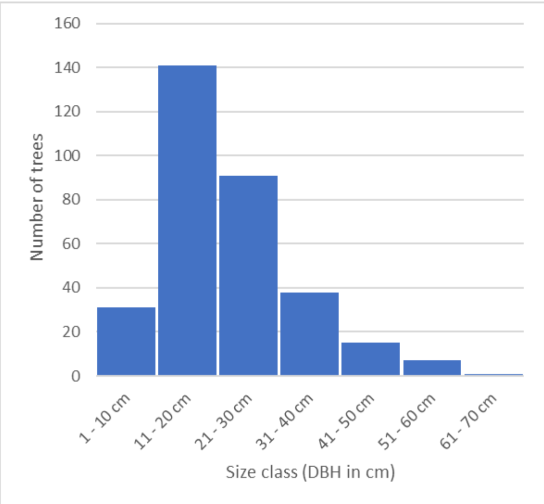

Figure 6.3. Number trees in each size class (based on DBH measurement of main stem) for 324 *B. dalzielii* trees in Burkina Faso. Minimum DBH 1.4 cm, mean 21.6 cm, maximum 68.8 cm.

Only 12% of trees had cuts for resin tapping. Of the 442 stems surveyed 43% had recent cuts, and the mean number of cuts per stem was relatively low (see Table 1). The size class (DBH in cm) that had the most stems with cuts was 21 – 30 cm. There were no cuts on stems < 10 cm DBH. No flowering or fruiting was recorded in any of the plots and there was no evidence of any insect damage. Ten of the 21 plots had low levels of damage to trees from either from fire, cutting for wood or forage, or damage by animals. In community interviews, all respondents (57 in total) used bark for medicinal purposes but only two respondents used resin. The leaves, roots and fruits are also used for medicinal purposes.

Overall, the sample data suggest that populations of *B. dalzielii* in Burkina Faso are in relatively good condition compared to other range states for this species. In addition to the presence of large stands of trees (see Figure 6.4), there were low numbers of cuts on stems, and cuts appeared to be restricted to stems above 10 cm DBH which may increase the chances of young trees reaching maturity. None of the plots had ground layer cleared for crops, thereby giving seedlings a better chance of survival. For comparison, Sabo *et al.,* 2021 suggest that 80.18% of trees surveyed on different land use types in the Boucle du Mouhoun region (northwestern Burkina Faso, approximately 130 km west of the nearest rapid survey plot) were “unhealthy” (based on indices of human exploitation) due to intensive debarking and cutting. Over half of the trees surveyed (949 in total) were “severely unhealthy” in farmlands and fallows, whereas woodlands were dominated by “healthy” or “moderately healthy” individuals.

Figure 4. Stand of *B. dalzielii* in Burkina Faso.

Ghana

In August 2023 the survey team in Ghana visited 24 locations across three regions (Savanna region, Upper West and Upper East regions) to search for *Boswellia* trees. At each location they walked two 1 km x 20 m transects. Only one stand of *B. dalzielii* (66 trees; Figure 6.5) was located and all trees recorded were confined within a 50 m x 50 m plot area.

All live trees were noted to be juvenile (all 66 stems measured were in the 1 – 10 cm DBH size class), growing from suckers (basal shoots) or stumps. Minimum DBH was 1 cm, mean 2.8 cm, maximum 6.4 cm. No mature or seed-bearing trees were found and there were no seedlings. The location is regarded as sacred by the local community and while live trees are not cut for wood, dead trees are cut, and firewood is collected after the yearly fires. *Boswellia* leaves are used locally as medicine, but resin tapping is not a known practise in the area. The survey team made cuts in stems for resin samples but after three weeks, they reported that no significant amount of resin had been exuded.

Sample data suggest that *B. dalzielii* populations may be restricted to a specific habitat in Ghana and the team noted that there may be a problem with regenerating from seed. The team suggest that frequent fires are preventing juvenile trees from reaching maturity, and the also reported evidence of larger trees (i.e. potentially mature, seed-bearing trees) that had been cut or burnt.

Figure 6.5. *B. dalzielii* habitat in Ghana.

Nigeria

Surveys were carried out in five states in Nigeria (Bauchi, Kaduna, Kwara, Niger and Taraba) in June 2023. A total of 30 trees (31 stems) were recorded by the team. Size class of trees (based on DBH of main stem) is shown in Figure 6.6. Nine trees in and around New Busa town were isolated individuals near buildings. The remainder were outside of urban areas. Eleven trees were on land used for agriculture (usually isolated trees – see Figure 6.7a), seven trees were in very open woodland, and three trees were within patches of more dense woodland (see Figure 6.7b). Similar to Benin and Niger, the sample data suggest a very patchy distribution, often isolated individuals, or occurring together in very low numbers (unlike the dense stands of *B. dalzielii* in Burkina Faso).

A very high percentage of trees (93%) of trees (94% of stems) had cuts for resin tapping. The size classes (DBH in cm) that had the most stems with cuts were 31 – 40 cm and 41 – 50 cm. Trees of less than 10 cm DBH had cuts. There is some uncertainty over whether all cuts recorded were for resin extraction. In interviews, incense was listed as a local use, but resin was not specifically mentioned as a part of the tree that is used or sold. Additionally, they provided prices per bag for bark (NGN70 – 7000, approximately USD 0.44 – 4.49 per bag, weight not specified) but no information about prices for resin.

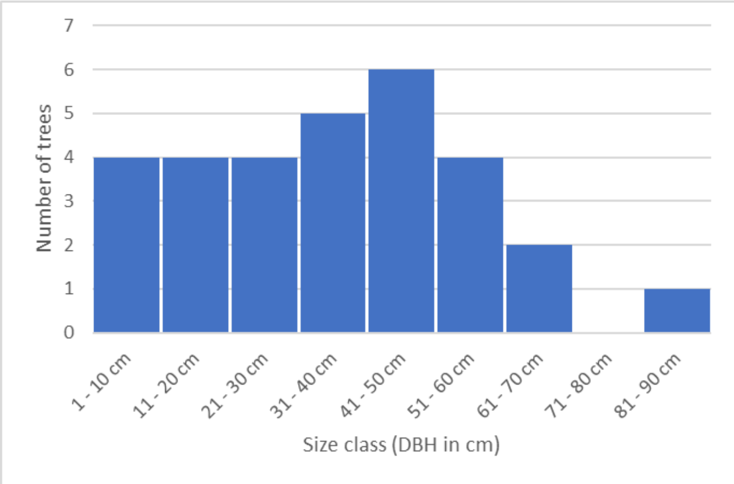

Figure 6.6. Number of trees in each size class (based on DBH measurement of main stem) for 30 *B. dalzielii* trees in Nigeria. Minimum DBH 4.8 cm, mean 35.8 cm, maximum 86.2 cm.

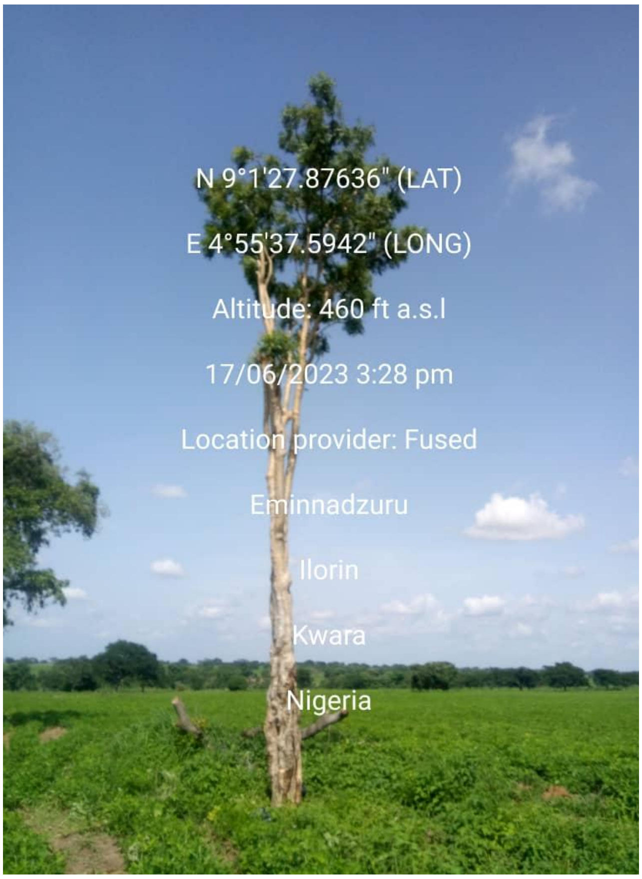

Figure 6.7a. *B. dalzielii* on land where ground layer has been cleared for agriculture in Kwara State, Nigeria.

Figure 6.7b. *B. dalzielii* habitat, Kaduna State, Nigeria.

Niger

A total of 28 trees were recorded across two locations (Zinder and Maradi) in Niger in August 2023. Examination of site photos and satellite images suggest that all locations were impacted in some way by land use, e.g. ground layer cleared for crops (see Figure 6.8a), or *Boswellia* trees next to buildings. Most trees in the Maradi area were recorded in the city, usually within small patches of tree cover that have been retained. Most Zinder trees were recorded away from settlements but often within areas of land used for agriculture, sometimes within patches of very open woodland (see Figure 6.8b). None of the trees had flowers or fruit. The presence or absence of insect damage was not recorded.

It is unclear from datasheets whether the team used plots. Most of the trees recorded were isolated individuals. The highest number of trees recorded in close proximity to each other (i.e. where individuals are less than 30 m apart) was six. The DBH size class with the highest number of trees was 1–10 cm (see Figure 6.9).

Cutting data for Niger were unclear and no additional information was provided on use and trade of resin or other parts of *Boswellia* trees. Twelve of the Maradi trees had a mark in the 'bark' column but there is uncertainty over whether this was a recent cut for resin tapping, stripping of bark for medicinal use, or a cut made by the team to extract a resin sample for analysis. Eight trees were marked as 'pruned' and site photographs clearly show some trees with cut branches, but no additional information was provided on threats.

With such a small sample size, and without knowledge of the full extent of the area that was searched for trees, it is difficult to determine whether these data are a good representation of the population as a whole. This dataset suggests a very scattered distribution, comprised mostly of solitary individuals (no dense stands) occurring within human modified landscapes.

Figure 6.8a. *B. dalzielii* on land where ground layer has been cleared for agriculture in Niger.

Figure 6.8b. Small *B. dalzielii* in very open woodland in Niger.

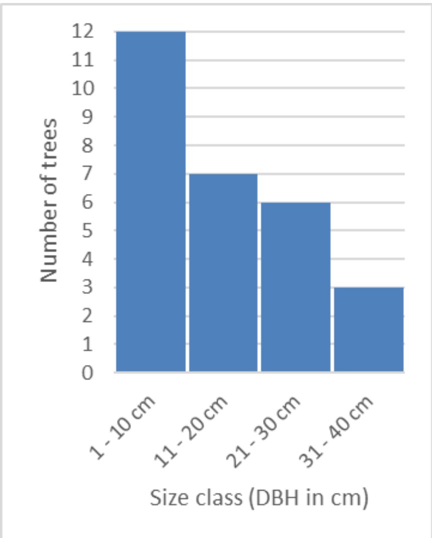

Figure 6.9. Number of trees in each size class (based on DBH measurement of main stem) for 28 *B. dalzielii* trees in Niger. Minimum DBH 1.9 cm, mean 15.5 cm, maximum 38.2 cm.

Conclusions for *Boswellia dalzielii*

It is clear from these surveys that there is considerable variation in the status, uses and harvesting of *B. dalzielii* across its' distribution. It can be problematic to differentiate between bark and resin harvesting when assessing damage to trees, and whether these involve significantly different practices, although it was apparent from images that de-barking as well as pruning, cutting and felling were witnessed. Some surveyed areas in Burkina Faso appeared healthy and extensive but across many other areas the species was either absent when expected or was severely fragmented in a human-influenced landscape. This was also documented by Sabo *et al* (2021) where the density of trees was lower in agricultural lands in Burkina Faso., with woodland trees smaller and more numerous. Presumably some trees were retained when much of the forest was cleared for agriculture, revealing the potential value of these trees to local communities.

The timescale over which these trees have been affected remains conjectural; assessment of the modelled natural potential distribution against a time series of satellite imagery may reveal recent land use change that could be useful in future conservation assessments, demonstrating a decline.

There are few guidelines for what is considered "good practice" in terms of harvesting resins or indeed bark. The latter is clearly affecting individual trees to some extent and is noted by Sabo *et al* (2021) as a major issue. Sabo *et al* (2022) conducted resin tapping experiments concerned with obtaining maximum yield but these did not directly assess potential damage to trees and populations although stated that proper methods would reduce damage to extensive debarking currently taking place.

Range state	Total number of trees	Number of trees with recent cuts	% of trees with recent cuts	Total number of stems	Min stem DBH (cm)	Mean stem DBH (cm)	Max stem DBH (cm)	No. stems with recent cuts	% stems with recent cuts	Min recent cuts per stem	Mean recent cuts per stem	Max recent cuts per stem	Min DBH (cm) of stem with recent cuts	Mean DBH (cm) of stem with recent cuts	Max DBH (cm) of stem with recent cuts
Benin	22	14	64	27	2.3	9.4	19.6	16	59	1	7	15	5.9	11.4	19.6
Burkina Faso	324	38	12	442	1.4	19.2	68.8	43	10	1	5	18	10.2	27.3	59.2
Nigeria	28	26	93	31	7.6	40.3	86.2	29	94	3	18	50	7.6	36.9	86.2
Ghana	66	Not applicable.		66	1.0	3.8	6.4	Not applicable. Resin tapping is not a known practise in the area.							
Niger	28	Data unclear.		28*	1.9	15.5	38.2	Cutting data were unclear.							

Table 6.2. Comparison of stem measurements and resin harvesting data for *B. dalzielii* trees in Benin, Burkina Faso, Ghana, Niger and Nigeria. * Survey photos clearly show some trees had multiple stems. These were not measured.

Boswellia sacra

A total of 94 trees (205 stems) were recorded across two range states – Yemen and Somaliland.

Yemen

Yemen surveys were carried out in August 2023. A total of 34 trees (109 stems) were recorded across 11 plots. Method for determining plot locations is not known but data suggest a scattered distribution with no large stands of trees (minimum number of trees in a plot was 1, mean was 3, maximum was 5). Figure 6.10a shows population structure based on size class of DBH (in cm). For ease of comparison with Somaliland data (where DBH data were not reliable) for the same species, Figure 6.10b shows population structure based on tree height. Yemen trees had a slightly lower mean height (3.3 cm) than Somalia (3.8 cm).

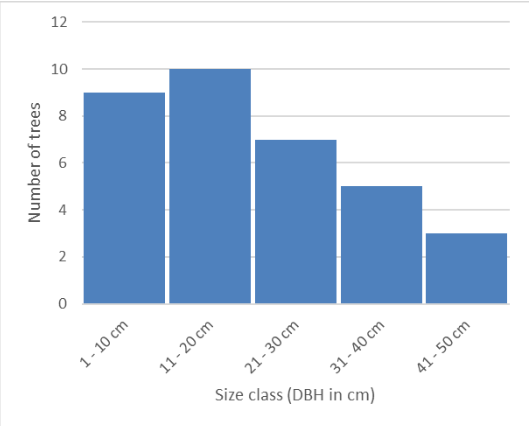

Figure 6.10a. Number of trees in each size class (based on DBH measurement of main stem) for 34 *B. sacra* trees in Yemen. Minimum DBH 5.4 cm, mean DBH 19.7 m, maximum DBH 45.9 cm.

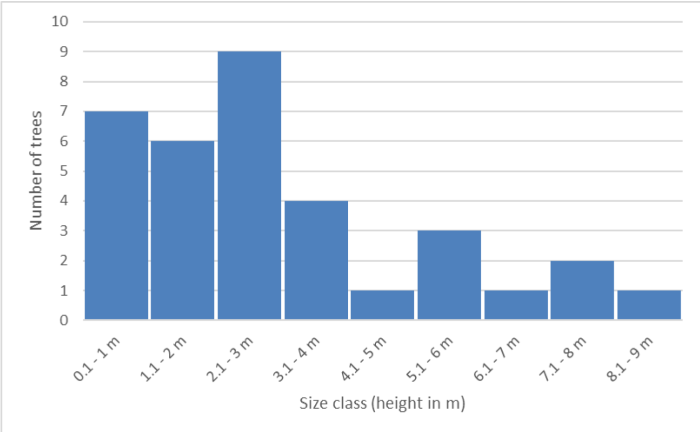

Figure 6.10b. Number of trees in each size class (based on tree height) for 34 *B. sacra* trees in Yemen. Minimum height 1.0 m, mean 3.3 cm, maximum 9 m.

Examination of photographs and satellite images at specific tree locations suggest all surveys were carried out away from urban areas and settlements (with the exception of one tree which has coordinates for the city of Aden). The majority of trees were on rocky slopes near wadis (see Figure 6.11). In contrast to Somaliland populations of *B. sacra*, Yemen data suggest there were no large stands of trees (minimum number of trees in a plot was 1, mean was 3, maximum was 5). Flowers were recorded on 21 trees and fruits were recorded on 31 trees. One tree was noted to have insect damage. There was no evidence of browsing (or other damage) caused by animals, and no evidence of trees being cut for wood or forage. Other threats were listed as residential & commercial development and natural system modifications.

For this dataset (and for *B. sacra* in Somaliland) we noted that for each tree, all cuts were recorded against one stem (the main/largest stem). For all other multi-stemmed species observed during these surveys, cuts were not restricted to one stem. It is not clear whether this is an error in data recording or whether the local practise is to cut only the main stem. To allow for comparison of Yemen data with Somaliland data for the same species, we have presented data for cuts per tree rather than cuts per stem – see Table 6.2.

62% of trees had cuts for resin tapping (68% for same species in Somaliland). Resin is harvested from trees twice per year and there are no rest years. It is used locally as incense and is sold for 5-20 USD per kg. No other information was provided on use of other parts of the tree.

Figure 6.11. *Boswellia sacra* habitat in Yemen.

No large stands of trees were recorded at survey sites in Yemen. A relatively high percentage of trees are harvested with no rest years, and the mean number of cuts per tree is more than double that of Somaliland trees. This could indicate an unsustainable level of resin harvesting. Clarification of whether cuts are restricted to one stem is needed.

Somaliland

Surveys in Somaliland were carried out in August 2024. A total of 60 *B. sacra* trees were recorded across three locations. Precise coordinates for plot locations were not provided. For all three locations, it is unclear whether *B. sacra* was growing alongside *B. frereana*, or whether they were in separate areas. Twenty trees were recorded at each location, all with similar habitat (rocky slopes, with trees sometimes growing on exposed boulders and rock faces – see Figure 12).

Number of stems were not recorded accurately for the majority of trees and the DBH data had a high level of errors, therefore we examined population structure using tree height– see Figure 6.13. The majority of trees were in the smaller size classes. Somaliland trees had a slightly higher mean height (3.8 m) than Yemen trees (3.3 m).

68% of Somaliland trees had cuts for resin tapping (a slightly higher percentage than Yemen) but Somaliland trees had a much lower mean number of recent cuts per tree.

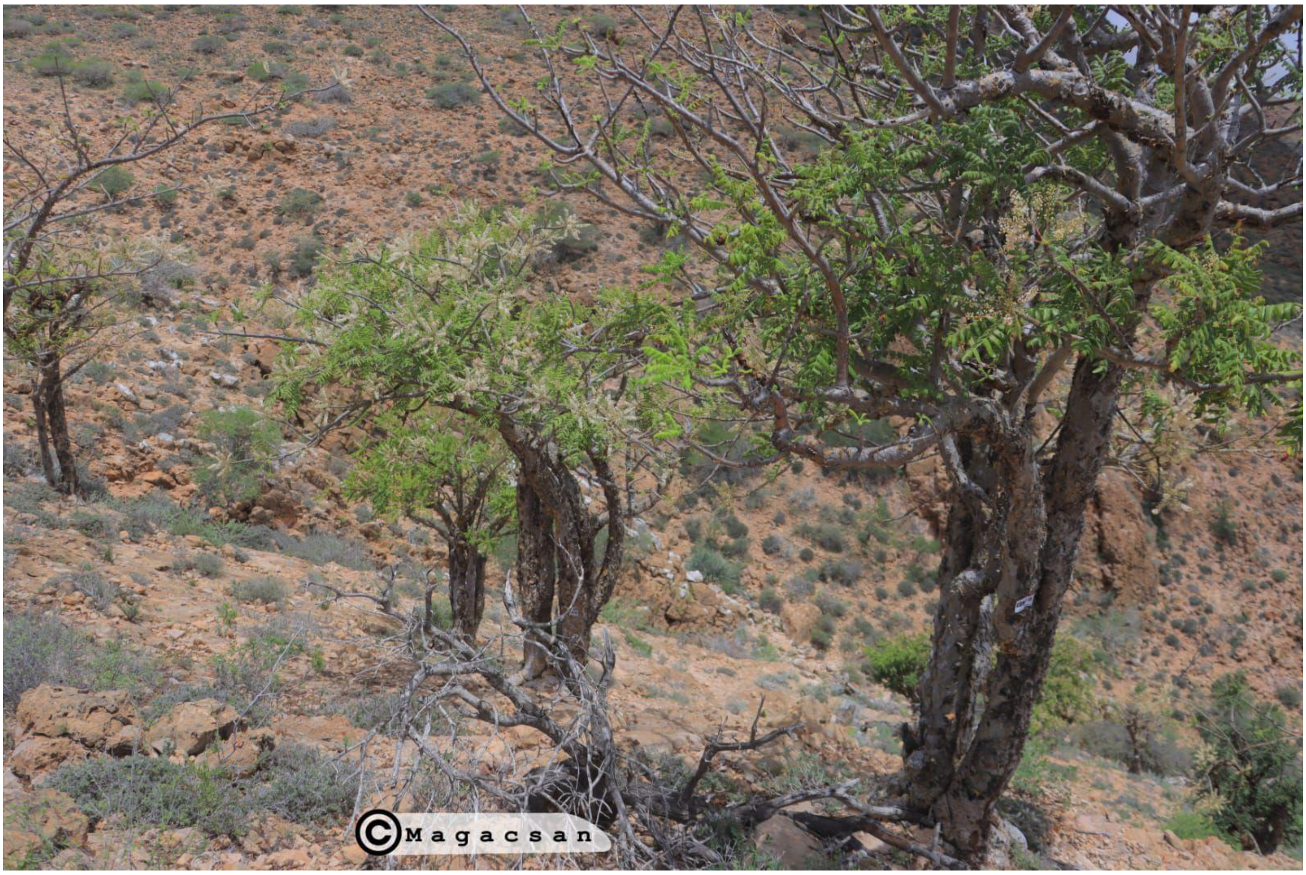

Figure 6.12. *Boswellia sacra* habitat in Somaliland.

Without accurate stem and cut data (and with no information on frequency of resin harvesting), it is not possible to determine the intensity of resin harvesting. However, in contrast to low numbers of trees at survey sites in Yemen, the Somaliland data suggest that there are relatively dense stands of trees in some areas, and that although relatively close to settlements, these trees are not threated by browsing (or other damage caused by animals), or cutting for wood or forage.

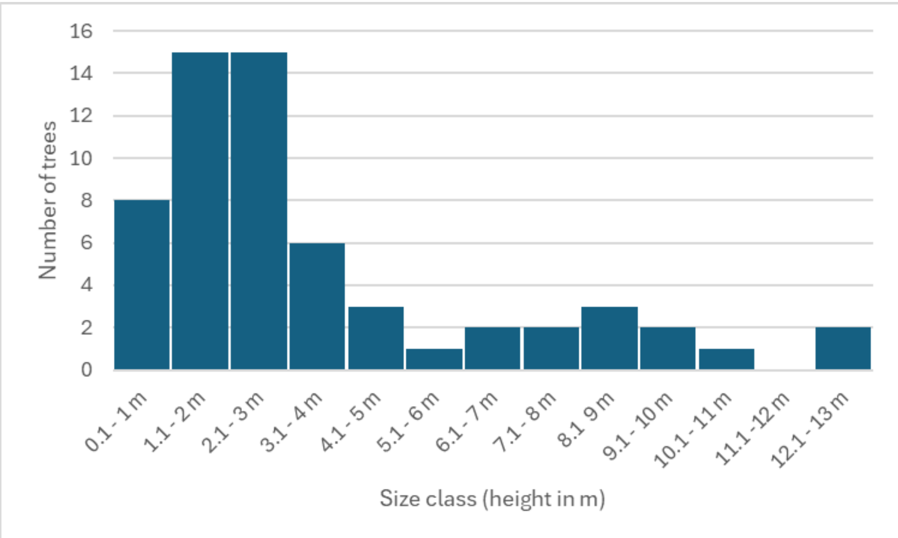

Figure 6.13. Number of trees in each size class (based on tree height in m) for 60 *B. sacra* trees in Somaliland. Minimum height 0.3 m, mean 3.8 m, maximum 13 m.

Range state	Total number of trees	Number of trees with recent cuts	% of trees with recent cuts	Min recent cuts per tree	Mean recent cuts per tree	Max recent cuts per tree	Min height (m) of tree with recent cuts	Mean height (m) of tree with recent cuts	Max height (m) of tree with recent cuts
Somaliland	60	41	68	1	9	18	2	5	13
Yemen	34	21	62	1	20	63	1	4	9

Table 6.2. Comparison of tree measurements and resin harvesting data for *B. sacra* in Yemen and Somaliland.

Conclusions for *Boswellia sacra*.

It is clear that trees of B. sacra in both Somaliland and Yemen are being extensively cut and harvested for resin. This has been previously reported both conjecturally and empirically. However, unlike for published reports for *B. papyrifera* most areas are dominated by young trees suggesting that reproduction and population structure have as yet not been negatively affected in the long term at these sites. There could be several reasons for this. Firstly, although tapping appears to be at high levels, the local management of the trees including some rest years may be ameliorating any negative effects seen from over-tapping in other areas and other species. Further monitoring across the range of this species will help to reveal a wider picture of tree condition and population health. Secondly, trade may not be at the level required to increase demand to levels that result in over-harvesting. This is extremely difficult to prove without detailed and accurate trade and supply chain data to reveal the direct links between harvesting and trade.

Previously published survey data for B. sacra (eg. DeCarlo *et al* (2020) coupled with data currently being collected in Oman as well as differences in the implementation of survey methodology in this study mean that data gathered may not be directly comparable. Finalizing and implementing identical surveys designed as these were to measure directly levels of harvesting and population status will be critical to enable decision making for conservation and the maintenance of sustainable harvesting in this widely traded species. This will further require collaboration among range states which could be mediated via the CITES community alongside expertise in regulation of sustainable trade.

It is further recognised that capacity and security in both Somaliland and Yemen, and also Puntland where *B. sacra* occurs widely, is an issue that requires careful planning and implementation to ensure sustainable harvesting and trade.

Boswellia frereana

A total of 109 *B. frereana* trees were recorded across two areas – Puntland and Somaliland.

Puntland

Surveys were carried out in June 2023. A total of 49 trees (120 stems) were surveyed across two plots in Muudiye, a settlement in the Bari region. The land provides grazing areas for herds managed by the local pastoral community. The woodland has been maintained by the local community because of its longstanding cultural and economic significance.

Plots were located in an area described by the survey team as the 'Boswellia woodland ecosystem' in mountainous terrain (see Figure 6.14). *Boswellia frereana* was described as abundant by the survey team. There was no evidence of insect damage, but termites were noted to be a potential threat to tree health. There was no evidence of trees having been cut for wood or forage, but human-wildlife conflict presents a significant challenge for the community. Monkeys raid *Boswellia* trees for food causing damage to the trees. Severe weather events were also reported as a threat. Due to shallow root systems, the trees are vulnerable to strong winds.

There were 24 trees in the first plot and 25 in the second plot. The DBH size class with highest number of trees was 11 – 20 cm (see Figure 15a). For comparison of population structure with *B. frereana* trees in Somaliland (where DBH data were not reliable) see Figure 15b, which shows size classes based on tree height. Puntland trees had a higher mean tree height (5.1 m) than Somaliland trees.

Table 6.3 shows a summary of cutting data. For ease of comparison with Somaliland data (where we do not have cuts per stem), the table shows cuts per tree. Every tree *B. frereana* tree surveyed in Puntland had recent cuts for resin tapping. Of the 120 stems surveyed, 77% had recent cuts for resin tapping. The size class (DBH in cm) that had the most stems with cuts was 11 – 20 cm. Interview respondents indicated that stems would be tapped for resin regardless of their size. The size class (based in DBH in cm) that had the most stems with cuts was 11 – 20 cm DBH.

Resin is not used locally, and no other parts of the tree are utilised. The primary focus is on the extraction of resin which serves as an important source of income for the community. Although all trees had cuts, and a high percentage of stems had cuts (and some of those stems are relatively small), resin extraction is clearly being managed. Trees are tapped for continuous period of 18 months and are then rested for a year.

Figure 6.14. *Boswellia frereana* habitat in Puntland.

Figure 6.15a. Number of trees in each size class (based on DBH measurement of main stem) for 49 *B. frereana* trees in Puntland. Minimum DBH 4.8 cm, mean 31.4 cm, maximum 63.7 m.

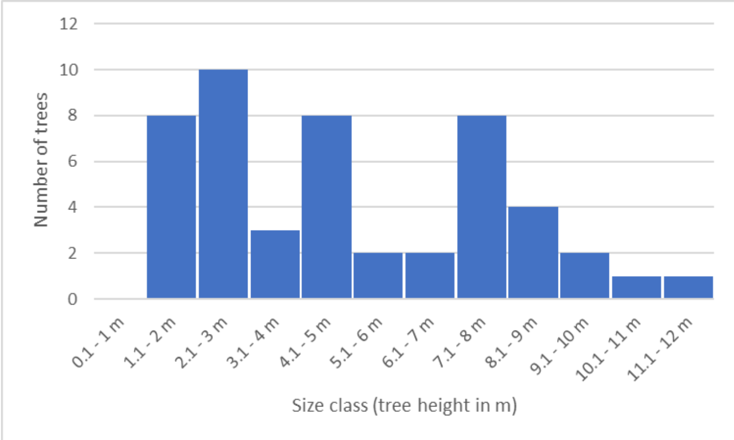

Figure 6.15b. Number of trees in each size class (based on height in m) for 49 *B. frereana* trees in Puntland. Minimum height 1.2 m, mean 5.1 m, maximum 12.0 m.

Somaliland

Surveys in Somaliland were carried out in August 2024. A total of 60 *B. frereana* trees were recorded across three locations (20 trees at each location). Precise coordinates for plots were not provided but the approximate locations were indicated on a map. For all three locations, it is unclear whether *B. frereana* was growing alongside *B. sacra*, or whether they were in separate areas. Twenty trees were recorded at each location, all with similar habitat (rocky slopes, with trees sometimes growing on exposed boulders and rock faces – see Figure 16).

Figure 16. *Boswellia frereana* habitat in Somaliland.

Population structure was examined using height in m (see Figure 17). Trees in Puntland had a mean tree height of 5.1 m whereas Somaliland mean height was 2.2 m. Evidence of insect damage was recorded on three *B. frereana* trees. Flowers were recorded on 36 trees. Fruits were recorded on 34 trees.

57% of trees had recent cuts for resin tapping, which is considerably lower than for the same species in Puntland (see Table 3). As for *B. sacra*, without accurate stem and cut data (and with no information on frequency of resin harvesting), it is not possible to accurately determine the intensity of resin harvesting. There are relatively dense stands of trees in some areas, and they are not threated by browsing (or other damage caused by animals), or cutting for wood or forage.

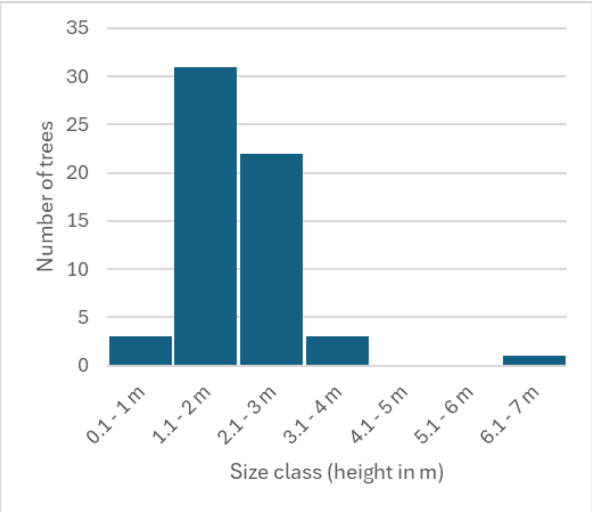

Figure 17. Number of trees in each size class (based on height in m) for 60 *B. frereana* trees in Somaliland. Minimum height 0.7 m, mean 2.2 m, maximum 6.5 m.

Range state	Total number of trees	Number of trees with recent cuts	% of trees with recent cuts	Min recent cuts per tree	Mean recent cuts per tree	Max recent cuts per tree	Min height (m) of tree with recent cuts	Mean height (m) of tree with recent cuts	Max height (m) of tree with recent cuts
Puntland	49	49	100	1	9	37	1.2	5.1	12
Somaliland	60	34	57	2	10	20	1.7	2.5	6.5

Table 6.3. Comparison of tree measurements and resin harvesting data for *B. frereana* in Puntland and Somaliland.

Conclusions for *Boswellia frereana*

Boswellia frereana has rarely been surveyed in the way that other species have; it appears to have "flown under the radar" as it is a less widespread species and is perhaps not considered to be under as much threat from over-harvesting and trade. These surveys demonstrate that despite this species being used only for resin harvesting and nothing else, and being harvested at quite high levels borne out by the number and percentage of cuts, neither survey site demonstrated unhealthy trees or skewed population statistics. It was clear from harvesting communities that rest years were an integral part of their tree management protocols, and a large number of trees were noted as being in flower or fruit – with the caveat that this strongly depends on the time of year when surveys are undertaken.

There is no doubt that more detailed estimates of population numbers would be beneficial to compare with trade volumes. It was not possible to calculate tree density from the data collected and this should be remedied in future surveys. A wider survey area needs to be assessed to give a more accurate picture of the status of this species.

Boswellia rivae: Somalia

At total of 50 trees (161 stems) were surveyed at two locations (El Barde and Bakool) in Somalia in May 2023. The first plot (21 trees) was located away from settlements and grazing areas (Figure 6.18) and there was only minor damage to tree bark from animals. The second plot (29 trees) was within a partially fenced area. Livestock were not present at the time of the survey because the community had temporarily migrated in search of pasture for grazing. There was evidence of damage to trees caused by livestock grazing around them. In times of severe drought and when there are no leaves on the trees, the livestock (and wild animals) will apparently resort to eating the bark. As well as problems with livestock, there is uncontrolled hunting, poaching, and deforestation for charcoal production in the area. Across a wider area the environment is threatened by reckless off-road driving (compacting soil and causing damage to vegetation), mining activities, an increase in extreme weather events (droughts and floods), and ongoing conflict.

The team noted *Boswellia rivae* and *Commiphora* sp. as the dominant species in the areas surveyed. Due to the growth habit of this species (sprawling multiple stems & branches with thorns), it was not possible to record DBH measurements. However, the survey team noted that in both plots, there were mature, middle-aged and young trees. Two trees were noted to have fruit. Population structure based on tree height and crown spread is shown in Figure 6.19a and 6.19b.

Boswellia trees are highly valued by local people and while the collection of resin does not harm the trees (resin is exuded naturally and so the trees do not need to be cut), they expressed concerns about the health and long-term management of trees. The younger and middle-aged trees are frequently repurposed as fencing materials by nomadic pastoral communities. In addition, seedlings are trampled by livestock and small trees are grazed. The survey team suggested that this is likely to be impeding natural regeneration.

More resin is produced by trees in warmer temperatures and is harvested from June – September, then December – March. During the wet season, very little resin is exuded by the trees. The majority of resin is used locally, and the remainder is sold to traders in the Ogaden region. The sale of resin is an important source of income for these isolated communities and interview respondents said they were aware that they were selling resin at "incredibly low rates" to Kenyan and Ethiopian traders (c. USD1 -1.50 per kg). Respondents had no knowledge of resale prices. The price may fluctuate during the year driven by supply and demand and/or the quality of the resin (based on odour and colour).

Figure 6.18. *Boswellia rivae* habitat, El Barde, Somalia.

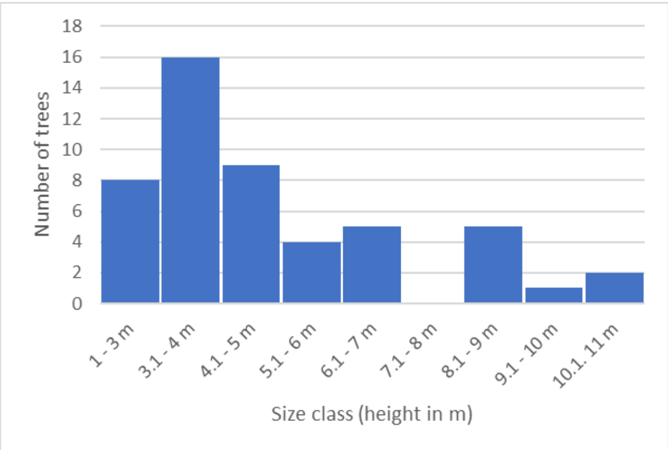

Figure 19a. Number of trees in each size class (height in m) for 50 *B. rivae* trees Somalia. Minimum height 2.6 m, mean 5.1 m, maximum 11 m.

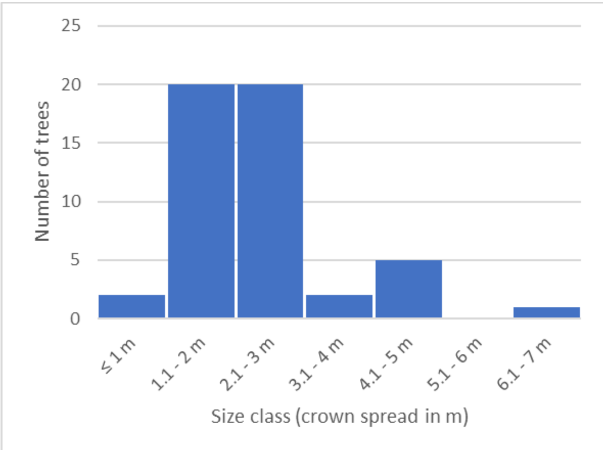

Figure 19b. Number of trees in each size class (crown spread in m) for 50 *B. rivae* trees in Somalia. Minimum crown spread 1.0 m, mean 2.7 m, maximum 6.1 m.

Boswellia neglecta: Kenya

Data were recorded for a total of 156 trees in Kenya in July 2023. Surveys were carried out at two sites – Mbarabati (flat ground with gullies at c. 480 m elevation, on rocky quartz in dense woodland) and Kachiuru (lower slope of a hill at c. 940 m elevation on gravel/lava in dense woodland). Vegetation was too dense to use the recommended 50m x 50m plot layout, so the team used the PCQ (point centred quarters) method. Forty points (15 –20 m apart) were surveyed at each site. For each tree, they recorded height (m), and crown spread (m). For the majority of trees DBH was not recorded, due to the difficulty in measuring trees with sprawling habit, multiple stems/branches and thorns (see Figure 6.20).

Figure 6.20. *Boswellia neglecta* habitat in Kenya.

Population structured was examined using tree height and crown spread. The mean height and crown spread of Mbarabati trees was larger than those at Kachiuru – see Figure 6.21a & b and 6.22a & b.

The density of trees was 277 trees per hectare at the Mbarabati survey site and 240 trees per hectare at the Kachiuru survey site (higher than the highest densities recorded in the eastern parts of Wajir County – see Luvanda *et al.,* 2014). At Kachiuru, 38 trees had fruit, none had flowers. There was no evidence of any insect damage. Six dead trees were recorded. At Mbarabati, 32 trees had fruit, 41 had flowers. There was evidence of insect damage on one tree. Two dead trees were recorded. At the Kachiuru survey site, 20 trees had evidence of damage caused by animals (scraping of bark but no browsing). One tree had evidence of cutting for wood, none were cut for forage. At the Mbarabati survey site, nine trees had evidence of damage caused by animals (scraping of bark but no browsing). There was no evidence of trees having been cut for food or fodder. There was no mention of fire damage at either survey site.

Boswellia neglecta does not need to be cut because the tree exudes resin naturally. In Kachiuru, black gum is collected and sold in the local market. It is used locally in mosques, churches and houses and sold to local buyers. Resin is harvested throughout the year. The price per kg for selling locally is KSH 100 per kg (c. USD 0.77). The price is the same for selling to buyers who are not local. Trees are not used for firewood or construction in this area. No use or trade data were provided for Mbarabati.

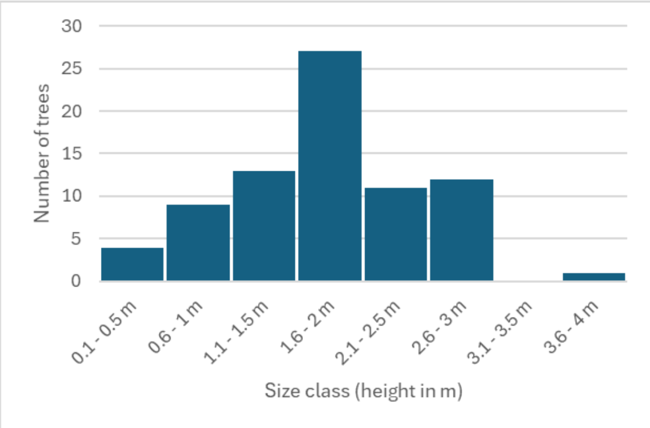

Figure 6.21a. Number of trees in each size class (based on height in m) for 77 *B. neglecta* trees at the Kachiuru survey site, Kenya. Minimum height 0.2 m, mean 2.0 m, maximum 4 m.

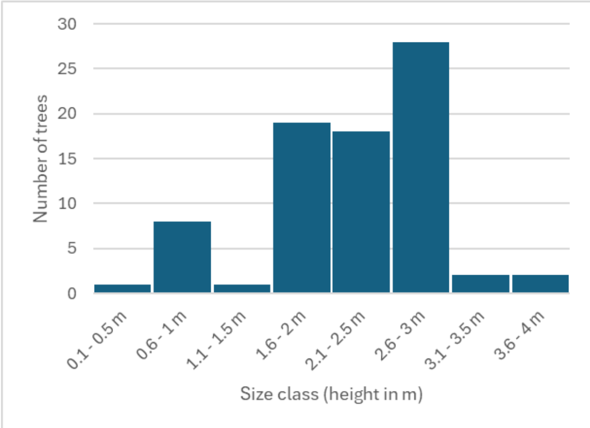

Figure 6.21b. Number of trees in each size class (based on height in m) for 78 *B. neglecta* trees at the Mbarabati survey site, Kenya. Minimum height 0.5 m, mean 2.4 m, maximum 4.0 m.

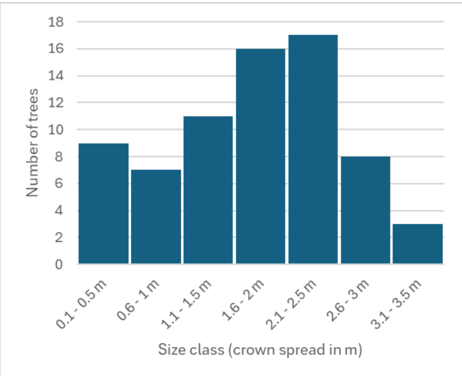

Figure 6.22a. Number of trees in each size class (based on crown spread in m) for 71 *B. neglecta* trees at the Kachiuru survey site, Kenya. Minimum crown spread 0.5 m, mean 1.9 m, maximum 3.5 m.

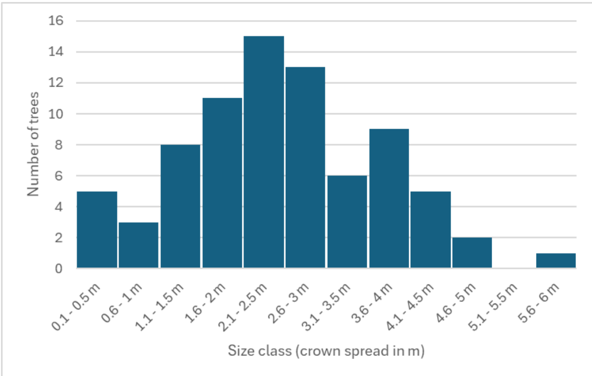

Figure 6.22b. Number of trees in each size class (based on crown spread in m) for 77 *B. neglecta* trees at the Mbarabati survey site, Kenya. Minimum crown spread 0.5 m, mean 2.7 m, maximum 6 m.

Conclusions for *Boswellia neglecta* and *Boswellia rivae*

These two species, along with *B. microphylla*, exude resin naturally and this is not stimulated by cutting and as such the harvesting of resin is naturally sustainable. However, there is clearly regional variation in tree use and condition. *B. neglecta* in northern Kenya shows a good age structure and density with trees flowering and fruiting, while the *B. rivae* trees in Somalia showed less evidence of reproduction and a variety of threats to trees was noted.

If these species are to fulfil their potential as sustainable harvesting systems the trees will need protection from a range of threats and development of resin harvesting as a valued income source. Due to the growth form and nature of harvesting a novel protocol for assessing tree and population health will be required.

Section 6.4

Discussion and conclusions

It is clear from the data received from these rapid surveys that each in-country team has interpreted the survey protocols differently, resulting in considerable variation in terms of content and quality. Consequently, a significant amount of time was spent trying to interpret data, match photos to data, match specimens to locations, etc. Fieldwork of this nature will always be challenging, but it presents an opportunity to build the capacity of local teams to measure and monitor *Boswellia* trees. Delivery of training can be complex, particularly when it is not possible to do it in-person due to budget constraints, language differences or security issues. Across the ten survey areas survey teams had varying levels of experience, and not all teams had access to the same equipment. Some of the issues could be addressed by simplifying the survey protocol, including the use of videos and illustrations, and by providing translated materials where possible.

Despite issues of data gathering and subsequent comparability, a great deal of information has been gathered systematically, in many cases in areas and for species not previously assessed. This information has been extremely valuable in conservation assessments and considering whether there is evidence of tree and population health declines warranting listing on CITES appendices. As a learning exercise, it has also been valuable to assess engagement and implementation which will allow a better, more easily implementable and comparable methodology to be tested and implemented across all species and all range states.

While designed to assess the levels of harvesting intensity and the population status at individual localities, data was also collected on additional threats to trees, and it became apparent at several sites that alternate threats were significant compared to solely harvesting to collect resins. For *B. dalzielii*, the majority of trees encountered were young with a suggestion that larger trees had been removed for use, or had suffered from excessive bark harvesting – a far more directly damaging process that is widespread across the *B. dalzielii* range states as bark is used in a number of medicinal preparations. It was also notable that relatively few seedlings and saplings were present, due in some locations to the fact that the understorey had been cleared and planted with agricultural crops. Threats to *B. rivae* in Somalia – and likely to *B. neglecta* and *B. microphylla* in the same areas – included use for charcoal and fencing. This data is relevant because increasing damage from resin production where additional threats already exist could push trees to local extinction relatively quickly if not better managed. In the case of *B. dalzielii*, an increase in global trade – which is already starting to occur in some locations – could achieve this undesirable effect if not adequately managed and monitored.

In terms of comparability, the initial intention was to be able to compare harvesting levels as well as tree and population health among different species. This was in part related to the fact that much of the evidence of over-harvesting is restricted to studies on a single species (*B. papyrifera*) and extrapolation of claims made in those studies to additional taxa. It is not uncommon to find articles and discussions where the levels of harvesting are compared between species without any evidence of empirical evidence to support such claims. However, it is clear that each species is extremely difficult to compare with another, as growth forms, types of harvesting and uses differ considerably from place to place and species to species. Different methods will need to be developed to monitor species that are not cut to initiate resin production and that have growth forms that are not amenable to standard DBH and related measurements.

Recommendations are discussed below.

Tree data

Measuring single-stemmed trees is relatively straightforward but many *Boswellia* species have complex growth habits. Further research is needed to understand what measurements are most useful for determining population structure in trees with multiple stems, and/or sprawling prostrate forms. This research should inform the development of species-specific illustrated guides that clearly demonstrate what part of the tree to measure and how. Some teams recorded DBH values, some recorded circumference, some measured in inches, some in cm. Clearer instructions would help to standardise data collection across teams. These measurements can then be related to tapping data to give a direct measure of tree and population health related to harvesting pressure.

As an example, to avoid using more complex methods to measure and estimate tree density it was decided to measure all trees within a 50x50m square, and to continue sampling additional squares until a total of 20 trees had been surveyed. In some locations only single 50x50m squares were surveyed meaning that while a coarse estimate of density was possible there was not enough trees measured to estimate accurately different populations age structure. Increasing the number of populations samples and surveyed accurately with statistically relevant numbers will better allow for comparative analyses and judgements about levels of harvesting hat can be used to demonstrate sustainable resin trade.

Further, while many *Boswellia* populations are relatively open woodland, there are cases where taxa occur in dense thickets that can be difficult to access – in these cases alternate methods may be more amenable. The survey of *B. neglecta* in Kenya therefore tested the PCQ method which focuses on measuring the distance and angle between all trees to estimate density as these measures can be measured and estimated in habitats where demarcating a 50x50m square would be difficult. This method may also be valuable when assessing trees growing in topographically variable terrain where direct access to trees is also problematic.

In addition, while it was considered that surveys should be simple enough to compare among different species to give baseline differences in natural populations, this proved to be difficult in some species as measuring DBH was not possible due to extensive low branching. There is very little literature on how to measure DBH in arid environments to estimate population structure and surveys that have assessed species that can branch from the ground (eg. *B. neglecta*) make no mention of this issue. The vast majority of detailed studies of this in *Boswellia* focus on *B. papyrifera* which is a single stemmed tree in the vast majority of cases.

Linking tree data to field collections and photographs

Several voucher specimens could not be used because they were not linked to tree data and/or resin samples (e.g. different numbering systems were used, or no numbering at all) and some had no location data. All survey teams took excellent site and tree photos, but in some cases, photographs were not accurately labelled, making it difficult to match data to photographs. The importance of linking data for each tree (with a clear, illustrated example) needs to be better emphasized in the survey protocol.

It is also worth considering whether all teams should be provided with a basic standard field kit (e.g. GPS unit, camera with GPS, DBH tapes). Applications such as ArcGIS Survey123 can help to standardise data collection and while this may not be a viable option in some areas, it is recommended that a series of data collection options should be explored, developed, and field tested.

Local actors

In part, this exercise was designed also to assess levels of experience and ability to monitor tree populations on the ground so that data is available to measure tree and population health with reference to harvesting levels driven by trade. Surveys were implemented in all cases by local actors rather than by visiting scientists; this approach has led to local buy-in and indeed some participants stated that they were pleased to see a consolidated approach to measuring trees as they did not believe this was being done at all in the areas surveyed.

In terms of the application of the survey protocol by different actors in different locations, the surveys were undertaken by all actors without the need for direct intervention by any external researcher – either for more detailed instructions on how to conduct the survey (unless this was directly requested) or by visiting the states and localities concerned. This means that local actors had ownership of the surveys and did not feel excluded by the presence of external actors performing research in those locations – a not uncommon perception in many locations. Further, as the collection of resins and tree vouchers was often undertaken at the same time as surveys, local actors were responsible for interaction with State Authorities to require the relevant permissions and documentation for the collection and subsequent export of samples for further analyses – required as the resin identification methodology is currently unavailable in these locations.

Section 6.5

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