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Frankincense in peril

Frans Bongers ^{1*}, **Peter Groenendijk**^{1,2,3}, **Tesfaye Bekele**⁴, **Emiru Birhane** ^{5,6}, **Abebe Damtew**⁵, **Mathieu Decuyper** ^{1,7}, **Abeje Eshete**⁴, **Alemu Gezahgne**⁴, **Atkilt Girma** ^{5,8}, **Mohamed A. Khamis**⁹, **Mulugeta Lemenih**¹⁰, **Tefera Mengistu**¹¹, **Woldeselassie Ogbazghi**¹², **Ute Sass-Klaassen**¹, **Wubalem Tadesse**⁴, **Mindaye Teshome** ⁴, **Motuma Tolera**¹³, **Frank J. Sterck**^{1,14} and **Pieter A. Zuidema** ^{1,14}

¹Forest Ecology and Forest Management Group, Wageningen University and Research, Wageningen, the Netherlands. ²Departamento de Botánica, Escola Politécnica Superior, Campus de Lugo, Universidade de Santiago de Compostela, Lugo, Spain. ³Department of Plant Biology, Institute of Biology, University of Campinas, Campinas, Brazil. ⁴Ethiopian Environment and Forest Research Institute, Addis Ababa, Ethiopia. ⁵Department of Land Resources Management and Environmental protection, Mekelle University, Mekelle, Ethiopia. ⁶Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, Ås, Norway. ⁷Geo-Information and Remote Sensing Group, Wageningen University and Research, Wageningen, the Netherlands. ⁸ITC faculty, University of Twente, Enschede, the Netherlands. ⁹Department of Forestry and Range Sciences, University of Al Fashir, Al Fashir, Sudan. ¹⁰Farm Africa, Regional office, Addis Ababa, Ethiopia. ¹¹Forest Sector Development Program, UNDP/MEFCC, Addis Ababa, Ethiopia. ¹²University of Asmara, Asmara, Eritrea. ¹³Wondo Genet College of Forestry and Natural Resources, Hawassa University, Shashemene, Ethiopia. ¹⁴These authors contributed equally: Frank J. Sterck, Pieter A. Zuidema. *e-mail: frans.bongers@wur.nl

Supplementary Information for

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Frans Bongers, Peter Groenendijk, Tesfaye Bekele, Emiru Birhane, Abebe Damtew, Mathieu Decuyper, Abeje Eshete, Alemu Gezahgne, Atkilt Girma, Mohamed A. Khamis, Mulugeta Lemenih, Tefera Mengistu, Woldeselassie Ogbazghi, Ute Sass-Klaassen, Wubalem Tadesse, Mindaye Teshome, Motuma Tolera, Frank J. Sterck, Pieter A. Zuidema

This file contains:

Supplementary Figures 1-8

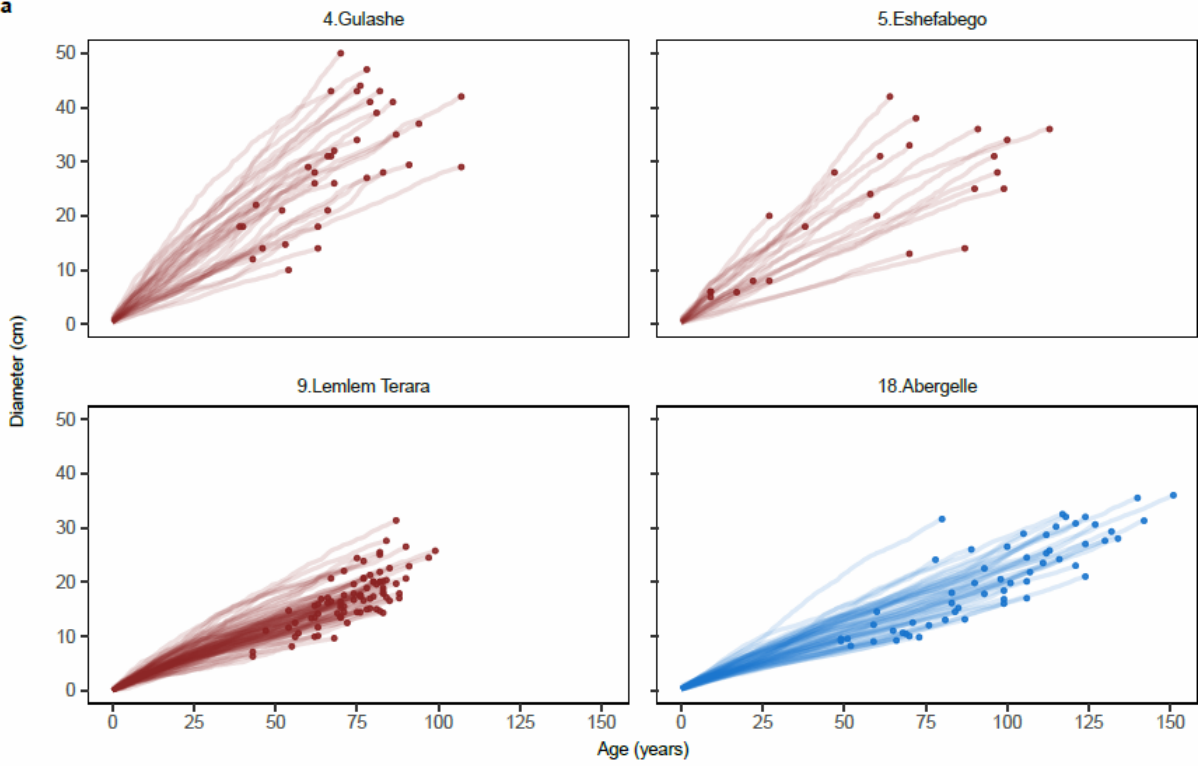
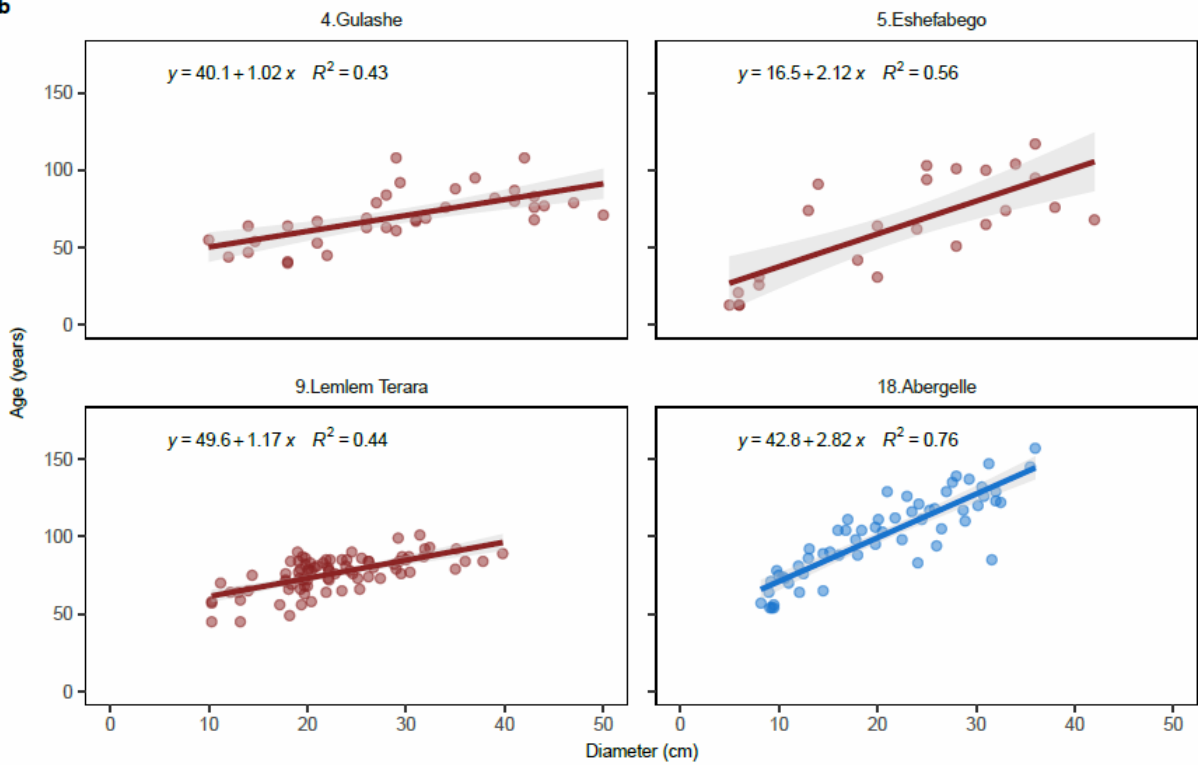
Supplementary Tables 1-5

Supplementary Methods 1

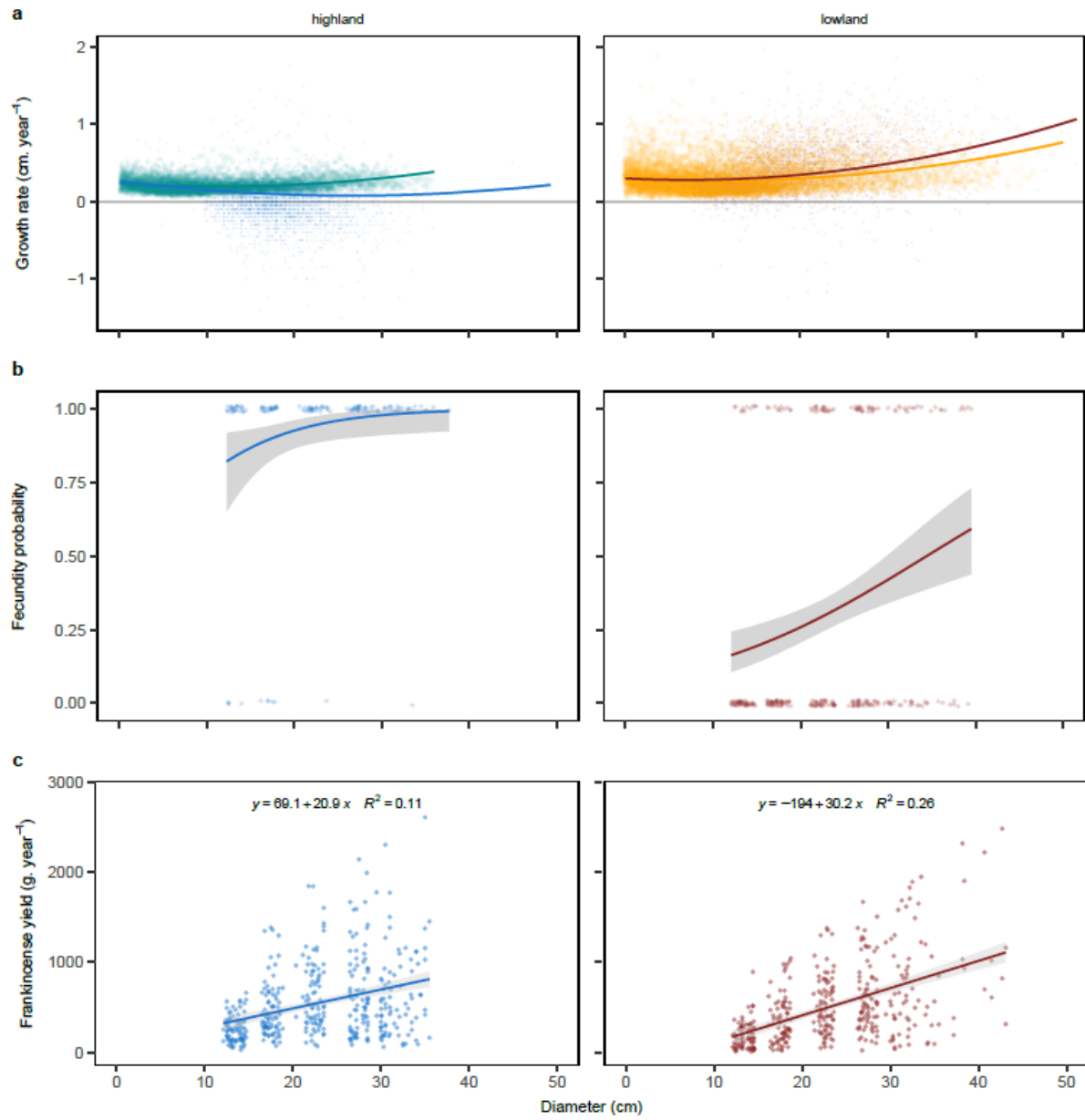
Supplementary Notes 1

References

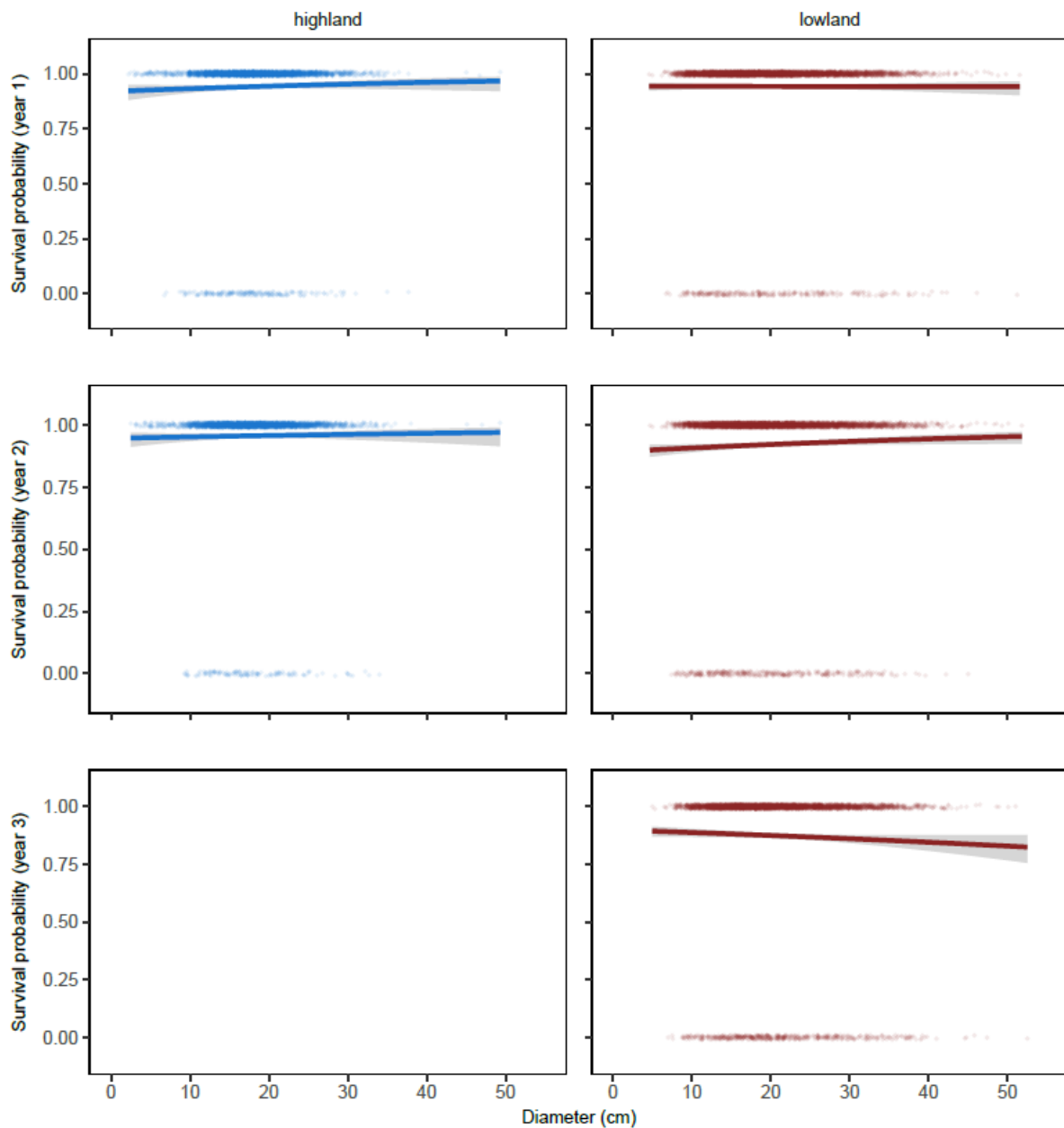
Supplementary Figure 1. Results of tree-ring studies of *Boswellia papyrifera* and age-diameter relations at four sites (3 lowland, red; 1 highland, blue). (a) Each line represents the lifetime growth trajectory of one tree, reconstructed from tree-ring analysis of a total of 202 fully cross-dated individuals (Supplementary Table 3). Only cross-dated trees were included and end-points (dots) were used to establish age-diameter relations. (b) Dots indicate individual trees, lines represent linear regressions of age vs. diameter and shading shows 95% confidence interval of these lines. Mean and 95% confidence intervals were used to estimate ages of all individuals in these populations (Fig. 3).

a**b**

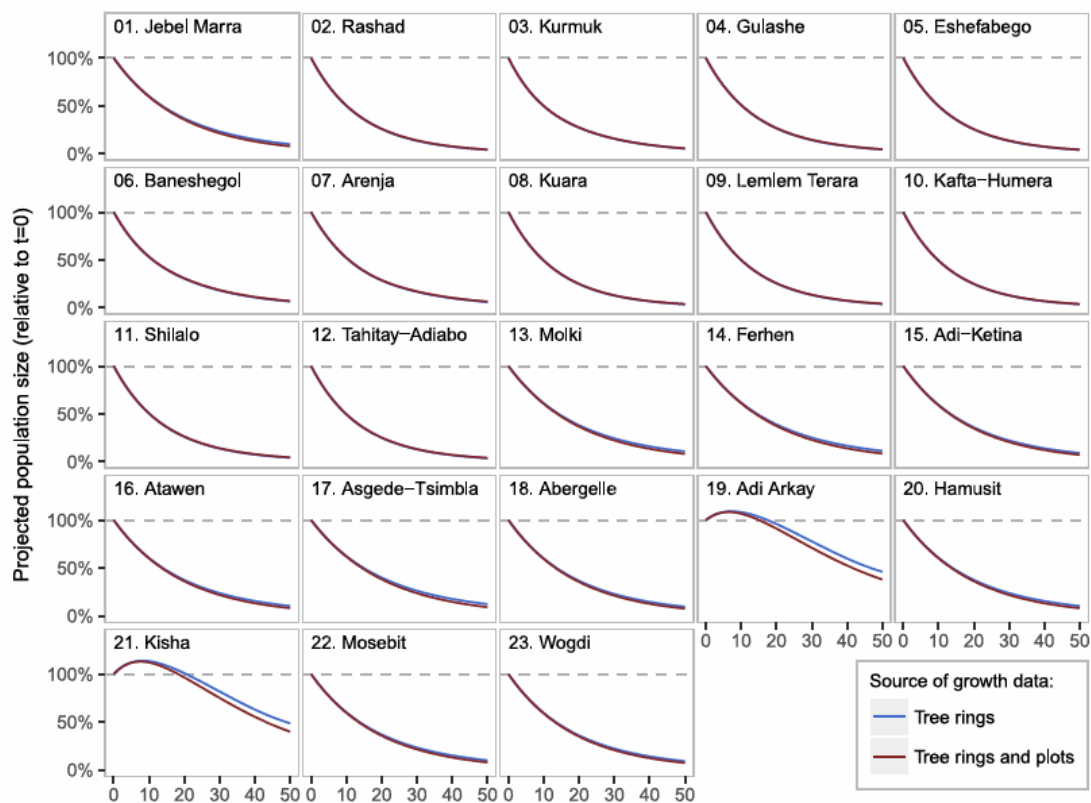
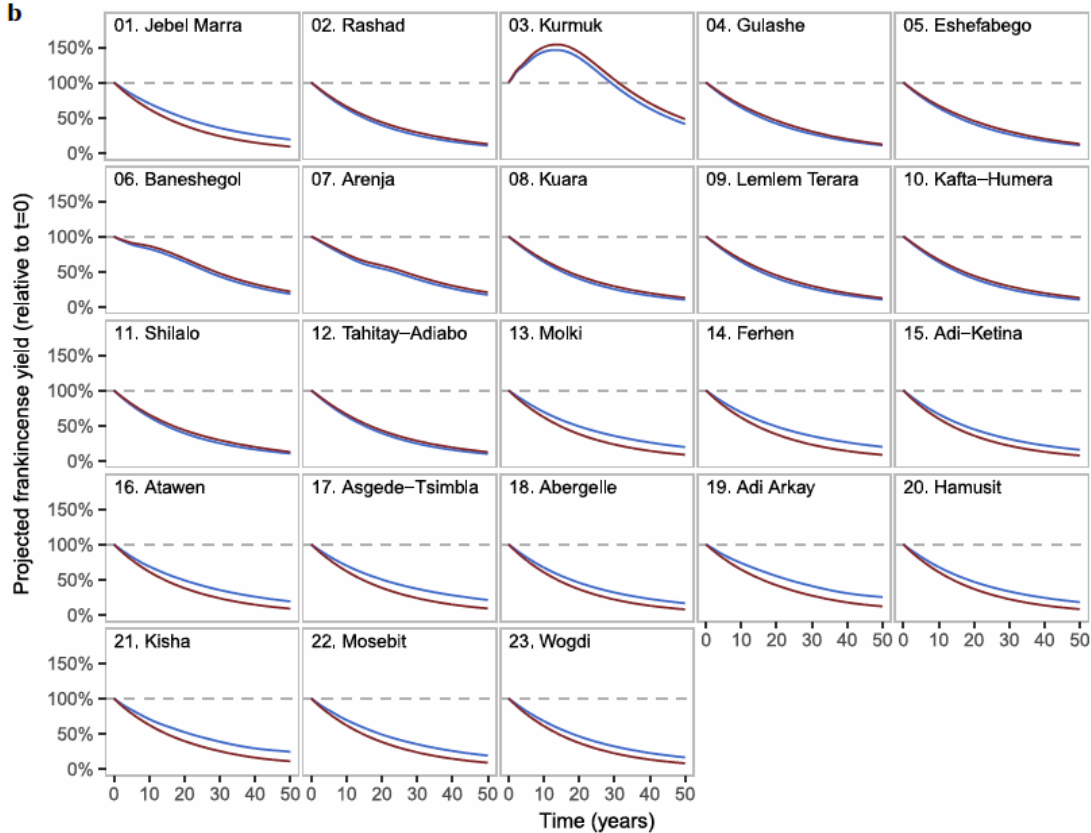
Supplementary Figure 2. Relations between diameter growth rate (a), fecundity (b) and frankincense yield (c) and diameter of *Boswellia papyrifera* trees at lowland and highland sites. (a) Growth rates were obtained from tree-ring measurements and from permanent plot data. As plot-based growth rates exhibited a large proportion of negative values, we conducted regression analyses in two ways: using only tree-ring derived diameter growth ('ring-only', cyan or orange) and using both tree-ring measurements and permanent plot data ('ring+plot', dark blue or red). (b) Dots represent individual trees that were reproductive (i.e., producing viable seeds) during at least one out of 2-3 years (1) or were not reproductive (0). Lines are significant logistic regressions of fecundity probability (with 95% confidence intervals). (c) Dots represent individual trees; lines are significant linear regressions of annual yield (with 95% confidence intervals). Regressions equations are given in Supplementary Table 4.



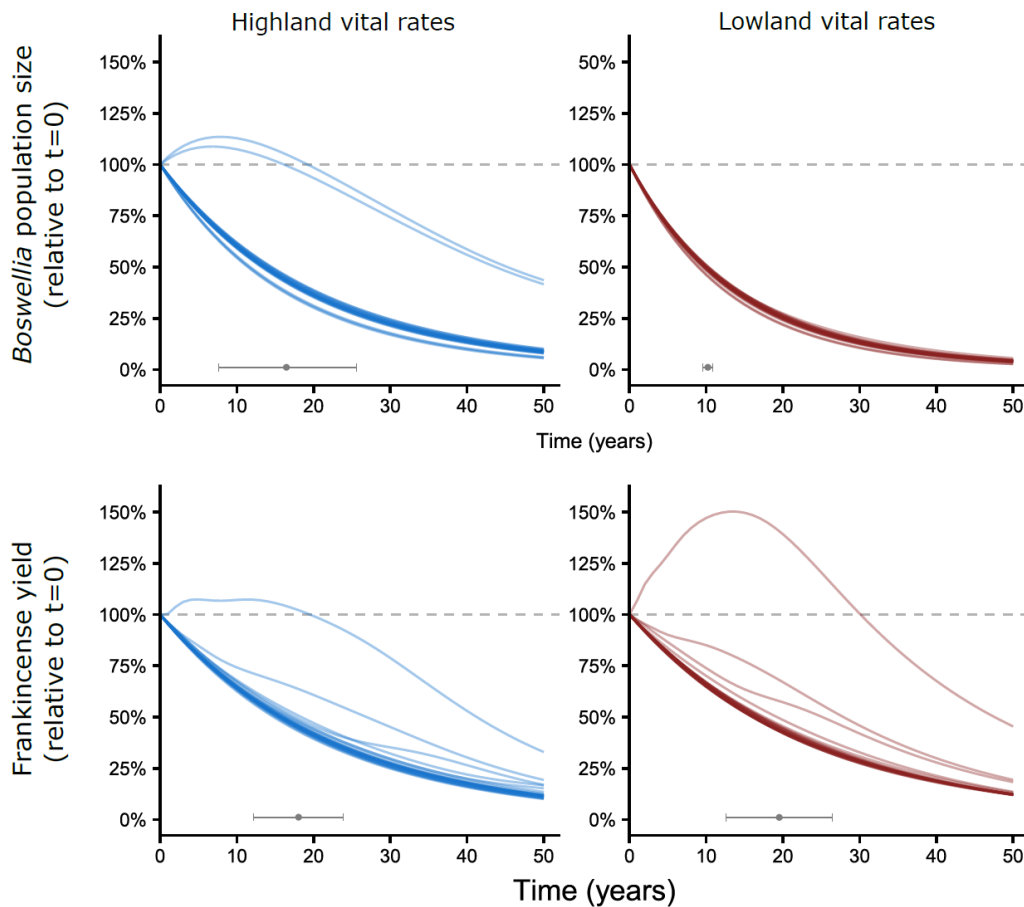
Supplementary Figure 3. Relations between survival and diameter of *Boswellia papyrifera* trees in highland and lowland populations during 2-3 years. Dots represent individual trees that survived (1) or died (0) during one year; lines are significant logistic regressions of annual survival probability (with 95% confidence intervals). Regression equations are given in Supplementary Table 4.



Supplementary Figure 4. Robustness of projected population (a) and projected frankincense yield (b) for 23 *Boswellia papyrifera* populations to changes in the source of diameter growth data. Growth data used in IPMs were either derived from tree-ring measurements only ('ring-only', blue) or from both tree-ring measurements and permanent plot data ('ring+plot', red). Values are relative to the population size at the start of the simulation. Yields (b) were calculated based on projected size distributions (a) and on tree-level yield-diameter relations (Supplementary Fig. 2c).

a**b**

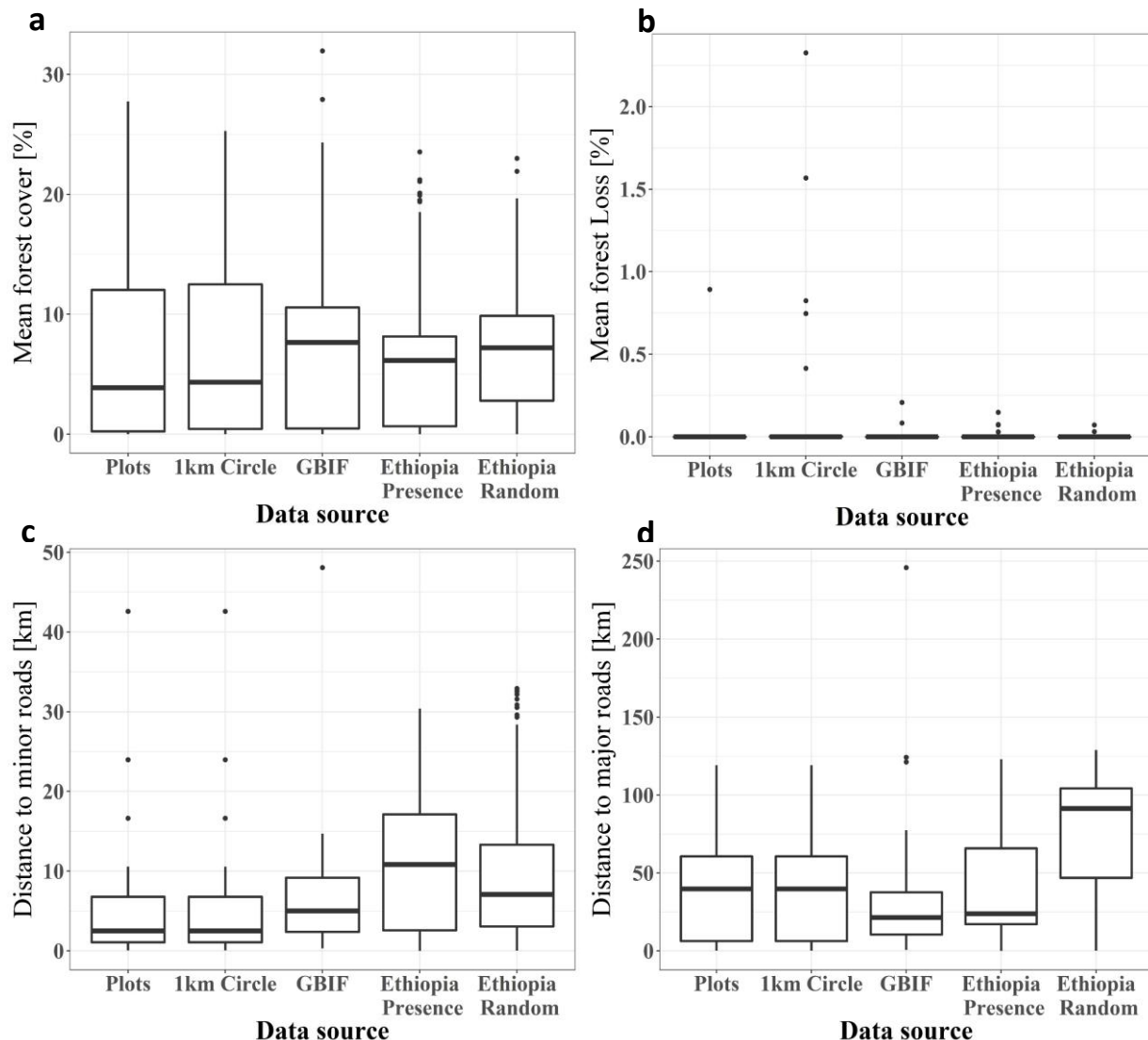
Supplementary Figure 5. Robustness of projected population (a) and projected frankincense yield (b) for 23 *Boswellia papyrifera* populations to changes in the source of vital rates. The four figures depict population and yield changes for all 23 populations, but based on population models (IPMs) with only highland vital rates (blue lines) or only lowland vital rates (red curves). Values are relative to the population size and yield at the start of the simulation. Yields (b) were calculated based on projected size distributions from (a) and on tree-level yield-diameter relations (Supplementary Fig. 2c). The dot in both figures represents the average time (plus standard deviations) to reach 50% of the population size or yield.



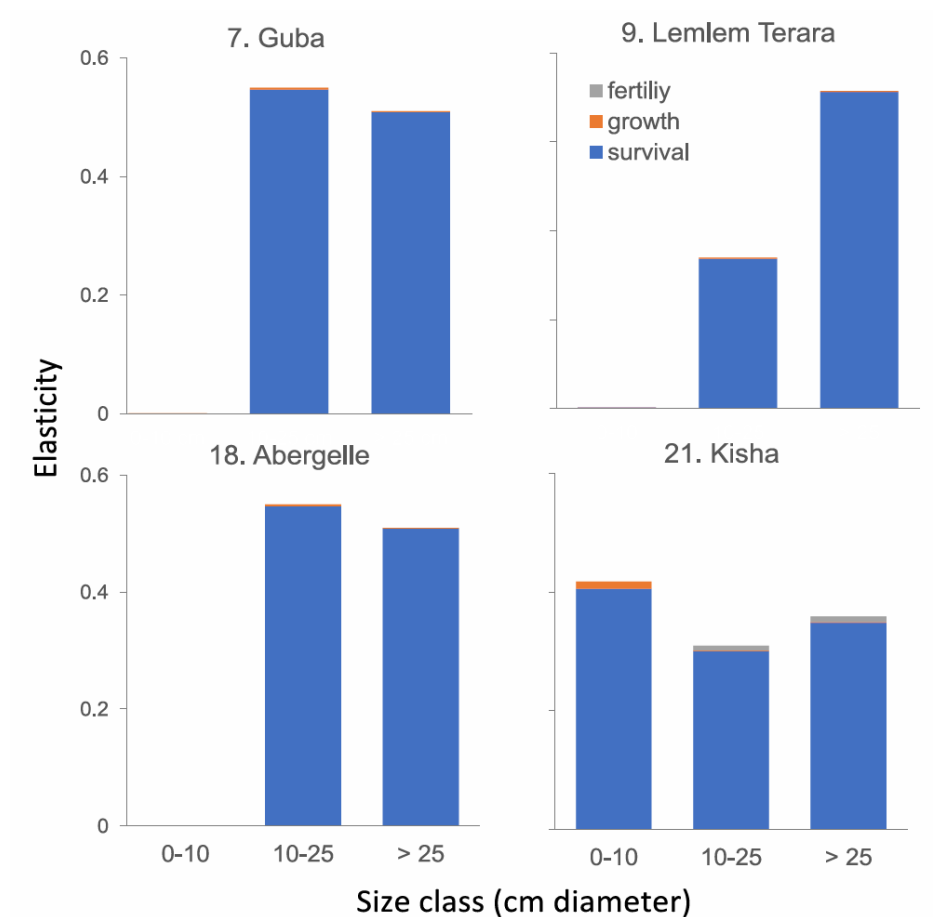
Supplementary Figure 6. Forest cover, forest loss and distances to roads, of sample plots and selected other locations.

Forest cover (a) and forest loss (% per year) (b) in sample locations (sites, n=23) and surrounding landscape (1km Circle, n=23), GBIF herbarium collection locations (GBIF, n=45), Ethiopian presence locations (Ethiopia presence, n=545) and random locations within *Boswellia* distribution area in Ethiopia (Ethiopia Random, n=545). Distances of these locations to nearby minor (c) and major (d) roads. In all four panels the differences between bars are not significant (Kruskal-Wallis test, $p > 0.05$).

Forest cover and loss is based on Hansen and coworkers¹. Data available on-line from: <http://earthenginepartners.appspot.com/science-2013-global-forest>.

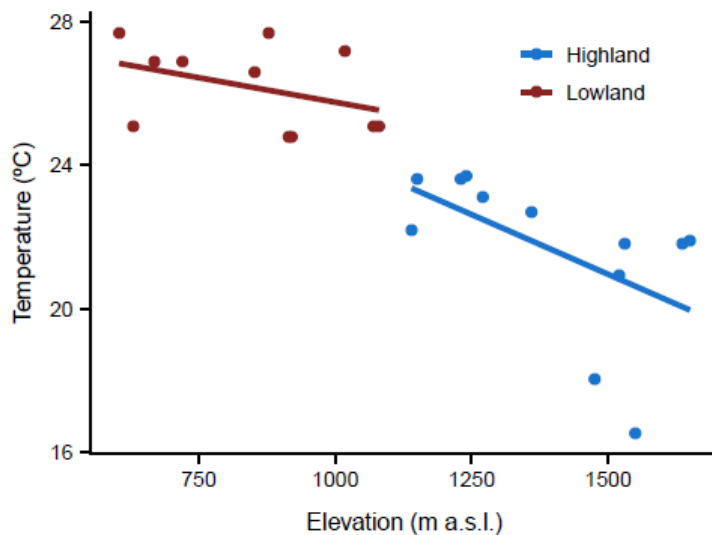


Supplementary Figure 7. Population growth is mainly driven by survival. Results from elasticity analysis for four example sites. Elasticities of transient population growth rate (during 50 years) were calculated for all three vital rates (survival, growth and fecundity) for three broad size categories, by evaluating the proportional change in population growth due to a proportion change (1%) in each vital rate. Results are shown for example populations in highland (18 and 21) and lowland (7 and 9), and both with (7 and 21) and without (9 and 18) regeneration. Survival contributed 97-99% to total elasticity.



Supplementary Figure 8. Lowland and highland populations of *Boswellia papyrifera*.

We categorized our 23 sites into lowland (<1100m asl; 11 sites) and highland (>1100m asl; 12 sites) as environmental conditions, and also exploitation history, differ strongly between lowland and highland populations. In Eritrea and Ethiopia resin collection started much earlier in the highlands, while in the lowlands this developed only during the past 3 decades. Combined with the much larger population densities in the highlands this had resulted in much earlier deforestation and *Boswellia* forest patch isolation in the highlands, compared to the lowlands, where this started only in the new millenium. Although we recognize that our study sites are located along an altitudinal gradient we categorized sites as lowland (<1100 m asl; 11 sites) or highland (>1100 m asl; 12 sites) as environmental conditions and exploitation history differ strongly between lowland and highland populations. The altitudinal cut off is based on elevational distribution of 545 *Boswellia* locations² combined with the elevation-temperature relationship shown here. Tests of the populations (see methods section and core text) show clear differences between highland and lowland in selected population parameters.



Supplementary Table 1. Estimated frankincense export by country, and *Boswellia* species IUCN Red-list status. Export estimates of the five main producing *Boswellia* species from nine countries were based on reports and data from national trade organisations, local reports, and interview data. Local production is higher but difficult to quantify. From Oman frankincense extracted oil is exported (estimated equivalent to 300-500 tons or resin). *Boswellia papyrifera* accounts for approximately two-third of global resin trade.

Country	<i>Boswellia</i> species	Export (tons/y)	Period
Ethiopia	<i>papyrifera</i> (+ <i>neglecta</i>)	2850	2006-2016
Sudan	<i>papyrifera</i>	390	1995-2005
Eritrea	<i>papyrifera</i>	300 ; none since 2002	1995-2002
Oman	<i>sacra</i>	none	since 1985
Yemen	<i>sacra</i>	none	last 2 decades
Somalia+Somaliland	<i>sacra/carteri</i> ; <i>frereana</i>	1400-2000; 200	recent years
Kenya	<i>neglecta</i>	several hundred	recent years
India	<i>serrata</i>	90	2015-2017

In total **the *Boswellia* genus contains 13 other species**, with negligible production: *dalziellii* (Nigeria, Ghana, Cameroon), *rivae* (Ethiopia, Kenya, Somaliland), *ogadensis* (Ethiopia, Somaliland), *pirotae* (Ethiopia), *microphyllae* (Ethiopia, Kenya, Somaliland) and *ameero*, *bullata*, *elongata*, *nana*, *dioscoroidis*, *socotrana*, *popoviana*, *Sp.A* (all Socotra, Yemen). Synonyms: *carteri* = *sacra* (under heavy debate); *globosa* = *frereana*; *ovalifoliata* = *serrata*. Recently a new species has been described from Somaliland (*B. occulta*)³.

A total of **13 *Boswellia* species are IUCN RED-listed** (www.iucnredlist.org) with status: *ogadensis* (CR, critically endangered), *nana*, *ameero*, *bullata*, *dioscoroides*, *elongata*, *ovalifoliata*, *pirotae*, *popoviana*, *socratana*, *sp.A* (all VU, vulnerable), *sacra* (NT, near threatened), and *rivae* (LC, least concern). *Papyrifera*, *serrata*, *neglecta*, *dalziellii* and *frereana* are not in the IUCN RED-list.

Supplementary Table 2. Description of the 23 sites with *Boswellia papyrifera* populations included in this study.

Site nr	Site name	Country	Latitude	Longitude	Eleva	MAP	MAT	#plots	Area (ha)	Sample size in dataset:			
			(decimal degrees WGS84)	(decimal degrees WGS84)	tion (m. a.s.l.)	(mm yr ⁻¹)	(°C)			1. Size distri- butions	2. Ages	3. Demo- graphic rates	4. Yield
1	Jebel Marra	Sudan	12.87917	24.12500	1359	595	22.7	151	15.1	2104 ^{4,5}			
2	Rashad	Sudan	11.77778	30.99444	852	718	26.6	352	33.2	789 ⁶			
3	Kurmuk	Ethiopia	10.58300	34.36257	668	949	26.9	1	2	934			
4	Gulashe	Ethiopia	10.56222	34.30222	720	949	26.9	1	2	462	52		
5	Eshefabego	Ethiopia	10.66314	34.69209	915	1097	24.8	1	2	200	52		
6	Baneshegol	Ethiopia	10.48718	34.76405	920	1097	24.8	1	2	136			
7	Arenja	Ethiopia	10.90667	35.26315	630	1100	25.1	1	2.64	227			
8	Kuara	Ethiopia	12.56266	36.06778	604	960	27.7	2	4	327		327(49)	
9	Lemlem Terara	Ethiopia	12.95920	37.25533	878	960	27.7	10	19.4	3980	112	3980(245)	200
10	Kafta-Humera	Ethiopia	14.00148	37.00152	1018	536	27.2	80	20	3662 ⁷			
11	Shilalo	Eritrea	14.39019	37.55235	1080	516	25.1	29	1.16	294			
12	Tahitay-Adiabo	Ethiopia	14.31537	37.71125	1070	516	25.1	33	8.5	1552 ⁸			
13	Molki	Eritrea	14.88293	37.99046	1230	600	23.6	31	1.24	286			
14	Ferhen	Eritrea	15.72048	38.47233	1270	489	23.1	26	1.04	78			
15	Adi-Ketina	Eritrea	14.96118	38.43651	1520	655	20.9	34	1.36	183			
16	Atawen	Eritrea	14.62918	38.96245	1530	612	21.8	24	0.96	171			
17	Asgede-Tsimbla	Ethiopia	13.96253	38.17813	1140	580	22.2	92	23	2861 ⁹			
18	Abergelle	Ethiopia	13.45398	38.85681	1636	800	21.8	6	8.8	2693	78	2693(150)	200
19	Adi Arkay	Ethiopia	13.46311	38.06680	1475	923	18.0	2	2.4	246		246	
20	Hamusit	Ethiopia	12.52750	38.16694	1650	1031	21.9	10	2.5	127 ¹⁰			
21	Kisha	Ethiopia	13.03333	37.23333	1240	869	23.7	31	1.24	108 ¹¹			
22	Mosebit	Ethiopia	11.60167	36.55722	1150	1283	23.6	5	1.25	43 ¹⁰			
23	Wogdi	Ethiopia	10.70213	38.89957	1550	1126	16.5	32	1.28	323 ¹²			
Total								955	157	21786	294	7246 (444)	400

MAP: mean annual precipitation; MAT: mean annual temperature. The four datasets are described under *Data collection*. 62% of all data points are ours. Superscripts in “1. Size distributions” give references for data taken from the literature, 47% of these 21786 tree data points are ours. Sample size between parentheses in "3. Demographic rates" refers to trees in the fecundity study.

Supplementary Table 3. Information and results of tree-ring studies on *Boswellia papyrifera* performed at four sites.

Site	4 Gulashe	5 Eshfabego	9 Lemlem Terara	18 Abergelle	Total /average
sampling year	2012	2012	2010/11	2013	
area sampled (ha)	2	2	8	5.6	17.6
n cores	45	45	100	70	260
n discs	3	4	12	8	27
n crossdated	35	24	84	59	202
diameter (cm) mean $\pm$ SD	23.4 $\pm$ 8.8	20.4 $\pm$ 8.4	20.4 $\pm$ 7.4	18.5 $\pm$ 4.6	19.9 $\pm$ 6.7
min-max diameter (cm)	10-50	5-42	10.3-39.8	8.2-36	5-50
recruitment year mean $\pm$ SD	1948 $\pm$ 9.0	1952 $\pm$ 17.8	1937 $\pm$ 8.6	1918 $\pm$ 12.8	1931 $\pm$ 15.1
recruitment year range	1924 - 1967	1906 - 1988	1901 - 1956	1864 - 1951	1864 - 1988
Average diameter growth (mm/y)	2.7 $\pm$ 0.82	2.8 $\pm$ 0.80	2.3 $\pm$ 0.44	1.5 $\pm$ 0.36	

n= tree sample size; n crossdated: number of samples that crossdated significantly and were used to establish age-diameter relations.

Supplementary Table 4. Statistical models and parameter estimates used to construct Integral Projection Models (IPMs) for *Boswellia papyrifera* in highland and lowland.

Demographic process	Region	Regression model	
Survival probability (s) yr1	Highland	Logit(s) = $2.428 + 0.01920x$	n = 3165, $R^2 = 1.510 \cdot 10^{-3}$, $P = 0.192$
Survival probability (s) yr2	Highland	Logit(s) = $2.871 + 0.01227x$	n = 2969, $R^2 = 0.054 \cdot 10^{-3}$, $P = 0.488$
Survival probability (s) yr1	Lowland	Logit(s) = $2.799 - 0.000475x$	n = 4371, $R^2 = 1.805 \cdot 10^{-6}$, $P = 0.958$
Survival probability (s) yr2	Lowland	Logit(s) = $2.105 + 0.018031x$	n = 4118, $R^2 = 2.766 \cdot 10^{-3}$, $P = 0.030$
Survival probability (s) yr1	Lowland	Logit(s) = $2.191 - 0.012242x$	n = 3803, $R^2 = 1.658 \cdot 10^{-3}$, $P = 0.065$
Fecundity probability (p_i)	Highland	Logit(s) = $-0.077 + 0.130420x$	n = 150, $R^2 = 0.1011$, $P = 0.025$
Fecundity probability (p_i)	Lowland	Logit(s) = $2.799 - 0.000475x$	n = 294, $R^2 = 0.0776$, $P < 0.001$
Increment (growth, μ) 'ring-only' model	Highland	$\mu = 0.2339 - 0.0072x + 0.000316x^2$	n = 5622, $R^2 = 0.0752$, $P < 0.001$
Increment (growth, μ) 'ring-only' model	Lowland	$\mu = 0.3102 - 0.0069x + 0.000320x^2$	n = 10086, $R^2 = 0.0457$, $P < 0.001$
Increment (growth, μ) 'ring+plot' model	Highland	$\mu = 0.2659 - 0.0014x + 0.00027x^2$	n = 8458, $R^2 = 0.0794$, $P < 0.001$
Increment (growth, μ) 'ring+plot' model	Lowland	$\mu = 0.2984 - 0.0056x + 0.00040x^2$	n = 13893, $R^2 = 0.0701$, $P < 0.001$
Variance of growth (σ^2) 'ring-only' model	Highland	$\sigma^2 = \text{Exp}(2.2767x)$; Residual $\sigma^2 = 0.04687$	n = 5622
Variance of growth (σ^2) 'ring-only' model	Lowland	$\sigma^2 = \text{Exp}(1.8202x)$; Residual $\sigma^2 = 0.09901$	n = 10086
Variance of growth (σ^2) 'ring+plot' model	Highland	$\sigma^2 = \text{Exp}(-7.9716x)$; Residual $\sigma^2 = 0.48388$	n = 8458
Variance of growth (σ^2) 'ring+plot' model	Lowland	$\sigma^2 = \text{Exp}(2.2495x)$; Residual $\sigma^2 = 0.00972$	n = 13893
Seedling establishment per size specific adult (p_e)	Highland	$p_e = 0.1420266$	n = 12
Seedling establishment per size specific adult (p_e)	Lowland	$p_e = 0.1420266$	n = 12
Seedling size distribution (f_d)	Highland	Gaussian with $\mu = 1.6126$, $\sigma = 0.7486$	n = 12
Seedling size distribution (f_d)	Lowland	Gaussian with $\mu = 1.6126$, $\sigma = 0.7486$	n = 12

Based on growth rates obtained from tree-ring measurements only ('ring-only') or both tree-ring measurements and permanent plot data ('ring+plot'). All regression models are functions of tree diameter size (x; diameter at breast height, in cm).

Supplementary Table 5. Results of recruitment analyses and simulations for populations of *Boswellia papyrifera* at all 23 study sites.

Site	Site name	RI (%1-4 cm)	Population size (ha ⁻¹)			Yield (kg ha ⁻¹)		
			Current	After 50 yrs	As % of initial	Current	After 50 yrs	As % of initial
1	Jebel Marra	0.0%	139.3	12.5	8.9	66.5	9.4	14.1
2	Rashad	0.0%	23.8	1.0	4.3	11.5	1.3	11.6
3	Kurmuk	5.1%	467.0	25.8	5.5	15.7	7.0	44.6
4	Gulashe	0.0%	231.0	10.7	4.6	125.0	14.5	11.6
5	Eshefabego	0.5%	100.0	4.2	4.2	44.7	5.3	11.9
6	Baneshegol	4.4%	68.0	4.7	6.9	7.1	1.4	20.3
7	Arenja	15.0%	86.0	5.4	6.3	8.6	1.6	19.0
8	Kuara	0.0%	81.8	3.1	3.8	31.1	3.6	11.7
9	Lemlem Terara	0.0%	205.2	8.5	4.1	91.0	10.6	11.6
10	Kafta Humera	0.2%	183.1	7.0	3.8	70.0	8.2	11.7
11	Shilalo	0.7%	253.4	11.2	4.4	129.8	15.2	11.7
12	Tahitay Adiabo	0.0%	182.6	7.2	3.9	75.5	8.6	11.4
13	Molki	0.7%	230.6	22.1	9.6	123.3	17.6	14.3
14	Ferhen	0.0%	75.0	7.5	10.0	43.1	6.2	14.4
15	Adi-Ketina	0.0%	134.6	11.1	8.2	62.1	7.4	11.9
16	Atawen	0.0%	178.1	16.3	9.2	88.6	12.5	14.1
17	Asgede Tsimbla	0.0%	124.4	13.2	10.6	74.8	11.4	15.3
18	Abergelle	0.0%	306.0	26.1	8.5	147.1	18.1	12.3
19	Adi Arkay	4.1%	102.5	43.1	42.0	33.8	6.4	18.8
20	Hamusit	0.8%	50.8	4.6	9.1	26.2	3.5	13.2
21	Kisha	7.4%	87.1	38.5	44.2	32.8	5.8	17.7
22	Mosebit	0.0%	34.4	3.1	8.9	16.4	2.3	14.0
23	Wogdi	0.0%	252.3	20.6	8.2	112.5	13.8	12.3
Average					10.0			15.2

RI: recruitment index, percentage of 1-4 cm dbh trees in the population; Population size: abundance of trees >1 cm dbh, currently observed, projected after 50 years (both absolute and % of current); Yield: calculated based on current population structure, projected after 50 years (both absolute and % of current).

Supplementary Method 1. Land use change and representativeness of our sites.

To evaluate till what extent the woodland vegetation in our plots is changing for all sites we evaluated tree cover change based on the global forest change product of Hansen and coworkers¹ from 2001 – 2017. Forest loss and gain were assessed for both the individual plots (n=42, within 23 sites) and for a circle of 1 km radius around the plot. Gain (pixels with no forest in 2000 and with forest since then) did not occur in the time period. Loss pixels represent areas which had tree cover in 2000 but lost cover later. To account for the difference in area between the individual plots and the circle of 1 km radius around the plot, the number of forest loss pixels was divided by the total number of pixels with tree cover (and presented as percentage loss). Additionally, the average tree cover and standard deviation were calculated for the tree cover base year (2000). Individual plots and the surrounding circle of 1 km radius were averaged to site level (n=23). For all plots we also measured the distance to the nearest local and mayor roads. All analyses were performed using ArcGIS Desktop (ESRI software) and the computing environment R (R Development Core Team, 2019). (Supplementary Fig. 6)

Supplementary Note 1. Representativeness of *B. papyrifera* woodlands

Our 23 study sites are representative for *B. papyrifera* woodlands in general. We quantified woodland tree cover and changes in tree cover for our sites compared to those obtained for other locations with known occurrence of *B. papyrifera*. For all 23 sites we quantified tree cover (trees >5m high¹) change between 2001 and 2017, both at plot-level and for the 1-km radius area around the plot. Tree cover was low, both at plot-level (average $\pm$ SD: $6.8 \pm 1.71\%$) and in surrounding area ($7.0 \pm 2.85\%$). Tree cover loss was also low, with median values of 0% per year at both scales and averages of 0.05% (plot) and 0.27% (1-km radius; Supplementary Fig. 6).

These values did not differ from those for *Boswellia* woodlands in general. First, woodland locations with presence of *Boswellia* (545 points) in Ethiopia² also exhibit low tree cover ($5.3 \pm 1.57\%$) with low change (0.0007%). Second, random locations within the distribution range of *B. papyrifera* in Ethiopia shows comparable results (cover: $6.7 \pm 1.86\%$; change 0.0003%). Third, GBIF herbarium collection locations for this species also show similar results (average cover $8.5 \pm 1.92\%$, cover loss 0.008%). Forest cover and loss did not differ significantly between our plots, 1-km radius and other *Boswellia* locations (Supplementary Fig. 6). In addition, we also compared distances to roads between our study sites and *Boswellia* woodlands. Our plots were not easily reachable overall: they are located at an average distance of 6.3km (± 9.8 km) to the nearest minor road and 41.2km (± 35.9 km) to the nearest main road. These distances did not differ significantly from those of GBIF locations, *B. papyrifera* presence locations in Ethiopia or random locations in *B. papyrifera* distributional area (Supplementary Fig. 6).

References

- 1 Hansen, M. C. *et al.* High-resolution global maps of 21st-century forest cover change. *Science* **342**, 850-853, doi:10.1126/science.1244693 (2013).
- 2 Girma, A., de Bie, C. A. J. M., Skidmore, A. K., Venus, V. & Bongers, F. Hyper-temporal SPOT-NDVI dataset parameterization captures species distributions. *International Journal of Geographical Information Science* **30**, 89-107, doi:10.1080/13658816.2015.1082565 (2015).
- 3 Thulin, M., DeCarlo, A. & Johnson, S. P. *Boswellia occulta* (Burseraceae), a new species of frankincense tree from Somalia (Somaliland). *Phytotaxa* **394**, 219-224 (2019).
- 4 Adam, A. A. & El Tayeb, A. M. A comparative study of natural regeneration on *B. papyrifera* and other tree species in Jebel Marra Darfur, Sudan. *Research Journal of Agriculture and Biological Sciences* **4**, 94-102 (2008).
- 5 Adam, A. A. *Some aspects of ecology and management of Boswellia papyrifera Del. (Hochst) in Jebel Marra mountains, Darfur, Sudan*. PhD thesis, University of Khartoum, (2003).
- 6 Abtew, A. A., Pretzsch, J., Mohamoud, T. E.-S. & Adam, Y. O. Population status of *Boswellia papyrifera* (Del.) Hochst in the dry woodlands of Nuba Mountains, South Korfofan State, Sudan. *Agriculture & Forestry* **54**, 41-50 (2012).
- 7 BoANR. Assessment of Spatial Distribution, Regenerating Capacity, Degradation and Development Prospects of *Boswellia papyrifera* in Kafta Humera., 63 (Bureau of Agriculture and Natural Resources, Mekelle, Ethiopia, 2003).
- 8 BoANR. Assessment of Spatial Distribution, Regenerating Capacity, Degradation and Development Prospects of *Boswellia papyrifera* in Tahitay Adiabo., 58 (Bureau of Agriculture and Natural Resources, Mekelle, Ethiopia, 2004a).
- 9 BoANR. Assessment of Spatial Distribution, Regenerating Capacity, Degradation and Development Prospects of *Boswellia papyrifera* in Asgede Tsimbla., 55 (Bureau of Agriculture and Natural Resources, Mekelle, Ethiopia, 2004b).
- 10 Biresaw, M. A. & Pavlis, J. Vegetation structure and density of woody plant species in two woodland areas of Amhara National Regional State, Ethiopia. *Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis Sborník Mendelovy Univerzity V Brně* **LVIII**, 21-32 (2010).
- 11 Eshete, A., Teketay, D. & Hulten, H. The socio-economic importance and status of populations of *Boswellia papyrifera* (Del.) Hochst. in northern Ethiopia: The case of North Gonder Zone. *Forests, Trees and Livelihoods* **15**, 55-74 (2005).
- 12 Abiyu, A. *et al.* in *Degraded Forests in Eastern Africa: management and restoration*. Vol. (eds F. Bongers & T. Tennigkeit) (Earthscan Ltd., 2010).