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Supporting Online Material for

CITES Designation for Endangered Rosewood in Madagascar

Meredith A. Barrett,* Jason L. Brown, Megan K. Morikawa, Jean-Noël Labat, Anne D. Yoder

*To whom correspondence should be addressed. E-mail: meredith.barrett@duke.edu

Published 28 May 2010, *Science* **328**, 1109 (2010)
DOI: 10.1126/science.1187740

This PDF file includes

Supporting Online Material

The Supporting Online Material includes:

Supporting Methods

1a. Estimation of Historic and Current Distributions (Figure S2). Species historic distributions were modeled from georeferenced museum specimens, climate and geographical data using the machine-learning program, Maxent (Tables S1, S3) (*S1*). Geographic data of *Dalbergia baronii, D. bathiei, D. davidii, D. louvelii, D. mollis, D. monticola, D. normandii, D. purpurascens, D. tsiandalana* and *D. viguieri* were obtained from Global Biodiversity Information Facility (Table S3). These data do not incorporate rosewood density or abundance information. The dataset consisted of 559 points that were identified by experts from reputable sources such as the Missouri Botanical Gardens (n=191), the Museum National d' Histoire Naturelle et Reseau des Herbiers de France (n=364), and Conservation International (n=4). 511 of the points (91.4%) were identified by respected experts in Malagasy flora, including J. Bosser, J-N. Labat, R. Rabevohitra, D. J. DuPuy, G. Schatz (noted in GBIF database (*S2-S3*)). Each data point was subsequently verified by J.N. Labat, coauthor and expert botanist at the Museum National d' Histoire Naturelle in Paris, France. We removed all redundant and non-verifiable data points.

Species distribution models (SDM) were generated for species with 6 or more unique localities, which excluded *D. davidii* and *D. normandii*. SDM were calculated in Maxent and incorporated the following 21 eco-geographic variables at 30 arc-second resolution: 19 bioclimatic variables from Worldcllim.org (these constitute a wide range of variables representing different measures of temperature and precipitation), geology and slope (Table S3). Continuous models were converted to binary models using the 'Fixed Cumulative Value 5' threshold.

We calculated rosewood species richness by summing the binary SDM for all 8 species (Figure S2). The historic range of all 8 *Dalbergia* species was estimated by converting the richness model to a binary model, and then translating all richness values greater than or equal to 1 to historic *Dalbergia* presence.

We estimated the current distribution of rosewood species under three scenarios on a gradient of deforestation. The most optimistic, Scenario 1, reduced the historic range of rosewoods to "forested" areas based on classified satellite imagery from 2005. Scenario 1 was further reduced by excluding forested areas with elevated human influence according to the Human Influence Index (HII), a composite measure combining human population density, human infrastructure, urban polygons, nighttime lights and land cover categories (Table S3)(Scenario 2). All areas with high human influence, defined as HII values above 14 (the mean HII value of recent deforested areas in Madagascar), were classified as "deforested," while all values below 14 were considered "forested" areas. Scenario 3 reduced the rosewood distribution in Scenario 2 to only those regions within protected areas using the most current information from the World Database on Protected Areas (Table S3). Anecdotal estimates propose that rosewood species do not currently exist outside of protected areas, which constitute only 3% of Madagascar's land mass (*S4*). In all scenarios, all protected areas were classified as forested, even if they occurred in areas of high human influence.

1b. Landscape Permeability to Logging. To estimate areas of high logging risk, we first modeled the degree of access, or "landscape permeability," of forested areas in Scenario 1. We completed this by weighting and then summing reclassified rasters of different characteristics of the landscape, such as terrain slope, waterways, transportation networks and human influence. We weighted each layer according to its estimated influence in the logging process. We weighted them in the following order: classified distance to coastline, classified distance to large rivers, classified human influence, classified distance to roads, classified distance to streams, classified distance to ports, classified distance to trails and classified slope. Weights ranged from 0.4-1.0; layers with a higher value held more influence in the model. The resulting layer represented the degree of access, or permeability, to any forested area. For example, an area with a high concentration of both roads and rivers would have a higher degree of logging access then a large, distant forest fragment.

1c. Rosewood Logging Risk and designation of at-risk protected areas. To estimate areas of high rosewood logging risk, we recognized that logging would tend to occur in those areas with both high suitability for rosewood and high logging accessibility. To acknowledge these criteria, we combined the calculated rosewood distributions (Methods 1a) with the landscape permeability model (Methods 1b). First, we summed the continuous rosewood SDM generated in Maxent from 1a. In these SDM, areas with values approaching 1 represent highly suitable rosewood habitat, and therefore an elevated probability of rosewood presence. By summing the continuous SDM for all eight rosewood species, we calculated a continuous surface that represented habitat suitability for all rosewood species. This resulting suitability layer was scaled to 1 and then multiplied by the "landscape permeability" layer from 1b. The resulting raster represented rosewood logging risk, which accounted for both landscape permeability to logging and probability of rosewood presence.

We then classified the continuous logging risk model into 3 risk categories (lower, medium and high risk) by comparing the model with known logging sites as documented in field reports (*S4*, *S5*, Figure 1). We extracted the logging risk value at each documented logging site (DLS), calculated the average and used this value as the cutoff for all "high risk" logging areas. We then used the lowest observed logging risk value at a DLS as the threshold for "medium risk" logging areas. In other words, all areas with a calculated logging risk value equal to or above the average logging risk value of DLSs would receive a "high risk" classification, while all areas with a calculated logging risk value equal to or above the lowest observed logging risk value of a DLS, but less than the "high risk" value, would receive a "medium risk" classification. All other areas within the logging risk model were considered "lower risk" for logging.

Protected areas with 10% or more of their land within high risk logging areas were considered "high risk" parks (Figure S3). Protected areas with 10% or more of their land within medium risk areas were considered "medium risk" parks, and those parks with less than 10% of their land in medium risk areas were considered "lower risk."

Section 2: Supporting Text

2a. Major protected areas affected by logging in northeast. Much of the current exploitation has occurred in Marojejy National Park, Masoala National Park and Mananara Biosphere Reserve, which together comprise part of the Atsinanana UNESCO World Heritage Site (*S4, S6-S7*). Death threats directed at villagers and park officials forced the closure of Marojejy National Park in April 2009 (*S6-S7*). Additional heavy logging has occurred in Makira Natural Park.

2b. Genus *Dalbergia*.

The genus *Dalbergia* (Family: Fabaceae) consists of 48 species in Madagascar; 47 (97.7%) of these species are found nowhere else in the world (*S2-3, S8-S9*). Recent evidence suggests one additional, undescribed species may exist. Rosewood species occur throughout Madagascar, but the most sought-after species occur predominantly in the northeast (Figure S2).

2c. Resemblance and CITES listing of other *Dalbergia*.

As stated in CITES Resolution Conf. 9.24 (Rev. CoP14) Annex 2b (*S10*), species, such as *D. davidii* and *D. normandii,* may be included in Appendix II if they "resemble specimens of a species included in Appendix II…or I, such that enforcement officers…are unlikely to be able to distinguish between them." If other *Dalbergia* species endemic to Madagascar are found to be sufficiently difficult to distinguish from the 10 species included in this study, we recommended extending this protection to them as well.

2d. Notes on CITES Appendices.

The CITES Plant Committee asks that the country submits a notification of its intentions, after which the listing could go into effect after 90 days. The next CoP will take place in Thailand in 2013 (*S11*). A CITES Tree Species Evaluation process already recognized *D. louvelii* as eligible for Appendix II listing in 1997 (*S4*); deforestation in the past 12 years has surely elevated its vulnerability.

Supporting Figures

Figure S1. Rosewood logging process. (A) Malagasy laborers locate trees, cut them by hand, then drag the log, averaging 0.11-0.21 tons, for kilometers through steep, forested terrain to the nearest stream or river access (*S4, S12*). (B) Dense rosewood logs are strapped to 4-5 lighter trees to create a raft. Rafts travel to the nearest roadway or coastal access point, where they are transported by boat or (C) truck to one of the major ports, such as (D) Vohémar, where foreign-owned shipping operations transport to Mayotte, Mauritius and then to China and other markets for use in the (E) furniture or musical instrument trade (*S4, S6, S12*). Photo credits: Reiner Tegtmeyer/EIA/GW, Toby Smith/EIA/GW and ©iStocktphoto.com/weim.

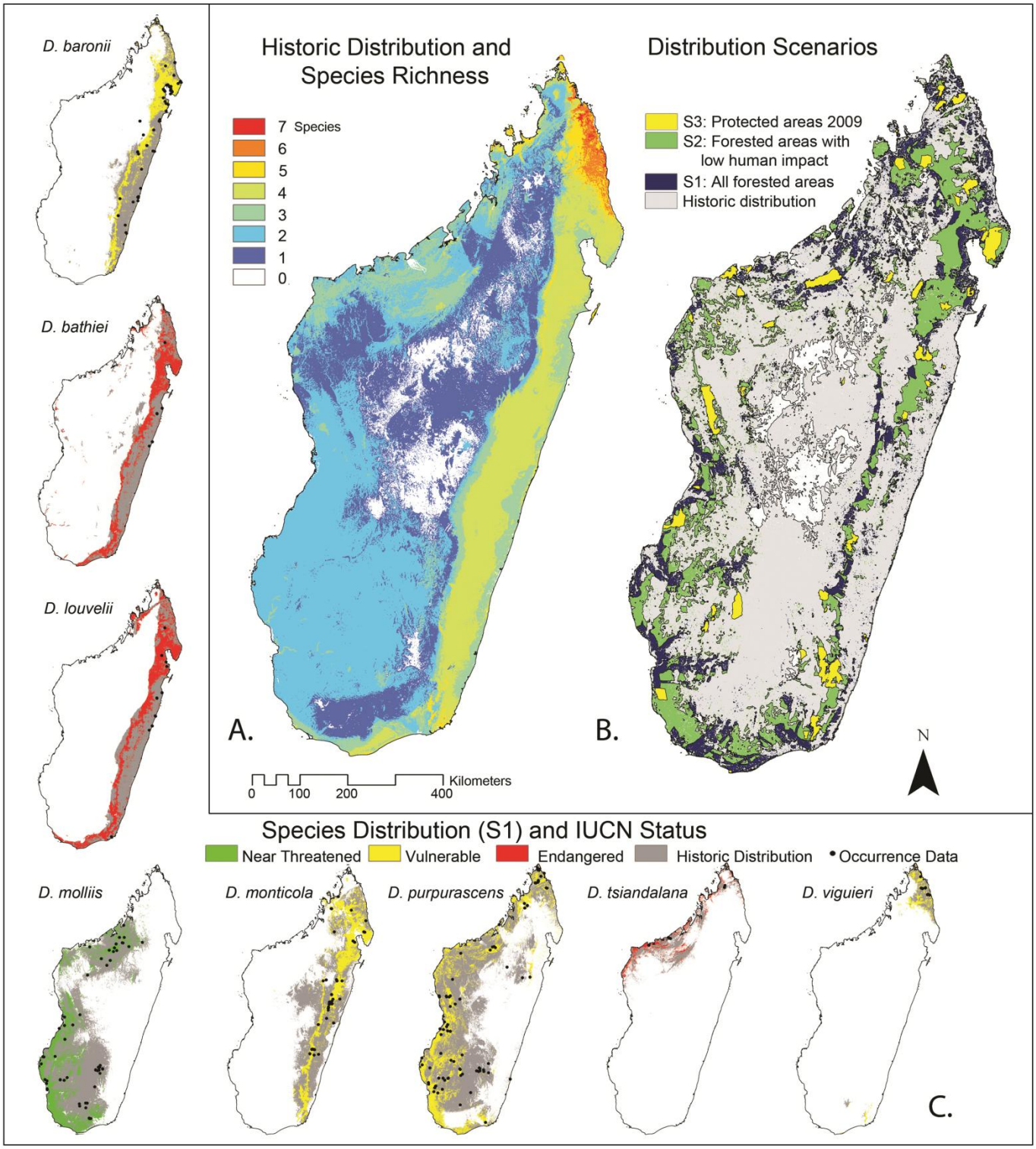

Figure S2. Rosewood species richness and distribution in Madagascar. (a) Rosewood distribution once covered 93% of Madagascar, with high species richness in the northeast region. Persistent deforestation has severely reduced the distribution of rosewood species. (b) We calculated the habitat reduction based upon three scenarios of forest loss: 1) potential rosewood habitat in forested areas (yellow + green + blue) (S1), 2) potential rosewood habitat in forested areas minus those areas heavily impacted by humans (yellow + green) (S2), and 3), potential rosewood habitat remaining only in protected areas (yellow) (S3). (c) Based upon the optimistic S1, we display maps of the current vs. historic ranges of 8 rosewood species. Colors indicate threat status (*S13*).s

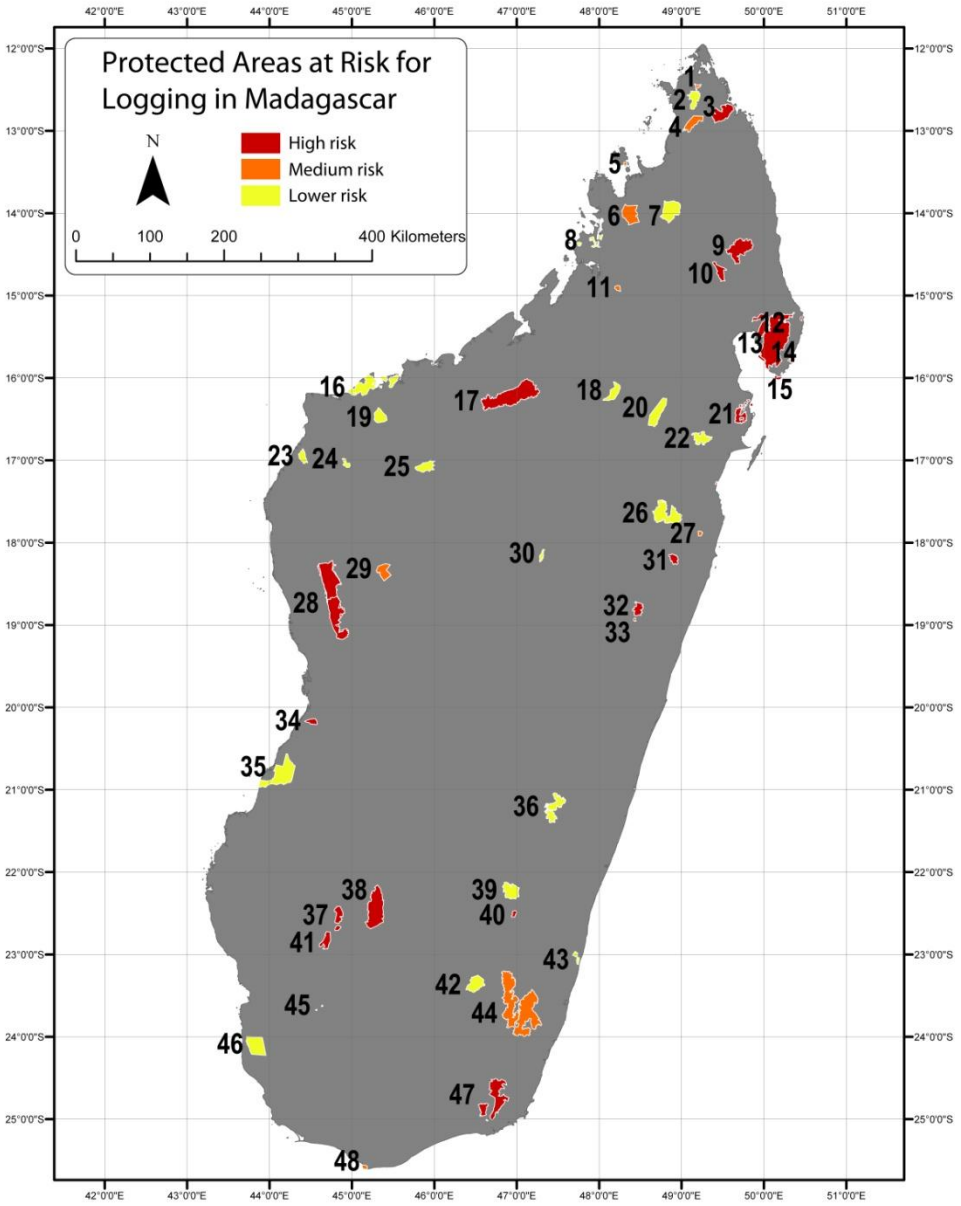

Figure S3. **Logging risk within current protected areas in Madagascar**. Classifications of protected area risk evaluated the percentage of each park's total area that fell within high, medium or lower risk logging regions: High risk (>10% of area within high risk), Medium risk (> 10% of area within medium risk), Lower risk (<10% of area at medium risk). 1) Forêt d'Ambre Special Reserve (S. R.), 2) Montagne d'Ambre National Park (N.P.), 3) Analamerana S.R., 4) Ankarana S.R., 5) Lokobe Strict Nature Reserve (S.N.R.), 6) Manongarivo S.R., 7) Tsaratanana S.N.R, 8) Sahamalaza Marine N.P., 9) Marojejy N.P., 10) Anjanaharibe-Sud S.R., 11) Bora S.R., 12 – 15) Masoala N.P. complex, including marine reserves, 16) Baie de Baly N.P., 17) Ankarafantsika N.P., 18) Tampoketsa Analamaitso S.R., 19) Tsingy de Namoroka N.P., 20) Marotandrano S.R., 21) Mananara-Nord N.P and M.P., 22) Ambatovaky S. R., 23) Bemarivo S. R., 24) Maningoza S.R., 25) Kasijy S.R., 26) Zahamena N.P. and S.N.R., 27) Betampona S.N.R., 28) Tsingy de Bemaraha N.P. and S.N.R., 29) Ambohijanahary S.R., 30) Ambohitantely S.R., 31) Mangerivola S.R., 32) Mantadia N.P., 33) Analamazaotra S.R., 34) Andranomena S.R., 35) Kirindy Mitea N.P., 36) Ranomafana N.P, 37) Vohibasia N.P., 38) Isalo N.P., 39) Andringitra N.P., 40) Pic d'Ivohibe S.R., 41) Zombitse-Vohibasia N.P., 42) Kalambatritra S. R., 43) Manombo S. R., 44) Midongy Befotaka N.P., 45) Bezaha Mahafaly S.R., 46) Tsimanampetsotsa N.P., 47) Andohahela N.P. and 48) Cap Sainte-Marie S.R.

Supporting Tables

Table S1. Georeferenced database of *Dalbergia* rosewood species occurrences in Madagascar (Excel file available in Supporting Material on Science Online.)

Table S2. Distribution and conservation status of rosewood species. We include the 10 economically important rosewood species in Madagascar and 3 non-Malagasy species currently under CITES protection. Reduction and ranges have been calculated based upon the three scenarios of deforestation (S1, S2, S3) (Figure S2).

	Species	% Long-term range reduction			% Range outside of protected areas			IUCN status[S13]	CITES criteria met[S10]	Recommended CITES designation
		S1	S2	S3	S1	S2	S3			
Malagasy species	*D. baronii*	58	72	95	88	82	0	Vulnerable	Annex 1 Ai,v; Bi,iii,iv; Ci,ii, which includes: marked decline of historical habitat greater than 5-30%, marked recent rate of habitat decline greater than 50% in the last 10 years, high vulnerability to extrinsic factors, restricted distributions, fragmented wild populations, habitat degradation, marked decline in population size based on a decrease in area/quality of habitat	Immediate listing by Madagascar to Appendix III (with uplisting to Appendix I at CoP 16)
	D. bathiei	59	73	95	88	81	0	Endangered		
	D. louvelii	55	70	95	89	82	0	Endangered		
	D. mollis	69	80	98	93	89	0	Near threatened		
	D. monticola	62	73	95	87	82	0	Vulnerable		
	D. purpurascens	70	81	97	91	86	0	Vulnerable		
	D. tsiandalana	72	86	97	90	80	0	Endangered		
	D. viguieri	54	73	93	85	75	0	Vulnerable		
	D. davidii	Data Deficient						Endangered	Assumption that CITES Annex 1 criteria would be met due to endangered status and similarity to other *Dalbergia* species, however, further data is required to confirm	Immediate listing by Madagascar to Appendix III (with uplisting to Appendix II at CoP 16)
	D. normandii							Endangered		
on-Malagasy	*D. nigra*	*	*	*	*	*	*	Vulnerable	CITES Appendix I (Brazil, 11/6/1992)	*
	D. retusa	*	*	*	*	*	*	Vulnerable	CITES Appendix III (Guatemala, 12/2/2008)	*
	D. stevensonii	*	*	*	*	*	*	Unlisted	CITES Appendix III (Guatemala, 12/2/2008)	*

Table S3. Data layers used for model calculations of rosewood distribution and current threats contributing to logging.

Calculation	Data Layer	Reference
Ecological Niche Modeling of historic rosewood distributions	Georeferenced museum specimens and field observation data	GBIF (http://www.gbif.org/)
	Climate data	Worldclim (http://www.worldclim.org/), 'current' Bioclim 1.4 dataset
	Slope	Calculated from 90m SRTM data (http://glcf.umiacs.umd.edu/index.shtml)
	Geology	Royal Botanic Gardens, Kew (http://www.kew.org/gis/projects/madagascar/geolsimp_meta.html)
Reduction of estimated historic distributions by remaining forested area based upon satellite imagery (S1)	Remaining forested areas	MEFT, USAID et CI, 2009. Evolution de la couverture de forêts naturelles à Madagascar, 1990-2000-2005. Ministere de L'Environment, des Forêts et du Tourisme
Reduction of estimated historic distributions by remaining forested area and high human influence (S2).	Remaining forested areas and Human Influence Index	Last of the Wild Data Version 2, 2005 (LWP-2): Global Human Influence Index (HII). Wildlife Conservation (WCS) and Center for International Earth Science Information Network (CIESIN). (http://sedac.ciesin.columbia.edu/wildareas/downloads.jsp)
Reduction of estimated historic distributions by protected areas (S3).	Current protected areas	World Database on Protected Areas 2009 (http://www.wdpa.org/), Madagascar National Parks authority
Prediction of areas vulnerable to logging	Distance to roads	Calculated from Roads layer (http://www.diva-gis.org/gdata)
	Distance to trails	Calculated from Roads layer (http://www.diva-gis.org/gdata)
	Distance to ports	Calculated from World Port Index layer (http://www.nga.mil/portal)
	Distance to rivers	Calculated from Inland Water layer (http://www.diva-gis.org/gdata)
	Distance to coast	Calculated from Administrative boundaries layer (http://www.diva-gis.org/gdata)
	Slope	See above
	Human Influence Index	See above

Supporting Online Movie Links

Supporting Online Movie Link 1. Rosewood logs are floated down streams and rivers in small boats, canoes and as rafts (Global Witness/Environmental Investigation Agency).
http://www.youtube.com/watch?v=payUUJed0dc

Supporting Online Movie Link 2. Rosewood logs that have been floated down streams and rivers are then loaded onto trucks for road transport to shipping depots for export (Global Witness/ Environmental Investigation Agency).
http://www.youtube.com/watch?v=LBtsNBpWW0E

Supporting References and Notes

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S13. IUCN, "IUCN Red List of Threatened Species. Version 2009.2"(2009).