

Appendix 6. Cross-scale social actor relation and power relation analysis

Table A6.1 Ecosystem services and Nature's Contributions for People (NCPs) provided by pau-brasil trees

Service type	Ecosystem goods and services	Source that indicates the service provision	Benefits †	Benefitting actor group
Material NCP	Wood for string instrument bows	Rocha 2004	Material (string instrument bows)	Bow/violin makers, musicians, audience
	Bark and leaves of potential pharmaceutical value, e.g., for cancer treatment (not yet commercially used)	Grangeiro 2009, Zanin et al. 2012, da Silva Gomes et al. 2014, Siqueira et al. 2014, Fraga Campos et al. 2015	Material (medicine)	Pharmacy, patients
	Wood used for red dye	Rocha 2004	Material (red dye)	Bourgeoisie in Europe
Non-material NCP	Value for the Brazilian indigenous tribe 'tupinambá'	Bueno 2002, Buono 2012, 2016	Material (red dye)	Indigenous tribe 'tupinamba'
	Source of inspiration mainly in Brazil (poetry, compositions, labelling)	Pinheiro 1991, Silva and Andrade 2006, Allen 2011	Poetry, composition, music, etc.	Artists, 'audience'
	Intangible cultural value for Brazilians (identity and representation of history of exploitation)	Retford 1964, Bueno 2002, Rocha et al. 2007, UNESCO 2012, Dapson and Bain 2015	Identity, place/ heritage	Residents of Brazil
	Traditional knowledge in violin- and bow-making craftsmanship based on pau-brasil use	Own research finding	Knowledge, identity, employment, bequest	Bow/violin makers, musicians, audience
	Classical music played with string instruments and pau-brasil bows (part of Europeans identity)	Own research finding	Knowledge, employment, bequest	Musicians, audience

Research (e.g., ecology, taxonomy, history, geography, wood anatomy, material science), education (plantings of pau-brasil trees and in front of schools and in parks)	Publications found with Scopus with the search string: "Caesalpinia echinata" OR "brazilwood" OR "pau-brasil" OR "pernambuco wood" OR " <i>Paubrasilia echinata</i> ": 205	Knowledge, bequest	Scientists, teachers, students, residents
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† According to the categories of benefits (material, aesthetic, place/heritage, activity, spiritual, inspiration, knowledge, existence/bequest, option, social capital & cohesion, identity, employment by (Chan et al. 2012).

Table A6.2 Key actor groups and their formal institutionalizations (INT=international, EU=Europe, BRA=Brazil, MA=Mata Atlântica, Reg=regional)

Actor groups	Formal organization/institution	Scale	
Policymakers / environmental agencies	Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)	INT	
	Council regulations of the European Union (European government)	EU	
	Brazilian government	BRA	
	Brazilian Institute of the Environment and Renewable Natural Resources (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, IBAMA)	BRA	
	Chico Mendes Institute for Biodiversity Conservation (Instituto Chico Mendes de Conservação da Biodiversidade, ICM-Bio)	BRA	
	Programa Nacional de Conservação do Pau Brasil - Programa Arboretum	BRA	
	Provincial governments (regional)	Reg.	
	Regional governments (local)	local	
	Scientists	International Union for Conservation of Nature (IUCN)	INT
		Botanical Garden of Rio de Janeiro	MA
Instituto Florestal Sao Paulo		BRA	
Environmental NGOs	International Alliance of violin and bow makers for endangered species	INT	
	International Pernambuco Conservation Initiative (IPCI)	INT	
	Confederation of Craftsmen and Users of Natural Resources (Comurnat),	EU	
	International Pernambuco Conservation Initiative (IPCI)	EU	
	Fundação Nacional do Pau-Brasil (FUNBRASIL)	MA	
	Association of Plants from the Northeast (APNE)	MA	
	Instituto Floresta Viva	MA	
	Programa Pau-brasil (CEPLAC)	MA	
	Instituto Verde Brasil	MA	
	Violin and bow makers	International Association of Violin and Bow makers (EILA)	INT.
Violin and Bow making associations of each European country		EU	
No formal organization within Brazil		BRA	
Musicians	International Federation of Musicians	INT.	
	European Music Council (EMC)	EU	
Farmers and plantation owners	No formal organization of Brazilian musicians	BRA	
	No formal organization on the level of the whole Mata Atlântica (only local farmers associations)	BRA	
Residents	No formal organization encompassing pau-brasil	MA	

Social actor and power relations matrix

Table A6.3 Social actor and power relations of key actor groups considering: (1) the level of dependence from pau-brasil's NCPs/ESs (3 = highly dependent on material and non-material NCP/ES provided by pau-brasil for livelihoods of actor groups, 2 = moderately dependent on pau-brasil's immaterial NCPs/ESs, 1 = low dependence on pau-brasil as species, as the topic of their work is replaceable), (2) the level of influence on decision making processes regarding the management of pau-brasil's NCPs/ESs (3 = very large influence through active participation in decision/policy-making processes related to the management of NCPs/ESs implemented and mediated by formal institutions; 2 = moderate (subtle) influence; 1 = limited influence; 0 = no influence), and (3) a dependence-influence matrix indicating the level of disadvantage within the Mata Atlântica (MA), Europe (EUR) and internationally (INT)

Actor groups	Level of dependence			Level of influence			Dependence-Influence (x-axis/y-axis)			Level of disadvantage
	MA	EUR	INT	MA	EUR	INT	MA	EUR	INT	
Policymakers / environmental agencies	1.5	-	1	3	3	3	1.5/3	-/3	1/3	low
Scientists	1.5	1	1.5	1	1	1	1.5/1	1/1	1,5/1	low
Environmental NGOs	1.5	1.5	1.5	1	2	1	1.5/1	1.5/2	1,5/1	low
Violin makers	2.5	2.5	2.5	1	2	1	2.5/1	2.5/2	2.5/2	high
Bow makers	3	3	3	1	2	1	3/1	3/2	3/1	very high
Musicians	2.5	2.5	2.5	1	2	1	2.5/1	2.5/2	2.5/1	high
Farmers and plantation owners	2	-	-	2	-	-	2/2	-	-	moderate
Residents of the MA	1.5	-	-	2	-	-	1.5/2	-	-	low

Descriptive social relations and power relations analysis

Based on our interviews, we identified the following most relevant social actor groups: bow makers, environmental NGOs, musicians and violin makers, farmers and plantation owners, residents of the Mata Atlântica, scientists and policy makers (Table. A3.1). The farmers and plantation owners as well as the residents of the Mata Atlântica can only be found at the scale of the subsystem Mata Atlântica, all other actor groups are represented at all three scales (Fig. 1). As described by Peterson (2000), actor groups are usually quite heterogenous and can be subdivided considering hierarchical taxonomic distinctions. In our case, the Brazilian string bow manufactories represent one of these subgroups of the bow makers, since they act simultaneously as bow makers, wood traders, and some additionally as private plantation owners and members of environmental NGOs. Another case is the NGO IPCI, a subgroup of the environmental NGOs, consisting mainly of bow makers, violin makers, and musicians (actors that also form part of other actor groups), hence it follows a main interest (a commercial provision of pau-brasil wood in the future) when supporting pau-brasil conservation. Furthermore, IPCI is one of the most important supporters of pau-brasil planting projects.

Similarly to Martín-López et al. (2019), yet limited to one tree species, we define dependence as the degree of reliance on pau-brasil and its ecosystem services of a certain actor group for their livelihoods or well-being (Table A6.3). Our most important finding regarding the dependence level assessment is that the bow makers, in numbers a relatively small group of actors (there are globally only a bit more than 200 bow makers (Pfeifer 2002, Rymer 2004)), are most dependent at all scales (3 = high dependence) on the availability of pau-brasil wood with limited options of using alternative materials. Musicians and violin makers are also highly dependent on pau-brasil at all scales (2.5 = high-moderate dependence) but their dependence is spread to other raw materials and species in comparison to bow makers. The decision makers in the European subsystem implement the regulations of CITES but are not specifically concerned about pau-brasil as a species, so they do not appear at the European scale. Specific regulations and laws only for pau-brasil in Brazil show that pau-brasil is part of the work of some decision makers of the Mata Atlântica (1 = low dependence). The listing of pau-brasil in the Appendix II of CITES shows that pau-brasil occupies decision-makers in their work at the global scale (1 = low dependence). Within the subsystem of the Mata Atlântica, residents, farmers, and plantation owners in the Mata Atlântica depend on supporting and provisioning ecosystem services (such as nutrient cycling, soil formation, pollination and fuel wood), although not directly on the species of pau-brasil. Regarding cultural identity, pau-brasil is, by being the eponym and national tree of the country, of utmost relevance for residents, farmers and Brazilian plantation owners (2 = moderate – key relevance of pau-brasil and its ecosystem services but not directly for the livelihood). Regardless of their dependence, farmers and plantation owners influence the Mata Atlântica ecosystem with their management strategies and might induce land-use changes to increase their agricultural areas and thus sacrifice land of the Mata Atlântica.

International decision makers and the ones of the Mata Atlântica show the largest influence on the CES (3 = high influence), being responsible for relevant legislative decisions (CITES listing, laws regarding pau-brasil). In Europe, decisions at the international scale are implemented (3 = high influence). Considering our spatiotemporal analysis, bow makers, musicians, and violin makers were able to increase their influence level with the foundation of IPCI and the International Alliance, which was facilitated due to the historically existing formal international and European organizations, e.g., in guilds and associations (International: EILA, Europe: associations of professions) of these social actor groups. Therefore, they show a

moderate influence (3 = moderate) on pau-brasil management strategies internationally and in Europe and even on decisions of CITES (e.g., excluding the finished product of string instrument bows from the CITES regulations in the Annotation #10). Partly due to a missing formal association of bow makers in the Mata Atlântica or Brazil their level of influence is limited. Environmental NGOs show a moderate influence at all scales, while farmers and plantation owners, organized in different local associations, show a moderate influence within the Mata Atlântica but have internationally and in Europe no influence at all. Residents as well as musicians and bow makers of the Mata Atlântica have a very limited influence and residents have no influence in Europe or internationally. In contrast to that, the musicians and bow makers are better organized in Europe and internationally and show a moderate influence at these scales. Scientists at the international level have a large influence and represent the *interests* on pau-brasil as species influencing listings in the IUCN red list and with further participation in the CITES meetings also decisions on the listings in the appendices with direct implications on management strategies for its conservation. While the influence level is very limited at the European subsystem and limited within the Mata Atlântica subsystem both subsystems contribute through their cross-scale connection to the international influence level. We found that cross-scale interconnections between the same actor groups at different scales increase their influence especially on decisions taken at the global scale with local impacts (e.g., scientists, bow makers).

Our analysis indicates that historic considerations allow to identify changes in the influence level and instruments that empower actor groups. The direct and non-replaceable dependence of the entire profession of bow-makers on that specific primary raw material coupled with limited to moderate influence levels, makes them the most vulnerable actor group (highest dependency, as defined by Martín-López et al. (2019)) at all scales for this CES. But bow makers were able to decrease their vulnerability by increasing their influence level at all scales within the last 20 years by founding an interest oriented environmental NGO (IPCI) in 2000 and in 2018 the 'International Alliance of violin and bow makers for endangered species'. We found that existing formal associations that represent the interests of certain actor groups increase their possibilities to influence decision-making processes, high dependencies unify the interest and help to unite actors. Unconscious and immaterial dependencies on ecosystem services of pau-brasil, as in case of farmers and plantation owners and even more of residents of the Mata Atlântica, are usually ignored by the actors themselves. Additionally, e.g., the residents are formally not organized which seem to be one aspect of their low influence level as social actors of the CES.

Unequal distributed stocks of pau-brasil between the bow makers at all scales contribute to a lack of distributional equity within its social actor group and strategies to face that inequity should be faced. Possible factors might be age (young bow makers hardly have big stocks of pau-brasil wood), gender (bow making is a traditional male profession), and origin (being from a traditional bow making family might provide you with a stock of pau-brasil wood); however, this requires further analysis. For sustainable conservation strategies, increasing the interest of and even more the stake of these 'unconsciously' dependent actor groups might help to increase changes for a transformation process that equalizes also historical inequalities traceable back to colonization. A conscious participation and exchange with farmers and plantation owners and residents of the Mata Atlântica might also increase distributional and especially procedural equity. The PB-CES represents an example for international decision makers (CITES and UNESCO) and social actors (bow makers, NGO IPCI) at the international level having a greater interest in the sustainable management and species protection than local actors (farmers and plantation owners, as well as residents of the Mata Atlântica).

Legal framework represents manifested power structures

Table A6.4 Relevant laws and conventions regarding pau-brasil and the tradition of bow making considering the international level (INT), Brazil (BRA), European Union (EU), the Mata Atlântica biome (MA), and the state of Bahia (BA).

Type	Scale	Year	International conventions, laws, and regulations	Implications for pau-brasil and/or bow making
Int. Con.†	INT	1998	IUCN Red list of threatened species, pau-brasil status: endangered	Recognition of international threat status of pau-brasil being an endangered species.
		1999	UNESCO declares Discovery Atlantic Forest Reserves as Natural World Heritage Site	International protection status for these areas of the MA including reserves with important natural <i>Paubrasilia echinata</i> occurrence.
		2007	Pau-brasil listing in CITES, Appendix II	Laws for pau-brasil trade restrictions must be implemented in each member country.
		2012	UNESCO declares Traditional Violin Craftsmanship in Cremona as Intangible Cultural Heritage of Humanity	International recognition of that craft with mainly local implications for the city of Cremona and violin makers from Cremona with their own trademark, not specifically attributing the bow making craftsmanship.
Trade	BRA	1986	DECRETO N° 92.446	Legal implementation of CITES.
	EU	1997	VO (EU) 2017/160 (EU Wildlife trade regulation)	Legal implementation of CITES in the subsystems of the CES with consequences for pau-brasil protection, trade regulations, and travels of musicians, violin, and bow makers.
Forest	BRA	1965	LEI N° 4.771	Forest Code that mainly regulates forest use and its protection with implications for the protection for pau-brasil.
		1978	LEI N° 6.607	National tree pau-brasil (pau-brasil).
		1992	Portaria IBAMA N° 06-N	<i>Paubrasilia echinata</i> listed as endangered species.
		2012	PORTARIA N° 320	National Conservation Program of pau-brasil to enforce its protection and regeneration.

	2015	INSTRUÇÃO NORMATIVA Nº 9	Allows the commercial use of naturally fallen protected tree species (rare incident). This is a possible occasional chance for a legal and sustainable use of pau-brasil.	
MA	2006	LEI Nº 11.428	Law of Atlantic Forest, specifically protects the biome thus also pau-brasil.	
	2008	DECRETO Nº 6.660	Exploitation and ecological enrichment of Mata Atlântica - relevance for the protection of pau-brasil, complicating commercial use of native species.	
BA	2014	DECRETO Nº 15.180	Bahia state law for the cocoa agroforestry systems that enables using pau-brasil from these agricultural areas.	
Agr. areas‡	BRA	2014	DECRETO Nº 8.235	Rural Environmental land register (Cadastro Ambiental Rural (CAR)).
		2014	PORTARIA MMA Nº 443	Regulates the use of cultivated endangered plant species, it directly affects pau-brasil and bow making due to difficulties with commercial plantations and a legal future use.
		2014	IBAMA INSTRUÇÃO NORMATIVA Nº 21	Control of exploitation, use and commercialization of products derived from planted native species with the introduced new Forest Control System.
Seeds	BRA	2003	LEI Nº 10.711	Regulation of seed collection, reproduction, and nurseries to protect natural populations; however, it also complicates the planting of pau-brasil.

† Int. Con. = International conventions

‡ Agr. areas=Agricultural areas

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