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RESEARCH ARTICLE

Against the grain: environmental laws, local botanical knowledge, and housing access in Rio de Janeiro

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Abstract
This article considers how the construction practices of marginalized communities in Rio de Janeiro link the provision of essential housing to distant forest environments and markets for wood building materials. As elsewhere in Brazil, many families without access to real estate markets have built their own homes using locally available materials, a right protected by the 1988 Constitution and federal law. Today, these houses are typically built from reinforced concrete and clay bricks and finished with a roof of clay tile or cheaper fiber-cement corrugate. Production and sale of fiber-cement, which contains asbestos, were restricted by Rio de Janeiro State law in 2001 and ruled unconstitutional by Brazil's Supreme Court in 2017. But little attention has been given to the human and environmental health effects of other building materials. This article examines the timber frame to which roof tiles are affixed. Maçaranduba is the main wood used in roof construction and is the most traded wood in Brazil, with production practices linked to environmental and social violence. Brazil's laws presently subsidize plantation-grown pine and eucalyptus as "sustainable" alternatives to native hardwoods. The chemical treatments commonly applied to render these woods resistant to decay, however, contain potent environmental toxins. Moreover, the degree to which builders of essential housing actually use these products is unstudied. We argue that legislation has moved "against the grain" or without close attention to the botanical knowledge expressed in vernacular architectures and the needs of marginalized socio-ecologies intimately linked through the production of essential housing.

Keywords Environmental justice · Housing access · Marginalization · Political ecology · Brazil

> "The trees constitute a presence. They maintain–each according to its species–an extraordinary balance between movement and stillness, between action and passivity...That they held up the roofs of houses for so long is not surprising. They offer company."
>
> —John Berger (1991), Fig. 1

Introduction

In 2013, the authors partnered with a project called *Arquiteto de Família* to study roofing in the community of Morro do Vital, Niterói, where a majority of homes had roofs covered in fiber-cement corrugate. Fiber-cement, which contains asbestos, was restricted under Rio de Janeiro state law in 2001 but alternatives often require more and heavier wood framing, a primary expense associated with roof improvements. In Brazil, industrial wood products are themselves associated with numerous forms of socio-environmental damage. Our study shows how grassroots urban planning has begun to connect housing rights to environmental laws and markets for building materials in ways not yet comprehended by current legislation. These new ways of achieving access to essential housing and equal access to the city—articulated through collective work, collective resources, and community-based ecological knowledge—illuminate alternative possibilities for environmental policies departing from basic social needs and the principles of social equity and environmental justice.

Urban inequality and the community of Morro do Vital, Brazil

In terms of national wealth and income distribution, Brazil is among the most unequal countries in the world (Alvaredo

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Fig. 1 Interior visited by authors, 2014. Rafters and battens support "French" tiles, each marked with a heart

et al. 2018; Souza 2018). Beginning in the nineteenth century, land laws restricted access to basic shelter and subsistence, forcing rural populations, and especially freedmen and women, into exploitative forms of waged labor and sharecropping (Silva 1996). In urban areas too, high land rents and limited housing markets obliged residents to seek temporary and precarious forms of shelter (Bonduki 2011; Chaloub 1996; Hahner 1986). Today, access to land and housing in Brazil's cities remains unequal and racially disparate. In the Municipality of São Paulo, 19% of Black and brown residents live in areas classified as "aglomerados subnormais," more than double the rate among whites. In Rio de Janeiro, 31% of the city's residents of color inhabit "subnormal" housing.[1]

Historically, Brazilian social and environmental legislation has addressed environmental inequality as a problem inherent to racialized communities rather than a structural condition in which state actors have played a determinate role (Carvalho 1987; Fischer 2008; Herculano and Pacheco 2008; McCann 2014; Valladares 2019). Since the nineteenth century, public health provided the primary practical and epistemological framework for these state interventions in environments conceived of as congenitally poor, unhealthy, and underdeveloped. No historical figure embodies the growth and institutionalization of that episteme more perfectly than Vital Brazil Mineiro da Campanha, who began his career in 1892 with the newly created Serviço Sanitário do Estado de São Paulo, following outbreaks of yellow fever, malaria, and smallpox across the expanding coffee lands of the *Vale do Paraíba* and *Oeste Paulista*.[2] In 1895, he established a clinic in rural Botucatu, "porta-do-sertão," attending snakebites suffered by workers on surrounding plantations and beginning studies in antivenin serotherapy that would lead to his appointment as the first director of São Paulo's Instituto Butantan, which joined the Federal *Instituto Soroterápico* (eventual Instituto Oswaldo Cruz) as the nation's first centers for vaccinology (Vital Brazil 2011, 19).

In his history of public health in nineteenth-century Rio de Janeiro, Sidney Chalhoub (1996) described "slum clearance" as constituting the single point of origin for vaccinology, and for the "slum" as public health's essential site of intervention and inverse image. Ironically, the scientist chiefly associated with that twin naissance is also the namesake of one of the many hundreds of urban settlements in Metropolitan Rio de Janeiro actually defined as areas of "subnormal" housing by the Instituto Brasileiro de Geografia e Estatística (IBGE 2010a, b). Contracted by Rio de Janeiro's government to found the State's first center for vaccinology and serotherapy in 1919, Vital Brazil watched as the workers employed at the new laboratory built their own homes and established kitchen gardens on a neighboring hillside or *morro*. The Instituto de Higiene, Soroterapia e Veterinária do Estado do Rio de Janeiro epitomized the ambitions of public health as a tool of governance and social transformation, but remarkably, the housing of its workers perfectly replicated the supposedly "archaic" social relations structuring rural waged labor.

These relations, organized around usufruct, allowed land owners to both discipline labor and subsidize wages, as described by Antonio Cândido (1964) in his famous ethnography of rural lifeways—incidentally conducted in Botucatu a half-century after Vital Brazil's brief sojourn there. The same control over land access used by rural landowners to dominate agricultural workers allowed the state-run institute to maintain a labor force without provisioning housing or wages sufficient to secure housing on the local market. The ambiguous legal status of the homes workers built for themselves impeded consolidation of intergenerational wealth and excluded workers and their families from basic public services enjoyed by other residents of the city. Even today, fundamental infrastructure like roads, public transportation,

[1] Compared to 14% of whites, see IBGE. 2019. "Desigualdades sociais por cor ou raça no Brasil." *Estudos e Pesquisas, Informação Demográfica e Socioeconômica,* no. 41.

[2] Vital Brazil Mineiro da Campanha was so-named by his Republican and abolitionist parents after the nation itself (Brazil) and its interior (Campanha, Minas Gerias) as a substitute for the patriarchal name of the elite family from which he came. While biological cousins–including Wenceslau Braz Pereira Gomes and Delfim Moreira da Costa Ribeiro—became Presidents of the young Republic, Vital Brazil would serve in the care of its most marginalized populations.

and trash collection do not reach many residents of the hillside community of Morro do Vital Brazil.[3]

The community association AMOVIBRA (Associação de Moradores do Morro Vital Brazil), founded in 1983, is emblematic of the nation-wide movement of community associations formed to address urban inequality in the 1980s (Sousa 2009; Rocha 2019). These grassroots political organizations affected major changes in local, state, and federal laws culminating in the 1988 Constitution, which established new political and legal tools for communities to secure essential housing and public services (Caldeira & Holston 2015; Friendly 2016). AMOVIBRA achieved a 99-year lease to lands occupied from the State Government of Rio de Janeiro in 1992 and established a community medical clinic through the Federal program *Médico de Família* in 1996 (Sousa 2009).

These fundamental social rights received further legal sanction under the City Statute of 2001 and Federal Law 11.888 of 2008, obliging community participation in urban planning, and direct government assistance to low-income families building essential housing through the Fundo Nacional para Habitação de Interesse Social (FNHIS) (Rocha 2019). In 2009, the FNHIS financed a partnership between AMOVIBRA, the Instituto Vital Brazil, the NGO Soluções Urbanas, the Universidade Federal Fluminense, and the Escola de Saúde Pública da Fundação Oswaldo Cruz to provide technical assistance to residents making structural improvements to their homes. That project, called *Arquiteto de Família*, reallocated government resources to families already provisioning their own housing by conducting research on the safety and efficacy of local building materials and methods, and creating alternative networks to access new building resources outside existing market channels.

Urban space, trees, and timber

John Berger's 1984 meditation on space, entitled "Here," includes a vignette describing the work of harvesting a tree. In a register somewhere between poetic reflection and critical social theory, Berger observes that "trees constitute a presence … they offer company" (Berger 1991, 76). Reflecting on a specific space of work, the vignette captures the dual existence of human and more-than-human lives as social relations—e.g., a home, company—which are also commodities—e.g., lumber, labor power, and housing. Our study departs from the intimate scale of Berger's method of observation, designed to describe relationships that cannot be obtained from national level or even local statistics. The "presence of trees" in human lives described by Berger suggests how the production of housing does more than merely determine the flow of timber to urban markets. The home actually links more-than-human lives, with profound implications for environments that may be closely connected in spite of physical distance.

Studies of urbanization in Brazil and globally suggest that urban spaces are both increasingly heterogeneous and increasingly connected to distant ecologies (Güneralp et al. 2013; Santos 1993; Wentz et al. 2018). Similarly, anthropologists argue that the socially induced global environmental processes associated with the "anthropocene" exhibit a discontinuity that ecologists refer to as "patchy" (Tsing et al. 2019). "Attending to the specific circumstances of each patch opens a discussion on environmental justice in uneven planetary geographies" (Tsing 2021). Here, we explore the implications of urban heterogeneity and connections between distant locations for understanding how woods used in essential housing may be marginal in relation to national timber markets and policies for "sustainable" forest management. In doing so, we build on critical theoretical approaches to marginalization as a problem that is at once empirical—derived from observable socio-environmental relationships—and methodological—created by an analytical process of comparison moving from theoretical and statistical scales of analysis (national or global) to supposedly subsidiary or "nested" scales (local, particular).

Urban studies scholars have adapted the concept of teleconnection from climate science to refer to "the virtual shrinking of distances between places, strengthening connectivity between distant locations, and growing separation between spaces of consumption and production" (Seto et al. 2012). Unlike most studies of teleconnection, however, which rely on large landscape-scale data sets, our research is designed to shed light on how a smaller sample size and closer range of analysis can reveal socio-environmental relationships obscured by larger data sets and studies conducted over wider areas. This analytical problem has been discussed by scholars of environmental justice with regard to its effects for legal accountability and epidemiological standards of agency and causation (Carvalho et al. 2022; Mah 2017; Rector 2022). Localized environmental risks can be rendered effectively invisible by extensive data sets, leaving assessments of harm and accountability over-determined by sampling methods. Here, we focus on the possible socio-environmental effects of such methodological bias for policies and programs designed to achieve the equitable management of Brazil's forests. We argue that finer-grained local

[3] In the period studied, the majority of residents of Morro do Vital had a median income less than half the State average (R$1106). The median income in Niterói was nearly double the State average, and the 2nd highest in the nation (R$2102), immediately trailing the wealthy São Paulo suburb of São Caetano do Sul (R$2106). By way of comparison, the lowest per capita income (R$132)—recorded in Cachoeira Grande (MA)—was 6% that of Niterói. See Sousa 2009, and IBGE 2010a, b,"Tabela 3974: Rendimento médio mensal domiciliar…" in *Censo demográfico 2010.*

analyses of the wooden building materials used in marginalized communities are needed to understand how policies for sustainable timber markets affect access to safe housing as well as rates of deforestation and rural violence. Our study provides a methodological and practical model for how this knowledge might be developed; it does not, however, attempt to provide a complete data set for analyzing access to roofing timbers either in Morro do Vital or in other marginalized urban communities.

Our approach contributes to a number of conversations in the trans-disciplinary fields of urban and environmental studies. Althor and Witt (2020) observe that English-language discussions of environmental distributive justice have privileged local-scale studies of geographies in the global north or global-scale studies using largely quantitative methods. They suggest that inter-scalar studies focused on the global south and mixed-methods research offer key areas for further research. Pellow (2018) offers a related critique of environmental justice scholarship oriented towards singular categories and scales of environmental inequality rather than intersectional and inter-scalar analyses. He suggests, moreover, that scholars can do more than assess environmental harm according to the juridical-political structures already implicated in maintaining inequitable socio-environments. Rather, critical environmental justice research, like critical urban theory, builds upon the insights of critical theory more broadly to conceive alternative political ecologies and normative frameworks (Brenner 2012). In particular, we have been inspired by collaborative explorations of field research as capable of not merely studying local/global and more-than-human phenomena but of refashioning these relationships in practice as subjects of study (Tsing 2021). In attending to the relationships established between people and trees through the provision of essential housing, we ask what a critical approach to housing justice research might look like, beginning not from the level of state agencies but from the practices and socio-ecologies created by marginalized communities involved in building access to essential housing.

Materials and methods

Different state agencies in Brazil compile detailed data on wooden building materials and domestic timber markets. But these databases do not describe how wood is in fact accessed in the provision of housing. Given the urban heterogeneity of Rio de Janeiro, and its pattern of racialized inequality in housing, market records may or may not reflect the building materials actually used by communities with limited access to those markets. Our research explores a method for describing the presence of wood in the built environment of marginalized communities. Our survey size is not intended to statistically represent local building practices in relation to national or regional trends, but to shed methodological light on how local practices might be more accurately described in collaboration with community-based organizations involved in the provision of essential housing. More accurate fine-scale knowledge of local practices can help to evaluate the socio-environmental effects of environmental legislation, timber markets, and management practices in relation to local knowledge and local needs surrounding essential housing.

The IPT or Institute for Technical Research in São Paulo has compiled a database on wood (IPT 2003, 2013; Mainieri 1983; Mainieri & Chimelo 1989). Based on laboratory experiments, the database describes the properties of hundreds of native hardwoods, including detailed analyses of anatomical structures like vessels, ray cells, and axial parenchyma; physical characteristics like color, texture, and density; and chemical/mechanical properties like resistance to termite infestation, flexion and compression. Because these woods originate in socio-ecologies threatened by the exploitation of marketable timber, the IPT has also established recommendations for the use of trees with healthy species' populations and properties similar to currently threatened or endangered species (IPT 2003).

The IPT's recommendations, however, do not address the local availability of different woods. Information on timber markets is collected by a separate agency, the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA). Since 2006, the IBAMA has recorded the origin, species, volume, and destination of national wood products coming from native forests using the Documento de Origem Florestal (DOF) (Brasil 2006, 2012a, b). A DOF is issued by the IBAMA for all wood products originating in native forests (i.e., excluding plantations of exotic species, like pine and eucalyptus). We designed a method to compare the relative predominance of the species used in houses surveyed in Morro do Vital with their local market availability in the years directly preceding our study (2007–2013). This method may help to inform further research on the production and marketing of wood and wood products oriented not by the ideal characteristics of taxonomic groups, the principles of structural engineering, or demands of national and regional markets, but rather by local needs and local knowledge as expressed through the reality of the built environment.

Our research materials reflect relationships already established between the architects and social workers of the *Arquiteto de Família* project and members of the community. We spent 18 months observing construction practices in the community and participating in collective work projects (*mutirões*), keeping field notes and drawings (Figs. 5 and 6). We also obtained small samples of roof rafters from 18 homes of varying ages spread out across the hillside community. Samples were selected from 3 different rafters per house in order to register diversity within individual constructions as well as between constructions.

Samples were prepared at the Wood Anatomy and Dendrochronology Laboratory of the Universidade Federal Fluminense using a block plane to expose the transverse, radial, and tangential sections and polished using 80–1200 grit wet/dry sandpaper (Nascimento et al. 2017). We examined macroscopic anatomical characteristics, with the aid of a 10× hand lens to identify each sample, following the procedure provided by Coradin and Muñiz (1991) and using a number of taxonomies and identification guides including Mainieri (1983), Mainieri and Chimelo (1989), and Coradin et al. (2010). We also compared our samples to those held in the Jardim Botânico do Rio de Janeiro Wood Collection (RBw) and Herbário de Niterói Wood Collection (NITw).

In cases where these macroscopic analyses proved inconclusive, we prepared samples for microscopy, once again using a block plane to obtain transverse, radial, and tangential histological sections, bleaching (sodium hypochlorite) and staining (safranin and astra blue) (Bukatsch 1972), and mounting permanent slides using synthetic resin. Identification using microscopic anatomical features followed the procedure described by the IAWA Committee (1989). Microscopic wood identification was performed using wood anatomy databases (InsideWood 2004 onwards; Richter & Dallwitz 2000 onwards; Wheeler 2011) and was verified with slides from collections (RBw and NITs). We captured images with a Leica MZ16 stereomicroscope and a Zeiss Primostar bright-field microscope, attached to Leica DMC 4500 and Zeiss AxioCam Erc 5s cameras, using the Image Manager (IM50) and Zeiss Zen softwares. Wood samples and permanent slides were deposited in the Herbário de Niterói Wood Collection (NITw) and Slide Collection (NITs).

We used the annual DOF records from 2006 to 2013 to approximate local markets in the 18 municipalities comprising the metropolitan area of Rio de Janeiro. Looking specifically at roofing timbers—including beams (vigas), rafters (caibros, caibrinhos), and battens (ripas)—we excluded all other wood products and filtered these results by the genera and species found in our survey. Following the recommendations of Nascimento and collaborators (2017), we treat the genera *Manilkara*/*Pouteria*, which include numerous species having nearly identical wood anatomy and alternatively sold under the popular names of maçaranduba or abiu, as a single generic-complex.

Table 1 Identified woods. Taxa (scientific names), common names, samples, and percentage

Taxa (scientific names)	Main common names	Number	%
Manilkara sp./*Pouteria* sp.	Maçaranduba, abiu	18	35
Aspidosperma sp.	Peroba	4	8
Buchenavia sp.	Tanibuca, cuiarana	3	6
Caryocar sp.	Pequiá, pequi	3	6
Aspidosperma polyneuron	Peroba-rosa	2	4
Erisma uncinatum	Cedrinho, quarubarana	2	4
Peltogyne sp.	Pau-roxo, roxinho	2	4
Vochysia sp.	Quaruba	2	4
Astronium sp.	Aroeira, muiracatiara	1	2
Bertholletia excelsa	Castanheira	1	2
Bixa arborea	Urucu-da-mata, urucu-arbóreo	1	2
Cedrelinga cateniformis	Cedrorana	1	2
Copaifera sp.	Copaíba	1	2
Curatella americana	Cajueiro-bravo	1	2
Handroanthus sp.	Ipê	1	2
Lecythidaceae	Sapucaia, Tauari, Imbirema, etc	1	2
Lecythis sp.	Sapucaia	1	2
Lonchocarpus sp.	Embira-de-sapo	1	2
Paratecoma peroba	Peroba-de-campos, ipê-peroba	1	2
Pinus sp.	Pinus	1	2
Tapirira guianensis	Tapirira, pau-pombo	1	2
Vatairea sp.	Angelim, angelim-amargoso	1	2
Virola sp.	Virola, bicuíba	1	2

Results

The oldest house surveyed was built in 1968 and the most recent in 2014, with others constructed in the 1970s (1), 1980s (2), 1990s (4), and 2000s (2). Most of the houses were constructed with reinforced concrete (7) and bricks (14), with a shed (6) or gable roof (8) covered by ceramic roof tiles (7) or fiber-cement corrugate (9). Roofs covered by ceramic tiles had 36–48 wood rafters and many smaller battens, while those using fiber-cement corrugate used only 3–8 rafters in their framing (Figs. 5 and 6). The source of most building materials was unknown, with the exception of two houses built using wood recycled from the demolition of older buildings. We analyzed 51 samples from 17 houses and identified 23 different woods (scientific names). Fourteen were identified at the genus level, eight at the species and one family (Table 1; Figs. 2, 3, and 4).

Most of the samples (35%) belonged to the complex *Manilkara*/*Pouteria*, which are known by the common names maçaranduba and abiu (Fig. 2A). Seven other woods with more than one sample represented another 35% of the samples: *Aspidosperma* sp. (peroba), *Buchenavia* sp. (tanibuca, cuiarana), *Caryocar* sp. (pequiá, pequi), *Aspidosperma polyneuron* (peroba-rosa), *Erisma uncinatum* (cedrinho, quarubarana), *Peltogyne* sp. (pau-roxo, roxinho), and *Vochysia* sp. (quaruba) (Fig. 2). Fifteen

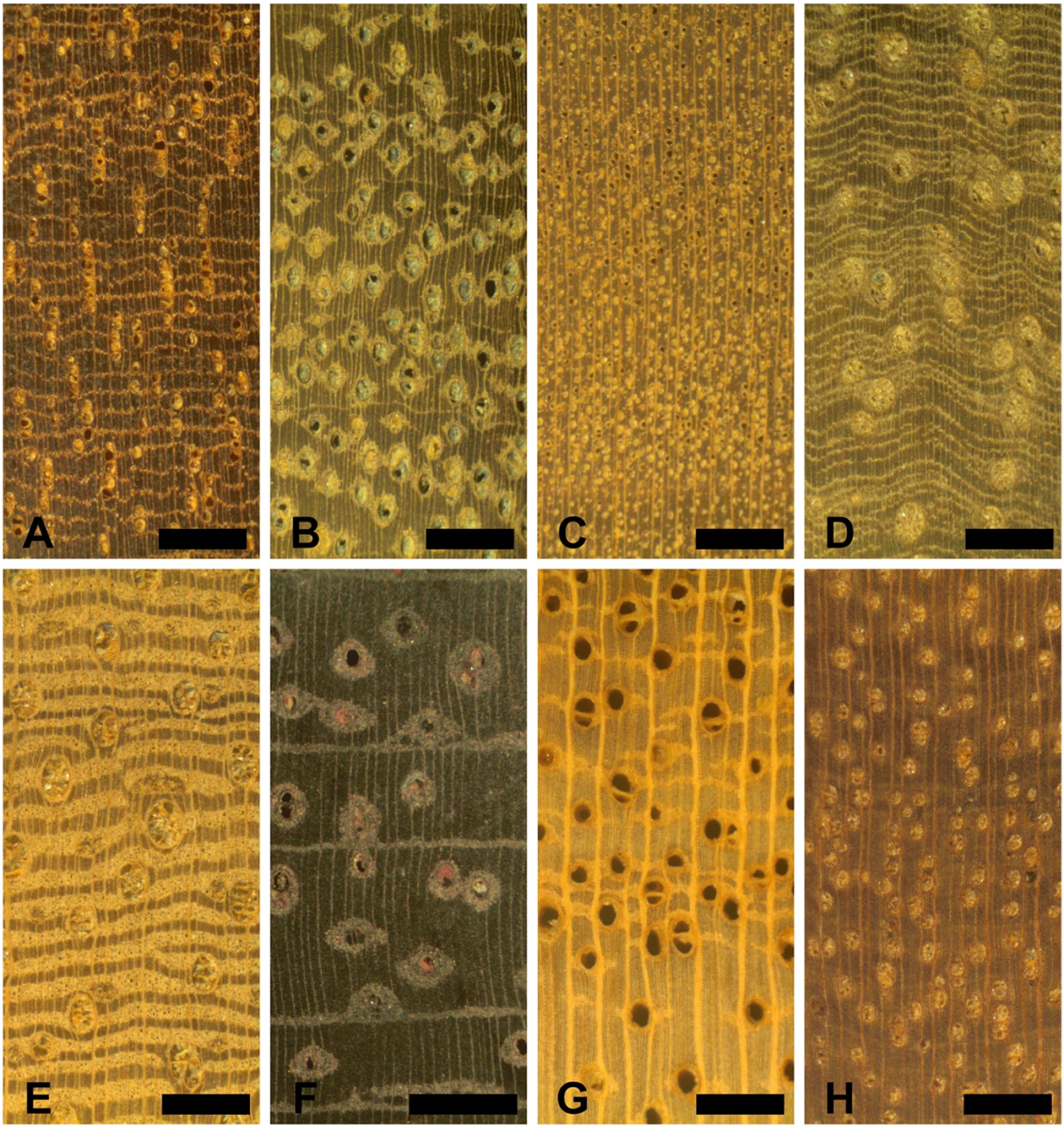

Fig. 2 Transverse surfaces under stereomicroscopy. **A** *Manilkara* sp./*Pouteria* sp. (maçaranduba, abiu). **B** *Buchenavia* sp. (tanibuca, cuiarana). **C** *Aspidosperma polyneuron* (peroba-rosa). **D** *Caryocar* sp. (pequiá, pequi). **E** *Erisma uncinatum* (cedrinho, quarubarana). **F** *Peltogyne* sp. (pau-roxo, roxinho). **G** *Vochysia* sp. (quaruba). **H** *Astronium* sp. (aroeira, muiracatiara). Scale bar = 1 mm

woods with only one sample identified accounted for the remaining 29% of samples (Figs. 3 and 4).

Not all woods used in roofing in the community of Morro do Vital appear in the DOF records from 2006 to 2013. Some of the genera found in the community, including *Bertholletia*, *Bixa*, and *Paratecoma*, are entirely absent from lumber sales in the metropolitan area. Other woods appeared more frequently in the community than in the local market. The genus *Aspidosperma* accounted for 10% of our samples but only 0.1% of the wider market. Similarly, the genera

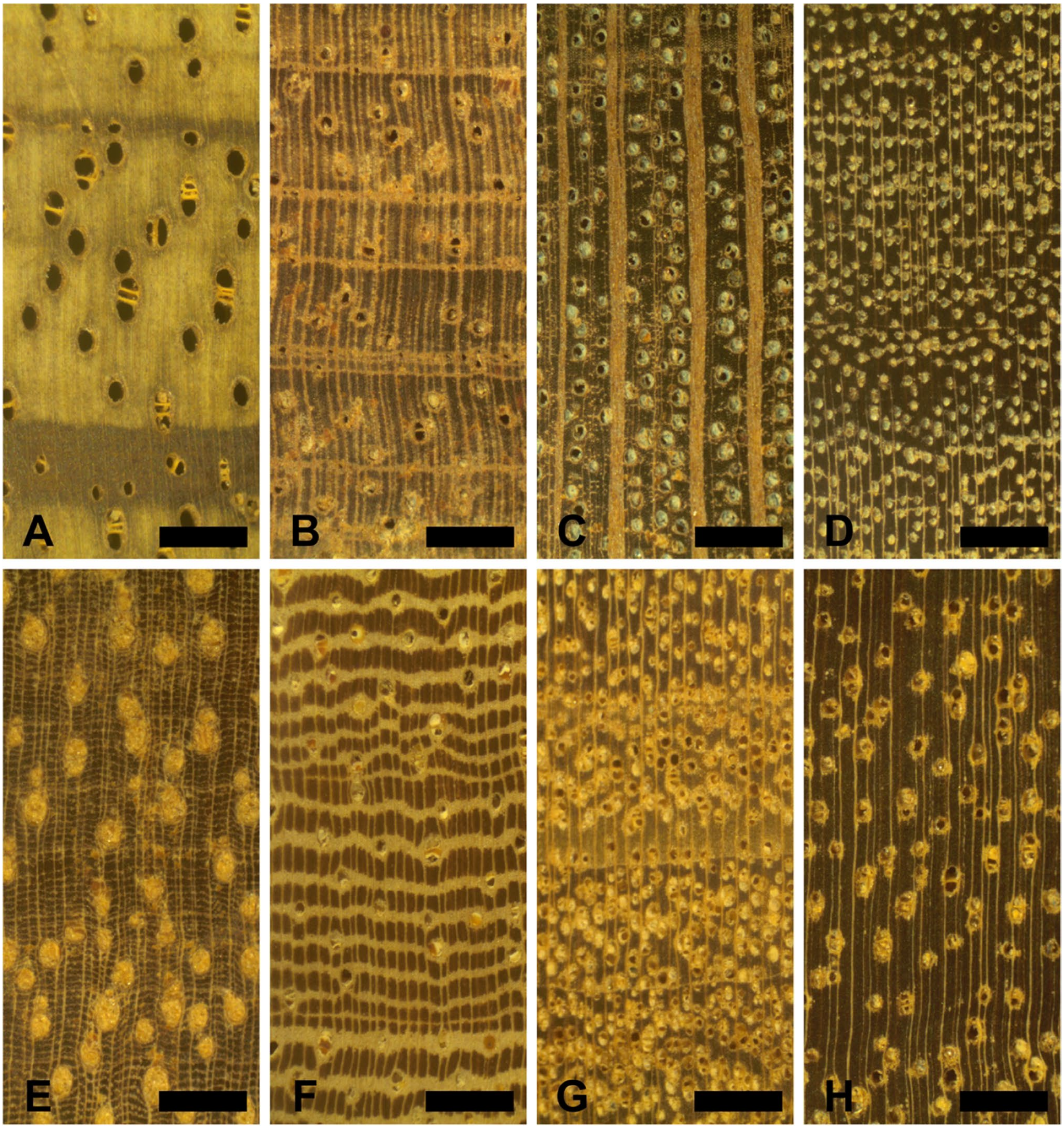

Fig. 3 Transverse surfaces under stereomicroscopy. **A** *Cedrelinga cateniformis* (cedrorana). **B** *Copaifera* sp. (copaíba). **C** *Curatella americana* (cajueiro-bravo). **D** *Handroanthus* sp. (ipê). **E** *Lecythis* sp. (sapucaia). **F** *Lonchocarpus* sp. (embira-de-sapo). **G** *Paratecoma peroba* (peroba-de-campos, ipê-peroba). **H** *Tapirira guianensis* (tapirira, pau-pombo). Scale bar = 1 mm

Buchenavia and *Caryocar* each accounted for 6% of our samples, a frequency many times greater than their share of the local market (Table 2).

Over half of our samples (26) were from genera or species with market volumes below 1%. Among these were genera very rarely sold as framing timber, such as *Curatella*, *Lonchocarpus*, and *Tapirira* (Table 2; Fig. 3). Conversely, the genera *Manilkara/Pouteria*, *Erisma*, and the family Lecythidaceae were under represented in our survey. *Manilkara/Pouteria*, in particular, averaged 55% of local timber volume, while the diverse genera comprising Lecythidaceae averaged 5.4%.

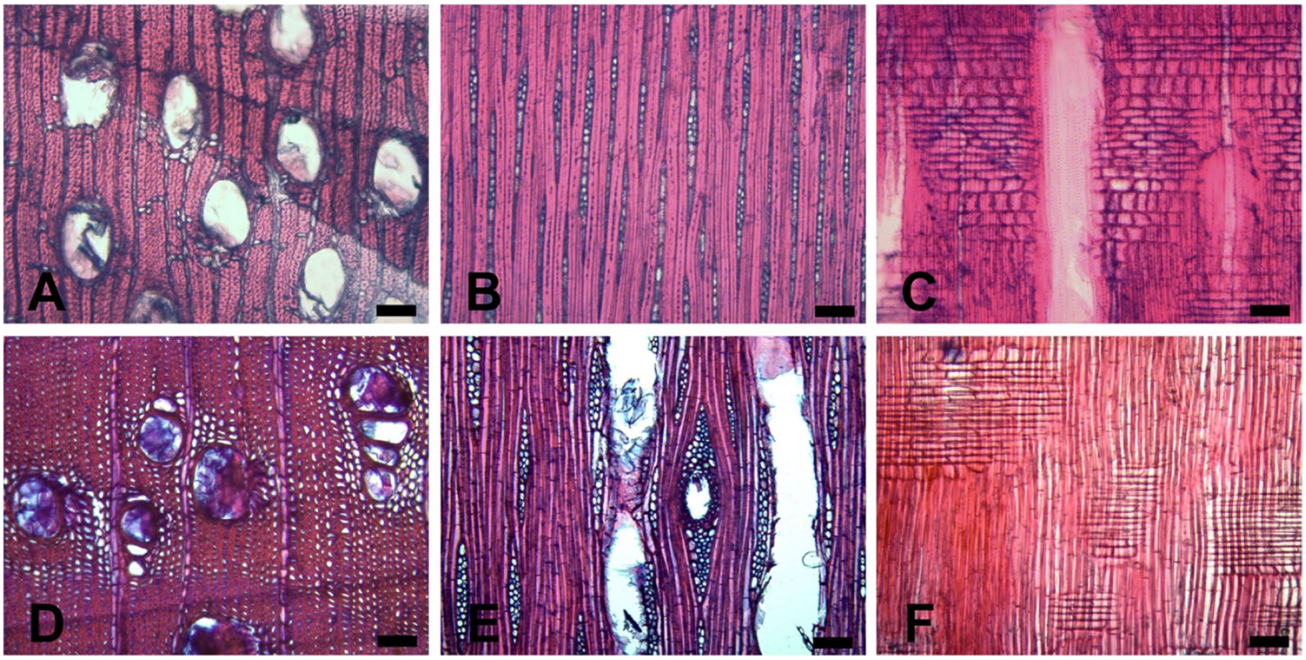

Fig. 4 Microscopic view of *Virola* sp. (virola, bicuíba) (**A**–**C**) and *Astronium* sp. (aroeira, muiracatiara) (**D**–**F**). Transverse section (**A** and **D**), longitudinal-radial section (**B** and **E**), longitudinal-tangential section (**C** and **F**). Scale bar = 100 µm

Table 2 Identified woods. Market volume 2007–2013 for Metropolitan Rio de Janeiro, mean and percentage of market

Taxa (scientific names)	2007 (m^3)	2008 (m^3)	2009 (m^3)	2010 (m^3)	2011 (m^3)	2012 (m^3)	2013 (m3^3)	Mean (m^3)	%
Manilkara spp./ *Pouteria* spp.	18,313.71	29,512.14	41,264.92	51,825.98	48,832.21	46,214.90	44,460.32	40,064.46	55.0
Aspidosperma spp.	121.77	42.96	139.49	51.45	22.92	28.59	62.47	67.09	0.1
Buchenavia spp.	375.4	487.25	279.71	386.96	273.33	348.4	380.36	361.63	0.5
Caryocar spp.	1116.62	1187.74	659.43	795.59	372.15	508.58	393.26	719.05	1.0
Aspidosperma polyneuron	25.18	1.44	21.42	28.51	7.77	6.97	11.24	14.65	0.0
Erisma uncinatum	2064.65	2860.74	2171.75	2367.44	2299.51	1972.56	1718.97	2207.95	3.0
Peltogyne spp.	552.06	672.61	605.44	702.56	371.91	334.28	404.97	520.55	0.7
Vochysia spp.	737.93	831.09	418.13	368.06	225.53	49.82	584.99	459.36	0.6
Astronium spp.	371.69	982.68	777.99	561.38	378.97	229.58	327.85	518.59	0.7
Bertholletia excelsa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Bixa arborea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Cedrelinga cateniformis	231.78	426.26	325.33	275.19	201.71	204.38	119.61	254.89	0.3
Copaifera spp.	74.67	327.86	336.3	206.58	122.78	177.74	98.48	192.06	0.3
Curatella americana	0.00	0.00	0.00	0.00	0.00	0.00	14.00	2.00	0.0
Handroanthus spp.	51.74	177.66	124.19	19.48	42.46	70.03	39.38	74.99	0.1
Lecythidaceae	2122.30	4025.15	4185.03	3701.18	4922.07	4800.42	4021.45	3968.23	5.4
Lecythis spp.	1078.37	1199.63	1066.93	1714.92	1965.42	1963.39	1266.86	1465.07	2.0
Lonchocarpus spp.	0.00	0.00	0.00	14.00	4.81	12.95	2.66	4.92	0.0
Paratecoma peroba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Pinus spp.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tapirira guianensis	43.08	13.84	31.71	0.56	22.34	0.21	3.92	16.52	0.0
Vatairea spp.	57.98	249.65	449.94	326.43	176.73	169.71	141.31	224.54	0.3
Virola spp.	13.04	23.65	95.59	76.79	94.48	98.35	12.83	59.25	0.1
All species	48,300.15	67,091.27	76,495.10	90,674.29	79,992.68	77,359.06	72,326.00	73,176.94	100.0
% *Manilkara*/*Pouteria*	38%	44%	54%	57%	61%	60%	61%	55%	

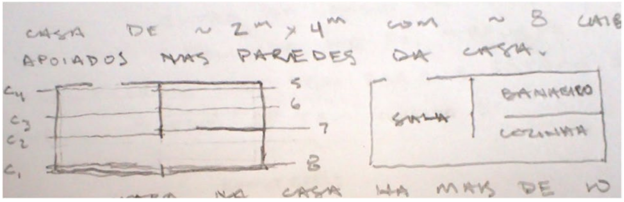

Fig. 5 Author's notes, 2014. "Home of ~ 2 × 4 m. with ~ 8 rafters resting on the walls of the house. Interior plan: room, bath, kitchen"

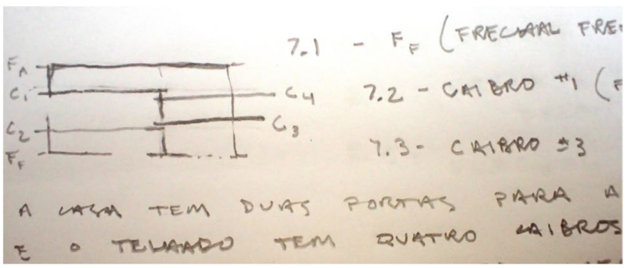

Fig. 6 Author's notes, 2014: "The house has two doors…and the roof has four rafters…"

Timber traffic in the metropolitan region of Rio de Janeiro grew overall during the period studied. Excluding results for 2006, the first year of the DOF program, which reported only 15% of the volume recorded in subsequent years, timber traffic grew by approximately 66%. Considering the woods in our sample, however, only *Manilkara* sp./*Pouteria* sp., *Vatairea* sp., and the family Lecythidaceae increased their overall sales and share of the total market, while others, including important building timbers like *Caryocar* sp. and *Erisma uncinatum*, showed a local decline. *Manilkara/Pouteria*'s total sales and share of the market grew most. In 2010 and 2011, the volumes traded in these genera alone exceeded the volume of the entire market in 2007. Their market share grew from 38% in 2007 to 61% in 2013.

Discussion

Equitable access to safe housing is affected by markets for land and essential building materials, and by state policies shaping these political economies. Orienting policies towards environmental justice requires close attention to marginalized socio-ecologies, particularly as these may not be well represented by national-level statistics. Our research offers a model for studying the diversity of building practices employed by communities excluded from land ownership and secure access to housing. Our findings suggest that finer-scale surveys of building materials at the community level can contribute information not available in existing databases of Brazilian woods and timber markets. The presence of recycled timbers and persistence of historically important woods in essential housing suggest that local knowledge and needs may be relatively more important than previously acknowledged in shaping the architectures of marginalized communities. These local needs and knowledge shape alternative forms of access to wooden building materials and relationships to distant forest environments. The *Arquiteto de Família* and *Médico de Família* programs, which emerged out of grassroots political organizing to provide essential public services at the community level, compel new perspectives on the kinds of research needed to assess the socio-environmental effects of policies for the equitable and just management of Brazil's forests. They also illuminate a radically different direction for forest policy, beginning not from the abstractions of species' populations, materials engineering, or resource economics, but from the intimate relationships built between people and trees in achieving secure access to a home.

Local timber markets and national trends

The homes we visited evidenced a remarkable diversity of woods used in roof construction but with a clear predominance of species from the genera *Manilkara* and *Pouteria*. This was true of all homes included in our study, irrespective of the time of construction. Of the hundreds of genera harvested and sold in Brazil each year, *Manilkara* and *Pouteria* are consistently among the most commercialized genera (Brandes et al. 2020; Farani & Oliveira 2019; Veríssimo et al. 2002). Between 2012 and 2016, *Manilkara huberi* was the species with the highest transport volume in Brazil (3,825,164 m^3), representing 6.3% of the records in the DOF, coming primarily from the Amazonian state of Pará (63%), followed by the states of Roraima (12%), Mato Grosso (7%), Rondônia (7%), Amapá (5%), and Amazonas (4%) (Brandes et al. 2020; Farani & Oliveira 2019). At the municipal level, 55% of production originated in just 10 municipalities in the Amazon: Santarém-PA; Almeirim-PA; Prainha-PA; Rorainópolis-RR; Portel-PA; Caracaraí-RR; Paragominas-PA; Porto Velho-RO; Juruti-PA; Aveiro-PA. The bulk of this timber came from forest concessions for timber management (88%) with the remainder coming from authorized suppression of native vegetation for other land uses (12%). Only 0.01% of *Manilkara* production during this period came from timber plantations (Farani & Oliveira 2019).

Theoretically, the DOF system allows the IBAMA to ensure these sales originate in approved sources with controlled social and environmental effects. In practice, however, illegally harvested wood enters the supply chain by means of numerous loopholes (Brancalion et al. 2018; Carvalho et al. 2019; Wellesley 2014). Beginning in 2008, annual analyses of satellite imagery of the Amazonian state of Pará, which is the principal exporter of *Manilkara/Pouteria*, have shown that the majority of areas cut and harvested are in fact unauthorized (Cardoso & Souza 2020; Cardoso & Souza 2017; Monteiro et al. 2009, 2010, 2011, 2012, 2013; Silgueiro et al. 2019). This has been true for every one of the 8 years for which data has been published.

Among the many loopholes allowing such illegally harvested timber to enter the supply chain is the fact that highly trafficked genera like *Manilkara/Pouteria* and those of the family Lecythidaceae present numerous species similar in their wood anatomy, making accurate identification and tracing difficult (Nascimento et al. 2017; Brandes et al. 2020). Overexploitation of these genera has already endangered numerous species including *Manilkara bella*, *Manilkara dardanoi*, *Manilkara decrescens*, *Manilkara maxima*, *Manilkara multifida*, *Pouteria bapeba*, *Pouteria bullata*, *Pouteria butyrocarpa*, *Pouteria coelomatica*, *Pouteria decussata*, *Pouteria furcata*, *Pouteria macahensis*, *Pouteria macrocarpa*, *Pouteria oxypetala*, *Pouteria pachycalyx*, *Pouteria peduncularis*, *Pouteria petiolata*, *Pouteria vernicosa*, and *Pouteria virescens* (Brasil 2014; Martinelli & Moraes 2013). Illegal timber harvesting is also directly linked to violence against small farmers, quilombola communities, and indigenous communities, with areas characterized by high rates of deforestation and timber export also showing the highest per-capita rates of homicide in a nation that is generally afflicted by violence (Calentano et al. 2018; Santa'Anna and Young 2010; UNODC 2019; Waiselfiz 2008).

Markets for highly trafficked woods are driven not by the provision of essential housing but by the furniture, plywood, sawn lumber, and construction industries (Dores et al. 2007; Juvenal & Mattos 2002; Vidal and Hora 2014; Vital 2009). In the case of *Manilkara/Pouteria*, the principal products sold are timbers used in framing and especially in roof construction, including beams (35%), rafters (23%), and battens (11%) (Farani & Oliveira 2019). Rio de Janeiro is the 2nd largest metropolitan housing market in Brazil and was the second largest municipal consumer of *Manilkara/Pouteria* (CBIC 2016; Farani & Oliveira 2019). Homes of one or fewer rooms, however, like homes visited in the community of Morro do Vital, account for less than 10% of national construction (CBIC 2016; Figs. 5 and 6).

Alternative forms of local use and timber access

Given their market abundance, and particular concentration in Rio de Janeiro, it is not surprising that highly commercialized genera, and especially those with relatively low market prices—like *Manilkara/Pouteria*—predominate in essential housing (Sobral et al. 2002).[4] Their underrepresentation of in our sample, however, relative to the overall market, shows that the community also relies on alternative sources for wood, including the recycling of materials from historic constructions elsewhere in the city. This is particularly evident in the prevalence of the genera *Aspidosperma* and *Paratecoma*, which predominated in the Atlantic Forest timber trade of the nineteenth and early twentieth centuries (Cabral 2014; Cabral and Cesco 2008; Chimelo 1989; Gerhardt 2016).[5] Their persistence in the built environment reflects the historic transformation of local timber markets and reveals the importance of reuse, evident also in the appearance of other genera, like *Peltogyne*, which are highly trafficked but not typically used in roof construction. Furthermore, the presence of numerous genera that have never been commercially important as timber also indicates ecological relationships and forms of knowledge not determined by local lumber markets or state policies.

Forest management policies

Historically, Brazil's laws for environmental conservation and "sustainable" timber production have moved to protect commodities, "natural resources," or taxonomically defined species without close attention to the diverse human and more-than-human relationships in which these "resources" are embedded. In the late nineteenth century, for example, railroad construction inspired government support for forest conservation, eucalyptus and pine plantations, and technical innovations to preserve woods with

[4] A number of the woods found in construction in Morro do Vital were included by Sobral et al. (2003) in their list of relatively low-priced Amazonian timbers, including maçaranduba and abiu, as well as pequiá/pequi, quaruba/quarauba, and jatobá. At the same time, however, we also found woods like roxinho and ipê with prices 150-240% that of *Manilkara/Pouteria.*

[5] See also Lisboa, Baltazar da Silva. 1823. Riqueza do Brasil em madeiras de construção e carpintaria. Rio de Janeiro: Tipografia Nacional; and Alemão, Francisco Freire, Custodio Alves Serrão, Cadislau Netto, e F. de Saldanha da Gama. 1867. *Breve noticia sobre a coleção das madeiras do Brasil.* Rio de Janeiro: Tipografia Nacional. Pouteria, which appears under the popular name Abiurana is described as "used in civil construction and especially in interior work." Manilkara, listed as Massaranduba, is attributed with being "among the most durable, used in civil construction and furniture making."

Table 3 Timber from forests and from plantations of pine, eucalyptus, and acacia, 2007–2013, mean and percentage total market

Year	Timber from forests excluding firewood, charcoal, etc. (m^3)	Timber from plantations excluding firewood, charcoal, pulp and paper etc. (m^3)
2007	16,398,265	44,167,434
2008	14,136,497	43,080,058
2009	15,260,157	41,565,728
2010	12,668,821	45,962,916
2011	14,126,928	49,970,760
2012	14,935,430	58,041,847
2013	13,692,387	58,234,040
Mean	14,459,783	48,717,540
%	23%	77%

Source: IBGE. *Produção da extração vegetal e da silvicultura*. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística

chemical substances (Dean 1995; Pádua 2012).[6] Designed to maintain an environment hostile to fungi, termites, and other xylophagous insects, chemicals like creosote, and eventually chromated copper arsenate, began to be used widely in Brazil in the second half of the twentieth century (Moraes 1996; Seba 2019; Silva 2006; Vidal et al. 2015). Since the 1950s, government subsidies for plantation grown lumber have been directed towards the paper, energy, and steel industries, prioritizing the production of pulp and charcoal (Hora 2015). The 2018 national plan for forest plantations by Brazil's Ministério da Agricultura, Pecuária e Abastecimento (MAPA), however, specifically outlined policies to increase the production of sawn lumber from timber plantations and foment demand for these products in the construction of housing (MAPA 2018).

During the years immediately leading up to our survey (2007–2013), sawn lumber from pine and eucalyptus plantations accounted for 77% of national lumber production (Table 3). The increasing availability of chemically treated wood products in Brazil has not been evaluated with regard to these products' environmental impacts in the communities where they are marketed and potentially used (Silva 2006; Cox 2017).[7] It is also unclear whether such industrialized timber products actually curtail the clearing of forests, as both deforestation and the commercialization of indigenous species, including species protected by law, have continued (Brandes et al. 2020). In fact, the expansion of pine and eucalyptus monocultures has itself been a leading cause of deforestation as government subsidies have helped plantations to expand across the country (Zarth & Gerhardt 2009; Cerqueira Neto 2012). Rather than achieve environmental repair, these industries have created new forms of environmental and social violence.

Similarly, Brazil's forest legislation, drafted in 1910, implemented in 1935, and revised in 1965 and 2012 has primarily regulated the environmental management of privately owned lands. Often construed by legal scholars as guaranteeing the "social or socio-ecological function of property," and in theory, as limiting the privatization of common goods, the law has practically privileged private property over other forms of land access, legalizing the historical forms of dispossession necessary to its production (Abessa et al. 2019; Brancalion et al. 2016; Campbell 2015; Cunha and Mello-Théry 2017; Lesser 2022; Rajão, Carvalho and Merry 2020). This has lit a match (literally) under rural land markets, with speculators deforesting huge areas of rural land (frequently by fire) and violently displacing indigenous, afro-descendant (quilombola) and landless communities.

[6] ANRJ, GIFI, Diversos, 4b-174, "Prolongamento da estrada de ferro de Pernambuco"; these 1877 documents discuss in great detail a proposal by the firm Fives-Lille for pressure treated lumber, comparing the average durability of different "madeiras de lei" as well as creosote soaked pine along different railroad lines throughout the Empire. See also Dean 1985 op cit. and Augusto Jeronimo Martini 2004, "O Plantador de eucaliptos: a questão da preservação florestal no Brasil e o resgate documental do legado de Edmundo Navarro de Andrade," Masters Thesis, Department of History, University of São Paulo, for details regarding measures taken by railroads to establish eucalyptus plantations for fuel in the early twentieth century.

[7] Current legislation regulates only the licensing, importation, sale and industrial usage of CCA and other chemical wood treatments, but do not apply to the wood products containing these substances. See Ministério do Meio Ambiente—Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Portaria Interministerial No. 292 de 28 de Abril de 1989; and Instrução Normativa No. 5 de 20 de Outubro de 1992.

For marginalized urban communities, who are seldom considered in discussions of forest management, state environmental "protections" have not only failed to guarantee well-being but have often compounded structural inequalities by privileging the commodification of land and land-based resources. In particular, efforts to replace endangered native species used in the provision of housing with plantation grown pine and eucalyptus have not diminished the presence of over-harvested genera on local timber markets. Although they account for 77% of national timber markets, plantation grown species accounted for only 2% of our sample, suggesting that local builders may in fact prefer native angiosperms, which have historically been used in domestic construction due to their local availability and natural resistance to rot and insect damage (Table 3; IBGE 2007–2013).

Further research is needed to determine if these results are generalizable to the community of Morro do Vital and other marginalized communities in the metropolitan area of Rio de Janeiro. Such research requires close attention to community-scale practices and knowledge surrounding the provision of essential housing. Building on the work of community associations like AMOVIBRA, scholars have begun to explore new models for participatory and citizen-science research on access to land, urban infrastructures, and other social-environmental services (Martins et al. 2020). We propose a specific research model for better understanding the more-than-human relationships created through the provisioning of essential housing and their wider socio-environmental effects. At present, national level policies for the sustainable management of forests and timber products do not adequately describe these relationships nor account for their effects for social equity and environmental justice.

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Declarations

Conflict of interest This research was conducted while the researchers were affiliated with the NGO *Arquiteto de Família*. The research and conclusions shared here are solely those of the researchers and do not represent those of the NGO or the community of Morro do Vital.

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