New Sources of Biological Data Supporting Environmental History of a Tropical Forest of South-Eastern Brazil

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ABSTRACT

The Tijuca Forest results from a reforestation project executed in the second half of the nineteenth century, with native and exotic species planted in the mountains of Rio de Janeiro, Brazil. Aiming at a theoretical reflection, the use of integrated methodologies from different areas of knowledge was evaluated to expand the research of the environmental history of a tropical forest in south-eastern Brazil, using everything from the search for historical documents to the counting of tree growth rings. It was possible to find some of the trees from the initial reforestation efforts, to circumscribe the locations of the first plantations, hitherto unknown, as well as the original intentions of tree selection: a reflection of the silvicultural model of the period that incorporated the tropical identity of the forest without giving up the market demand. The project area indicates that the planted forest would cover approximately 330 ha, prioritizing restoration by micro basins. In the 33 years analysed, about 155,000 trees were planted (110,000 with success) from a repertoire of at least 107 species, prioritizing the native ones. The quality of the wood, mainly for the naval segment, was prioritized, but other purposes were also met. The model and selection criteria for planting areas and species characterize a strategic plan that foresaw the recovery of water sources simultaneously with the generation of wealth in the medium and long term, diversifying the use of the soil and inaugurating a cycle of silvicultural exploitation in the country. This study re-signifies the understanding of the Tijuca Forest ecology, not only in space but mainly in time, revealing the subtle relationships between tropical nature and society in formation.

Keywords: research methodology; ecological restoration; historical ecology; Tijuca Forest; Atlantic Forest.

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Environmental historians elaborate on complex questions and develop creative approaches, consequently, needs "learning to speak new languages and ask new questions".[3] To undertake research in that area necessarily demands integration of manners of thinking of human and natural sciences, as overlapping processes of observation, and the simultaneous use of various methods and theories.[4] Some authors stress that environmental history does not have any single methodology, and that the investigations must necessarily take advantage of numerous approaches, using written, visual, and oral sources, and fieldwork, etc.[5]

Creativity characterizes that type of research, with investigations that consider hurricanes and infectious diseases, railways, and plastic flamingos – almost anything and everything can be included in the repertoire of environmental histories.[6] It is this attention to the natural world – pollution, water, air, the climate, and animals (including humans) – that mark the many approaches available to environmental historians.[7]

Environmental historians also take advantage of discoveries extracted from bioarchives (such as pollen deposits and indications of earlier vegetation patterns) and from geoarchives (such as soil profiles and indicators of ancient land-use practices).[8] From that perspective, environmental history labours at the boundary between traditional historiography and other related fields – building new bridges between them[9] that incorporate concepts of ecology, botany, geography, economy, and anthropology, among others. That convergence of approaches has been fertile for its evolution, and the continuous interactions between researchers have favoured its rapid expansion and consolidation in Brazil and throughout the world.

[3] Donald Worster, "Appendix: doing Environmental History", in D. Worster (ed.), The ends of the Earth: perspectives on modern environmental history (Cambridge: Cambridge University Press, 1988), pp. 289-307.
[4] Esa Ruuskanen and Kari Väyrynen, "Theory and prospects of environmental history", Rethinking History 21 (4) (2017): 456-473.
[5] Stefania Gallini, "Problemas de metodos en la historia ambiental de América Latina", Anuario IEHS 19 (2004): 147-171; Timo Myllyntaus, "Methods in Environmental History", in T. Myllyntaus (ed.), Thinking Through the Environment: Green approaches to Global History (Cambridge: The White Horse Press, 2011), pp. 1-14.
[6] Ellen Stroud, "Does nature always matter? Following dirt through history", History and Theory 42 (4) (2003): 75-81.
[7] Ibid.; Diogo de Carvalho Cabral, "No mutirão da vida: pensando como um historiador ambiental", Desenvolvimento e Meio Ambiente 31 (2014): 139-154.
[8] John R. McNeill, "The state of the field of Environmental History", Annual Review of Environment and Resources 35 (2010): 345-374.
[9] Alfred Crosby, "The past and Present of Environmental History", The American Historical Review 100 (4) (1995):1177-1189.

The historiographical method predominantly uses consultations of archival and museum documents, maps, and iconographies, gaining access to traditional knowledge and oral histories, discourse analysis and landscape reconstruction. Within this context of experimentation, uniting space and time, we selected as our study area an Atlantic tropical forest that presents challenges of (1) biological nature in terms of its characterization, its interactions at different scales, and its biotic and abiotic components, (2) cultural nature in the sense of the stratigraphy of territories established there overtime within the web of social interactions with the city of Rio de Janeiro from colonial times to the present, and, (3) sociological nature as the biological conservation area is subjected to tensions arising from the urban expansion typical of large cities.

This study aims to show the challenge and value of adopting integrated methodologies from historiography, botany, ecology, and geography to unveil the first major reforestation project carried out in Brazil. It also sought to reflect on the challenges and new possibilities when using multiple approaches in the investigation of forests and present a brief recent advance in environmental history practised in Brazil.

THE INTERTWINING BETWEEN BIODIVERSITY AND HISTORY: USES OF ENVIRONMENTAL HISTORY IN BRAZIL

Environmental history forms a theoretical body of knowledge that appeared during the 1970s. It is derived not only from a set of multifaceted studies of the natural environment along a temporal scale – combined principally with ecology and history – but also reflects the effervescence of a general trend of recognizing ecology/conservation as a common value to be shared and defended in contemporary life.[10] Growing contributions of this area of knowledge have advanced our understanding of the relationships between society and the natural environment – subsides indispensable to dealing with the increasingly profound alterations in nature resulting from the current use of natural resources and climate change.

[10] José Augusto Pádua, "As bases teóricas da história ambiental", Estudos Avançados 24 (68) (2010): 81-101.

Donald Worster[11] considers environmental history to be dedicated to elucidating the manners in which humans have, over time, affected their natural environment, including how much it has been changed and what were the results of those interventions. Along that same line, John R. McNeill[12] stressed that the discipline should focus on the history of the relationships and the dependence of human societies on the rest of nature. In a final analysis, all those definitions focus on the relationships between societies and the natural environment, as set out by J. Donald Hughes[13] stated that any historical study that did not include these concepts could not be understood as environmental history.

Brazil is a country appropriate for the development of studies of environmental history for several reasons, including its territorial size that comprises many different ecosystems and landscapes, as well as its highly diverse cultural heritage and its biological megadiversity.[14] There has been a significant increase in Brazilian scientific production in the field of environmental history in recent decades[15] through the publication of articles and books[16], dissertations and theses, as well as the growth of the number of academic disciplines offered in institutions of higher learning and research, and scientific events.[17] Environmental history in Brazil initially emerged as a discipline dedicated principally to the examination of the destruction of

[11] Donald Worster, "Appendix: doing Environmental History", in D. Worster (ed.), The ends of the Earth: perspectives on modern environmental history (Cambridge: Cambridge University Press, 1988), pp. 289-307.
[12] John R. McNeill, "The state of the field of Environmental History", Annual Review of Environment and Resources 35 (2010): 345-374.
[13] J. Donald Hughes, "Three Dimensions of Environmental History", Environment and History 14 (2008): 319-330.
[14] José Augusto Drummond, "Por que estudar a História Ambiental do Brasil? – ensaio temático", Varia História 26 (2002): 13-32.
[15] Research undertaken in April/2020 based on data from "SciELO Citation Index", utilizing the search codes "(TS=('História Ambiental')) AND COLEÇÃO DA SCIELO: (SciELO Brazil)", and, in "Scopus (Elsevier)", utilizing the search codes "TITLE-ABS-KEY ('Environmental History' AND 'Brazil')", verified increases in the number of scientific articles focusing on environmental history in Brazil. Other investigations that showed increased numbers of publications and the consolidation of environmental history in Brazil were performed using the CAPES Catalog of Theses and Dissertations (https://catalogodeteses.capes.gov.br/). That portal considers publications elaborated by graduate students in Brazil. The CAPES Catalog listed a total of 381 works (Doctoral, Master's, and Professional Master's) using the search words "História Ambiental", with the first publication dating from 1996; between 1996 and 2005, ten years, there were 14 publications, while between 2012 and 2021 the total was 289, which represents an expressive increase in the numbers of research papers published in the last decade. It is worth noting that there are numerous research groups and laboratories in the country undertaking investigations related to environmental history, including: the Laboratório História e Natureza at UFRJ, the Laboratório de Imigração, Migração e História Ambiental at UFSC, the Fronteiras: Laboratório de História Ambiental at UFFS, the Grupo de Pesquisa História Ambiental dos Cerrados at UniEVANGÉLICA, among others. Finally, it is important to note that various events dedicated to environmental history have been undertaken in the last decade, including: the "Simpósio Internacional de História Ambiental e Migrações" (a biannual event), the II and III editions of the "Escuela de Posgrados de Sociedad Latinoamericana y Caribeña de Historia Ambiental" (realized in 2015 and 2017 respectively), the "Diálogo em História Ambiental: BRICS" (realized in 2014) and, most recently, the "3rd World Congress of Environmental History" held in 2019, and the "I Encontro Virtual de Grupos de Pesquisa e Laboratórios de História Ambiental do Brasil" held in 2020.
[16] José Augusto Pádua and Alessandra Izabel de Carvalho, "A construção de um país tropical: uma apresentação da historiografia ambiental sobre o Brasil", História, Ciências, Saúde – Manguinhos 27 (4) (2020): 1311-1340.
[17] Alessandra Izabel de Carvalho, José Augusto Pádua and Lise Sedrez, "A Pós-Graduação e o avanço da História Ambiental na América Latina", Fronteiras: Journal of Social, Technological and Environmental Science 7 (3) (2018): 11-20.

tropical forests.[18] Starting in the 1990, however, those considerations diversified and shifted in the direction of theoretical[19], urban[20], geographic[21], and biological[22] perspectives, among others.

How the environment is perceived and recorded is the results in the specificity of the historical-social nature of everyone, conjugated with their rationality and organized within a given theoretical framework. The individual reading and understanding of the interactions between humans, nature, and societies will be based on the criteria used, unique to each study. They will get a certain universality within the geographic and temporal scales of the questions that go with the evolution of humans in their occupation of natural environments in terms of the tensions that develop concerning the where, when, and why.

The encounter of perceptions and perspectives, originating both from the fields of humanities and biological studies, will aid environmental history in constructing itself as a theoretical body of expression dealing with cultural valorisation and will help bring into focus history and ecology, articulating them, expanding their zones of contact, and allowing re-dimensioning them to generate subsidies for both biodiversity and cultural conservation.

The Convention on Biological Diversity (CDB), set up in 1992, combined a robust agenda of Brazilian public policies on that theme. It was substantiated on three principal pillars: the conservation of biological diversity, the sustainable use of that biodiversity, and fair division of the benefits derived from the use of genetic resources. The CDB drew together different academic segments to consider societal

[18] Warren Dean, *A ferro e fogo: a história e a devastação da Mata Atlântica brasileira*' (São Paulo: Companhia das Letras, 1996).
[19] José Augusto Drummond, "A História Ambiental: temas, fontes e linhas de pesquisa", Estudos Históricos 4 (8) (1991): 177-197; José Augusto Drummond, "Por que estudar a História Ambiental do Brasil? – ensaio temático", Varia História 26 (2002): 13-32; José Augusto Pádua, "As bases teóricas da história ambiental", Estudos Avançados 24 (68) (2010): 81-101.
[20] Lise Sedrez, "Desastres socioambientais, políticas públicas e memória - contribuições para a história ambiental", in E. S. Nodari and S. M. S. Correa. (eds), Migrações e Natureza (São Leopoldo: Oikos, 2013), pp. 185-202; Bruno Capilé, "Rios urbanos e suas adversidades: repensando maneiras de ver as ciudades", Historia Ambiental Latinoamericana y Caribeña (HALAC) 5 (1) (2016): 81-95.
[21] Rogério Ribeiro de Oliveira, "Mata Atlântica, paleoterritórios e história ambiental", Ambiente & Sociedade 10 (2) (2007): 11-23; Alexandro Solórzano, Rogério Ribeiro de Oliveira and Rejan R. Guedes-Bruni, "Geografia, História e Ecologia: criando pontes para a interpretação da paisagem", Ambiente & Sociedade 7 (1) (2009): 49-66.
[22] José Luiz de Andrade Franco, "História da *Panthera onca* no Brasil: entre o terror e a admiração (séculos XVI-XXI)", in J. L. A. Franco, S. D. Silva, J. A. Drummond and G. G. Tavares (eds), História Ambiental: territórios, fronteiras e biodiversidade – volume 2 (Rio de Janeiro: Garamond, 2016), pp. 393-426; Marcos Gerhardt and Eunice Sueli Nodari, "Patrimônio Ambiental, História e Biodiversidade", Fronteiras: Journal of Social, Technological and Environmental Science 5 (3) (2016): 54-71.

demands and promote advances in different fields of knowledge and a confluence of purpose.

One can perceive a flowering of productions from biological perspectives, with the development of knowledge concerning, for example, the folk classification of fish and the preferences and dietary taboos held by fishers and hunters in different areas of Brazil[23], the use of local knowledge in the monitoring marine species[24], bird trappers in north-eastern Brazil[25] or mammal hunters in the southern region of that country.[26] Similar perceptions occur in ethnobotanical studies, especially those focusing on the traditional knowledge of indigenous populations – although those studies are still very incipient, considering the 305 knowns ethnic[27] indigenous groups in Brazil[28], with both rural and riverine populations[29], as well as African descendants[30] ("quilombolas").

Scientific leaders have been incentivizing research in the Atlantic Forest as well as in "Caatinga" dryland vegetation areas in north-eastern Brazil, bringing significant contributions concerning rural populations, including, for example, studies

[23] Alpina Begossi et al., "Usos de Peixe e Caça por Habitantes de uma Reserva Extrativista (Alto Juruá, Acre, Brasil)", Meio Ambiente, Desenvolvimento e Sustentabilidade 1 (1999): 73-93; José S. Mourão, Helder F. P. Araújo and Fabiana S. Almeida, "Ethnotaxonomy of mastofauna as practised by hunters of the municipality of Paulista, state of Paraíba – Brazil", Journal of Ethnobiology and Ethnomedicine 2 (19) (2006): 1-7.

[24] Gustavo Goulart Moreira Moura, Daniela Coswig Kalikoski and Antonio Carlos Sant'Ana Diegues, "A resource management scenario for traditional and scientific management of pink shrimp (*Farfantepenaeus paulensis*) in the Patos Lagoon estuary (RS), Brazil", Journal of Ethnobiology and Ethnomedicine 9 (6) (2013): 1-18; Márcio Luiz Vargas Barbosa-Filho et al., ""Shark is the man!": ethnoknowledge of Brazil's South Bahia fishermen regarding shark behaviors", Journal of Ethnobiology and Ethnomedicine 10 (54) (2014): 1-14.

[25] Hugo Fernandes-Ferreira et al., "Hunting, use and conservation of birds in Northeast Brazil", Biodiversity and Conservation 21 (2012): 221-244.

[26] Fabiana Rocha-Mendes et al, "Mamíferos do município de Fênix, Paraná, Brasil: etnozoologia e conservação", Revista Brasileira de Zoologia 22 (4) (2005): 991-1002.

[27] IBGE, Sinopse do censo demográfico 2010 (Brasil: Instituto Brasileiro de Geografia e Estatística, 2010). http://www.censo2010.ibge.gov.br/sinopse (Accessed 20 April 2020).

[28] Margarete Emerich, Luci de Senna-Valle and C. Emerich, "Estudos de Etnobotânica no parque indígena do Xingu -IX – Urucu (*Bixa orellana* L.) no Alto Xingu", Bradea 6 (26) (1993): 232-236; Diogo de Souza Lindenmaier and Jair Putzke, "Estudo etnobotânico em três comunidades Mbya/Guarani na região central do Rio Grande do Sul, Brasil", Cadernos de Pesquisa, Série Biologia 23 (3) (2011): 6:18;; D. A. Ribeiro et al., "Potencial terapêutico e uso de plantas medicinais em uma área de Caatinga no estado do Ceará, nordeste do Brasil", Revista Brasileira de Plantas Medicinais 16 (4) (2014): 912-930; Carolina Weber Kffuri et al., "Animalarial plants used by indigenous people of the Upper Rio Negro in Amazonas, Brazil", Journal of Ethnopharmacology 178 (2016): 188-198.

[29] Alexandre Gabriel Christo, Rejan R. Guedes-Bruni and Viviane Stern da Fonseca-Kruel, "Uso de recursos vegetais em comunidades de Poço das Antas, Silva Jardim, Rio de Janeiro: estudo de caso na Gleba Aldeia Velha", Rodriguésia 57 (3) (2006): 519-542; Alexandre Gabriel Christo et al., "Evidence for conservation and sustainable use in a fragment of the Atlantic forest in southeastern Brazil by a traditional human group", SpringerPlus 1 (2012): 1-21; Amelia Carlos Tuler, Ariane Luna Peixoto and Nina Claudia Barboza da Silva, "Plantas alimentícias não convencionais (PANC) na comunidade rural de São José da Figueira, Durandé, Minas Gerais, Brasil", Rodriguésia 70 (2019): 1-12.

[30] Maria Otávia Silva Crepaldi and Ariane Luna Peixoto, "Use and knowledge of plants by "Quilombolas" as subsidies for conservation efforts in an area of Atlantic Forest in Espírito Santo State, Brazil", Biodiversity and Conservation 19 (2010): 37-60; Bruno Esteves Conde et al., "Local ecological knowledge and its relationship with biodiversity conservation among two Quilombola groups living in the Atlantic Rainforest, Brazil", PLosONE 12 (11) (2017): 1-13.

on the impacts of urban expansion on the erosion of local and traditional knowledge.[31] Conflicts arising from the exploitation of natural resources, which significantly affect Indigenous peoples and rural communities in the Amazon region, have gained expression in studies that evaluated the impacts of land use[32] and the implementation of large energy generation projects.[33] As pointed out by Cummings[34], those questions had previously been treated in fragmented manners by the different specialists and specializations involved (each considering only wildlife, soil erosion, or human rights, or sometimes only focusing on indigenous populations while ignoring rural communities), thus weakening any comprehension of the broader range of events involved, disarming local leadership, and leaving natural areas vulnerable, whether in terms of biodiversity per se or as potential resources for sustainable development. Hence, it is necessary to consolidate and diversify the ethnoscience involved, which, according to Rosa and Orey, include subject areas that "study and investigate the perceptions, classifications, and modelling those members of distinct cultural groups use to solve everyday problems through the establishment of interactions with the environments in which they are inserted".[35]

The biological sciences, linked to anthropology, can promote a unified view of nature and culture that amplifies their exploratory dimensions considering the challenges arising from the efforts to conserve biodiversity and from cultural values, especially in mega-diverse countries such as Brazil. Such an interdisciplinary view, linked to the urgency of its execution is needed. The sociological aspects that appear from that view of nature demand a new paradigm that can contextualize them within a spatial perspective and a temporal context. From that perspective, environmental history is relevant for interpreting those processes.

[31] Heitor S. N. Liporacci et al., "Where are the Brazilian ethnobotanical studies in the Atlantic Forest and Caatinga?", Rodriguesia 68 (4) (2017): 1225-1240.
[32] Joan Martinez-Alier, "Ecologia e os pobres: uma dimensão negligenciada da história da América Latina", Journal of Latin American Studies 23 (3) (1991): 621-639.
[33] Philip M. Fearnside, "Impacts of Brazil's Madeira River Dams: Unlearned lessons for hydroelectric development in Amazonia", Environmental Science & Policy 38 (2014): 164-172; Camila D. Ritter et al., "Environmental impact assessment in Brazilian Amazonia: Challenges and prospects to assess biodiversity", Biological Conservation 206 (2017): 161-168.
[34] Bárbara J. Cummings, "Dam the rivers; damn the people: Hydroelectric development and resistance in Amazonian Brazil", GeoJournal 35 (2) (1995): 151-160.
[35] Milton Rosa and Daniel Clark Orey, "Aproximando diferentes campos de conhecimento em educação: a etnomatemática, a Etnobiologia e a etnoecologia", Vidya 34 (1) (2014): 1-14.

AN INTERDISCIPLINARY APPROACH TO INVESTIGATING A FOREST OF IMPORTANCE FOR BIOLOGICAL CONSERVATION AND FULL OF STORIES

Despite its pristine appearance, the Tijuca Forest that belongs to the Tijuca Massif in Rio de Janeiro (RJ), Brazil (Figure 1), can be viewed as a type of palimpsest in the sense that different use-histories overlap. The Tijuca Forest itself is currently circumscribed by the Tijuca National Park (Figure 2), covering approximately 4000 ha in the middle of Rio de Janeiro city; added with the extensive areas of neighbouring forests, it constitutes one of the most extensive urban forests in the world.

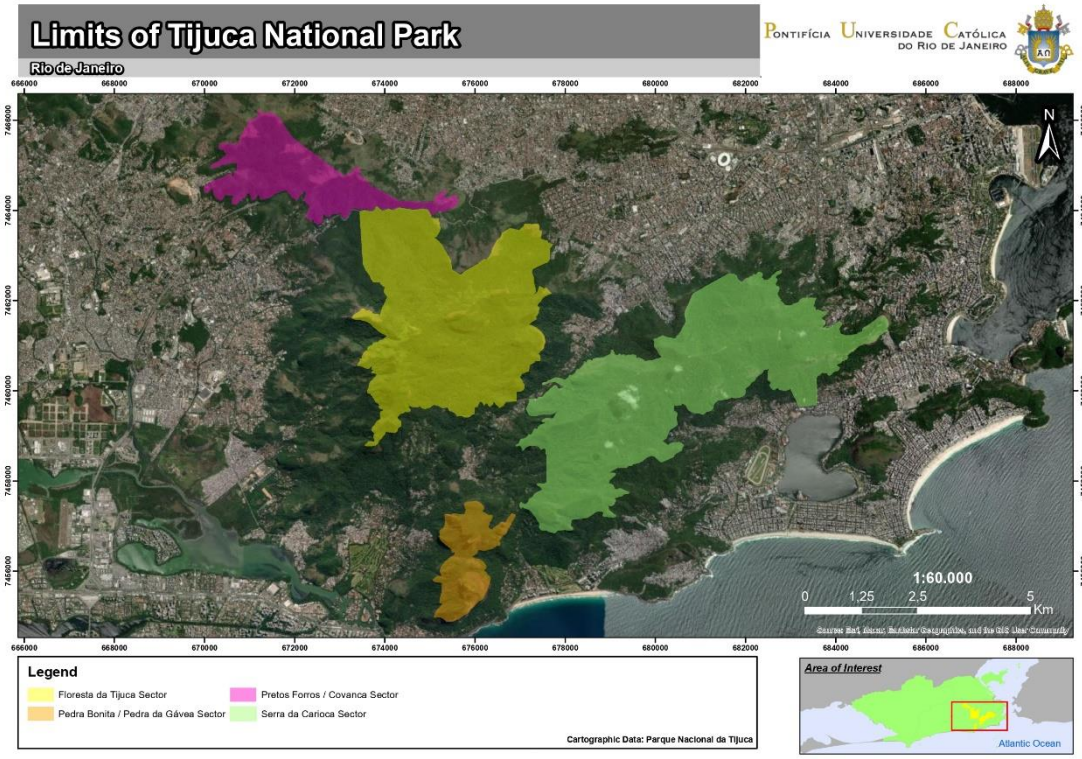
Figure 1. A) The highlight for Cascatinha Taunay, one of the best-known spots of the Tijuca National Park. B) View of the Tijuca Forest and Cascatinha Taunay, as seen from the Mirante da Cascatinha overlook.

Source: Photograph by the authors.

Today's forest is the product of human and nonhuman agencies, with trees spared from cutting, species whose populations were locally reduced, and introduced species. They were part of the reforestation project that started in 1862 and continued to the end of the nineteenth century by planting of thousands of trees of several species. It was one of the first, if not the very first, reforestation project undertaken in a tropical region, and it is an original and innovative undertaking.

Historiographical studies undertaken about the Tijuca Forest[36] were based fundamentally on primary sources in the last three decades. However, now, even more than 150 years after the reforestation efforts, the forest still holds many undisclosed issues that stimulate academic inquiry (as well as the popular imagination, given its cultural importance to the city of Rio de Janeiro).

Figure 2. Map showing the localization of the Tijuca National Park in Rio de Janeiro, Brazil, emphasizing its four sectors. The sector known as the Tijuca Forest is showed in yellow.



Source: Elaborated by Rafael da Silva Nunes.

The present study employed multiple tools, ranging from searches of historical documents to counting tree growth rings. By uniting the past and present, it sought to establish a dialogue between history, ecology, botany, and geography, generating an integrated knowledge of the most important Brazilian urban forest. The investigation of Tijuca Forest can be characterized as a blending of history and nature,

[36] José Augusto Drummond, "O jardim dentro da máquina: breve história ambiental da Floresta da Tijuca", Estudos Históricos 1 (2) (1988): 276-298; Claudia Heynemann, Floresta da Tijuca: natureza e civilização (Rio de Janeiro, RJ: Secretaria Municipal de Cultura, Departamento Geral de Documentação e Informação Cultural da Secretaria Municipal de Cultura, 1995); Maurício de Almeida Abreu, "A cidade, a montanha e a floresta", in F. Fridman and R. Haesbaert (eds), Escritos sobre espaço e história (Rio de Janeiro: Garamond, 2014), pp. 299-357.

which materializes through human rationality as the analytical field of environmental history. The study concerning reforestation was based initially on textual documentation, maps, and iconographies, among other records. Besides, in this study, each tree can be understood as a historical document, as each is associated with ecological information that can potentially allow our understanding of the successional processes in that forest, which reveals, simultaneously, the past and the present through its flora.

Rio de Janeiro, from its founding, continually faced problems related to its water resources and was affected by various episodes of drought, principally during the nineteenth century (notably in 1824, 1829, 1833 and 1844). Thus, the Tijuca Forest is commonly understood, even today, as a product of the reforestation project conceived by Major Manoel Gomes Archer, accompanied by only six enslaved people, who were charged with saving the city from an imminent crisis of its water supply.[37]

The following points oriented searches in historical archives: (1) what plant species were used and why; (2) what model was used; (3) where were the plantings made; (4) how many individuals were planted; (5) what was the total area reforested; (6) what were the academic and political inspirations of those reforestation planners and their administrators in adopting the reforestation model. From a historical perspective, the archives consulted covered Imperial Decrees, the reports of travellers and naturalists, work summaries, commercial export and import records for wood products, outlines and cartograms of roads, demonstrative maps, deeds, and property descriptions of coffee plantations in the study area, as well as newspaper and photographic records from the nineteenth century.

The analyses of the decrees, reports, and historical maps aided our understanding of the changes occurring during that epoch and provided information concerning reforestation efforts. An example of this is the Ordinance of December 11, 1861, which can be considered as the "birth certificate" of the Tijuca Forest and, more than that, as a document that resembles a "restoration manual". In this law, it is possible to observe, for example, the prohibition against cutting or removing any tree

[37] José Augusto Drummond, "O jardim dentro da máquina: breve história ambiental da Floresta da Tijuca", Estudos Históricos 1 (2) (1988): 276-298.

of any type, punishment for those who infringed that order, the identification of areas where reforestation efforts were concentrated, and the model adopted for the project. The reforestation model involved planting in straight and parallel rows, perpendicular to each other, and beginning at the margins of banks of small springs. The trees were spaced at a regular distance of twenty-five palms (ca. 5.5 m).[38] Analysing the reports of the forest work performed annually and reports from the Ministry of Commerce and Public Works, it was also possible to identify the species chosen, the most used and the criteria adopted for their selection.

In this way, more than 155,000 trees were planted, and at least 107 species were used, with a preference for natives (91.6%) compared to exotics (8.4%). This equates to an area of about 330 hectares. More than that, reading the documents of the first large-scale forest recovery project carried out in Brazil revealed that about 70% of everything that was planted survived. Considering also that the current 'Tijuca Forest' sector corresponds to approximately 1/3 of the total area of the Tijuca National Park and knowing the distances between the trees, it was calculated that approximately 22% of that sector had been reforested in the second half of the nineteenth century, which evidences the fundamental role that the replanted forest nuclei exerted on the processes of ecological succession and, consequently, natural regeneration of the forests of the Tijuca Massif.

The use of images as historical evidence[39] and the comparative analysis of photographs can facilitate accompanying environmental trajectories and evaluation of changes in land use over time.[40] The use of iconography in studies of environmental history, whether paintings, engravings, or photographs, has been utilized in other publications[41] and it was sought, to this investigation, historical records/images of the

[38] Manoel Felizardo de Souza e Mello, "Dá instrucções provisórias para o plantio e conservação das florestas da Tijuca e Paineiras", in M. F. S. Mello (ed.), Ministério da Agricultura – Relatório da repartição dos negócios da Agricultura, Comércio e Obras Públicas (Rio de Janeiro: Typographia Universal de Lammert, 1862), pp. 537-538.
[39] Peter Burke, Testemunha ocular: o uso de imagens como evidência histórica (São Paulo, SP: Editora Unesp, 2017).
[40] Christian Kull, "Historical landscape repeat photography as a tool for land use change research", Norwegian Journal of Geography 59 (2005): 253-268.
[41] Ana Marcela França, "As imagens de paisagem como testemunhos de transformação e memória de áreas de conservação", Boletín de estudios geográficos 112 (2019): 9-45; Bruno Capilé, Ana Marcela França and Gabriel Paes da Silva Sales, "La agencia compartida de plantas y humanos en la elaboración del mosaico paisajístico de Rio de Janeiro del ochocientos. Una propueste metodológica", Anuario de Historia Regional y de las Fronteras 26 (2): 43-74.

Tijuca Forest, especially from the Marc Ferrez collection deposited in the archives of the Instituto Moreira Salles (IMS).

Those images made it possible to name some of the species that composed the Tijuca Forest landscape approximately 150 years ago and confirm that there were cleared areas as well as other areas overgrown by grasses and ferns in the past. Current visits to those areas during botanical field excursions and comparisons of photographic images taken from the same angles and localities as those taken by Marc Ferrez and other photographers (Figure 3), revealed distinct landscapes, now covered with regenerated forests.

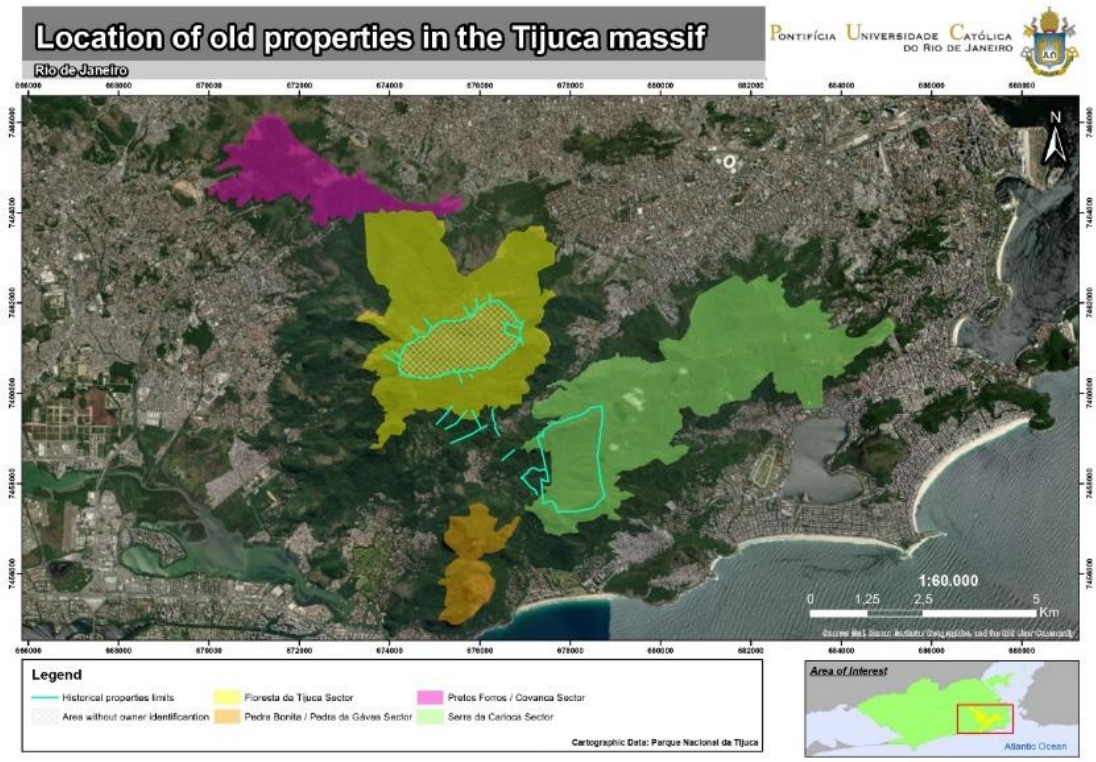
Figure 3. A) 'Vista da Floresta da Tijuca', from 1885, by Marc Ferrez; B) View of the Pedra da Gávea peak as seen from the Vista do Almirante viewpoint in the Tijuca Forest, Rio de Janeiro, Brazil.

Source: A) Source: Marc Ferrez/Coleção Gilberto Ferrez/Instituto Moreira Salles; B) Photograph by the authors, taken in 2018.

The image taken by Ferrez in 1885 shows the predominance of vegetation typical of the first phases of ecological succession (after the cutting of the original forest). Those images show grasses (possibly exotic) and large ferns (presumably *Cyathea corcovadensis* (Raddi) Domin., *Cyathea delgadii* Sternb and *Cyathea phalerata* Mart.), as well as deforested areas and small patches of forest composed of only small trees. Today's photograph reveals a different landscape with a continuous forest cover and many individuals of *Euterpe edulis* Mart., a palm tree typical of the Atlantic Forest and widely used in the reforestation project. Furthermore, it is also possible to

observe *Cecropia hololeuca* Miq., a species typically found in small clearings in the Atlantic Forest (their silvery leaves are easily visible on mountainsides).

Figure 4: Map showing the spatial distribution of some of the old properties located in the Tijuca massif, in the second half of the 19th century, based on information from the following maps: (1) Plan of the springs that form the Cascata Grande and outline of the line they must follow the waters to be piped to Boa Vista, from 1866; (2) Planimetric plan of Alto da Boa Vista between Bico do Papagaio Hill and Pico da Tijuca, indicating paths, buildings, drainage network and names of owners, of uncertain date (probably made between 1880 and 1900).



Source: Elaborated by Rafael da Silva Nunes.

From a geographic perspective and using historical cartography and techniques of geographic information systems[42], it was possible to verify the processes of occupation on the Tijuca Massif, bringing to those analytical field concepts widely used in geography such as border, space, and territory. The use of historical maps allowed the identification of the transformation of the landscapes of areas formerly used for coffee plantations and areas acquired for the reforestation project, providing including the names of the landowners/farmers at that time (Figure 4).

[42] Marina Miraglia, "Aplicaciones de la Cartografía Histórica y las Tecnologías de la Información Geográfica en la Historia Ambiental", Revista de História Regional 24 (1) (2019): 24-41.

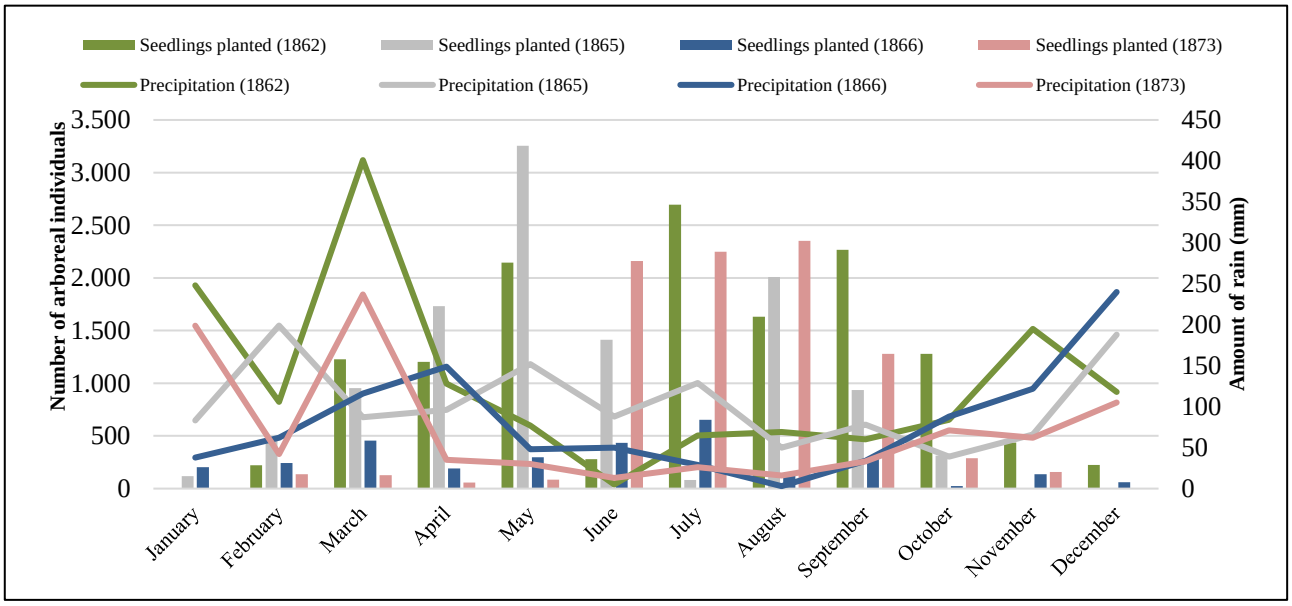
Historical maps associated with the place names and property references met in reports, and other archival documents allowed the identification and the delimitation of previously unknown reforested areas. Additionally, knowing where the plantations were carried out, from field activities, it was possible to find regular lines of the past planted trees in the current forest (quite different from the random distributions found in natural areas).

By examining climatological data from the period between 1851 and 1900[43], it was possible to understand the influence of rainfall on the success or failure of seed germination and seedlings establishment. Climatological data during the period, associated with official reports, demonstrated that the principal factor responsible for the failure of the seedling establishment was not the lack of rainfall, as might be expected, but rather a reduction in the number of workers dedicated to the project, which impeded adequate monitoring of labour efforts and the successful development of the seedlings that were planted. Starting in 1868, the numbers of workers increased, resulting in the visible success of reforestation efforts as, of the 7447 seedlings planted, very few were unsuccessful.[44] Those results can also be explained by changes made to the planting system during the first six years after the initiation of the project. Those changes involved migrating from collecting seedlings and small trees from neighbouring forests (or even from other mountains) between eight and 15 years old and then directly transplanting them – to choosing seedlings only 1 to 2 years old (between 22 and 33 cm tall). Those seedlings were held in small baskets until they attained appropriate sizes for replanting, and their roots were then buried together with the baskets.[45] Historical climate records, subsidized with dendrochronological studies, allowed the determination of the climatic conditions during that time, the dating of the tree ages, and the reconstruction of past forest disturbances.[46]

[43] Louis Cruls, O clima do Rio de Janeiro (Rio de Janeiro: H. Lombaerts & Comp., Impressores do Observatório, 1892).
[44] Miguel Antônio da Silva, "Silvicultura brasileira: trabalhos da Floresta Nacional da Tijuca", in M. A. Silva (ed.), Revista Agrícola do Imperial Instituto Fluminense de Agricultura Nº 5 (Rio de Janeiro: Typographia do Imperial Instituto Artístico, 1870), pp. 29-33.
[45] Ibid.
[46] András Grynaeus, "Dendrochroology and Environmental History", in József Laszlovszky and Péter Szabó (eds), Peoples and Nature in Historical Perspective (Budapest: CEU Medievalia, Department of Medieval Studies & Archaeolingua, 2003), pp. 175-193; Danaë M. A. Rozendaal and Pieter A. Zuidema, "Dendroecology in the tropics: a review", Trees 25 (2011): 3-16.

Considering the years 1862, 1865, 1866 and 1873 – years that are available how many individuals of each species were planted monthly – it is possible to notice the intensification of plantations, by Major Archer, in the less rainy months: between May and September. This option reveals its calculated risk analysis since the number of seedlings that could fail to grow would be high due to the torrential rains typical of the Rio de Janeiro summer. In 1873, even, it was seen that there were no plantings in the typically rainy months, such as January and December (Figure 5).

Figure 5. Number of trees planted monthly in the years 1862, 1865, 1866 and 1873 in the Tijuca Forest, RJ, and the respective amount of rain in Rio de Janeiro city.



Source: Elaborated by the authors.

The importance of biological collections has been amplified beyond the primary taxonomy of fungi, plants, and zoological specimens. Whereas before, they were more restricted in understanding the limits between species and their areas of occurrence (and, to a lesser degree, the history of science), those collections have since subsidized studies of biological conservation, ecology, and environmental studies. Lavoie reviewed 385 biogeographic studies that were based primarily on herbarium data[47], and noted that all those studies had been undertaken within the last

[47] An herbarium is a biological collection dedicated to plants or fungi, or their parts, which are technically and scientifically preserved (Peixoto and Maia, 2013), usually through dehydration. It has the function of documenting plant and fungal diversity. Biological collections can also be defined as cumulative sets of knowledge generated over time, expressing the biological entities present in nature at a given locality, at geographic and temporal scales. According to Funk (2003), herbaria have more than seventy types of uses.

ten years and that only 1.4% of all the herbarium samples available worldwide had ever been used to respond to biogeographic or environmental questions.[48]

There are 180 herbaria in Brazil, holding 8,442,588 specimens[49], with two of the largest national collections being found in the Rio de Janeiro Botanical Garden and the Rio de Janeiro National Museum. Considering the importance of Brazilian biodiversity and the complexity of questions related to it, each exsiccate can be considered a historical document that can aid in understanding the evolution/retraction of forests.

It was examined all the herbarium specimens of plants collected in the localities denominated "Tijuca", "Corcovado", "Gávea", "Paineiras" and "São Conrado", which represent the principal areas visited on the Tijuca Massif. Species collected between 1818 and 1899 at those localities have allowed the partial reconstruction of the original forest structure on the Tijuca Massif, even while acknowledging that those collections captured not all the richness of the historical flora.

Some of those collections must have occurred in forest patches in difficult access areas, as those sites would be less favourable for coffee plantations (as they would require more labour to clear, cultivate, and harvest). Auguste François Marie Glaziou stands out among the naturalists that collected in the Tijuca massif (exemplified by records for *Clethra scabra* Pers., *Melanoxylon brauna* Schott, and *Xylopia brasiliensis* Spreng.), in addition to Ernest Heinrich Georg Ule, Carl A. Wilhelm Schwacke, and William J. Burchell, who documented many species of the local flora.

The use of scientific names derived from herbarium collections, lists and historical bibliographies is not trivial, and it demands significant attention and becomes even more complicated when only popular names are available. Scientific names circumscribe species according to their diagnostic morphological characteristics, distinguishing them from related plants according to taxonomic norms. A specific scientific name corresponds to only a single species, wherever it may occur on earth. The same is not valid for popular names, as a single name may

[48] Claude Lavoie, "Biological collections in an ever changing world: herbaria as tools for biogeographical and environmental studies", Perspectives in Plant Ecology, Evolution and Systematics 15 (2013): 68-76.
[49] Barbara M. Thiers, "The World's Herbaria 2019: a summary report based on data from Index Herbariorum", *Index Herbariorum*, 10 January 2020. http://sweetgum.nybg.org/science/docs/The_Worlds_Herbaria_2019.pdf (Accessed 19 June 2020).

show more than one taxonomic species, or the same species can be known by various popular names (depending on where it occurs and when it was collected). Therefore, necessary to individually analyse each of the species cited in any document, considering the taxonomic group to which it is subordinated, its geographic distribution, its popular name(s), and the uses attributed to it according to the literature or the herbarium labels. Finally, nomenclatural revisions must be conferred, considering the ongoing taxonomic studies that can synonymize names or create new ones, altering the valid designation attributed to the study material.

From the perspective of botanical systematics, each popular name mentioned in the plantation reports was associated with its corresponding scientific name, which resulted in the first list of species used in a reforestation project carried out in Brazil. It is a unique database that can be used to understand the project better, as well as to realize that in addition to saving the city of Rio de Janeiro from the imminent water crisis, the planting of the Tijuca Forest was also an action to create of a forest that would work as a future repository of wood, evidenced by the many "madeiras-de-lei" used in the plantations. It is, therefore, a project with a silvicultural purpose.

An example of the complexity of that process is the native species *Apuleia leiocarpa* (Vogel) J.F.Macbr. (garapiapunha), which is considered vulnerable to extinction.[50] To that species can be added many others equally challenging to identify, such as *Joannesia princeps* Vell. (anda-açu), *Roupala montana* Aubl. (catucanhé), and *Enterolobium contortisiliquum* (Vell.) Morong. (tamboril). Interestingly to note that the common names used for those species varied depending on the region and changed over time. While in the past, *J. princeps* was popularly known as "anda-açu" or "indaguaçu", expressing the influence of Indigenous knowledge, it is principally known today as "cutieira", as it is consumed and dispersed by small rodents popularly known as "cutias" (*Dasyprocta leporina*). The same occurred with *R. montana*, known as "catucanhém" but is currently popularly called "cow-meat" (carne-de-vaca) due to its characteristic odour when its trunk is cut or when its leaves are crushed.

[50] Flora e Funga do Brasil (2020).

The selection of species for reforestation also involved taxa from other areas of Brazil, all having commercial value ("madeiras-de-lei"), showing the value attributed to native natural resources. Non-indigenous species were also planted, such as acacias, eucalyptus, and jackfruit (*Acacia* spp., *Eucalyptus* spp., and *Artocarpus heterophyllus* Lam. respectively), because of their economic value and importance in international trade. That choice of native species, especially of trees found in the Atlantic Forest, previewed the more tropical silviculture set up in the 1980s during environmental restoration efforts in south-eastern Brazil. The experiences of Major Archer, within a systematic and detailed project are still often ignored even today by scientific and technical communities dedicated to studies of ecological restoration. The data gathered here demystify, to a certain extent, the consecrated romantic view of the reforestation of the Tijuca Massif as a project devoted to the regeneration of the vegetation on its slopes without any express knowledge of silviculture or botany and commercial interests.

At the scale of community ecology, considering the evidence obtained concerning potential localities for reforestation, the species used and, in an attempt, to find the seedlings planted in the past or their descendants, as leafy trees still standing, it was selected areas for forest surveys (using the point quadrant method[51]) to collect data and specimens of individual trees with diameters >15 cm. We considered trees with those diameters as older occupants in historically cleared or partially cleared areas. We set up twelve points per area, totalling 240 collections and identified more than sixty species (Figure 6). That sampling method allowed us to confirm that active plantings were made in those areas and to identify species of commercial value used in reforestation efforts, such as *Joannesia princeps* Vell. (anda-açu), *Centrolobium tomentosum* Guillem. ex Benth. (araribá), *Erythroxylum pulchrum* A.St.-Hil. (arco-de-pipa), *Cedrela odorata* L. (cedro), *Copaifera lucens* Dwyer and *Copaifera trapezifolia* Hayne (copaiba), *Terminalia acuminata* (Allemão) Eichler (guarajuba), *Hymenaea altissima* Ducke (jatobá), *Paubrasilia echinata* (Lam.) Gagnon, H.C.Lima & G.P.Lewis (pau-brasil), *Libidibia ferrea* (Mart. ex Tul.) L.P.Queiroz (pau-

[51] According to Martins (1991), the sampling unit of the point quadrant method is a point and not an area.

ferro), *Hyeronima alchorneoides* Allemão (urucurana), and *Sterculia apetala* (Jacq.) H.Karst. (xixá), among others.

It was assumed that not all the trees with large diameters were ancient, but all the old trees were found to have large diameters, as they can be species of rapid growth or species that require many years to obtain significant diameters. During this phase of the sampling, we collected data on trunk diameters, tree heights, the heights of the erect trunk (the latter measurement being important for evaluating the commercial potential of the lumber), as well as samples of their vegetative branches for taxonomic identification and incorporation into the Friburguense Herbarium at PUC-Rio (FCAB). We employed dendrochronology techniques within this process to find trees that Major Archer and his successors planted during the original reforestation efforts (and not established through natural forest dynamics).

Dendrochronology, which studies the growth rings formed by trees, can determine trees' ages and growth dynamics in response to both endogenous and environmental factors (such as reproduction and climate).[52] In situ samples were therefore collected from trees cited in the lists of reforested species (and known by wood anatomists to form distinct growth rings) using a non-destructive collection method (a Pressler increment borer). The bore samples were sent to techniques of dehydration and polishing, with posterior identification, analysis, marking, and counting their growth rings using a stereomicroscope. Sets of measurements were correlated among all the trees sampled, and those that showed the greatest ring alignments were used to establish inferences concerning the local climate over time.[53]

Cedrela odorata L. (cedro) is a native species used in the reforestation project and is currently classified as vulnerable[54] to extinction. It verified the existence of a series of individuals of that species with ages corresponding to the planting period of reforestation: between 160 and 128 years. All of them were met among sets of other

[52] Harold C. Fritts, *Tree rings and climate* (London: Academic Press, 1976); Fritz Hans Schweingruber, Wood structure and environment (Berlin: Springer, 2007); Martin Worbes, "One hundred years of tree-ring research in the tropics: a brief history and an outlook to future challenges", Dendrochronologia 20 (2002): 217–231; Cátia H. Callado et al., "Studies in cambial activity: advances and challenges in knowledge of Brazilian species growth dynamics", Anais da Academia Brasileira de Ciências 86 (2014): 277-283..
[53] Edward R. Cook and Leonardas Kairiukstis, Methods of Dendrochronology: applications in the Environmental Sciences (Kluwer Academic Publishers, 1989).
[54] Flora e Funga do Brasil (2020).

original reforestation species, and their original planting lines in the areas indicated by Major Archer and his successors could sometimes be identified. Therefore, those specimens are living testaments to that important chapter in the history of the tropical Atlantic Forest.

Figure 6. A) Collection of the botanical material during field activity in Floresta da Tijuca, RJ; B) Preparation of the botanical material collected in the forest for processing and identification.

Source: Photographic record by the authors.

FINAL THOUGHTS

After more than 150 years of forestry work, it was possible to return to some areas of past plantations and find, in the current forest, expressing themselves as leafy trees, some of the seedlings planted in the second half of the nineteenth century. These are real living documents, as they contain a series of information that contribute to elucidating the history of the forest. When analysed from many perspectives, the Tijuca Forest reiterates the inestimable value of its forest recovery project. It is the most extended and emblematic silvicultural enterprise conducted in Brazil. As such, it continues to project itself into the future, both concerning issues of

science, biological conservation, and culture, as well as the model of society that provides for new environmental rationality, without which the sustainability given in contemporaneity will meet solely to market demands, to the detriment of nature and human beings.

This study illustrated the expansion of investigative techniques when different approaches and methodologies from areas of knowledge are integrated into environmental history studies. It can be understood as an articulated mosaic of distinct knowledge that favours interdisciplinary research. Historical documents are fundamental for the development of this type of research, but their absence does not necessarily prevent studies of environmental history, although it can limit the understanding of complex and dynamic systems that involve natural and political-social processes. Documentary sources extend texture and conceptual depth from other types of records not typical of historical archives and libraries. Understanding the historicity captured in biological collections, tree sizes and plant and animal names will give dimension to its conceptualization and expand its interpretive possibilities. In the present study, we employed (1) the use of a sampling method to understand the composition, structure, and organization of a current forest (community ecology); (2) analyses of herbarium collections (made by naturalists who explored the area) to identify plant species that constituted the forest of the past (historical taxonomy and botany); (3) dendrochronological (plant anatomy) evidence to assess tree ages and address biological issues. Other documentary sources (composed of reports and maps) provided valuable historical and geographic information, such as lists of species used for reforestation, lists of total seedlings planted, annual seedling production, climate records, among others. The combination of these approaches, uniting environmental perception and academic rationality, allowed the richness of environmental history to emerge and find its place among the subsidiary actions of biological and cultural conservation. It thus contributes not only to a greater understanding of the past, but also joins forces for a future in which these biological and cultural heritages can be valued and shaped in the constitution of contemporary societies, especially those with high biodiversity, but still with marked social inequalities.

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Nuevas Fuentes de Datos Biológicos que Apoyan la Historia Ambiental de un Bosque Tropical del Sureste de Brasil

RESUMEN

La Floresta de Tijuca resulta de un proyecto de reforestación ejecutado en la segunda mitad del siglo XIX, con especies nativas y exóticas plantadas en las montañas de Río de Janeiro, Brasil. Con el objetivo de una reflexión teórica, se evaluó el uso de metodologías integradas de diferentes áreas del conocimiento para ampliar la investigación de la historia ambiental de un bosque tropical en el sureste de Brasil, utilizando desde la búsqueda de documentos históricos hasta el conteo del crecimiento de los árboles. anillos Fue posible encontrar algunos de los árboles de los esfuerzos iniciales de reforestación, circunscribir las ubicaciones de las primeras plantaciones, hasta ahora desconocidas, así como las intenciones originales de selección de árboles: un reflejo del modelo silvícola de la época que incorporó la selva tropical. identidad del bosque sin renunciar a la demanda del mercado. El área del proyecto indica que el bosque plantado cubriría aproximadamente 330 ha, priorizando la restauración por microcuencas. En los 33 años analizados se plantaron cerca de 155.000 árboles (110.000 con éxito) de un repertorio de al menos 107 especies, priorizando las autóctonas. Se priorizó la calidad de la madera, principalmente para el segmento naval, pero también se atendieron otros fines. El modelo y los criterios de selección de áreas de siembra y especies caracterizan un plan estratégico que preveía la recuperación de fuentes hídricas simultáneamente con la generación de riqueza en el mediano y largo plazo, diversificando el uso del suelo e inaugurando un ciclo de aprovechamiento silvícola en el país . Este estudio resignifica la comprensión de la ecología de la Floresta de Tijuca, no sólo en el espacio sino principalmente en el tiempo, revelando las sutiles relaciones entre la naturaleza tropical y la sociedad en formación.

Palabras clave: metodología de investigación; restauración ecológica; ecología histórica; floresta de tijuca; Mata Atlántica.

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