

Review

Historical Ecology in Brazil: A Systematic Mapping of Scientific Articles (1998–2021)

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Citation: Lazos-Ruíz, A.E.; Rodrigues, A.F.; Sales, G.P.d.S.; Brasil, L.S.C.d.A.; Fraga, J.S.; D'Orey, M.; Solórzano, A.; Oliveira, R.R.d. Historical Ecology in Brazil: A Systematic Mapping of Scientific Articles (1998–2021). *Sustainability* **2021**, *13*, 11526. <https://doi.org/10.3390/su132011526>

Academic Editors: Alejandro Rescia and Giuseppe Bazan

Received: 30 June 2021

Accepted: 29 September 2021

Published: 19 October 2021

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Abstract: Historical Ecology is a multidisciplinary field that studies long-term relationships between humanity and the environment. There is a missing synthesis effort to organize and present the state of the scholarship in Historical Ecology in Brazil. We aimed to characterize by whom, when, where, what, and how research in Historical Ecology has been conducted in Brazil. We made a systematic mapping of 118 scientific articles published in Portuguese, Spanish, and English that fit our inclusion criteria. The results showed articles from 1998 to May 2021, published in 79 different journals. We found 264 national and international authors (60% men and 40% women); 91% of all investigations were carried out in the Amazon and Atlantic Forest biomes. There are few works about Cerrado, Caatinga, and Pampa, and none for Pantanal. The most mentioned keywords were historical ecology, Amazon, forest, and archaeology. Twenty-three articles focused on a particular species, primarily plants; 37% of all articles used Historical Ecology as its central axis of research, and 63% as auxiliary. We found more than 35 methodological procedures, both from the social and natural sciences. This overview revealed achievements, research gaps, and opportunities in this field.

Keywords: biomes; methodologies; historical approach; multidisciplinary; research gaps

1. Introduction

The term “Historical Ecology” has been defined by two different research scholarships: (1) as a field that draws upon diverse evidence to trace complex, long-term relationships between humanity and Earth [1]; and (2) as a field related to evolutionary ecology and the use of phylogenetic systematics [2], which may or may not involve anthropogenic agency [3]. In this paper, we embrace and refer to the first definition. Hence, Historical Ecology is a multidisciplinary field (or research program) that investigates human–environment relationships resulting in continuous interactions of spatial, environmental, historical, and cultural dimensions. Its primary focus is the physical evidence etched in the landscape. The use of landscape as an analytical framework and spatial unit is valuable and widely used in Historical Ecology. It is at the same time both a physical reality and a social construct [4]. Landscapes go beyond landform; thus, they are not limited to land but extensive to marine environments. They encompass a mixture of subtle and evident marks in the present as a

result of the accumulation of past activities and processes, including the responses of all life forms to human activities and distinctive archaeological marks such as anthropogenic soils, material culture, and *landesque* capital [5–12].

Historical Ecology recognizes that human activity can be considered an ecological factor influencing the biophysical environment [13]. Nature and culture are impossible to tell apart, making it challenging to define a “natural” landscape [3]. Balée [6] proposes four central postulates to the research program of Historical Ecology. One of those considers that humans have affected every environment on Earth. Changing one part of a system (e.g., species composition, management system, settlement pattern) inescapably influences all other parts since all the variables are intertwined [3]. In our understanding, Carole Crumley’s definition of Historical Ecology best encapsulates how we understand this field:

“Historical Ecology traces the ongoing dialectical relations between human acts and acts of nature, made manifest in the landscape. Practices are maintained or modified, decisions are made, and ideas are given shape; a landscape retains the physical evidence of these mental activities. Past and present human use of the Earth must be understood in order to frame effective environmental policies for the future” [14] (p. 9).

The marks on the landscape resulting from the interaction between human and non-human nature, analyzed through Historical Ecology, have contributed to expanding knowledge about ecological patterns and processes related to specific cultural aspects of societies [15–17]. Historical Ecology studies are often related to ecological restoration studies (for a deeper reflection on this issue, see [3,11,18]) and are a valuable source of information for conservation and management. The latter connotation is based on the logic of knowing and understanding the past to properly manage ecosystems and landscapes for the present and the future [1,19,20], especially as it shows the uniqueness of every site [11].

As a multidisciplinary field [21], Historical Ecology does not have a single research methodology [18,22] but rather aggregates several methods from various academic disciplines that incorporate cultural, historical, linguistic, biological, and environmental data [23]. These include the use of natural (e.g., palynology, packrat middens, dendrochronology) and documental (e.g., forest inventories, climate records, remote sensing) archives [20]. Historical Ecology also integrates different sources, including physical evidence such as archaeological vestiges of material culture or pollen records, and sources from the humanities like oral history or historical archival consultation [19]. In any case, an essential characteristic of the methods is the spatio-temporal component, necessary when investigating a specific landscape and its historical processes [23]. According to William Balée [6], Historical Ecology received contributions from many fields such as environmental history, historical geography, palaeoecology, and landscape archaeology [18]. Solórzano, Oliveira, and Guedes-Bruni [24] also identify bridges between Historical Ecology, environmental history, and historical geography in their goals to investigate the relationships between humans and nature in landscapes throughout time, with different interconnections among these three fields. Historical Ecology, on the one hand, has roots in European (paleo)ecology and landscape history/archaeology, and on the other hand, roots in North American cultural/historical geography, specifically Carl Sauer’s Berkeley school, and also in environmental anthropology, especially in the 1990s [3,18,22].

In Brazil, Historical Ecology was addressed initially in studies located in the Amazon region [25], for example, in the course of the Xingu River [6,26]. One of the leading research topics has been forest management by indigenous societies, which results in changes in the landscape and modification of species composition [27–29]. Several Historical Ecology publications have appeared in the last twenty years, not only for the Amazon but also for other biomes—especially the Atlantic Forest—with diverse temporal and spatial scales and using assorted methodologies.

Historical Ecology often uses biocultural approaches [30]. In the Brazilian biomes, biocultural diversity refers to the interdependence between biological and cultural diversity, indicating how significant sets of biological diversity are managed, conserved, and

created by different cultural groups (including indigenous and other traditional communities) [31]. Current research in Historical Ecology and correlated fields have revealed interconnections between culture and biodiversity in the Amazon [32,33], Atlantic Forest [34–37], Caatinga [38,39], Cerrado [40–42], Pampa [43,44], and Pantanal [45,46]. Historically informed environmental investigation coupled with cross-disciplinary conceptual frameworks (such as biocultural diversity, social-ecological systems, and novel ecosystems) are key to understand current landscape dynamics and help inform decision-making [36].

Two recent works make a synthesis effort revising publications in the field of environmental history in Brazil: one from José Augusto Pádua and Alessandra Izabel de Carvalho [47], who published a thorough review on Brazilian environmental history analyzing books; and the book chapter of Lise Sedrez and Eunice Nodari [48] presenting an overview of research and principal themes in the same field. However, there is no work organizing and presenting the state of the scholarship in Historical Ecology in Brazil.

This paper aims to explore the published scientific articles of Historical Ecology in Brazil through a systematic mapping, presenting by whom, when, where, what, and how research has been conducted. This study reveals the achievements, research gaps, and opportunities in this field from the perspective of published articles.

2. Methods

Systematic mapping is a method to describe the literature across a broad subject of interest. It does not attempt to answer questions that require critical analysis; instead, it describes available evidence; this is useful to identify general patterns and knowledge gaps about the research topic [49]. Systematic mapping formulates a narrative description of the state of the evidence base [50]; this descriptive approach is similar to other published review studies [50–52]. We conducted a systematic mapping to catalog all the published scientific articles about Historical Ecology in Brazil in Portuguese, English, and Spanish until May 2021. We excluded other publications such as books, book chapters, theses, congress memories, and other grey literature, as the amount of information, accessibility, and effort overpassed our ability to manage all the information. We are aware that many research results are published in the form of books in the Humanities. We found some titles specifically about Historical Ecology in Brazil [53–56]. Other books contain chapters dedicated to Historical Ecology research in Brazil [57–60]. The majority of the editors of these books have also authored scientific articles selected in this systematic mapping. The books and book chapters mentioned are mostly about studies in the Amazon. In a quick search for examples of postgraduate theses, we found a greater diversity of biomes studied [61–65]. We pursued the following steps:

1. We searched for articles containing the words “Historical Ecology” and “Brazil” in the three selected languages. We did not set any data limit. The search engines that we consulted were Scopus, Scielo, Web of Science, and Google Scholar. To our surprise, Scielo did not find any work, while Web of Science showed only one (which also appeared in Google Scholar results). Therefore, Scopus and Google Scholar were our main sources of data. The results for Portuguese and Spanish were the same; the spelling difference is only one accent.
2. We excluded all publications different from scientific articles. This was especially difficult with Google Scholar because its filters did not separate the publication types correctly. We found out that Google Scholar has an error when reaching page 99; this problem has already been reported [66]; yet, it provided much information that we could not access with the other search engines.
3. We downloaded all the articles selected up to this point. We then excluded the articles containing the words “Historical Ecology” and “Brazil” (in Portuguese, Spanish or English) only in the references, but not in the main text.
4. After that, we excluded those articles which (a) used Brazil only as an example, that appeared only once in a list of countries, or that the main research was conducted

somewhere else; (b) referred to Historical Ecology as a field related to evolutionary ecology [2]. After these four stages of filters, we had 118 articles to review in-depth.

While reading the articles, we discovered that, in many cases, Historical Ecology was explicitly the main research topic. In contrast, in other times, it was applied as an auxiliary notion to support or to dialogue with an investigation topic in a correlated field. Some examples about the use of Historical Ecology as an auxiliary notion are a publication in environmental public policy [67] and another in political ecology [68] that only mention briefly Historical Ecology in its research. This study includes articles having both, Historical Ecology as main or as an auxiliary research topic.

2.1. Variable Design and Analyses

We designed the variables to overview by whom, where, when, what, and how Historical Ecology research was conducted in Brazil. For the question “by whom”—we included variables of authors’ affiliations (as stated in the article at the moment of publication), gender, journal of publication, and language. We determined gender through the author’s name and an author information search on the internet and applied a classification of women and men. Although we are aware of the diversity of gender types, we opted for a binary gender classification for practical reasons as questioning all authors about their gender affiliation was out of the scope of this study. We classified the departments and research centers of affiliation of the authors in general fields of knowledge. This gives an idea of the fields that embrace Historical Ecology in their research. It is common to find a department named with more than one field of knowledge, for example, “Department of Geography and Environment,” in these cases, we counted it in both areas, geography and environment. Another frequent union is of archaeology and anthropology, or ethnology and history. Concerning the publication journals, we verified their inclusion in the CAPES/MEC Portal of Journals from the Brazilian Ministry of Education (<http://www.periodicos.capes.gov.br/>, accessed on 1 June 2021). This virtual library subsidizes and provides free access to scientific publications for all education and research institutions in Brazil.

For the question “when”—we had two different approaches. On the one hand, we registered when the articles were published. On the other hand, we were interested in the historical period studied in the papers; we categorized the temporal scales: geological era, before the 16th century, 16th, 17th, 18th, 19th, 20th, and 21st centuries. We registered the references to different times of history in the articles. Each article often referred to several epochs, and so we registered.

For the question “where”—we had two different approaches. On the one hand, we considered the studied biome and, on the other hand, the spatial scale of the research. In Brazil, the biomes are well-characterized as Amazon, Atlantic Forest, Cerrado, Pampa, Caatinga, and Pantanal [69]. To have a spatial idea of where research is concentrated, we mapped the number of authors in Brazil per city according to affiliation and the number of works per biome. We also compared the biome of affiliation’s city with the studied biome to know if the authors research where they are based. Concerning the spatial scales, we categorized them as local (i.e., specific sites or landscapes), regional (e.g., a large river basin or portion of a biome, like southeastern Atlantic Forest), biome, national, international (i.e., global, continental, intercontinental studies).

For the question “what”—we included the keywords and the specific species studied. We gathered all the keywords, translated and standardized for singular (i.e., we count the word ‘forests’ as ‘forest’). We placed them in a word cloud (<https://www.wordclouds.com>, accessed on 1 June 2021), where the font size differentiates the number of mentions; the bigger the letter, the more it was mentioned. For the plant species, we revised the updated scientific names in the Tropicos database (<http://tropicos.org>, accessed on 1 June 2021).

For the question “how”—we verified whether Historical Ecology was the main research topic or if it was used as an auxiliary topic, as explained in the previous section. We also focused on the methodologies employed in the papers. The use of a mix of methods is usual in Historical Ecology studies. However, we considered it relevant to differentiate

between theoretical and in situ fieldwork-based approaches. We classified an article as 'practical' when the researchers did fieldwork, using diverse methodologies in situ; when they explicitly expressed that they went to the location of study to collect data, such as archaeological excavations, botanical collections, water and soil sampling, interviews to local people, among others. In contrast, we classified as 'theoretical' research papers to those that did not carry in situ fieldwork, such as consulting historical archives, literature reviews, or other ex situ methods.

In order to assess these variables, we had two members of our team reading each article and extracting the information for each variable. After that, if there were any conflicting interpretations about the assessment, it was discussed in our weekly meeting.

In the results section, we cited each of the 118 articles found in this systematic mapping at least once so that the readers have access to a comprehensive review of the Historical Ecology in Brazil through the references. The multiple citations to the studied articles along the text are helpful to present various perspectives and topics dialoguing with Historical Ecology.

2.2. Limitations

We worked only with digital scientific articles, leaving out other important publications such as books and theses. Although unlikely, it is possible that we are leaving out some scientific articles published in paper format with no current online access (likely to be older than 1998). Another possibility is that some articles were not included in the results of our search engines; this happened with one of the author's research [12]. Another limitation can be that our proposed scales of time and space could be subject to debate.

3. Results

3.1. Whom

This section presents information related to the authors and publishers.

3.1.1. Authors

We found that 43% of the articles were written by one author, 13% by two authors, 14% by three authors. The articles with the most authors have 14 and 16. There are a total of 264 authors, being 158 men researchers (60%) and 106 women researchers (40%). Concerning the country of affiliation of the authors: 68% belong to Brazil, 11% to the United States of America, 6% to the United Kingdom, 3% from The Netherlands, 2% from Argentina, and 2% from Spain. The rest of the affiliations are from other countries such as Australia, Canada, Finland, France, Germany, Italy, Korea, Mexico, Norway, Panamá, Portugal, South Africa, Spain, Uganda, and Venezuela. Four of these countries were included in the last three years. In six cases, the authors had affiliations in two countries; thus, we counted as one participation for each country. The foreign institutions with the largest amount of authors are Wageningen University (The Netherlands) with nine authors; the University of Florida (USA) with six authors; Oxford University (UK), the Autonomous University of Barcelona (Spain), the University of Montpellier (France) with four authors each, and La Plata National University (Argentina), the University of New Hampshire (USA), the University of Zulia (Venezuela) with three authors each.

There is a participation of 34 Brazilian universities (state, federal, communitarian, and private), and other affiliations including federal institutions - Brazilian Agricultural Research Corporation (Embrapa), National Research Institute of the Amazon (INPA), National Institute of Spatial Research (INPE), Museu Paraense Emílio Goeldi, Rio de Janeiro Botanical Garden (JBRJ), Oswaldo Cruz Foundation, Chico Mendes Institute for Biodiversity Conservation; state institutions—Rio de Janeiro State Secretary of the Environment, Rio de Janeiro State Environment Institute (INEA), Paulistan Agency of Technology for Agribusiness (APTA), São Paulo State Secretary of Education, Acre State Secretary of Administrative Management; and other non-governmental organizations-Bird Life/SAVE Brasil, C&T Assessoria e Consultoria Ambiental, Itati Environmental Consultancy, Mamirauá Sustainable

Development Institute, Socioenvironmental Institute. These results show the diversity of research centers that recognize Historical Ecology as a topic worth researching.

The institutions with more publications are University of São Paulo (including its different campi, schools, and institutes) (23), Museu Paraense Emílio Goeldi (16), Federal University of Pará (12), Amazonia National Research Institute (8), Tulane University (7), Federal University of Santa Catarina (7), Federal University of Rio de Janeiro (7), University of Florida (7), Federal University of West Pará (6), Pontifical Catholic University of Rio de Janeiro (5), Mamirauá Sustainable Development Institute (4), Amazonas Federal University (4), Pernambuco Federal Rural University (4). The states of Rio de Janeiro and São Paulo hold the largest amount of research institutions.

The authors with more publications are: William Balée (Tulane University) (7), Nivaldo Peroni (Federal University of Santa Catarina) (6), Charles R. Clement (Amazonia National Research Institute) (5), Eduardo Goés Neves (University of São Paulo) (5), Glenn Harvey Shepard Jr. (Emílio Goeldi Paraense Museum) (5), Helena Pinto Lima (Emílio Goeldi Paraense Museum) (5), Michael Heckenberger (University of Florida) (5), Morgan J. Schmidt (Emílio Goeldi Paraense Museum) (5), Denise Schaan (Federal University of Pará) (4), Marcos Pereira Magalhães (Emílio Goeldi Paraense Museum) (4), Rogério Ribeiro de Oliveira (Pontifical Catholic University of Rio de Janeiro) (4), Alexandro Solórzano (Pontifical Catholic University of Rio de Janeiro) (3), André Pinassi Antunes (Amazonia National Research Institute) (3), Carolina Levis (Federal University of Santa Catarina) (3), Simone Rezende da Silva (University of São Paulo) (3).

The recurrent fields of knowledge in the departments and centers of affiliation with more than 40 authors are ecology, environment, and biology; anthropology appears with 34 authors. Humanities and social sciences have 28 authors. Archaeology and geography have 22 and 20 authors, respectively. Ethnoscience count with 17 authors. Agriculture (which includes agronomy, aquaculture, and soil science) has 15 authors. History has seven authors. Other departments that appeared only once or twice are Language, pedagogy, education, and rural development. The wide array of knowledge areas confirms the multidisciplinary nature of Historical Ecology.

3.1.2. Journals

The selected articles were published in 79 different journals. The journals with the most publications are the Boletim do Museu Paraense Emílio Goeldi (6), Diversity (5), Human Ecology (4), Revista de Arqueologia (4), Cadernos do LEPAARQ (Laboratório de Ensino e Pesquisa em Antropologia e Arqueologia da Universidade Federal de Pelotas) (4), Amazônica-Revista de Antropologia (3), Forest Ecology and Management (3), Journal of Archaeological Science (3), and Ocean and Coastal Management (3). Concerning the inclusion of journals in the CAPES/MEC Portal of Journals, we found that most Brazilian journals are included in the CAPES/MEC Portal of Journals. In contrast, most of the international journals are not (Table 1).

Table 1. Inclusion of studied Brazilian and international journals in the CAPES/MEC Portal of Journals.

		Brazilian	International
CAPES/MEC Portal	in	22	14
	out	9	34

3.1.3. Languages

Concerning the publication language, 60% of the articles were written in English, 38% in Portuguese, and 2% in Spanish.

3.2. When

On the one hand, this section is about the year of publication of Historical Ecology articles; on the other hand, it is about the historical periods studied in the research papers.

3.2.1. Years of Publication

Figure 1 shows the number of articles published per year, the oldest we found is from 1998 [70]. The year 2010 presented a peak, 2015 reached the highest number of publications, and 2020 had another peak. Even though we include the information of all 118 articles in the whole article, we did not include the year 2021 in Figure 1 because the data is incomplete for this year as our search ended in May 2021. There is a trend of increasing the number of Historical Ecology publications, as shown by the trend line.

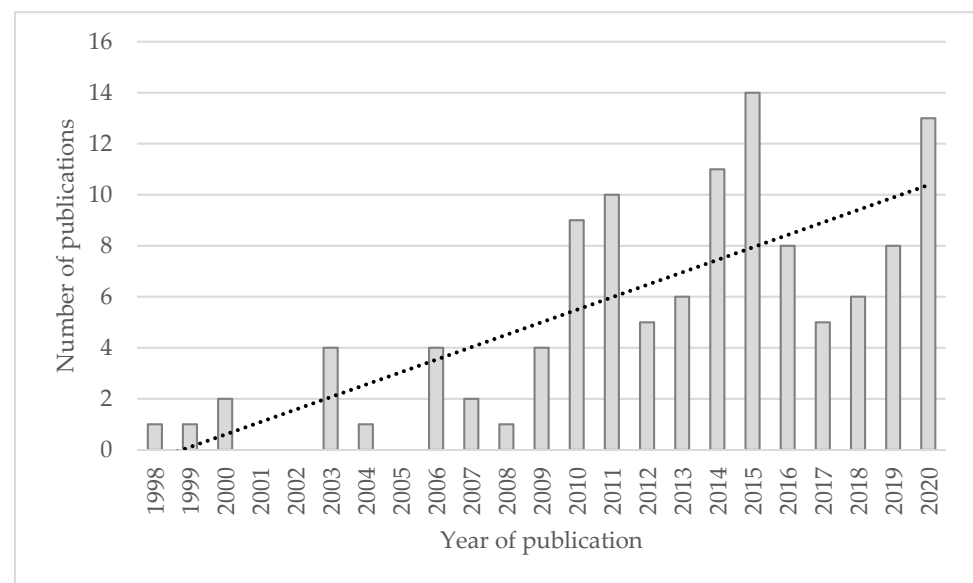


Figure 1. Year of publication of 115 articles until 2020. There is an increasing trend in the number of publications. For 2021, we found three publications but did not include them here, as the yearly data is incomplete.

3.2.2. Historical Periods Studied

Concerning the historical periods investigated, a total of 90% of the articles study the 21st century, whereas 83% study the 20th century, 56% refer to the time before the 16th century, 44% to the 19th century, around 30% consider the 16th, 17th and 18th centuries, and 8% point out different geological eras. We must remember that the articles often refer to various periods.

3.3. Where

On the one hand, this section presents the biome studied, and on the other hand, the spatial scale of the research.

3.3.1. Studied Biome and Affiliations Per Biome

We registered in which Brazilian biome the research was conducted. There were cases where the research dealt with more than one biome. We found that five articles did not work with any biome: two of them are studies about marine environments, and therefore, the terrestrial biomes classification could not be used. Totalizing, 60% worked in the Amazon, 31% in the Atlantic Forest, making 91% of the articles (these figures include the articles studying one or more biomes). Five works study the Amazon and the Atlantic Forest [68,71–74]; three articles study the Cerrado Biome (Brazilian savannah) and the Atlantic Forest [75–77]; one studies the Amazon, the Atlantic Forest, and the Cerrado [78];

one studies the Atlantic Forest and Pampa [79]; two study the Cerrado [80,81], one the Pampa [82] and three the Caatinga [83–85]. There are no articles about Pantanal. Figure 2 shows the number of works per biome, the number of authors per affiliation in Brazil, and the city of localization (for a more detailed list of affiliations, please see Table A1 of Appendix A). Some cities such as Bauru, São Carlos, and Belo Horizonte are located in the transition zone between the Atlantic Forest and the Cerrado.

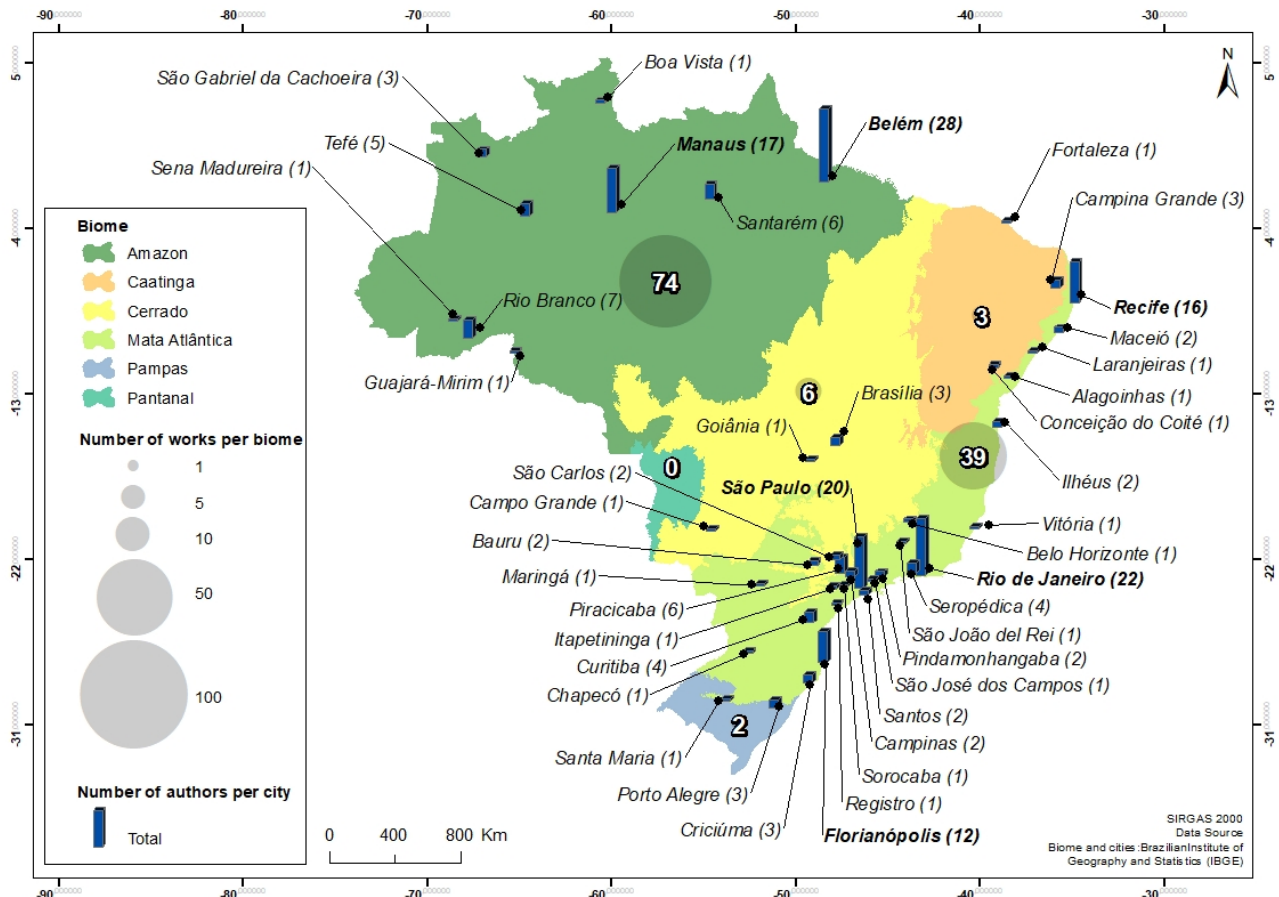


Figure 2. Informative map of the number of works per biome and number of authors by city according to affiliation in Brazil. For more detailed information on affiliations, please see Appendix A.

Figure 3 shows the relation between works per studied biome and biome of affiliation's city. This is helpful to know if the authors research in the biome where they are based. Almost 80% of the authors with international affiliation -outside Brazil- researched the Amazon, 12% in the Atlantic Forest, and the rest studied the other biomes. Argentina stands out as the country that researches the Pampa: an ecological region shared between the southern part of Brazil, the northern part of Argentina, and Uruguay. For studies in the Amazon, 77% of authors are affiliated to institutions located in the Amazon, whereas 19% are located in the Atlantic Forest. For research in the Atlantic Forest, on its own or in combination with other biomes like Cerrado, Pampa, or the Amazon, 79% of the authors are affiliated to institutions in the Atlantic Forest. For Caatinga, 75% of the authors are affiliated to institutions in the Atlantic Forest, the rest in the Caatinga. Cerrado and Pampa are studied by authors affiliated with institutions out of these biomes. There are no works and no authors affiliated in any city in Pantanal.

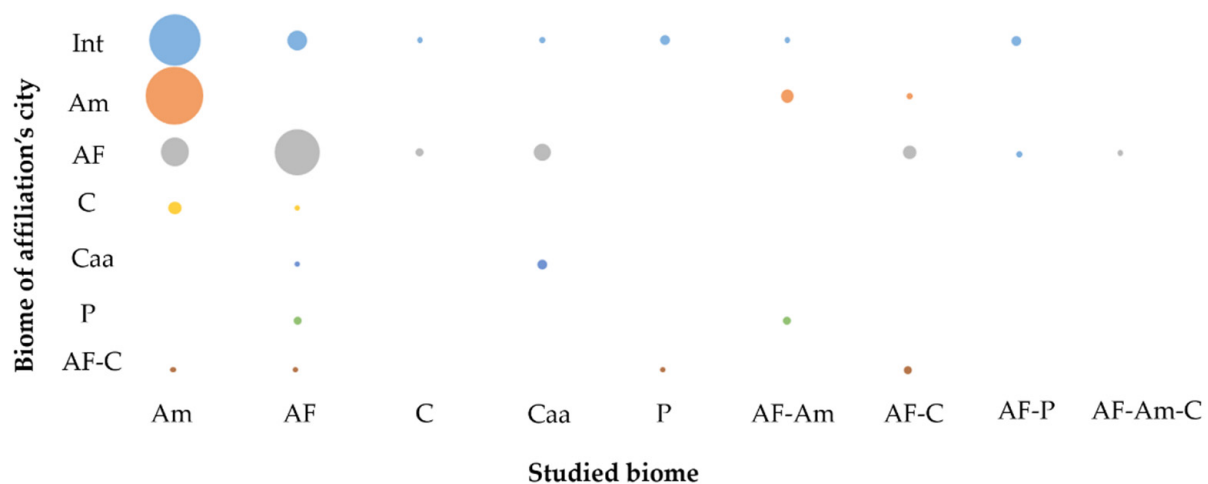


Figure 3. Relation between works per studied biome and biome of affiliation's city. The size of the circles represents the number of works done—the bigger the circle, the higher amount of works—in each specific combination of studied biome and biome where the city of affiliation is located. Int-International; Am-Amazon; AF-Atlantic Forest; C-Cerrado; Caa-Caatinga; P-Pampa; AF-C—Atlantic Forest, Cerrado; AF-Am—Atlantic Forest, Amazon; AF-P—Atlantic Forest, Pampa; AF-Am-C—Atlantic Forest, Amazon, Cerrado.

3.3.2. Spatial Scale of the Study

Regarding the spatial scales, the most common one is working at a regional scale with 49% of the articles [68,86–92], 25% were conducted at a local level [93–95], 11% worked at a biome level [96–99], 10% worked at the international level [100–102], and 4% analyzed the national level [72,103,104].

3.4. What

This section is about the research topics of the articles. We addressed them in two ways, through the keywords and the specific species studied.

3.4.1. Keywords

The keywords show the essential topics of an article (Figure 4). From 502 keywords, the words with at least 10 mentions were historical ecology (32 mentions), Amazon (27 mentions), forest (24 mentions), archaeology (20 mentions), landscape (19 mentions), environmental (15 mentions), indigenous (15 mentions), conservation (14 mentions), dark-earth (12 mentions), Amazonian (11 mentions), Brazil (11 mentions), management (10 mentions), and traditional (10 mentions). As Historical Ecology works with the relationship between people and the environment, numerous keywords refer to ethno-sciences such as ethnoarchaeology [105], ethnobiology [106], ethnobotany [107], ethnoecology [84], ethnomusicology [15], ethnoprimateology [71], and ethnotaxonomy [84]. The suffix anthro also reveals this relationship as in Anthropocene [97], anthropogenic forests [108], anthrosols [109], anthropogenic landscapes [110], and ecological anthropology [111]. Other examples of this people-environment relationship are biocultural diversity [87], biopolitics [94], cultural ecology [111], domesticated forest [109], domesticated landscape [112], environmental history [113], environmental management [114], environmental racism [68], human ecology [115], and local ecological knowledge [116]. There are also works about indigenous peoples and traditional populations, for instance, the Ka'apor [15,117], the Guajá [118], the Guarani [114], the Nadahup-Arawak-Tukano [119], the Marajoara [120,121], indigenous groups of the Middle Purus [122]; *quilombolas* [77,94,123,124], *beiradeiros* [125], and *caçaras* [126] have also been included. There are also mentions to immigrant groups such as the Japanese [124] and the German [127].

3.4.2. Species

Out of the whole universe of articles, 23 focused on a particular species. The species that figured as the central theme of investigation are a protozoan species from the genus *Plasmodium* as an agent of malaria in humans and other primates [71]; fish species such as largemouth sawfish (*Pristis pristis*) and goliath grouper (*Epinephelus itajara*) [116], and lane snapper (*Lutjanus synagris*) [106]; the neotropical otter (*Lontra longicaudis*) and the giant otter (*Pteronura brasiliensis*) [136]. The remainder of the 19 articles is regarding plant species. Manioc (*Manihot esculenta* Crantz) [73,113,129] and Brazil nut (*Bertholletia excelsa* Bonpl.) [137–140] stand out with three and four works, respectively. Concerning other arboreal species, there are two articles about mangrove species (*Rhizophora mangle* L., *Laguncularia racemosa* (L.) C.F. Gaertn., *Avicennia germinans* (L.) L., *Avicennia schaueriana* Stapf & Leechm. Ex Moldenke, *Conocarpus erectus* L.) [83,141], two articles about cocoa (*Theobroma cacao* L.) [117,140], two for araucaria (*Araucaria angustifolia* (Bertol.) Kuntze) [134,142], one for carrapeta (*Guarea guidonia* (L.) Sleumer) [143], one for treegourd (*Crescentia cujete* L.) [107], one for jackfruit (*Artocarpus heterophyllus* Lam.) [144], one for rubber tree (*Hevea brasiliensis* (Willd. Ex A. Juss.) Müll. Arg.) [145], one for feijoa (*Acca sellowiana* (O. Berg) Burret) [134], and one for exotic species eucalyptus (*Eucalyptus* spp.) [146]. There is also one work about bamboo (*Guadua* spp.) [135] and one about grass (*Spartina alterniflora* Loisel.) [147].

3.5. How

This section is how the research in Historical Ecology has been conducted. We differentiated between using Historical Ecology as the main research topic or as an auxiliary topic as detailed in the Methods section. We determined that 37% (44 articles) of the publications had Historical Ecology as the main topic and 63% (74 articles) as auxiliary. We distinguished between practical and theoretical works. Practical studies—using in situ fieldwork methodologies—represent 57% of the works, whereas theoretical—using only ex situ methodologies—are 43% [111,148].

We identified more than 35 different methodological procedures used in the 118 articles. It is worth stressing that many studies comprised more than one method to achieve their objectives. All articles include the traditional literature review, 33 of them conducted interviews [27,95,123,132,133,149], 26 used Geographical Information Systems (GIS) and remote sensing techniques [144,150–155], 26 made floristic and phytosociological analyses, including botanical collections [131,135,142,143,156], 19 collected archaeological materials [74,120,157–160], 16 made soil analysis [80,105,115,161–163], 13 analyzed laws and decrees [124,164,165], 12 made some kind of material dating, including C₁₄ [79,93,158], 11 used free listing [27,166–168], 10 used oral history [117,169], and 10 worked with historical archives consultation [110,113,150], including hemerographic material (newspaper files) [170], and commercial shipping records [136]. With less than 10 works, other methods used were participatory research techniques—including participative cartography and participative archaeology—[84,149,171], travelers' journals consultation [113,147], anthracological analysis (analysis and identification of charcoal based on carbonized wood anatomy) [74,130,143,172], water analysis [155], participative observation [77,121,173], guided tour [127,168], linguistic analysis [117,169], archaeology of the landscape [174,175], photographic sequences analysis [176], discourse analysis [17], among others.

4. Discussion

4.1. Authors

There is important participation of authors affiliated with foreign countries doing Historical Ecology in Brazil, especially in the Amazon biome, though the Brazilian affiliations still hold the majority. This shows the importance of the Amazon biome for international research due to it historically being regarded as the largest tropical forest remnant in the world and its relevance to global ecology and climate change [177]. Furthermore, it has attracted the attention of numerous foreign anthropologists, ecologists, and biologists,

many of which helped develop the field of Historical Ecology (e.g., William Balée, Michael Heckenberger).

Concerning the gender perspective, men make up a higher proportion of historical ecology researchers in Brazil within our study period compared to women. Considering only the researchers with Brazilian affiliation, we find a slightly more equitable proportion of 58% men and 42% women. This is more equitable than a gender study analyzing the differences between men and women researchers getting the scientific productivity funding from the Brazilian National Council for Scientific and Technological Development (CNPq), which shows a significantly bigger proportion in absolute numbers of men researchers getting the funding. However, if we focus on Applied Social Sciences and Biological Sciences, where Historical Ecology topics might be included, the disproportion is smaller [178].

4.2. Affiliations

Rio de Janeiro and São Paulo are the main centers of research aggregating different institutions in the southeastern region (Table A1 of Appendix A). The results showed the participation of many public universities. Sedrez and Nodari [48] explained that the federal universities in Brazil were strengthened by federal government funding and the creation of new universities in the early 2000s with a pro-science and education platform (Lula and Dilma era). The ample funding opportunities and science-friendly scenario (different from Brazil's current research funding policy) increased research agendas in federal universities and improved their research outcomes. Even though we found broad participation of institutions across Brazil, the most productive institutions on Historical Ecology investigation are based in the Amazon and the Atlantic Forest, coinciding with the results on research per biome.

4.3. Practical Work

Considering that more than half of the articles needed in situ fieldwork, it is understandable that given the physical dimensions of Brazil (*circa* 8,500,000 km²) and the difficulty of access to many places, there is a need for generous funding for in situ fieldwork. In some cases, foreign universities have more access to research grants than national institutions (especially since the second half of the 2010s). Therefore, strategies like alliances between national and international institutions, reinforcement of institutions, and an urgent and serious strengthening of national support for research should be encouraged.

Here we may discuss in more detail about accessibility and difficulties to conduct in situ fieldwork in Historical Ecology so that it is easier to understand the situations that researchers face. Let us use as examples some of the methodologies found in the results, and which the authors of this paper have extensively explored: floristic and phytosociological analyses and botanical collections. Our experiences include a fair amount of in situ fieldwork, comprising many hours climbing trees and learning how to identify leaf morphological traits, bark tree textures, and odors to determine the species or genus of Atlantic Forest trees. It is difficult to identify large trees in some forest tracts because of their sheer height and the dense understory vegetation, not being possible to see the foliage on the treetop. This becomes especially challenging for the Atlantic Forest, that albeit it has been significantly transformed, it still harbors great biodiversity. In the case of the Cerrado, research is conducted under extreme climatic conditions when it is hot and dry (for up to nine months, depending on the portion of the biome). Therefore, water and hydration are critical limiting factors, whereas data collection becomes challenging during the rainy season (especially vegetation samples). Also, due to the current rate of land conversion, it is tough to find specific physiognomies of Cerrado vegetation, such as the *cerradão*, a very rare form of woodland savanna. Land degradation and habitat loss are accelerating at a rate much faster than Historical Ecology research is being done in the Cerrado biome. Other factors that influence in situ fieldwork are the accessibility to roads, the availability and costs of transport, the coexistence with mosquitoes, snakes, and other animals, time, and safety. Safety is especially critical in the northern region of Brazil as it has been reported as

a hostile environment for women and their research activities [179]. This situation should not discourage women, but it demands careful planning and accompaniment, finding partners to avoid that women go on their own.

4.4. *Fields of Study*

Historical Ecology appears to be dominated by environmental sciences, anthropology, and archaeology; the little participation of history departments is noticeable. Nonetheless, the contribution of historians in the similar field of environmental history [47,48] is remarkable. It is worth considering that affiliation departments are not a precise indication of research fields, especially in interdisciplinary departments. For instance, some researchers may be housed within Geography or Environmental Policy programs and identify themselves as historical ecologists.

4.5. *Journals*

Regarding the journals of publication, it is remarkable that most Brazilian journals are included in the CAPES website; thus, they are available for a free consultation, which makes a strong publications body. In contrast, most international journals are not contained in the open CAPES site; this is usually compensated with the university's libraries. The usual dilemma of publication language for non-English speakers is an important decision for researchers, as English-written articles target a worldwide audience and help to increase the possibility of the journals being more widely known. In contrast, Portuguese written articles may be more available to a lusophone audience, especially undergraduate students and policymakers.

4.6. *The Beginnings of Historical Ecology*

The first publications of Historical Ecology in Brazil that we found in the present systematic mapping are about archaeology in the Amazon [70,169,180]. Interestingly, Neves's 1998 [70] article is an overview of twenty years of archaeological research in the Amazon, where he brings about the Historical Ecology concept from Balée works [54,181] as a kind of paradigm change. However, the fundamental understanding of the relationship between humans and the environment throughout history might have been addressed before the term 'Historical Ecology' or 'Environmental History' appeared. We coincide with Sedrez and Nodari [48], who argue that some authors delivered early efforts in this direction. For instance, the work "*Nordeste*" [182] by the anthropologist and sociologist Gilberto Freyre, which narrates the history of sugarcane in the Brazilian Northeast; or "*Caminhos e fronteiras*" [183] by the historian and sociologist Sergio Buarque de Holanda, which is about the territorial occupation of Brazil, discussing the tensions between nature, indigenous peoples and the colonizers.

4.7. *Temporal Scales*

Concerning the temporal scale in the articles, it is interesting to observe the capacity of Historical Ecology to address and answer questions in a lengthy scope of time. It also demonstrates the necessary collaboration with fields such as archaeology or geology. Some methodologies like palynology, anthracology, or C₁₄ dating can bring data from thousands of years ago, whereas some other methods like hemerographic consultation or analysis of photographs show information on the contemporary period. We noticed the constant references to the European colonization of Brazil as a critical driver of landscape transformation in the 16th century. This made us fine-tune our categories from the 16th century onwards but not before that. Even though there are fewer articles from the 16th, 17th, and 18th centuries, there are many topics that can be further investigated that occurred within this time, such as the effects in the landscape from sugar cane plantations or mining exploitation, the earliest introductions of foreign plants and animals during colonization, whale hunting, the early influence of the African diaspora in the landscape, and so on. There is research about these topics, but we did not find articles published under the perspective

of Historical Ecology. This seems a good opportunity to team up with researchers from other fields.

4.8. Biomes

One of the most obvious results of our paper is the small number of articles in the biomes different from the Amazon and the Atlantic Forest. We do not underestimate the merits of the research in these biomes; it is necessary and useful. There is still much room for further research questions and tackling contemporary problems. However, given Brazil's biomes' biocultural diversity and ecological importance, it is essential to indicate the spatial gaps to encourage more research in the Pantanal, Pampa, Caatinga, and Cerrado. Interestingly, Sandro Dutra points out that the definition of biomes in Brazil historically favored the protection of the Amazon and the Atlantic Forest, leaving other regions out of the spotlight and deemed less important [184]. This observation coincides with our results showing the prominent attention on these two biomes.

4.9. Spatial Scales

It is interesting and enriching to have works at local, regional, biome, national, and international scales. They all have advantages and disadvantages in terms of focus, degree of detail, and availability of information. At a local level, the concrete, the sensitive, and the individual behavior become more critical, whereas, at a regional level, the landscape becomes an intellectual construction where details are often blurred [185]. All scales are necessary as each of them addresses different problems and perspectives.

4.10. Ethnic Diversity

One remarkable point is the diversity of ethnic groups revealed through the compilation of keywords in the works surveyed. Even though the groups' names did not appear in the word cloud (Figure 4) because they had few mentions, we highlighted them in the description of the results. These ethnic groups are both from traditional communities (e.g., *quilombolas* and *caiçaras*) that have their origins linked to the colonization process, and the indigenous people (e.g., Ka'apor, Nadahup-Arawak-Tukano) that resisted—and still resist—for more than 500 years. This demonstrates part of the Brazilian ethnic diversity and the relationship between this diversity and ecological diversity, a central theme in Historical Ecology.

4.11. Study of Species

There is a vast opportunity to research different species in Historical Ecology. We can think about the footprints in the landscape derived from the relationship between the history of Brazil and the brazilwood tree (*Paubrasilia echinata* (Lam.) Gagnon & H.C.Lima & G.P.Lewis). There is much to do considering animals, plants, and organisms from other kingdoms like fungi, algae, bacteria, or even viruses. Ironically, we are confined in our houses while writing this paper due to the global expansion of a zoonotic virus that is forcing humanity to change our ways of working, organizing, and relating to each other. The socio-environmental effects of Covid-19 constitute an interesting raw material for Historical Ecology.

4.12. Methodologies

Regarding methodologies, our results confirmed the multidisciplinary nature of Historical Ecology. We tried to categorize the methodologies in disciplinary origins. Some methodologies have an obvious disciplinary origin, such as stratigraphic excavations, shovel tests, archaeological material collection coming from archaeology, or Geographic Information Systems, and cartography coming from geography. However, other methods are used across various disciplines, such as interviews and statistical analysis. We even had trouble with classifying between social and natural sciences origin. Santana and Szabó [23] mentioned the various approaches used in Historical Ecology, such as

qualitative, quantitative, and experimental. Szabó highlights that “the higher variety of sources of information, the more secure knowledge about the past (and therefore about the present) is” [3] (p. 384). This opens the possibilities to search not only for documental sources but also for other historical data corresponding with periods during which human impacts were not registered as ecological data [19]. Social perception studies can be helpful when no official data is available or incomplete [106].

We learned about the importance of the participation of local people in different research approaches, given the various participatory research methods reported, such as participatory archaeology, participatory cartography, oral history, or interviews. More concealed (often considered in the Acknowledgements section of published articles) and yet essential is the local people collaboration as guides localizing research sites, identifying species, protecting from local dangers, helping with local remedies, leading to key informants, and so on. Teaming up with local populations, not only as informants but also as colleagues for exchanging ideas, recognizing the value of empirical knowledge, is required to conduct field research in Historical Ecology.

5. Conclusions

This study provided a comprehensive overview of the scientific articles on Historical Ecology in Brazil, informing by whom, when, where, what, and how research has been conducted. It also found achievements, research gaps, and opportunities for this field:

5.1. Achievements

Some of the achievements in the field of Historical Ecology in Brazil are:

- The generation of a large body of knowledge of anthropogenic dark-earth and the anthropogenic forests/landscape domestication in the Amazon. This could be used as a solid scientific argument to demonstrate how indigenous populations have historically shaped the Amazon forest, harboring rich biocultural diversity. There is still much to be done regarding the conservation of its biocultural patrimony.
- Historical Ecology in Brazil has grown in diverse research topics, methodologies, departments, national and international institutions in the last two decades.

5.2. Research Gaps and Opportunities

Some of the research gaps and areas of opportunity are:

- Historical Ecology research brings a perspective that valorizes the environmental and cultural importance of landscapes. This approach could be helpful to make better management decisions, for example, in environmental restoration, and become a more policy-driven applied science.
- In terms of the spatial gap, more research is needed in the Pantanal, Caatinga, Pampa, and Cerrado biomes. Research in these biomes is crucial because they are reservoirs of unique biodiversity and provide particular environmental services on the local and regional scales. This implies the need to strengthen institutions and research groups promoting cross-disciplinary research located in these biomes.
- More research is needed focusing on animal species. This would require social scientists to work with experts in zoology, biology, ecology, and *vice versa*. Other life kingdoms should also be explored.
- Special attention should be paid to marine environments, especially the interface between the land and the ocean, which is key to understanding the dynamics of the Brazilian population in the coastal Atlantic Forest.
- Given Brazil’s dimensions, diversity, and accessibility, there is a need for generous funding for conducting in situ fieldwork research, both with national funds and with international collaborations, given the biocultural importance of all Brazilian biomes not only for the country but also at a global level. Cooperation with neighboring countries for research in biomes such as Amazon, Pampa, and Pantanal is necessary, as demonstrated in the Pampa region.

- The overview presented by whom, when, where, what, and how research has been conducted in Historical Ecology in Brazil. It showed a great diversity of authors, institutions, journals, study sites, periods of study, research topics, and methodologies. The further development of Historical Ecology research in Brazil, valorizing the achievements and considering the research gaps and opportunities, can provide solid scientific evidence to support informed actions towards the urgent need for better conservation and management of the biocultural patrimony in all biomes.

Author Contributions: Conceptualization, A.E.L.-R., A.F.R., G.P.d.S.S., L.S.C.d.A.B., J.S.F., M.D.; methodology, A.E.L.-R., A.F.R., G.P.d.S.S., L.S.C.d.A.B., J.S.F., M.D.; software, J.S.F.; formal analysis, A.E.L.-R., A.F.R., G.P.d.S.S.; investigation, A.E.L.-R., A.F.R., G.P.d.S.S., L.S.C.d.A.B., M.D., A.S., R.R.d.O.; writing—original draft preparation, A.E.L.-R., A.F.R., G.P.d.S.S. writing—review and editing, A.E.L.-R., A.F.R., G.P.d.S.S., L.S.C.d.A.B., M.D., J.S.F., A.S., R.R.d.O.; supervision A.S., R.R.d.O. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by Coordenação de Aperfeiçoamento de Pessoal—Brasil (CAPES) Finance Code 001 that supported PhD (G.P.S.S., A.F.R., L.S.C.A.B., J.S.F.) and postdoctoral stipends (A.E.L.R.). R.R.O. thanks the National Council for Scientific and Technological Development of Brazil (CNPq) for a research grant. A.E.L.R. thanks the Pontifical Catholic University of Rio de Janeiro (PUC-Rio) for the postdoctoral support for the main part of this research and the National Council for Science and Technology of Mexico (CONACYT) (226832) for the postdoctoral stipend while writing the manuscript.

Data Availability Statement: The datasets generated during the current study are available from the corresponding author on reasonable request.

Acknowledgments: We thank the valuable comments from the anonymous reviewers that enriched and helped to improve this manuscript substantially. We are deeply grateful for the kind help from the Sustainability Editorial Office.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A

Table A1. Details of affiliations per city of localization of all authors working in Brazil.

Affiliation	Abbreviation	City, State ¹	Biome
Universidade do Estado da Bahia	UNEB	Alagoinhas, BA	Atlantic Forest
Universidade Sagrado Coração	UNISAGRADO	Bauru, SP	Atlantic Forest and Cerrado
Museu Paraense Emílio Goeldi		Belém, PA	Amazon
Universidade Federal do Pará	UFPA	Belém, PA	Amazon
Universidade Federal de Minas Gerais	UFMG	Belo Horizonte, MG	Atlantic Forest and Cerrado
Intitudo Socioambiental		Boa Vista, RR	Amazon
Universidade de Brasília	UnB	Brasília, DF	Cerrado
Universidade Federal de Campina Grande	UFCG	Campina Grande, PB	Caatinga
Universidade Estadual de Campinas	Unicamp	Campinas, SP	Atlantic Forest
Universidade Federal do Mato Grosso do Sul	UFMS	Campo Grande, MS	Cerrado
Universidade Comunitária da Região de Chapecó	Unochapecó	Chapecó, SC	Atlantic Forest
Universidade do Estado da Bahia	UNEB	Conceição do Coité, BA	Caatinga
Universidade do Extremo Sul Catarinense	UNESC	Criciúma, SC	Atlantic Forest
Universidade Federal do Paraná	UFPR	Curitiba, PR	Atlantic Forest
Universidade Federal de Santa Catarina	UFSC	Florianópolis, SC	Atlantic Forest
Universidade Federal de Ceará	UFC	Fortaleza, CE	Caatinga
Universidade Federal de Goiás	UFG	Goiania, GO	Cerrado
Universidade Federal de Rondônia	UNIR	Guajará-Mirim, RO	Amazon
Universidade Estadual de Santa Cruz	UESC	Ilhéus, BA	Atlantic Forest
C&T Assessoria e Consultoria Ambiental		Itapetininga, SP	Atlantic Forest
Universidade Federal de Sergipe	UFS	Laranjeiras, SE	Atlantic Forest
Universidade Federal de Alagoas	UFAL	Maceió, AL	Atlantic Forest
Instituto Nacional de Pesquisas da Amazônia	INPA	Manaus, AM	Amazon
Universidade Federal do Amazonas	UFAM	Manaus, AM	Amazon
Universidade Estadual de Maringá	UEM	Maringá, PR	Atlantic Forest
Agência Paulista de Tecnologia dos Agronegócios—Polo Regional do Vale do Paraíba	APTA - Polo Regional do Vale do Paraíba	Pindamonhangaba, SP	Atlantic Forest
Escola Superior de Agricultura Luiz de Queiroz / Universidade de São Paulo	ESALQ/USP	Piracicaba, SP	Atlantic Forest

Table A1. Cont.

Affiliation	Abbreviation	City, State ¹	Biome
Escola Superior de Agricultura Luiz de Queiroz / Universidade de São Paulo	ESALQ/USP	Piracicaba, SP	Atlantic Forest
Universidade Federal do Rio Grande do Sul	UFRGS	Porto Alegre, RS	Pampa
Instituto Bioma Brasil		Recife, PE	Atlantic Forest
Universidade Federal Rural de Pernambuco	UFRPE	Recife, PE	Atlantic Forest
Universidade de São Paulo	USP	Registro, SP	Atlantic Forest
Secretaria de Gestão Administrativa do Estado do Acre		Rio Branco, AC	Amazon
Universidade Federal do Acre	UFAC	Rio Branco, AC	Amazon
Empresa Brasileira de Pesquisa Agropecuária - Solos	Embrapa Solos	Rio de Janeiro, RJ	Atlantic Forest
Fundación Oswaldo Cruz	Fiocruz	Rio de Janeiro, RJ	Atlantic Forest
Instituto de Pesquisas do Jardim Botânico do Rio de Janeiro	JBRJ	Rio de Janeiro, RJ	Atlantic Forest
Instituto Estadual do Ambiente	INEA	Rio de Janeiro, RJ	Atlantic Forest
Pontifícia Universidade Católica do Rio de Janeiro	PUC-Rio	Rio de Janeiro, RJ	Atlantic Forest
Secretaria de Estado do Ambiente do Rio de Janeiro		Rio de Janeiro, RJ	Atlantic Forest
Universidade Federal do Rio de Janeiro	UFRJ	Rio de Janeiro, RJ	Atlantic Forest
Universidade Federal de Santa Maria	UFMS	Santa Maria, RS	Pampa
Universidade Federal do Oeste do Pará	UFOPA	Santarém, PA	Amazon
Universidade de Santa Cecília	UniSanta	Santos, SP	Atlantic Forest
Universidade Federal de São Paulo	Unifesp	Santos, SP	Atlantic Forest
Universidade Federal de São Carlos	UFSCar	São Carlos, SP	Atlantic Forest and Cerrado
Escola Indígena Baniwa e Coripaco Pamáali		São Gabriel da Cachoeira, AM	Amazon
Instituto Socioambiental		São Gabriel da Cachoeira, AM	Amazon
Universidade Federal de São João Del-Rei	UFSJ	São João Del-Rei, MG	Atlantic Forest
Instituto Nacional de Pesquisas Espaciais	INPE	São José dos Campos, SP	Atlantic Forest
BirdLife/SAVE Brasil		São Paulo, SP	Atlantic Forest
Itaiti Consultoria Ambiental		São Paulo, SP	Atlantic Forest
Universidade de São Paulo	USP	São Paulo, SP	Atlantic Forest
Instituto Chico Mendes de Conservação da Biodiversidade		Sena Madureira, AC	Amazon
Empresa Brasileira de Pesquisa Agropecuária-Embrapa Agrobiologia	Embrapa Agrobiologia	Seropédica, RJ	Atlantic Forest
Universidade Federal Rural do Rio de Janeiro	UFRRJ	Seropédica, RJ	Atlantic Forest
Secretaria de Educação do Estado de São Paulo		Sorocaba, SP	Atlantic Forest
Instituto de Desenvolvimento Sustentável Mamirauá		Tefé, AM	Amazon
Universidade Federal do Espírito Santo	UFES	Vitória, ES	Atlantic Forest

¹ States of Brazil: AC-Acre, AL-Alagoas, AM-Amazonas, BA-Bahia, CE-Ceará, DF-Distrito Federal, ES-Espírito Santo, GO-Goiás, MS-Mato Grosso do Sul, MG-Minas Gerais, PA-Pará, PB-Paraíba, PR-Paraná, PE-Pernambuco, RJ-Rio de Janeiro, RS-Rio Grande do Sul, RO-Rondônia, RR-Roraima, SC-Santa Catarina, SP-São Paulo, SE-Sergipe.

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