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Research on the Brazilian Atlantic Forest (1989-2021): bibliometric and scientometric analysis

A pesquisa sobre a Mata Atlântica Brasileira (1989-2021): análise bibliométrica e cientométrica

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Abstract

Introduction: this study characterizes the results of research on the Brazilian Atlantic Forest, indexed in the databases of the Web of Science platform. It seeks to contribute to the formulation of strategic actions for the biome conservation, identifying publication gaps and trends. From a bibliometric and scientometric perspective, this study caracterizes the body of scientific articles on the biome during the 1989-2021 period. **Methods:** the methodological procedures involved the following steps: 1) Information Retrieval at the Web of Science databases; 2) Data processing, making use of text mining routines, which implied data cleaning, crossings, and elaboration of matrices; 3) Data representation, using Microsoft Excel® and Gephi tools. **Results:** the growth of scholarly communication on the Brazilian Atlantic Forest seems to be related to several historical and political factors that took place along 1989-2021. Inter-institutional relations occur mainly in the State of São Paulo, and a greater productivity and collaboration between researchers and institutions is observed in the Southeast Region of Brazil. Main research subjects are related to taxonomy, systematics, conservation and endemism. Recent themes have emerged over the last decade, such as ecosystem restoration, changes in land use and ecosystem services. **Conclusions:** publication metrics on the domain can contribute to prospect research partnerships and collaborations between researchers and institutions, and serve as a source of information for identifying niches of competence about the biome. A more focused understanding on the addressed topics can indirectly support technical and managerial areas for actions aimed at conservation and restoration of the biome.

Keywords: Scientific periodical production; Brazilian Atlantic Forest; Bibliometrics; Scientometrics; Scholarly communication.

Resumo

Introdução: *este estudo caracteriza os resultados da pesquisa sobre a Mata Atlântica brasileira, indexada nas bases de dados da plataforma Web of Science. Busca contribuir para a formulação de ações estratégicas para a conservação do bioma, identificando lacunas e tendências de publicação. A partir de uma perspectiva bibliométrica e cienciométrica, este estudo caracteriza o corpo de artigos científicos sobre o bioma durante o período de 1989-2021.* ***Métodos:*** *os procedimentos metodológicos envolveram as seguintes etapas: 1) Recuperação de informações nas bases de dados Web of Science; 2) Processamento de dados, fazendo uso de rotinas de mineração de texto, o que implicou limpeza de dados, cruzamentos e elaboração de matrizes; 3) Representação dos dados, utilizando as ferramentas Microsoft Excel e Gephi.* ***Resultados:*** *o crescimento da comunicação científica sobre a Mata Atlântica brasileira parece estar relacionado a diversos fatores históricos e políticos ocorridos ao longo de 1989-2021. As relações interinstitucionais ocorrem principalmente no estado de São Paulo, e observa-se uma maior produtividade e colaboração entre pesquisadores e instituições na Região Sudeste do Brasil. Os principais temas de pesquisa estão relacionados à taxonomia, sistemática, conservação e endemismo. Temas recentes surgiram na última década, como restauração de ecossistemas, mudanças no uso da terra e serviços ecossistêmicos.* ***Conclusões:*** *as métricas de publicação no domínio podem contribuir para prospectar parcerias de pesquisa e colaborações entre pesquisadores e instituições, além de servir como fonte de informação para identificar nichos de competência. Uma compreensão mais focada nos temas abordados pode subsidiar indiretamente áreas técnicas e gerenciais para ações voltadas à conservação e restauração do bioma.*

Palavras-chave: *Produção periódica científica; Mata Atlântica Brasileira; Bibliometria, Cientometria; Comunicação científica.*

INTRODUCTION

The Atlantic Forest, a biome considered as "National Heritage" in the Brazilian Federal Constitution of 1988, has been impacted by deforestation and forest fragmentation, during five centuries of occupation and use of its resources. It is considered one of the most diverse and threatened biomes in the world (Baltazar & Gibertoni, 2009). As it consists of a mosaic of heterogeneous and complex vegetation, created by different climatic, geomorphological and edaphic conditions, it presents one of the most diverse biota on the planet

(Figueiredo et al., 2021). Currently, between 27 and 32% of its endemic species are threatened with extinction (Strassburg et al., 2020).

Reduced to less than 12% of its original size, it is among the most critical biodiversity hotspots on the planet, due to the high levels of biodiversity combined with the degree of destruction and fragmentation that characterize its occupation and predatory exploitation (Rosa et al., 2021). Historically, this biome has been suffering from deforestation, selective tree cutting, fires, poorly planned land use, degradation of its water resources, among other factors, which have impacted the composition and floristic diversity of forest fragments and jeopardized survival, and the ecosystem services the biome provides to the population living in its surroundings (Joly, Metzger, & Tabarelli, 2014; Yamada, Pedrino, do Carmo Nicoletti, & Moschini, 2021). It was recognized by the United Nations Educational, Scientific and Cultural Organization (Unesco) as part of the worldwide network of biosphere reserves in 1991 (Atlantic Forest Biosphere Reserve, 2020).

Various social actors are involved in the conservation of the Atlantic Forest, contributing to the planning, elaboration, execution, regulation, and monitoring of conservation initiatives, programs, and public conservation policies. Particularly, the public sector has the mission of establishing medium and long-term mechanisms for conservation and "enforcing" environmental legislation, coordinating actions of different actors to fulfill the objectives of the biodiversity conservation policies (Young & de Castro, 2021). The National Institute of the Atlantic Forest (INMA) is a research unit linked to the federal government, through the Ministry of Science, Technology, and Innovation, which acts as one of the public agents that work in the planning of actions aimed at the conservation of the Atlantic Forest. INMA works by carrying out research, training human resources, as well as strengthening research capabilities that contribute to its purpose (Instituto Nacional da Mata Atlântica, 2022).

Characterizing the body of scientific knowledge on the Brazilian Atlantic Forest biome that is indexed in renowned international databases, such as those of the Web of Science (WoS) platform, is an important activity that supports indirectly strategic actions for planning public policies aimed at its conservation. Mapping and synthesizing the research carried out on the biome helps in understanding the dynamics of research outcomes in this domain, as well as in prospecting opportunities to strengthen its subject core.

Thus, the aim of this article is to characterize, from a bibliometric and scientometric perspective, the brazilian research outcomes on the Atlantic Forest indexed in the WoS databases during the 1989-2021 period. To this end, several analyzes were performed, including time series of publications, authors acting in this domain (and their respective affiliation institutions), journals that published research, as well as the research subjects represented by keywords. Information is presented based on productivity indicators and co-occurrence relationships between actors and themes.

BIBLIOMETRICS AND SCIENTOMETRICS APPLIED TO SCHOLARLY COMMUNICATION ANALYSIS

Bibliometric and scientometric analyzes are widely used in Information Science, as well as in other knowledge areas, to generate indicators on scholarly communication and collaborative research, to evaluate different aspects of the scientific activity carried out in a specific domain, for example, research areas, journals, participating institutions, or countries.

This type of analysis is also used to identify research gaps and trends, scientific collaboration patterns and networks, in different contexts. One of the studies that associates bibliometrics and scientometrics with data on deforestation and restoration practices is that of Zupo, Freitas, Reis, and Siqueira (2022). Authors mapped research in the context of restoration of the Brazilian Atlantic Forest, by presenting trend subjects, potential gaps and collaboration networks, in addition to showing the benefits of these collaborations. Santos, Malhado, Ladle, Correia, and Costa (2015) mapped the geographic and temporal distribution of publications on conservation in the Amazon and compared it with areas under threat of deforestation or with a high probability of a gradual transition from tropical forest to savannah. Aleixandre-Benavent, Aleixandre-Tudó, Castelló-Cogollos, and Aleixandre (2018) mapped research trends on deforestation and highlighted that social and economic aspects related to the topic have been little studied, while showing an important level of international collaboration between the United States, Brazil and the European Union.

Scientific collaboration studies have been used to identify and explain co-authorship relationships. However, it is known that possibilities of collaboration in science go beyond co-authoring articles and can include other forms of knowledge production and sharing, such as participation in research groups, partnerships in technical and scientific projects, guidance, supervision, participation in examining boards, cooperation in laboratories.

Even so, in the academic ecosystem, the co-authorship of articles occupies a prominent place in view of its materiality, expressed by the interaction between authors that generates a formal product, that is, a scientific paper. Journals are one of the most widely used means of scholarly communication, used by private or public databases, which index and systematize metadata and content according to objective selection criteria, and

make articles accessible in an integrated way. This context, reinforced by peer review, funding agencies' quality criteria and database indexing guidelines, consolidates a rigorous system that establishes relevance and impact parameters to classify journals, even influencing the distribution of resources for researchers and research groups, according to their performance within this system.

Thus, publication in journals is almost imperative and, given the complexity of obtaining acceptance of articles in the best classified vehicles, scientific collaboration is important, as it can impact on productivity, visibility and reach of scholarly communication (Glänzel, 2002; Lee & Bozeman, 2005; Persson, Glänzel, & Danell, 2004; Rosas & Grácio, 2014).

MATERIALS AND METHODS

This study uses techniques for retrieving information from databases, and bibliometrics and scientometrics methods to generate productivity and relational indicators on the field of scientific research on the Brazilian Atlantic Forest. In the following, the methodological procedures are presented according to the execution steps.

Data search and recovery strategy

The WoS (Clarivate Analytics) was used to identify and retrieve the literature on the Brazilian Atlantic Forest, as it is a well-known platform that provides access to several multidisciplinary databases, covering a significant part of renowned journals in the studied area. Searches were carried out in the Title, Abstract and Keyword fields of the Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (AHCI) and Emerging Sources Citation Index (ESCI) databases, using the following search strategy: ("Atlantic Rain Forest" OR "Atlantic Forest" OR "Atlantic Tropical Forest"). Retrieved articles and review articles included at least one author from a brazilian institution and were published during the period of 1989-2021. Data collection was performed on August 22, 2022. Records were exported in .txt format. Access to the platform was carried out through the Capes Journal Portal.

Data processing and representation

The set of records was made readable through a filter available in the VantagePoint®software. Clean up text mining routines were performed to clean and standardize data and, subsequently, cross variables, enabling the interweaving of fields for multivariate analysis, as well as the elaboration of representative matrices of co-occurrence networks.

The lists and matrices generated in VantagePoint®were imported into Microsoft Excel® for better formatting of tables and graphs. The Gephi software (v. 010) was used to analyze the set of relationships established between institutions and keywords, maximizing the perception of relationships between the observed variables.

Complementary data sources

Information from the Lattes Platform of the National Council for Scientific and Technological Development (CNPq) was also used to identify and contextualize the trajectory of those researchers who stood out in the scientific production on the Atlantic Forest and their scientific bibliographies. Regarding the journals in which articles are published, indicators from the Journal Citation Reports (JCR) made available by the Clarivate Analytics Platform were consulted.

Generated Indicators

The profile and development of research on the Brazilian Atlantic Forest were presented and analyzed using the following indicators: annual distribution of publications; distribution of publications by research area; subject co-occurrence networks based on the keywords of the articles; leading scientific journals and research institutions; institutional network of co-authorship and highly productive researchers.

RESULTS AND DISCUSSION

The data collection identified 8.891 publications (articles and review articles) on the Brazilian Atlantic Forest by authors from Brazilian institutions, published in journals indexed in WoS databases during the period of 1989-2021.

Figure 1 presents the diachronic evolution of publications and allows identifying three periods: 1989-1996, characterized by an incipient production ($n = 49; 0.5\%$ of the total), and less than 20 articles per year ($\overline{x} = 6.1$); 1997-2006, period that marks the beginning of the growth of production on this subject in Brazil ($n = 307; 3.4\%$ of the total) with more than 20 articles per year ($\overline{x} = 43.9$); 2007-2021, showing a sustained and significant

growth in research outcomes on the Brazilian Atlantic Forest (n=8,635; 96.0%), with more than 90 annual publications ($\overline{x} = 43.9$) = 479.7). However, the growth rates in the 32 years express distinct moments, even though, in continuous growth.

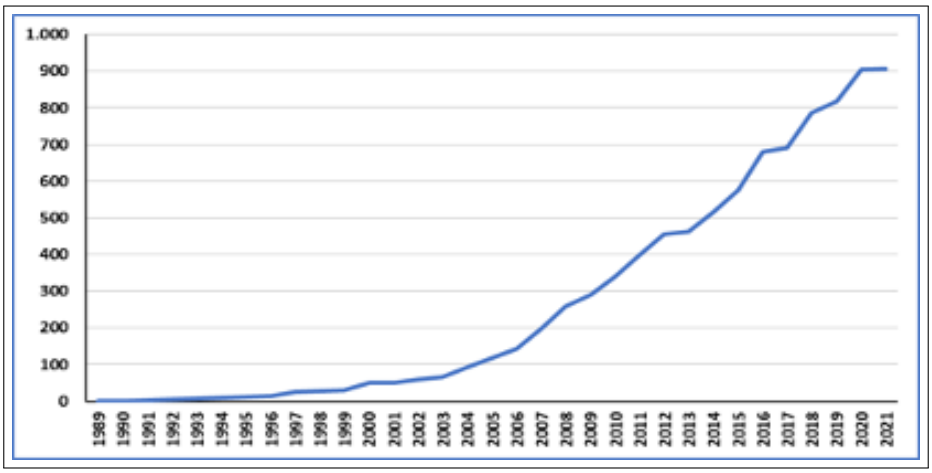

Figure 1. Distribution of articles on the Atlantic Forest in the WoS database by year (1989-2021).

It is observed that publications on the Atlantic Forest biome were not very expressive before the 2000s. The initial growth observed in the 1990s seems to be the result of several factors, including the ECO 92 World Conference, an event that Talamini, Schinaider, Schinaider, and Liberalesso (2017) consider a milestone that contributed to change the socio-environmental paradigm in Brazil. Although the conference is not characterized as an academic event, it was emblematic as a representation of a new world order that moved different segments of society, including academia.

Hochstetler and Keck (2007) characterize three phases of environmental activism in the world. The beginning of the third environmentalist wave, according to Sedrez (2009, p. 230) was marked, in Brazil, by the Federal Constitution of 1988. According to the author, the period was characterized by the triple challenge of democratic restoration, economic crisis and exponential increase in contacts with international agencies and activists, in a movement that continues up to the present. It is suggested here that these changes in the political context may have influenced the interest of researchers in relation to the environmental theme, which was gaining ground in different parts of the world and, above all, may have influenced the research agenda in the environmental area in Brazil.

This line of thought is in accordance with the results presented by Silva et al. (2020) who analyzed the results of research on non-timber forest products in Brazil (considering the Atlantic Forest), and identified that the consolidation of the publications on the subject also began in the 1990s.

Furthermore, recognition of the Atlantic Forest biome in Brazil was not very expressive before the 2000s. The first legal instruments for its protection, as well as the regulations for the explotation of its resources, began to be implemented during the period of 1989-2000, standing out the Federal Ordinances of IBAMA (218/1989 and 438/1989), the Federal Decree No. 99,547/1990, Bill No. 3.285/1992, and Federal Decree No. 750/1993, as well as the recognition of the Atlantic Forest as national heritage in the environment chapter of the Federal Constitution of 1988 (Conselho Nacional da Reserva da Biosfera da Mata Atlântica, 1999). Moreover, the National Environmental Program (PNMA), created in 1991, was the first major investment by the Brazilian government in the environmental area, and allowed for the improvement of the institutional capacity of federal and state environmental agencies and the formulation of environmental policies (Moura, 2016).

In principle, the reduced number of articles published in the period indicate these normative measures, did not directly impact the results of the research on the Atlantic Forest. Likewise, it seems that several relevant events occurred in the late 1980s and early 1990s, which culminated in social recognition of the Atlantic Forest biome in Brazil, also had no direct impact. One of them was the creation of Fundação SOS Mata Atlântica, in 1986, a non-governmental organization (NGO) with the mission of conserving the natural and historical heritage of the biome with a view to sustainable development for the preservation of flora and fauna (see https://www.sosma.org.br/). Another event was the recognition in 1991, by Unesco, of the Atlantic Forest as a Biosphere Reserve (RBMA, 2020).

Moreover, it should be noted that several scientific workshops took place in the 1990s and contributed to the creation of an important data collection on the Atlantic Forest. A case in point was the First "Atlantic Forest Science, Conservation and Policy Workshop" (Conselho Nacional da Reserva da Biosfera da Mata Atlântica, 1999) held in 1996, which brought together specialists from academic institutions, NGOs, state and federal environmental agencies and experient researchers, to discuss the "regulation of the legislation that provides

for the protection and exploitation of the biome, involving the definition of its scope, in addition to proposing guidelines for a national policy on the entire Atlantic Forest region" (Conselho Nacional da Reserva da Biosfera da Mata Atlântica, 1999, p. 15). Ten years later, the Atlantic Forest Law was instituted (Lei nº 11.428, de 22 de dezembro de 2006, 2006).

The growth of publications during the period of 2000-2010 may have been influenced by what Gläser and Laudel (2016) call the indirect effects of policy priorities in research (Gläser & Laudel, 2016). During this period, government implemented policies to encourage funding for specific research areas, seeking to influence researchers and institutions that, in turn, responded strategically to these demands, creating and developing projects and research lines linked to government actions.

Thus, in 2000, through Lei nº 9.985, de 18 de julho de 2000 (2000), the National System of Nature Conservation Units (SNUC) was created, which promoted a better organization of the Nature Conservation Units (UCs) and the protection instruments that already existed in other laws (Moura, 2016). In 2006, Lei nº 11.284, de 11 de março de 2006 (2006) was approved, which provides for the management of public forests and establishes the Brazilian Forestry Service (SFB), also creating the National Fund for Forestry Development (FNDF). In 2007, the Chico Mendes Institute for Biodiversity Conservation (ICMBio) was created, an NGO linked to the Ministry of the Environment, responsible for the management and inspection of federal UCs, promotion and execution of research programs, as well as of other programs of protection, preservation and conservation of biodiversity (Moura, 2016).

Research Areas and subjects

The scientific periodical production on the biome was concentrated in 37 major areas of research (20 publications or more) out of a total of 85 areas. The classification considered the WoS scheme and was introduced in this research to reorder the corpus of analysis through a thesaurus in VantagePoint, which locates the ISSN of journals and replaces them with their corresponding research areas. Thus, it is worth mentioning that an article categorized into one area, can also be considered in another(s) (Figure 2).

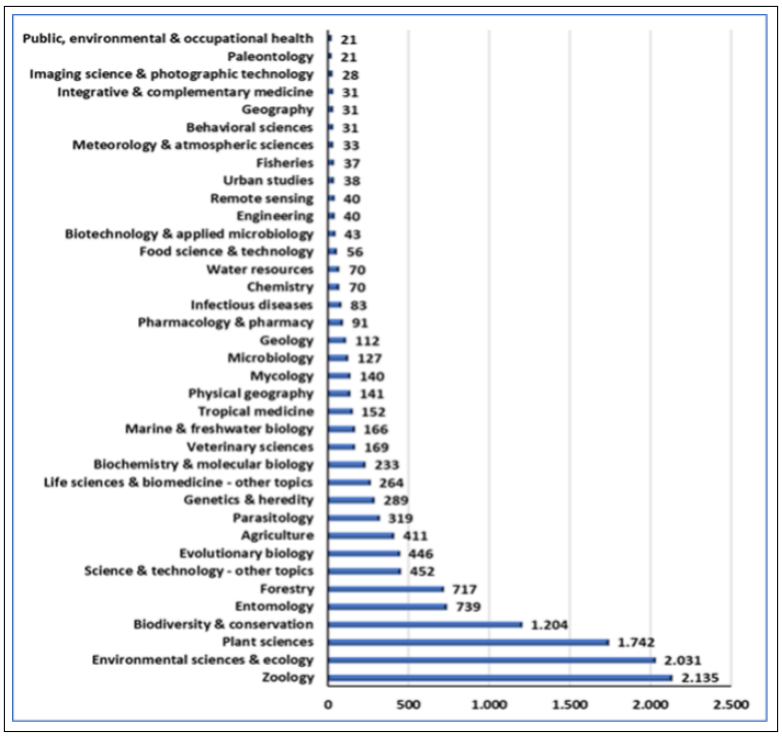

Figure 2. Research areas on the Atlantic Forest in the WoS (1989-2021).

The most prominent areas (1,000 articles or more) are: Zoology; Environmental sciences & Ecology; Plant sciences and Biodiversity and Conservation, which together represent 79.1% ($n = 7,112$) of the total number of articles ($n = 8,991$). Studies related to research in Social Sciences and Humanities do not appear in this list because they do not reach a minimum of 20 publications, therefore, they were considered as quantitatively inexpressive for the analyses.

The emphasis on Zoology, Ecology, Botany and Biodiversity Conservation is in line with the predominant subjects identified by the keywords analysis; at the same time there were 600 keywords out of 2,471 that reached less than 10 occurrences. For the conformation of Figure 3 were chosen 31 keywords that had 75 occurrences or more and that were correlated ten times or more with other keywords.

It is suggested that the predominance of research publications in the areas of Natural Sciences may reflect specific incentives arising from research programs on Biodiversity and the Environment. As an example, Biota Fapesp Program was launched in 1999 because of the articulation of the scientific community of the State of São Paulo around the premises advocated by the Convention on Biological Diversity, signed during ECO-92 and ratified by the National Congress in 1994[1]

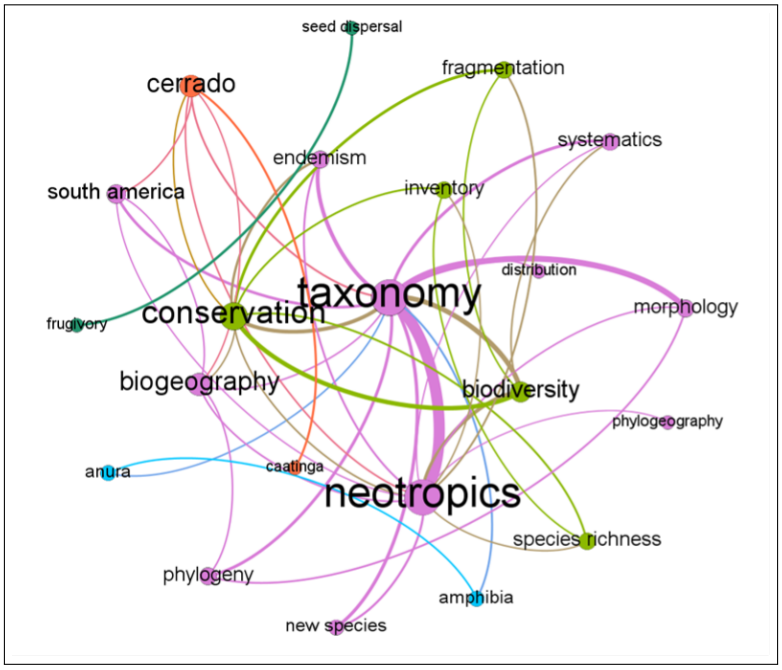

Figure 3. Correlation between authors' keywords.

The most common term "atlantic forest", as well as some of its variations, were excluded from the network, to obtain a more accurate picture of the main subjects. It was observed that, despite achieving great quantitative representation, this term was generic, thus, adding little to the analysis. Two keywords, "taxonomy" and "neotropics", stood out with more than 500 occurrences, and were followed by "conservation", "biodiversity", "fragmentation", "biogeography", "Cerrado", among others. Taxonomy represents a field of biology that defines, classifies and names groups of biological organisms based on common characteristics. Therefore, the high number of occurrences of this term was expected, since the Atlantic Forest is one of the biomes with the richest biodiversity of flora and fauna species on the planet, and considered one of the 25 world biodiversity hotspots (Tabarelli, Pinto, Silva, Hirota, & Bedê, 2005). The term "neotropics" and other analogues (e.g., neotropical region, neotropical flora, neotropical forest) reflect a focus on terrestrial tropical and temperate Atlantic Forest ecoregions. On the other hand, such keywords as "biodiversity", "conservation", and "fragmentation", reflect researchers concern with the environmental health of the ecosystems that make up the biome and, consequently, with its importance for the quality of life of the population in its surroundings.

Other keywords such as "restoration ecology", "land use", "climate change" and "ecosystem services", although not included in the network, are among the first 60 keywords, having a minimum of 70 occurrences. The first appearances of these keywords date back to 2009 and research on these subjects have shown an important growth trend in the last decade, pointing to concerns about ecosystems sustainability and life on the planet. This trend may be related to Brazil's adherence to international agreements, defining commitments and targets aimed at reducing greenhouse gas emissions, mitigating the effects of climate change and ecological restoration. In addition, the 2020s was named the Decade of Restoration for the United Nations (United Nation Environment Programme [UNEP]), a factor that also may also have stimulated research on the subject. Keywords, associated with such terms as deforestation, habitat loss and defaunation, showed between 50 and 70 occurrences, indicating important aspects to be addressed by ecological restoration activities.

Scientific journals

The identification and classification of the main vehicles used by researchers to communicate their works contribute to the comparison and representation of research outcomes on the Atlantic Forest, enabling researchers to better understand the dynamics of their own research field. Furthermore, these indicators can serve researchers as parameters to direct their research on this subject.

[1] https://www.biota.org.br/

The 8,891 articles were published in 975 journals, and 203 of them (20.8%) represent 81.7% of the articles ($n = 7,346$). This reveals that this corpus of articles presents a regularity that in bibliometric studies is expressed by Bradford's law (Bradford, 1934) and distinguishes journals that concentrate publications on a certain subject (seen as core), to the detriment of those that eventually publish on the topic (dispersal).

Additionally, 37 journals (3.8%) published 50 articles or more, with emphasis on 13 journals (with 100 articles or more) which concentrated 25.1% of the total number of papers ($n = 2,390$). Table 1 presents the number of articles published in these 13 journals over the period of 1989-2021, as well as the percentage contribution of each of them to the total number of articles on the Atlantic Forest. It is noteworthy that these 13 journals were continuously included in the JCR for more than a decade, showing outstanding Journal Impact Factor (JIF) and being classified in Q1-Q4 Quartiles in different journal categories (Table 2).

Journal Title	Country	Number of Articles	% of Total
ZOOTAXA	New Zealand	445	4.95%
BIOTA NEOTROPICA	Brazil	306	3.40%
PHYTOTAXA	New Zealand	303	3.37%
ACTA BOTANICA BRASILICA	Brazil	218	2.42%
PLOS ONE	United States	182	2.02%
BIODIVERSITY AND CONSERVATION	Not identified	130	1.45%
ZOOLOGIA	Brazil	130	1.45%
BIOTROPICA	Not identified	126	1.40%
SYSTEMATIC BOTANY	United States	118	1.31%
BRAZILIAN JOURNAL OF BIOLOGY	Brazil	111	1.23%
FOREST ECOLOGY AND MANAGEMENT	Not identified	111	1.23%
REVISTA BRASILEIRA DE ENTOMOLOGIA	Brazil	109	1.21%
CIÊNCIA FLORESTAL	Brazil	101	1.12%

Table 1. Journals with the highest number of publications (1989-2021)

Journal Title	Years in JCR	JIF (JCR) Range	Quartile	Journal Category
ZOOTAXA	2006-2021	0.612-1.091	Q2-Q3	Zoology
BIOTA NEOTROPICA	2012-2021	0.423-1.467	Q3-Q4	Biodiversity Conservation
PHYTOTAXA	2011-2021	1.007-1.797	Q2-Q4	Plant Sciences
ACTA BOTANICA BRASILICA	2010-2021	0.368-1.395	Q3-Q4	Plant Sciences
PLOS ONE	2009-2021	2.740-3.752	Q1-Q2	Multidisciplinary Sciences
BIODIVERSITY AND CONSERVATION	1992-2021	1.091-4.296	Q1-Q2	Biodiversity Conservation
ZOOLOGIA	2010-2021	0.373-0.859	Q3-Q4	Zoology
BIOTROPICA	1997-2021	0.542-2.989	Q2-Q3	Ecology
SYSTEMATIC BOTANY	1997-2021	1.106-2.300	Q3-Q4	Evolutionary Biology
BRAZILIAN JOURNAL OF BIOLOGY	2010-2021	0.479-1.651	Q3-Q4	Biology
FOREST ECOLOGY AND MANAGEMENT	1997-2021	0.817-4.384	Q1-Q2	Forestry
REVISTA BRASILEIRA DE ENTOMOLOGIA	2007-2021	0.354-1.103	Q2-Q4	Entomology
CIÊNCIA FLORESTAL	2007-2021	0.063-0.630	Q4	Forestry

Table 2. Journals with the highest number of publications in the JCR.

There are three journals that stand out when considering the number of published articles published, their JIF (JCR) and the quartile in which they are classified: PLOS ONE; Biodiversity and Conservation; and Forest Ecology and Management.

PLOS ONE is a multidisciplinary/interdisciplinary journal published by the Public Library of Science (PLOS), which accepts manuscripts presenting basic research results, systematic reviews, submissions describing methods and applications (e.g., software, databases), qualitative research and research protocols of more than two hundred subject areas, including the natural sciences, engineering, medicine, social sciences, human sciences, among others[2]. This journal has been classified in the JCR since 2009. During this period, it reached JIF values (JCR) ranging between 2.740 and 3.752 and was classified in Q1 and Q2 quartiles in the category of multidisciplinary sciences.

In turn, Biodiversity and Conservation is a renowned international multidisciplinary journal published by Springer since 1992. It publishes comprehensive topics, considering aspects of biological diversity, its conservation, and sustainable use. Its subject covers rapid assessment approaches, such as estimating species numbers and diversity (by traditional, molecular, or proxy methods), habitat management, conservation policies and regulations, threats,

[2]https://journals.plos.org/plosone/s/journal-information#loc-scope

biodiversity loss, extinction and documentation of long-term changes, and ex situ conservation[3]. It has been classified in the JCR since 1997, achieving high JIF values (1.091-4.296) and being included in Q1-Q2 quartiles.

Forest Ecology and Management, a journal published by Elsevier, reports research findings related to forest ecology and forest management, with a focus on the application of biological, ecological, and social knowledge to the management and conservation of plantations and natural forests[4]. The journal appears in the JCR since 1997, with JIF values ranging between 0.817-4.384, and framed in the Q1-Q2 quartiles until 2021.

Interinstitutional co-authorships

The 8,891 articles were published by authors associated with to 2,253 institutions, highlighting 20 Brazilian institutions with more than 270 publications. The leading countries by number of institutions include Brazil with 1,093 institutions (48.5%), the United States with 259 (11.5%), Germany with 85 (3.8%), the United Kingdom with 73 (3.8%), Argentina and Spain with 41 (1.8%), among others.

The list of institutions with the highest number of publications on the Atlantic Forest was related and compared with its position in the 2022-2023 ranking of the Times Higher Education (THE) (Table 3). This ranking classifies institutions around the world and in Latin America considering 13 performance criteria for five major areas: teaching, research, citation, internationalization, and impact on industry. In this paper, the research score was specified and ranked separately to compare the research productivity of institutions on the Brazilian Atlantic Forest. Brazil has 70 universities listed in this ranking.

This comparison sought to verify whether there is a relationship between the position in the institution's productivity ranking and the productivity in matters related to the Atlantic Forest, that is, whether the Brazilian Institutions that stood out in publications on the Atlantic Forest also stood out for being part of a group of renowned Latin American universities in relation to their research activities.

Institution	Number of Publications on the Atlantic Forest at WoS (1989-2021)	Latin America Ranking (THE 2022)	Latin America Research Score[a] (THE 2022)
USP	1,810	2	100
UNESP	966	12	99.5
UFRJ	939	11	97.3
UNICAMP	757	3	100
UFPR	605	20	85.4
UFPE	601	37	65.2
UFMG	551	9	87.5
UFV	472	19	85.4
UFRRJ	445	N/A	N/A
UFRGS	400	8	92.7
UESC	388	126-150	21.3
UFSC	383	6	94.7
EMBRAPA	366	-	-
UFES	363	54	50.3
FIOCRUZ	344	N/A	N/A
UFSCAR	341	17	91.0
UERJ	327	23	74.6
UFPB	299	78	45.0
JBRJ	293	-	-
UFLA	277	24	83.5

Table 3. Comparison of institutional rankings: Research productivity on the Atlantic Forest in WoS x THE Ranking of the best universities in Latin America.

[a]The Research Score corresponds to 30% of the score that makes up the general ranking of THE and is evaluated based on three criteria: research productivity, research into the university's reputation and the amount of funding the Institution receives.

Of the twenty most productive Brazilian institutions on the Atlantic Forest subject, ten are among the top 20 Latin American institutions in the 2022-2023 THE ranking, revealing that the prominence they achieved is consistent with their macro performance as reflected by their evaluation score in Latin America (Table 3).

It is observed that such institutions as the Federal University of Pernambuco (UFPE), the Federal University of Espírito Santo (UFES) and the State University of Santa Cruz (UESC) (Table 3) appear among the 11

[3] https://www.springer.com/journal/10531
[4]https://www.journals.elsevier.com/forest-ecology-and-management

most productive, however, they do not appear among the best evaluated in the Research Score item by THE Ranking. It is also important to highlight that several internationally renowned Brazilian Institutions, such as the Brazilian Agricultural Research Corporation (Embrapa), the Oswaldo Cruz Foundation (Fiocruz) and the Rio de Janeiro Botanical Garden Research Institute (JBRJ), do not appear in the THE ranking because they are not universities, although they have graduate programs and a significant and qualified production related to the Atlantic Forest.

All mentioned institutions are public, mostly Higher Education Institutions (HEIs). Many are geographically concentrated on the brazilian atlantic coast, a fact that may influence the prioritization of research topics. The study by Lima, De Marco Junior, and Lima-Junior (2021) corroborates the possibility of an association between the region where the authors work and research on regions, biomes, basins, and deficits in knowledge about biodiversity. The cited authors noticed a bias in the distribution of publications, thus, researchers located along the brazilian coast were the ones most focused on the Atlantic Forest.

Figure 4 shows the co-authorship network of research institutions with papers on the Atlantic Forest. To generate the graph, only those institutions with at least 30 co-occurrences were represented. In addition, the co-occurrence network represents only those institutions with a minimum weight of 6 among the links, to form a network centered on the most representative authors.

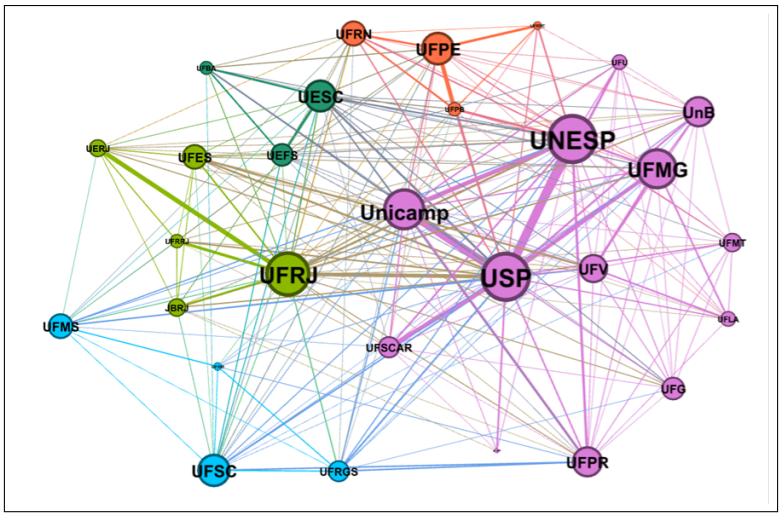

Figure 4. Co-authorship network between research institutions.

A total of 29 nodes and 230 edges were identified. Stronger inter-institutional coauthor relationships were observed between USP & Unesp ($n = 167$); USP & Unicamp ($n = 153$); UFRJ & UERJ ($n = 83$); Unesp & Unicamp ($n = 83$); USP & UFSCar ($n = 79$); UFPE & UFPB ($n = 76$); USP & UFMG ($n = 32$). Particularly, USP ($n = 1,143$), Unesp ($n = 753$) and UFRJ ($n = 581$) achieved the highest weighted degree, which according to Abbasi, Altmann, and Hossain (2011), represents the sum of all the weights of the edges connected to a node, that is, the number of times two nodes are related. This index is influenced by the number of interactions between one actor and the other actors in the network; thus, in this case, it demonstrates the articulation capacity of institutions to produce collaborative research.

USP and Unesp prominence is also noticeable in Closeness Centrality (C), a metric that represents the proximity of a given node to others. In this case, the values range from zero to one, with the latter indicating the highest proximity centrality in the network. Values obtained by USP and Unesp (C=1), and UFRJ ($C = 0.93$), indicate the paths between these institutions and other actors are shorter than average, and demonstrate that, in addition to producing a high number of publications, they also collaborate with various institutions. Another important measure is the Betweenness Centrality, a measure that indicates those actors (nodes) that interconnect regions of the network, that is, those who act as bridges between different groups (clusters), serving as interlocutors between the most prominent nodes, and the distant ones. The following institutions stand out in this regard: USP, UFRJ, Unesp, Unicamp, UFPE, UFMG.

A direct relationship was observed in co-authorship between geographically close institutions, which can be explained by the study developed by Sidone, Haddad, and Mena-Chalco (2017), showing that geographical distance is decisive in the articulation of scientific collaboration networks in Brazil, since the increase of 100 km of distance between two researchers implies a reduction, on average, of 16% in the probability of collaboration. Thus, there is greater intensity in interactions between institutions in the same state, or even in the same region of the country.

However, the Federal University of Mato Grosso do Sul (UFMS), stands out, highlighted in the blue cluster with

at least 30 co-occurrences, as it is located in the center-west of Brazil, a region that has a minimal portion of the Atlantic Forest biome.

Most representative authors according to the article productivity criterion

Regarding productivity, the ten most representative authors in the domain were specified in Table 4. Their education, training, professional and research background were mapped, as well as the existence of CNPq's productivity research fellows on this list. It is observed that nine out of ten researchers (90%) have CNPqs fellowships – (PQ modality), six at level PQ 1A, two at PQ 1B and one at PQ 1C level. The results are similar to those found in other areas; Grácio, de Oliveira, et al. (2011) observed that 64% of the most productive researchers in an Information Science segment were CNPq research fellows; Sobral, Duarte, Santos, and Mello (2020) found that 88% of the most productive researchers in a health area were CNPq research fellows too, with the vast majority belonging to the PQ modality; Martelli-Junior et al. (2010) also highlighted the importance of CNPq's research grants, as a mechanism to induce an increase in the publication of articles in high-impact journals.

Authors	Articles	Fund PQ CNPQ	Affiliation	Undergraduate Degree	Masters Degree	PhD Research area
Haddad, CFB	146	PQ 1A	Unesp	Biological Sciences	Ecology	Zoology and Ecology
Tabarelli, M	91	PQ 1 A	UFPE	Agronomic Engineering	Ecology	Ecology and Plant Conservation
Brancalion, PHS	89	....	USP	Agronomic Engineering	—	Tropical Forestry
Galetti, MR	89	PQ 1B	Unesp	Biological Sciences	Ecology	Ecology: defaunation and forest fragmentation
Metzger, JPW	89	PQ 1A	USP	Biological Sciences	Ecology	Landscape ecology and biodiversity conservation
Ribeiro, MC	81	PQ 1C	Unesp	Computer Science	Remote Sensing	Modeling in spatial ecology
Labruna, MB	80	PQ 1A	USP	Veterinary Medicine	Veterinary Medicine	Veterinary Medicine, emphasis on Parasitic Animal Diseases
Rodrigues, RR	80	PQ 1B	USP	Biological Sciences	Plant Biology	Ecology and forest restoration
Rocha, CFD	79	PQ 1A	UERJ	Biological Sciences	Ecology	Vertebrate Ecology
Freitas, AVL	74	PQ 1A	Unicamp	Biological Sciences	Ecology	Ecology: Systematics and Evolution of Lepidoptera

Table 4. Most productive authors on the Atlantic Forest subject: educational, training, profissional and research area.

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The authors in Table 4 are mostly from institutions located in the southeastern region of Brazil, with emphasis on the USP (40%) and the Unesp (30%); only one author was from a university located in the northeast region (UFPE). In addition, researchers' training is predominantly focused on the field of Biological Sciences, followed by Agricultural Sciences, Health Sciences and Exact and Earth Sciences, according to the classification of knowledge areas by CNPq.

CONCLUSIONS

The publication metrics on the Brazilian Atlantic Forest contribute to prospecting partnerships and research collaborations between researchers and institutions that work with the subject and serve as a source of information for the identification of niches of competence, a necessary action for the strengthening of public and scientific policies aimed at the conservation and restoration of this biome. The generated indicators highlight some aspects of the research results published on the Atlantic Forest, and its relationship with the main legal and political events that occurred in Brazil and contributed to the social recognition of this biome.

Knowledge gaps to be filled in the literature were also identified, for example, the topics that emerged in the last decade, such as ecosystem restoration, changes in land use, and ecosystem services. A deeper understanding of these issues in new research can support technical and managerial areas for actions aimed at conservation and restoration. It should be noted that inter-institutional relations occur mainly in the State of São Paulo, as well as greater productivity and collaboration between researchers and institutions in the Southeast Region of Brazil.

Research on the biodiversity of the Brazilian Atlantic Forest, as well as the balance between the conservation of it's natural resources and human development, must seek constant interaction between different scientific domains, as it is a geographic area that concentrates more than 70% of the Brazil's economy, while its conservation has social, environmental, political and economic importance, for the population that lives in its surrounding (around 145 million inhabitants).

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