Chapter 18

Trends and Patterns of Scientific Publishing during 1990-2020 on Conservation Genetics in Brazilian Atlantic Rainforest

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Trends and Patterns of Scientific Publishing during 1990-2020 on Conservation Genetics in Brazilian Atlantic Rainforest

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Abstract

The destruction of Brazilian ecosystems is among the most alarming national and international conservation issues. It is opportune to optimize management strategies in these areas. To protect the genetic resources in the long term, it is necessary to consider the characterization (or the study) of genetic diversity of its populations. This approach has been applied to different species, population sizes, distinct biomes and wide range of ecological and molecular questions. The objective of this study was to identify trends and patterns of scientific publications in conservation genetics in Brazilian Atlantic Rainforest, historically the most devasted Brazilian biome. Through a scientometrics approach, using the Scopus database, papers published between 1990 and 2020 were selected. Total 80 papers were found corresponded to the research topics. The University of São Paulo and the State University of Santa Cruz are the most representing institutions and the sponsors of projects. The high number of microsatellite markers or the combination of other markers revealed that genomics is not implemented yet as a current framework. The molecular tools have been used to attend 109 species, with 56 related to flora and 24 to fauna. It is pointed out that the low number of published papers in Brazilian Atlantic Rainforest biome is reflection of some factors, from insufficient funding to difficulties in carrying out studies with international partnerships. In addition, in the 1990s, most scientific publications in Brazil were in the native language, so the indexing bases did not count these papers. This work is the first overview of the published literature and allowed to diagnose the studies carried out in the conservation area of the Atlantic Forest biome with molecular markers.

Keywords

Biodiversity; Conservation Strategy; Population Genetics; Tropical Ecosystem

Citation

Siqueira, M.V.B.M., de Brito, G.R. and de Moraes Silvestre, M.A. (2023). Trends and Patterns of Scientific Publishing during 1990-2020 on Conservation Genetics in Brazilian Atlantic Rainforest (Chapter.18). *In* Hasrat Arjjumend (ed.), *Mountain Ecosystems and Resources Management*, vol. 1, pp.327-344. Montreal/Vancouver, Canada: The Grassroots Institute. eISBN: 978-1-7778455-0-6. Doi: https://doi.org/10.33002/mount.a/18

Edited by Dr. Hasrat Arjjumend

1. Introduction

Tropical forests are of immeasurable importance for the ecological stability of the planet; they support at least two-thirds of the world's biodiversity, despite covering less than 10% of the Earth's land surface. However, the prospects for tropical forests are becoming increasingly bleak due to continued deforestation and forest conversion (Giam, 2017). Beech *et al.* (2017) reported that there are 60,065 tree species recorded worldwide. The country with the most diverse tree flora is Brazil (8,715 species) followed by Colombia (5,776 species) and Indonesia (5,142 species). Almost 58% of all tree species are endemic to a single country, with Brazil having a prominent position with the highest number of species (4,333 species).

It has been reported that the current biota is entering a "sixth" mass extinction, because of chronic exposure to human activities (Khan *et al.*, 2016). Currently, the IPCC (Intergovernmental Panel on Climate Change) report indicated that there was an increase of 1.1˚C temperature compared to the pre-industrial period, causing a decrease in glaciers and high sea levels, due to the presence of high concentrations of greenhouse gases. Consequently, we have verified a higher average temperature in several regions of the planet. It is also predicted that around 8% of the plant species around the world will be affected by climate change in the next 20 years. To reverse this scenario, it is necessary to reduce emissions of these gases by 7.6% per year, by 2030 (IPCC, 2018) and encourage biological conservation in all countries.

However, Brazil lacks the conservation of its biological heritage, as shown by data available on government websites regarding Brazilian biomes. Existing Conservation Units (CUs) in the country do not even protect 50% of the total area of each biome. In the Amazon, the Brazilian terrestrial biomes are mostly protected by CUs. There are 77 CUs of Integral Protection (PI) conserving 411,114 km^2 covering about 9.4% of the biome's area, and 237 CUs of Sustainable Use (SU) having jurisdiction of 701,212 km^2 covering just 16% of the area, totaling approximately one million km^2 (26.1% of the biome, disregarded Indigenous lands). In the other biomes, the situation is more critical since there is only 9.3% of the protected area exists in the Brazilian Atlantic Rainforest (BAF), 8.3% exists in the Brazilian Savanah (Cerrado), 6.26% exists in the Caatinga, 2.63% exists in the Pampa, and only 2.94% exists in the Pantanal (ICMBio, 2020).

Recently some researchers reported the importance of forests to conserve biodiversity, to supply ecosystem services, and to provide steppingstones, corridors, fauna and flora refuges, and to assist other key conservation elements (Arroyo-Rodríguez *et al.*, 2009; Brancalion *et al.*, 2012; Chazdon *et al.*, 2009; Viani *et al.*, 2015). In this context, there was a significant increase in the numbers of researches in BAF. However, the volume of this information is still incipient taking into account the high number of endemic species in this biome (Joly *et al.*, 2014). Less than 1% of the remnant area in BAF has been sampled, and most of the current knowledge about this domain comes from private lands and areas outside of forest reserves (Lima *et al.*, 2015). Mangueira *et al.* (2021) underscore the importance of continuing research on how to proceed with the restoration of forest remnants to improve strategies for the biodiversity conservation in BAF.

Conservation biology strives to conserve biodiversity and biological processes in ecosystems, of which genetic variation is a key component (Geffen *et al.*, 2007). With the advancement of molecular biology techniques, the manipulation of genomic DNA in the laboratory has become a routine methodology in conservation programs. In Brazil, it began

in the 1980s with the use of the biochemical genetic marker of alloenzymes. In the 1990s, this marker technique started to be replaced by other techniques e.g., RAPD (*Random Amplified Polymorphism DNA*), RFLP (*Restriction Fragment Length Polymorphism*) and SSR (*Simple Sequence Repeats*). Currently, the most used markers are SSR and SNPs (*Single Nucleotide Polymorphism*), and there is a tendency to improve new methodology in accordance with advances in large-scale sequencing techniques. The clear presence of various types of molecular markers and differences in their principles, methodologies and applications require careful consideration in choosing one or more of these methods according to the application, as well as the resources (technical, financial and equipment) available in each research center (Turchetto *et al.*, 2017). In the coming decades, Fischer *et al.* (2017) suggests that, although SSR are well established in conservation genetics, they show limitations in certain genetic processes and that large SNP panels will represent genome-wide patterns in a more accurate way.

In this context, researchers have adopted the conservation genetics like a new approach to biodiversity studies and have used molecular genetic analysis to elucidate relevant aspects of species biology for management and conservation purposes (Frankham *et al.*, 2002). However, Holderegger *et al.* (2019) pointed out that it is necessary to establish coherence and trust between scientists and practitioners so that conservation genetics can play a more prominent role in future conservation planning and management.

Scientometry has been used to assess quantitative and qualitative aspects present in the literature in terms of science and innovation being widely used to: i) explore trends in research (Mingers and Leydesdorff, 2015); ii) to evaluate contributions from a researcher in a given discipline or group of researchers in a given area (Wainer and Vieira, 2013); iii) to compare research institutions or countries in relation to the world scientific production (Coutinho *et al.*, 2012); iv) to quantify the impact of a particular article (Correia, Paredes and Fonseca, 2018) among others.

Oliveira *et al.* (2019) investigated and described the application of molecular genetic markers in specific groups as sugarcane (*Saccharum* spp.) using scientometry, and Nunes *et al.* (2020) researched on Caryocaraceae family of plants widely distributed throughout the Neotropic region. However, this methodological approach has been applied scarcely to identify the state of the art in terms of genetic conservation in the different Brazilian tropical biomes.

Given the lack of information concerned with population genetic variability in BAF, and the importance to guide future projects in this field, the aim of this study is to identify trends of scientific publications in conservation genetics in BAF and to explore the following topics: (1) recognize the main scientific topics and methodologies in studies published between 1990 and 2020; (2) show representative countries, authors, and primary institutions involved; and (3) point out the main molecular markers applied in these studies.

2. Methodology

2.1 Dataset

An automated search was conducted in the Scopus (https://www.scopus.com) databases of International Scientific Indexing (ISI) from 1990 to 2020, using a combination of keywords: "conservation genetics," "genetic conservation," and "Atlantic rainforest". The search was limited to research articles. The search results were analyzed to obtain a abstract of the articles in order to verify if conservation genetics was specifically used in BAF

research. Relevant information, including authors' names, total number of publications, publication numbers by year, sponsors, countries involved in the research, affiliations, and subject areas of the papers, was extracted from the accessed works.

2.2 Pre-Processing and Classification

The exclusion of articles that did not demonstrate bias on the subjects "genetics", "conservation", or "Atlantic rainforest" as well as the removal of duplicate articles, was performed. Following data filtration, the papers were classified into six categories: total articles by year, authored paper count, affiliation, country or territory of origin, sponsoring, and subject area. Summary statistical techniques were employed to quantify and summarize data within each category. Considering the period between 1990 and 2020, a total of 80 papers met the criteria proposed in the methodology. The records contained in the Scopus database returned papers starting from 1996, indicating that either these papers were not included in Scopus database or that the keywords excluded them. All analyses were performed in R 4.1.2 (R Core Team, 2021).

3. Results and Discussion

The graphical analysis of 80 published papers is shown in figure 1. Although small peaks can be observed in 1996, 2000, 2002 and 2005, the number of papers started to increase almost exponentially from 2008, with the most prominent peaks occurring in 2011, 2013, and 2018, respectively (Figure 1).

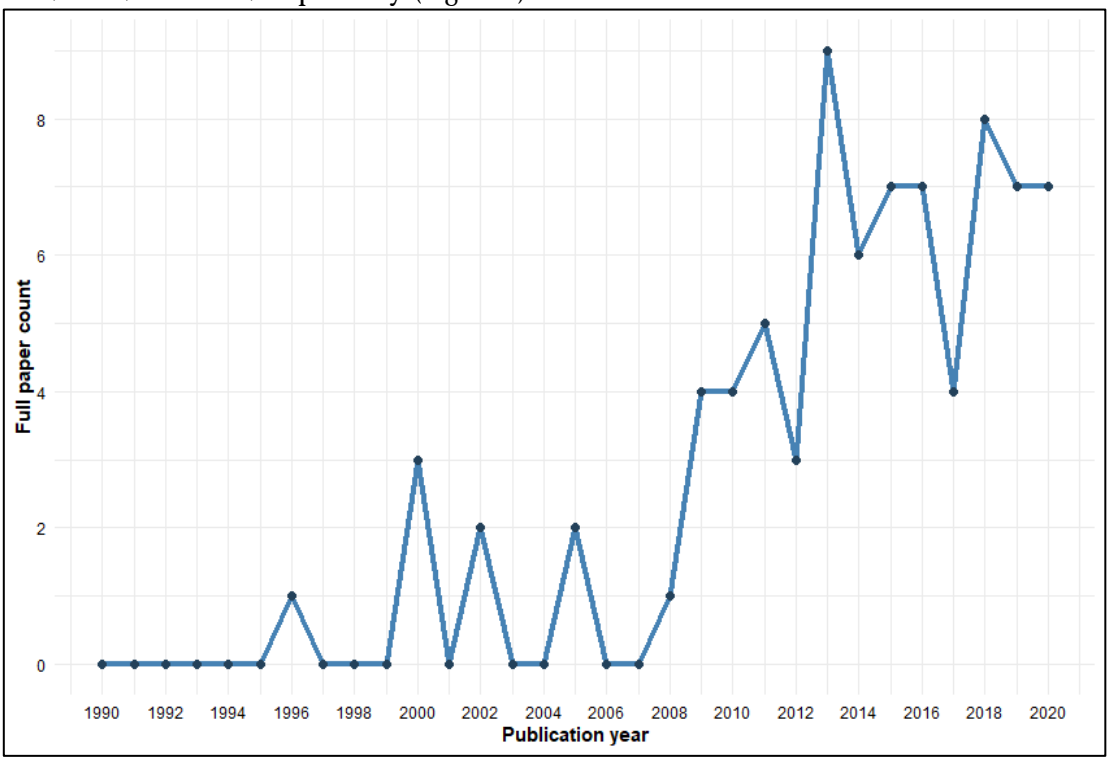

Figure 1: Number of full papers by year published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and 2020.

Studies on genetic conservation started in Brazil in the 1990s from the studies with isoenzymes, RAPD and AFLP. These first conservationist attempts, using molecular

approaches in BAF regions, took place in the state of São Paulo with the participation of the Companhia Energética de São Paulo (CESP) in partnership with researchers from public institutions with the objective of devising reforestation strategies in areas affected by hydroelectric constructions (CESP, 1992). However, at that time, research was mostly published in Portuguese, in national journals, thus reflecting a gap in the database of international journals, which includes Scopus.

However, observed publication peaks - 1996, 2000, 2002 and 2005 - may be related to investments. In Brazil, public investments in research are around 0.61% of Gross Domestic Product, which is closer to the percentage (0.69%) of the GDPs of the member countries of the Organization for Economic Cooperation and Development (OECD) (Francisco and Zucatto, 2018). After a cycle of regular and consistent spending growth until 2015 (approximately 16.8 billion USD), from 2016 onwards, investments in research and development (R&D), private and public, began to fall: 15.3 billion USD in 2016 and 15.4 billion USD in 2017. Excluding accumulated inflation (10.7%), the result for 2018 was 13.8 billion USD, which is lower than what was in 2015. Comparing Brazilian investment in R&D with OECD countries, Brazil is below the average of other countries in this bloc, and is having expenditures around 2.3% of Gross Domestic Product (GDP) (Norte, 2020). Thus, it is believed that from 2020 the volume of publications will decrease in the Scopus database. In this context, the reduction in funding for scientific research during this period is expected to result in a decline in the number of publications indexed in the Scopus database.

When clustered by country or territory, the number of papers is mainly originated in Brazil. Subsequently, the United Kingdom, the United States, and Germany are the main countries conducting studies on the subject of BAF (Figure 2). Very low number of Scopus publications on BAF topics from the countries other than Brazil indicates the lack of Brazilian international partnerships to compose research on genetic conservation of the BAF. There can be two assumptions behind this phenomenon: i) the lack of foreign interest in the BAF biome, and ii) the difficulty of Brazilian researchers in establishing partnerships with foreign countries. In the first situation, it is possible to infer the lack of knowledge of the BAF, which today is totally fragmented in the states were this biome occurs. It makes it difficult to study this topic and its dissemination.

According to Eisenlohr *et al.* (2015), the forest fragments that still exist, except in protected areas such as National Reserves and Biological Reserves, are concentrated on the tops of mountains and/or steeper slopes, where agricultural activity is difficult or unfeasible, either for access or due to the generally low soil fertility (Moreno, Nascimento and Kurtz, 2003). This biome is, however, recognized as one of the 35 world hotspots for conservation priorities (Myers *et al.*, 2000; Zachos and Habel, 2011), and has even been referred as a "hottest hotspot" (Laurance, 2009), "shrinking hotspot" (Ribeiro *et al.*, 2011), or "top hotspot" (Eisenlohr *et al.*, 2013). Nonetheless an extent of ecological finding and conservation initiatives were achieved in last years (Joly *et al.*, 2014; Lima *et al.*, 2020). Researchers have responded to this scenario, addressing important floristic and phytogeographic features of the Atlantic Forest vegetation, and producing works revealing major implications for biodiversity conservation (Eisenlohr *et al.*, 2015). Regarding the second situation, it is worth noting that not all public institutions have agreements with foreign institutions, and also, due to the country's own educational model, the vast majority of the population has difficulties with the English language (Ruiz, 2012). Because such international partnerships are of paramount importance for the enrichment of Brazilian

science and the training of human resources, it is necessary to pay attention to the scientific advancement of the country.

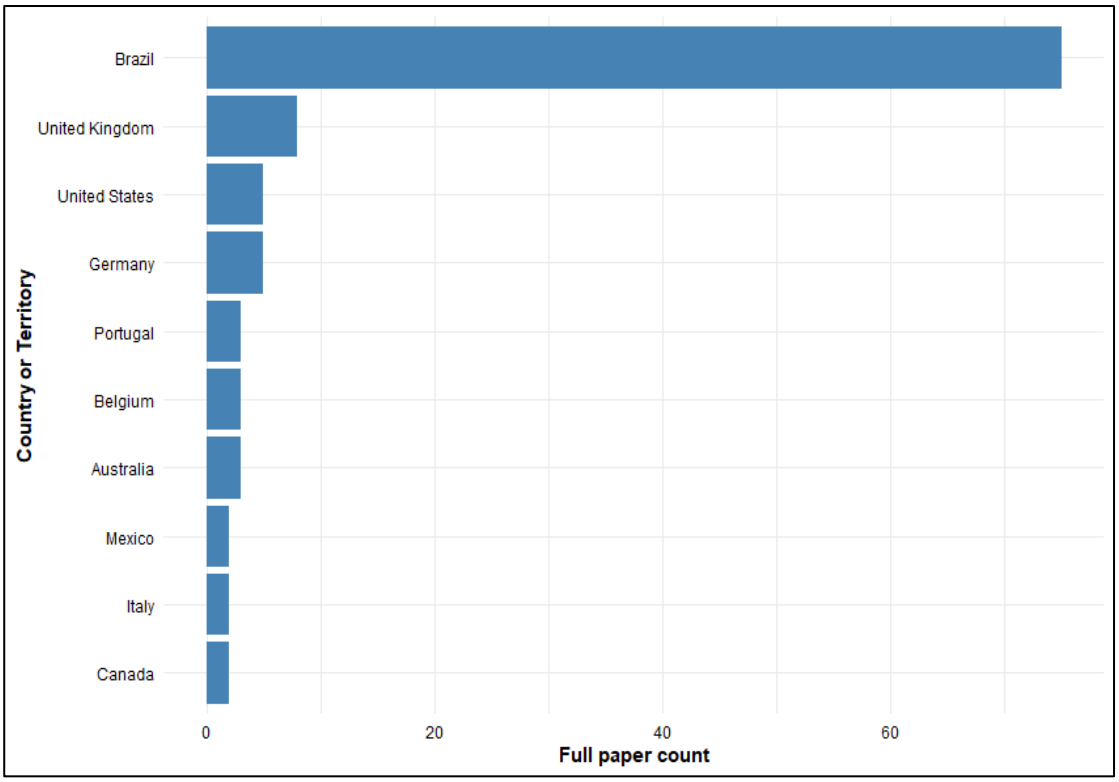

Figure 2: Number of full papers by countries published in Scopus databases related to genetics conservation in Brazilian Rainforest between 1990 and 2020

As shown in Figure 2, the number of papers produced in Brazil also reflected in the number of institutions involved with the BAF studies. As the BAF comprises an extension of the Brazilian territory from north to south (1,110,182 km^2), it was expected that the research would have been promoted by public institutions in several states, as shown in figure 3.

The data also shows that, from a total of 76 organizations involved with BAF studies, 65 produced/published between 1 and 3 papers[1], and a majority of these institutions are Brazilian. Particularly in the field of conservation genetics, the "top 10" institutions conducted the studies are as follows with a count of published papers: University of Sao Paulo – USP (13 papers), Federal University of Rio Grande do Sul – UFRGS (12 papers), State University of Santa Cruz – UESC (11 papers), Federal University of Santa Catarina – UFSC (10 papers), State University of Campinas (9 papers), Federal University of Rio de Janeiro – UFRJ (8 papers), Botanical Garden Research Institute of Rio de Janeiro – JBRJ (6 papers); the State University of Rio de Janeiro – UERJ (5 papers), the State University of São Paulo – UNESP (5 papers), and the Institute of Botany of São Paulo (5 papers) (Figure 3).

Aggregating the documents by sponsor revealed that there were five main sponsors for conservation genetics of the BAF during the period between 1990 and 2020, being the Ministry of Science, Technology and Innovation (MCTI), National Council for Scientific and Technological Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES), The São Paulo Research Foundation (FAPESP) and Carlos Chagas Filho

[1] Available at: https://github.com/britogustavo/BAF-Study/blob/main/scopus_analysis_affiliation_final.csv

Foundation for Supporting Research. These sponsors supported projects in the State of Rio de Janeiro mostly (Table 1). Occasional contributions by different agencies or institutions were also found, sponsoring between one and two documents. The full table with all the sponsors extracted from the data can be found in the additional files. Table 1 reflects the researchers' subordination to the Brazilian government's investment management. This data indicates, as around 90% of Brazilian research is carried out in public universities, that the main vector of this production being the *Stricto sensu* graduate programs (Bueno, 2014).

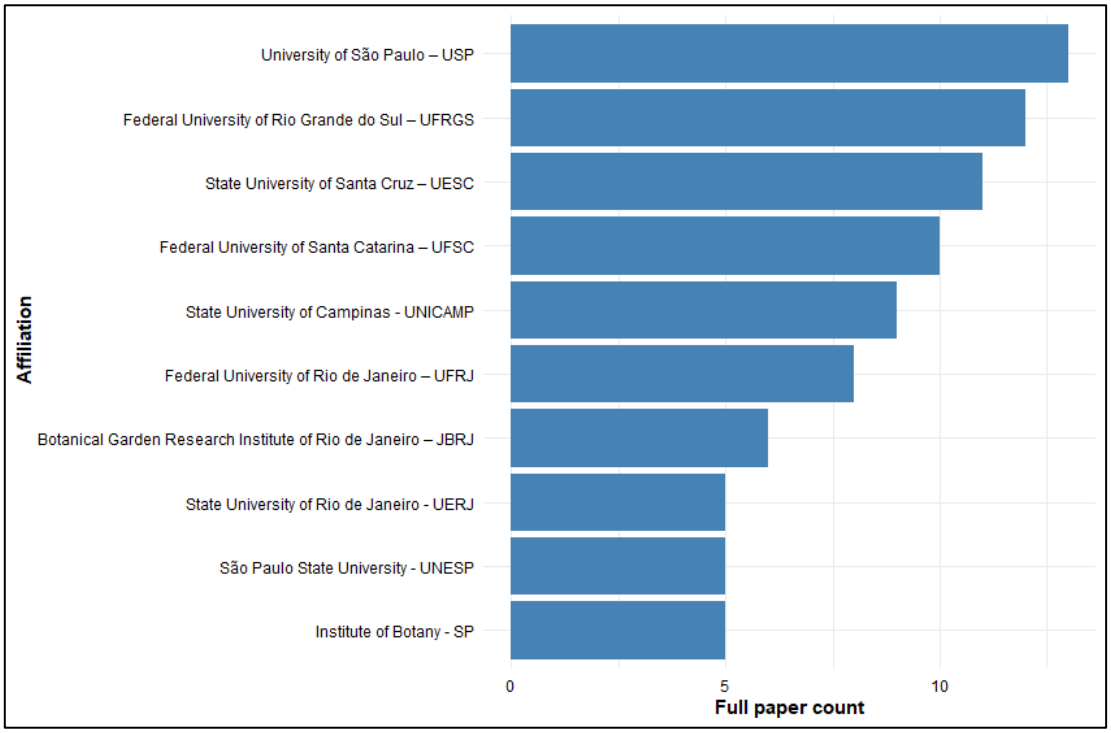

Figure 3: Number of full papers by affiliation published in Scopus database related to genetics conservation in Brazilian Rainforest between 1990 and 2020

Table 1: Main sponsors document count published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and2020

Sponsor	*Document count*
Ministry of Science and Technology	33
National Council for Scientific and Technological Development	33
Coordination for the Improvement of Higher Education Personnel	25
The São Paulo Research Foundation	10
Carlos Chagas Filho Foundation for Supporting Research in the State of Rio de Janeiro	7

According to information provided by the Institute for Applied Economic Research (IPEA), while in the United States of America (USA) the 90% of government funding for research is oriented towards the country's development, this is only 30% in Brazil. Currently, in Brazil, the private sector invests less than 0.6% of GDP, while in the US the private sector invests 1.97% of GDP, in Korea 2.6% and in China 1.2%. With these indicators, the trend is the dissolution of most entities that make up the National System of Science, Technology and

Innovation (SNCTI) (Norte, 2020; Vilela, 2020). As the main source of funding for Brazilian research is public, scientists do have many difficulties in conducting their work. In 2021, a decrease in the budget, compared to the base year 2020, of 34% to MCTI, 8% to CNPq, 1% to CAPES and 30% to FAPESP was forecast (Correia, 2020; Escobar, 2021).

Considering sponsored studies of 116 agencies or institutions during the period between 1990 and 2020, the number of authoring researchers was expected to be high. Surprisingly, the analysis of the data collected from Scopus revealed that a total of 9 authors are responsible for most of the papers produced in the referred period (Table 2). In addition, another 151 authors were responsible for authoring between one and three papers on the subject.

Table 2: Document count by authorship published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and 2020

Author	*Document count*
Gaiotto, F.A.	8
Bered, F.	6
Palma-Silva, C.	6
Goetze, M.	5
Montagna, T.	5
Nazareno, A.G.	5
Zanella, C.M.	5
Büttow, M.V.	4
dos Reis, M.S.	4

As shown in table 2, Gaiotto, F.A. was the researcher with the largest number of publications focusing in tree population *versus* conservation genetics. Having focus in tree population *versus* conservation genetics, with several contacts abroad (e.g., Florida University, USA), and also with the private sector, it was not a surprise that Gaiotto, F.A. stood out in this review. The data obtained from the Scopus search demonstrate that these authors are recognized as expressive scientists. Not only these authors are involved in research on genetic conservation at BAF, other databases need to be verified and cross-examined.

According to 80 documents retrieved from Scopus, the two main subject areas "Agricultural and Biological Sciences" and "Biochemistry, Genetics and Molecular Biology" were covered by 70% and 50% of the papers, respectively. The subject area "Environmental Science" also showed an expressive coverage by 18.75% of the published papers (Figure 4).

Since most researchers from Brazil involved in this topic are graduates in Agronomic Engineering, Forestry Engineering and Biological Sciences, the distribution of papers was done accordingly. Accordingly, of the total number of articles analyzed, the majority refers to endemic and vulnerable flora species (70%). Studies involving fauna are more laborious at field and need to be processed by the ethics council. Another limitation may be associated with the biome structure itself. This is very fragmented, which directly relates to the survival of these animals, making the sampling process hard work. In contrast, Torres-Florez *et al.* (2018) in an extended analysis (in all Latin America countries) discovered more than a third of the published articles focused on plants, while the rest on animals. These authors studied the period from 1992 to 2013, but the methodology was different. Nevertheless, the main goals were similar to this work.

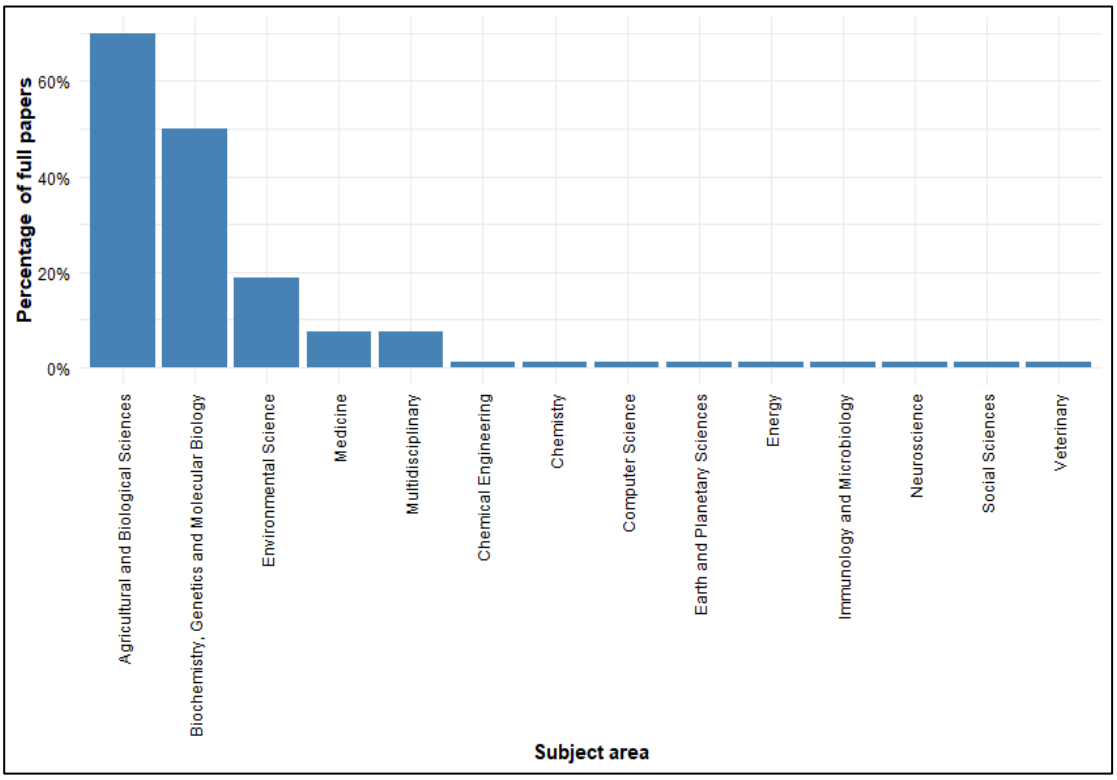

Figure 4: Percentage of full papers by subject area published in Scopus database related with genetics conservation in Brazilian Rainforest between 1990 and 2020

Regarding genetics methodologies, most molecular tools are expensive with limited additional resources in many low-income countries (Harris, 2004; Prasad and Santosh, 2019). Scientists' resort to other approaches in conservation biology, such as quantitative genetics, also makes it possible to estimate genetic variability linking direct management strategies for species in risk (Moran, 2002). Thus, the adoption of molecular markers in Brazil was slow and exclusive to only a few research centers. From the works evaluated here, a significant application of SSR markers and, to a lesser extent, AFLP, isoenzymes, ISSR and RAPD markers were observed. It is understood that the application of SSR is still limited in the conservation genetics in the BAF and other biomes. Although we are in a transition from genetics to conservation genomics (Ouborg *et al.*, 2010), SSR will still be of great use for conservation projects due to their characteristics, such as methodological practicality, low cost, ease of data processing, in addition to great acceptance in international journals (Ferreira, 2006; Hauser *et al.*, 2021).

Despite studies on conservation genetics being relatively new in Brazil and all the difficulties to its application both in field and laboratory scenarios, papers were retrieved emphasizing the importance of molecular markers and genetic studies in context of conservation efforts. Soares *et al.* (2019) made use of SSR markers to study how human interference can lead to losses both in the genetic structure and diversity of populations of *Euterpe edulis*, an endangered palm tree species facing challenges of habitat fragmentation and illegal logging. These authors have demonstrated how reducing illegal activities and reforestation efforts are keys to preserve gene flow. The idea of how habitat preservation/conservation can directly impact the genetic conservation of a species. Mariot *et al.* (2020) demonstrated how even a small number of populations can maintain the

genetic diversity of a species if conservation efforts aim to enhance gene flow. The works of Amaral *et al.* (2019) and Santos Júnior *et al.* (2019) both demonstrate how genetic data can be used in conservation and distribution studies in BAF, with the former showing how the use of genetic studies' techniques can produce good results in identifying 12 new amphibian species in BAF. Santos Júnior *et al.* (2019) used genetic data coupled with niche models to study the distribution (both historical and current) of two bumblebee species in BAF, demonstrating how genetic data can be integrated with other studies while becoming important tools to conservation planning and efforts.

As stated earlier, forest types in BAF have complex of typologies, as the montane moist forests are represented from higher altitude wet forests across mountains and plateaus of southern Brazil to Campo Rupestres represented by high altitude shrubby grasslands in southern regions. Works of Hodkinson (2005) and Lawton *et al.* (1987) show that the altitude gradient affects biodiversity (e.g. species richness). However, researches in BAF correlate altitude with levels of genetic patterns. The lack of studies regarding conservation genetics in montane regions may derive from many (or a combination of) factors, such as difficult access to sampling sites, restricted species distribution, and high levels of endemism, thus, making species difficult to observe (de Lima *et al.*, 2020; Eisenlohr *et al.*, 2013, 2015).

4. Conclusion

Though the Scopus platform is a reference in the academic panorama for consulting scientific papers, it was possible to observe some deficient points in the search for journals. This limitation was more present in the 1990s, when Brazilian researchers were more reluctant to publish in English, and confined to national journals. However, as they established partnerships with international institutions, this scenario gradually changed. In this way, the present paper generated a better understanding of the state of the art related to BAF conservation. However, it is necessary to continue such research by covering other databases and considering *ex situ* (BAF) and *in situ* (Brazilian biomes) genetic conservation.

5. Acknowledgments

The authors thank Minas Gerais State University for the generous grant.

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