

Baru (*Dipteryx alata* Voug.), the Brazilian savanna's brown gold: A scientometric analysis of investigative trend

Baru (*Dipteryx alata* Voug.), o ouro marrom do cerrado brasileiro: uma análise cienciométrica de tendência investigativa

Baru (*Dipteryx alata* Voug.), el oro marrón de la sabana brasileña: un análisis cienciométrico de la tendencia investigativa

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Abstract

This work is a scientometric analysis of articles published in journals related to the subject “*Dipteryx alata*, Baru and Brazilian savanna” in its main area of occurrence, the Brazilian savanna biome. The proposal was to draw a scientometric profile related to the aforementioned topic, which is a key species with enormous potential for socio-environmental development, presenting the panorama of the state of knowledge and the main areas of research until the year 2021. A total of 205 articles that had baru as the focus of the study were found, having been published in 114 journals between 1988 and 2021. The area of biotechnology had the greatest representation, followed by ecology. In the area of biotechnology, research had different approaches, such as the nutritional part of the development of new products for the industry, highlighting the importance and plasticity for the use of the species, as a potential product for socio-environmental development, and for some communities, mainly those formed by small family units, it is an important element in complementing the source of income. Another important point of the species is its potential use for the recovery of degraded areas, due to its morphophysiological characteristics, which, in addition to helping in sustainable production and productivity, have a broad, complex and highly important ecological relationship to the Brazilian savanna ecosystem.

Keywords: Regional development; Biodiversity; Sustainable use.

Resumo

Este trabalho trata-se de uma análise cienciométrica de artigos publicados em periódicos relacionados ao tema “*Dipteryx alata*, Baru e Cerrado” em sua principal área de ocorrência, o bioma Cerrado. A proposta foi traçar um perfil cienciométrico relacionado ao tema citado anteriormente, que é uma espécie chave e de um potencial enorme para o desenvolvimento socioambiental, apresentando seu panorama do estado do conhecimento e as principais áreas de pesquisa até o ano de 2021. Foram encontrados 205 artigos que tinham o baru como foco do estudo, publicados em 114 periódicos entre 1988 e 2021. A área de biotecnologia teve a maior representatividade, seguida da ecologia. Na área de biotecnologia, as pesquisas tiveram enfoques diversos como a parte nutricional ao desenvolvimento de novos produtos para a indústria, evidenciando a importância e a plasticidade de uso da espécie, como potencial produto para o desenvolvimento socioambiental, sendo para algumas comunidades, principalmente as formadas por pequenas

unidades familiares, um importante elemento na complementação da fonte renda. Outro ponto importante da espécie, tem como destaque seu potencial de uso para recuperação de áreas degradadas, por suas características morfofisiológicas, que além de ajudar na produção e produtividade sustentável, possui uma relação ecológica ampla, complexa e de grande importância para o ecossistema do Cerrado.

Palavras-chave: Desenvolvimento regional; Biodiversidade; Uso sustentável.

Resumen

Este trabajo es un análisis cuantitativo de artículos publicados en revistas relacionadas con el tema “*Dipteryx alata*, Baru y Sabana brasileña” en su principal área de ocurrencia, el bioma Cerrado. La propuesta fue trazar un perfil cuantitativo relacionado con el tema mencionado, que es una especie clave con un enorme potencial para el desarrollo socioambiental, presentando su panorama del estado del conocimiento y las principales áreas de investigación hasta el año 2021. Artículos que tuvieron baru como foco del estudio, publicado en 114 revistas entre 1988 y 2021. El área de biotecnología tuvo la mayor representación, seguida de ecología. En el área de biotecnología, las investigaciones tuvieron diferentes enfoques, como la parte nutricional del desarrollo de nuevos productos para la industria, destacando la importancia y plasticidad del aprovechamiento de la especie, como producto potencial para el desarrollo socioambiental, y para algunas comunidades, principalmente las formadas por pequeñas unidades familiares, elemento importante en la complementación de la fuente de ingresos. Otro punto importante de la especie es su uso potencial para la recuperación de áreas degradadas, debido a sus características morfofisiológicas que, además de ayudar en la producción y productividad sostenibles, tienen una relación ecológica amplia y compleja de gran importancia para el ecosistema del Cerrado.

Palabras clave: Desarrollo regional; Biodiversidad; Uso sostenible.

1. Introduction

The Cerrado, or Brazilian savanna, covers about 22% of the national territory, making it the second largest biome in extension in Brazil and South America. With diverse phytophysognomies, it contributes to the existence of a diversity of fauna and flora, which, according to Nóbrega et al. (2018), around 12,000 species of native plants can be found, and these conditions make this biome one of the world's biodiversity hotspots.

The fruit species of the Brazilian savanna are abundant and have great economic, medicinal and timber potential. The fruits are widely used by local extractivism, in the food industry, and some species are excellent in reforestation programs (Guedes, et al., 2017).

The species *Dipteryx alata* Vogel., popularly known as baru, cumari, cumaru, bean-baru, bugueiro, cambaru, cumbaru, barujo, imburana-brava, cumarurana, pau-cumaru and feijão-de-coco, is a tree species native to the Brazilian savanna, found in the states of Minas Gerais, Goiás, Mato Grosso and Mato Grosso do Sul, with great use in reforestation (Batista & De Sousa, 2019). Belonging to the Fabaceae family, it can reach up to 25 meters in height and is among the 10 fruit species with the largest productivity in the biome, producing an average of 2000 fruits per tree (Sano, Brito, & Ribeiro, 2016, Guimarães et al., 2019, Oliveira-Alves et al., 2020). In the states of Goiás and Mato Grosso, the production of Baru in 2019 was 69.3 tons, less than the previous year, when 95.8 tons were produced. The state of Goiás was responsible for 99% of the national production in 2019 (CONAB, 2020).

Baru can be extracted from the natural environment or from planted areas. It is part of the restoration processes, which can be integrated with other production systems, such as Livestock-Forestry, Crop-Forestry, or Crop-Livestock-Forestry systems. The growth and productivity of baru varies in relation to climatic conditions, soil conditions and water availability, and may produce in the sixth year of life. This rapid growth contributes to carbon fixation, soil aeration and infiltration of river water to the water table (Rocha et al., 2017).

Baru has multiple uses: it can be used in the timber, industrial, landscaping sector; in the production of mineral coal; in the recovery of degraded areas; in forage supplementation for cattle; the leaves can be used in the manufacture of handicrafts; and as food for people – it can be consumed naturally, roasted or by-product (Batista & De Sousa, 2019; de Souza et al., 2018). The fruit has a pulp rich that is in fat, proteins, total carbohydrates, fiber, starch, calcium, phosphorus and

potassium carbonate, in addition to having medicinal properties. It can also be consumed in natura or processed (da Cruz Nóbrega & Ferreira, 2021).

Baru's high nutritional value and antioxidant capacity has attracted commercial interest, being exported to South Korea (Brasil, 2020). Its oil has gained space in the production of cosmetics due to its moisturizing, protective, softening and soothing properties (Borges, 2009). The versatility of the species favors a higher exploitation of by-products by small, medium and large producers. Additionally, when associated with sustainable forest management or agroforestry systems, it tends to present a better economic return in relation to other land use activities, due to its high rate of seed germination and growth in the first two years of life (Sano, et al., 2016; Cunha et al., 2018).

The multiple uses of baru are known due to popular and scientific knowledge previously highlighted about the properties of this tree. In order to expand and disseminate other potentials of the species, it is necessary to analyze the areas of higher study concentration and the areas where there is insufficient scientific data, as well as evaluating the standard of research development. Among the techniques that are used to quantify the scientific progress, there is the bibliometrics, which is based on the volume of scientific production and on the variability of topics (Lima & Gomes, 2021). These studies point to scientific development, guide future production, favor sustainable plant exploitation and plant and environmental conservation.

Through the construction and quantitative investigation of scientometrics, this study sought to identify and quantify the development of research and the most studied areas on Baru. This research aims to identify gaps, advances and future perspectives of research in relation to the species, in order to stimulate research in other areas that demonstrate and reinforce the potential of *Dipteryx alata* Vogel, strengthening the use of new methodologies of sustainable use to assist in the measures of conservation and sustainable development of the Brazilian savanna.

2. Methodology

The Brazilian savanna is the second largest biome in South America, covering the states of Goiás, Tocantins, Mato Grosso, Mato Grosso do Sul, Minas Gerais, São Paulo, Bahia, Piauí, Maranhão, Rondônia, Pará, Paraná and the Federal District (Vidal, 2019). Located at 3° and 24° south latitude, and 41° and 63° west longitude, and with altitudes ranging from 500 to 1660 m, the biome has a predominantly seasonal tropical climate with an average annual temperature between 22 and 23°C, which can reach up to 40°C in spring. The periods of drought and rain are well defined and present precipitation ranging from 1200 to 1800 mm (Adámoli et al., 1986; Campos & Chaves, 2020).

The variations in altitude and rainfall pattern give the biome the composition of different phytophysiognomies, ranging from field vegetation (Campo Limpo – moist grassland, Campo Sujo – dry grassland, and Campo Rupestre - rupestrian grassland), savannah (Vereda, Palmeiral, Parque de Cerrado and Brazilian savanna in the strict sense) to forest components (Cerradão – closed savanna approaching a forest; Mata Seca – dry forest, Mata de Galeria – gallery woods, Mata Ciliar – riparian forest) (Ribeiro & Walter, 2008).

Scientometrics is described as an effective quantitative method used to quantify the scientific production of institutions, regions, journals, country or field of knowledge. It is performed through the frequency of articles and citations in indexed databases, which allows the measurement of the amount and of the impact of scientific publications, in addition to analyzing their interrelationships (Spinak, 1998).

The construction of the database was carried out through searches in the following repositories: SciELO (scielo.org), Scopus (scopus.com), Web of Science (webofknowledge.com), and Science Direct (ScienceDirect.com), using the following descriptors: *Dipteryx alata* Vogel, Baru and Brazilian savanna, both in Portuguese and in English. A time frame was not determined on the search for data as a means of evaluating the development of the studies on the subject over time, but only articles intrinsic to the species and its various applications were selected.

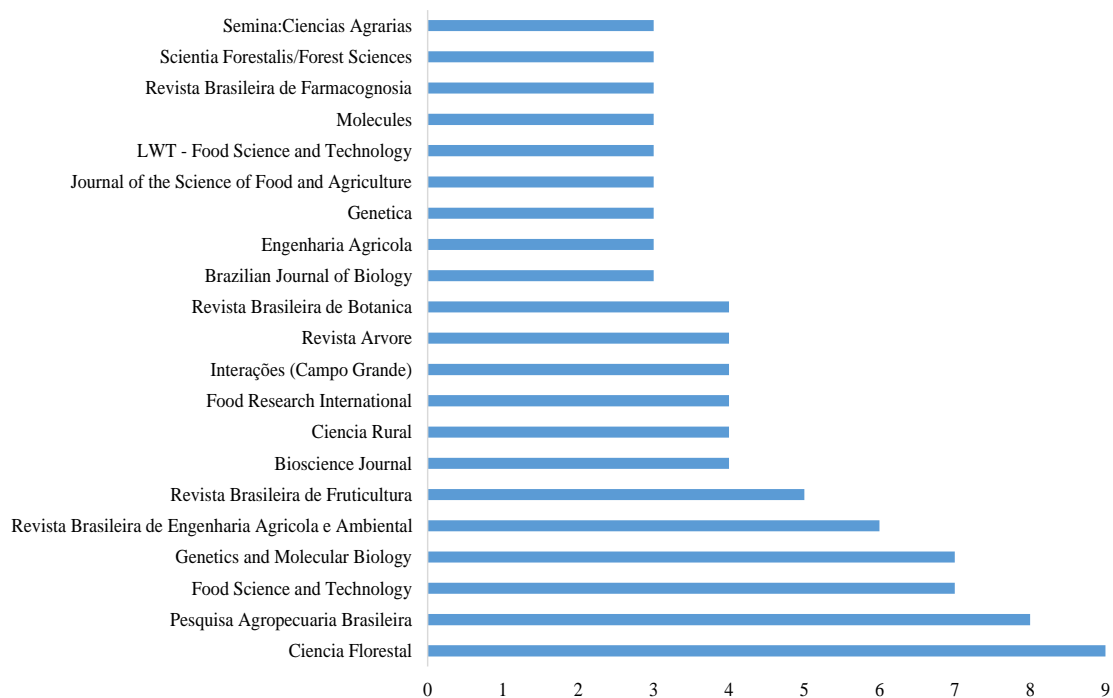
The scientific productions by authors and Higher Education Institutions (HEIs) described in the articles were evaluated through social networks using the VOSviewer software, where each author was represented by a circle (vertex/node) whose size reflects the number of publications.

3. Results and Discussion

The primary search among the four databases totaled 597 articles, with Scopus having the largest number (188), followed by Web of Science (182), Science Direct (152) and Scielo (75). After applying the descriptors *Dipteryx alata* Vogel, Baru and Brazilian savanna, the articles in which the species was only mentioned were disregarded, with 205 articles remaining.

When analyzing the performance of the results, taking into account the scientific production and the most used journals, it was observed that the articles were published in 114 journals between the years from 1988 to 2021, out of which 75 journals registered five or less articles each. The journals with the highest number of publications were: *Ciência Florestal*, *Pesquisa Agropecuária Brasileira – EMBRAPA*, *Food Science and Technology*, *Genetics and Molecular Biology*, and *Revista Brasileira de Engenharia Agrícola e Ambiental*, which represented 9, 8, 7, 7 and 6 publications, respectively. (Figure 1).

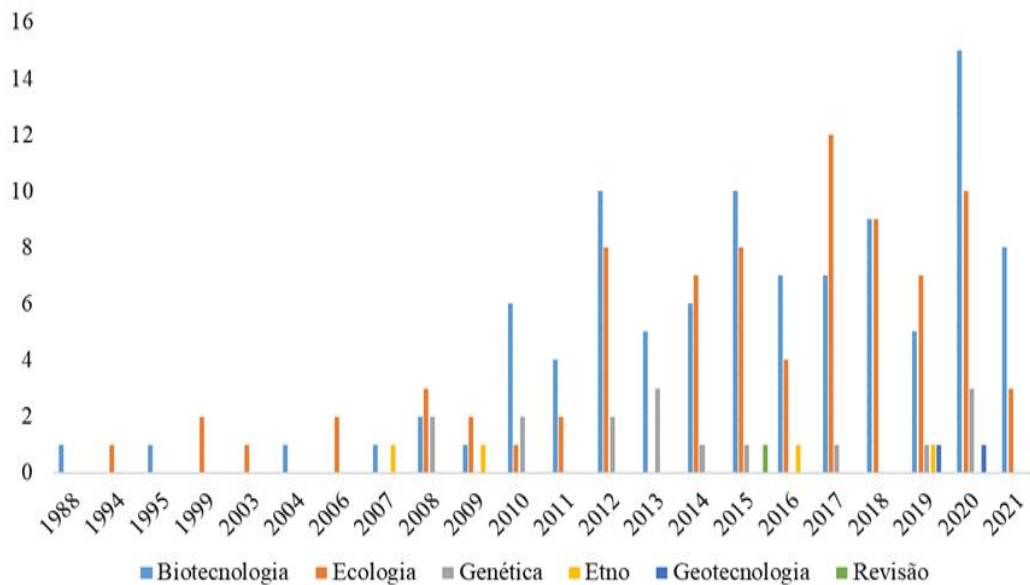
Figure 1 - Number of articles published by journals that are documented and registered in the SciELO, Scopus, Web of Science and Science Direct databases.



Source: Authors (2022).

In Figure 1, it is possible to observe the 21 journals that published the most articles about Baru between the years analyzed. The journals' coverage areas allow us to see that there is a relationship with the main published research areas. The diversity of studies on baru brings analyzes that range from morphology and development to its productivity and the silvicultural potential of the species, among other studies. Among the published articles, the year 2020 stood out with the highest number of publications, having 29 articles distributed in the areas of biotechnology (15), ecology (10), genetics (3) and geotechnology (1), respectively (Figure 2).

Figure 2 - Number of articles published by year and research area.



Source: Authors (2022).

The database shows that biotechnology is a growing area in Brazil, and it has been increasingly applied in different areas. The increase in articles focused on the biotechnology (Figure 2) of plant species has brought the study of several areas, from nutritional to medicinal potential, and the use in the food and cosmetic industry, mainly in native species of the Brazilian savanna.

Studies on the nutritional potential of Brazilian savanna fruits have shown that the bioactive compounds of baru are present in the pulp and in the kernel of the fruit, and that the ingestion of 100g of baru pulp provides 6% of the daily requirement of protein intake (Egea & Takeuchi, 2020; Alves-Santos, et al., 2021), and 28% of carbohydrate intake (Almeida et al., 2019). The high energy potential of the fruits was also confirmed by De Matos Teixeira et al. (2020). The pulp also has natural antioxidant potential (Araújo et al., 2016) and the kernel contains an oil with high levels of tocopherols, antioxidant activity and fatty acids, being promising for the pharmaceutical and food industry (Fetzer et al., 2018). The diversity of application and biochemical composition of the fruits was possibly responsible for the growing number of researches focused on the area.

According to Antunes et al. (2020), among the studies of bibliographic reviews found on baru, one was carried out on the physicochemical characteristics of the seed as a way to ascertain the presence of carotenoids, using the chromatography process to separate these chemical components; in another study, the oleaginous properties and packaging in nanocapsules, for herbal purposes, were ascertained (Batista & de Sousa, 2019). All these show the plasticity of the species and its ability to promote the sustainable development in the producing regions.

Studies on ecological interactions, germination and initial development of cumbaru plants are essential for the success of quality seedling production, which reflects on the success of reforestation and planting activities in natural forests. Luminosity plays an indispensable role in changing the morphological, physiological and biochemical characteristics, limiting the growth of the species in the field and in protected environment (Mota, et al., 2012). For Castex et al. (2018), as it is a large tree, it aggregates several ecosystems around it: insects, birds, mammals, fungi and bacteria, which build complex ecological relationships, and, thus, the baru strengthens and balances the biome, mainly with the reforestation of degraded areas and/or the construction of ecological corridors, since it has a good relationship with crop consortium.

The articles focused on genetics described the genetic diversity, the potential for regeneration of the species and the

pattern of distribution, and are directed to the research of variability in different places of the Brazilian savanna, where a great variety was perceived in the elements that constitute the plant, such as: size of the leaves, stem diameter, coconut size, seed length, root length and germination time under the same environmental conditions (Antunes et al., 2020).

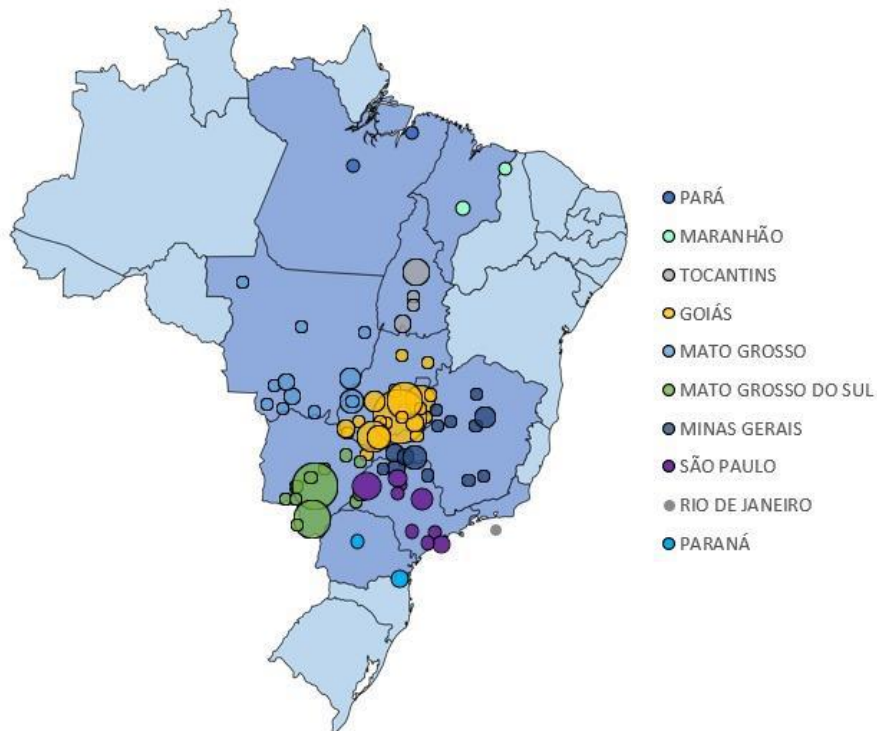
In ethnobiological studies, the articles demonstrate the importance of baru for different communities and social groups, revealing the important role that the species has for extractivism, sustainability, food, income supplement, civil construction, and, in some locations, economic and social development (Silva, et al., 2016). The fruits systematically contribute as a source of income for many families, for the conservation of biodiversity, and are intrinsically linked to the cultural richness of extractivism (Chuba et al., 2019).

Therefore, baru, as an economically viable fruit for regional communities and with the potential of available natural resources, serves as a stimulus for the development of communities, and this is part of the dynamic process for the economy, for knowledge, for culture, for the environment and for the quality of life in its completeness (Candil, et al., 2007). This potential is unconsciously explored through the traditional knowledge shown in studies about ethnoknowledge and in review studies, which generally address the development, the sustainable use and the medicinal potential of the species, as well as its importance in generating income for small farmers.

Data from the market research led by Fact.MR (<https://www.factmr.com/report/1362/baru-nuts-market>) show that the expected increase in the commercialization of baru kernel is approximately 25% annual through 2029 – specifically as a growing number of consumers shift their focus to healthy eating, in line with the trend towards improved health and well-being. The distribution is also the object of research in geotechnology studies, which make it possible to assess the geographic distribution of the baru both in the Brazilian savanna biome and in the Brazilian territory.

The distribution map of the work development in Brazil shows that the Midwest region is responsible for the highest percentage (69.23%), with the municipalities of Goiânia (GO) and Campo Grande (MS) holding the highest percentages. The southeast region is the second having the highest number of researches with baru, being responsible for 21.98% of the works (Figure 3).

Figure 3 - Distribution of works by region and state between 1988 and 2021.

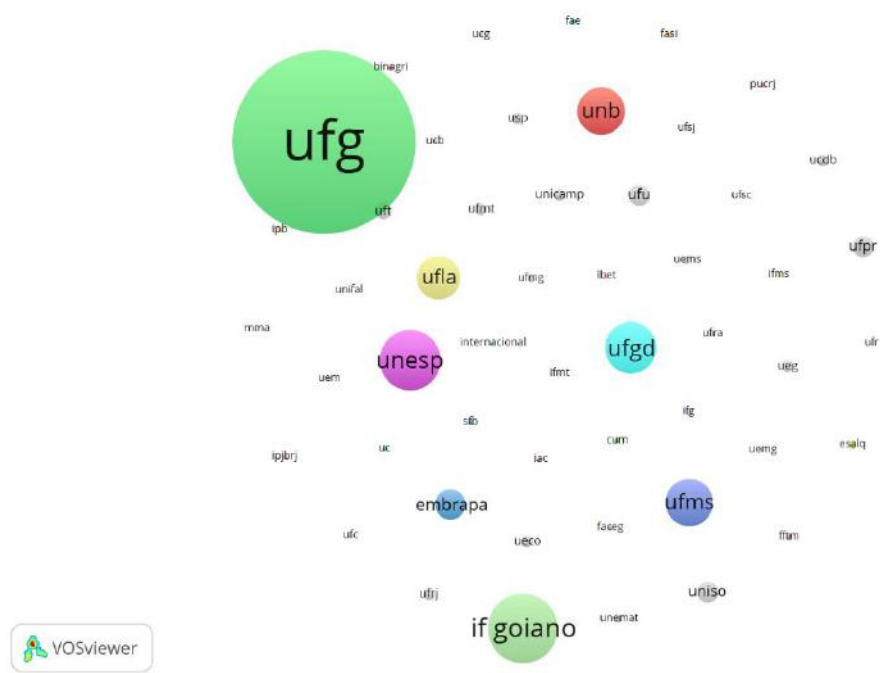


Source: Authors (2022).

Figure 3 allows us to analyze that, although Baru is a species that occurs in almost all of Brazil, the region with the highest numbers studied is the Midwest. This may be because the species is native to the Cerrado biome, or because of the number of research projects and the relevance of the species to the region.

The temporal dimension of the studies on Baru showed that, out of the 51 educational institutions that developed and continue to develop scientific work with Baru, the Federal University of Goiás is responsible for the highest number of registered works, followed by the Goiano Federal Institute, thereby explaining why the Midwest region holds the highest percentage of research. The third largest circle is registered at the University of the State of São Paulo (UNESP), demonstrating the increasing work with the species in the southeast region, most of which are focused on biotechnology and genetic analysis. The emergence and interest of other universities and other public-private companies regarding the study with Baru are also responsible for the increase in publications in the 33 years analyzed herein (Figure 4).

Figure 4 - Distribution of articles published by Higher Education Institutions (HEIs) and public-private companies related to *baru* from the SciELO, Scopus, Web of Science and Science Direct databases.

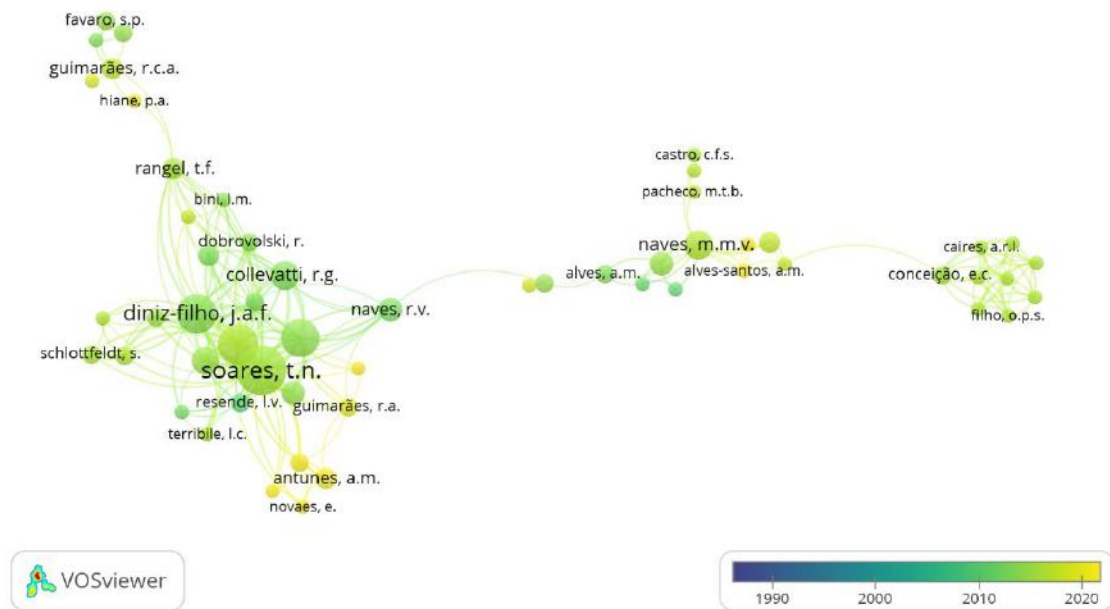


Source: Authors (2022).

The highlight for the UFG and the IF Goiano observed in Figure 4, reinforces what is observed in Figure 3, in which the central-west region and the state of Goiás stand out for the largest number of researches and the two main and most renowned educational institutions higher. The growing number of publications in other institutions shows us the importance of partnerships between HEIs in the dissemination of works with scientifically little known species.

The network nodes among researchers showed that the researchers with the largest and most intertwined circles (yellowish green color) are the ones who most produced and maintained a work group in the last 10 years. This is possibly due to the line of research between the UFG (Federal University of Goiás) and Dom Bosco Catholic University (UCDB), based in MS. However, between 2020 and 2021, the highest volume of publications is more represented by a second group on the rise, which maintains connections with the central group, thus showing the resilience and scientific progress in research focused on *Baru's* genetics and biotechnology in Brazil (Figure 5).

Figure 5 - Network size among *Baru* researchers in Brazil from SciELO, Scopus, Web of Science and Science Direct databases.



Source: Authors (2022).

The Figure 5, in addition to highlighting the interaction between authors from different research groups and universities, shows that despite the importance of the species, research with baru is recent in Brazil, with a highlight in the year 2020, and a reduction in the subsequent year. This may be related to the adversities in establishing new study methodologies and laboratory analysis, as well as the limited financial resources of public universities, the largest producers of scientific information in the country.

4. Final Considerations

This bibliometric research served as a reflection about the dimension and relevance that baru has as an element that promotes the economy and regional development. A relevant factor observed during this study was the versatility that this plant has. It is important for feeding humans and other animals, it has nutrients and phytotherapeutic compounds, used in different industries, such as pharmaceuticals and beauty, in addition to being an important piece for the development of new products in other industrial areas.

Its by-products add value to the species, such as the production of charcoal from the fruit residue. Additionally, its wood is a source of raw material for civil construction. Its nut, compared to cashew nuts and Brazil nuts, is superior in nutrition, omega 3, omega 6, fatty acids and fiber. Baru is considered by many to be a valuable natural resource known as the Brazilian savanna's brown gold and or natural Viagra.

It is a species used in the processes of recovery of degraded areas: it participates in the decompression of the soil; with its long roots, it helps to humidify the land; with its shade and fodder leaves, it shelters a variety of living beings in its canopies and trunks; in addition to having a complex and important ecological relationship for the Brazilian savanna ecosystem. Baru is a species that can be cultivated in crop consortium, thus promoting the development on sustainable bases, which collaborate

with the goals of reducing GHG emissions in Brazil.

It is understood then that baru can be an important element for the reconstruction of degraded areas, for food production, an income generator, and a promoter of the economic development of a region. The baru nut market is still incipient, but it is possible to have an optimistic look, mainly because baru is essentially an endemic product of the Brazilian savanna. Therefore, Brazil becomes the only owner of this nut and its derivatives. This could be the starting point for the growth and improvement of the exploratory collection, by extractivists, of this natural resource, under the careful gaze of adding economic value to the activity and regional value to this product, which can improve the lives of people involved not only in the economy, but also as a legacy of a sustainable economy.

This scientometric analysis research pointed out the relevance that baru has as an element that promotes the economy due to its various applications in by-products due to its nutritional composition and high productivity, thus being known as the brown gold of the Cerrado. The increasing number of works that demonstrate the high potential of the species has grown year by year, with emphasis on works in the universities of the state of Goiás, in which, some works reinforce the importance of Baru in integrated systems, having the species as a mitigator in the reduction of greenhouse gas emissions. The economic, social, cultural and nutritional importance of baru, as demonstrated in this work, highlights the importance of continuing research on the species and the sustainable management practiced by small extractive producers seeking to add even more economic value to the activity and regional and national value to the activity. species.

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