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AN OVERVIEW OF BIBLIOMETRIC INDICATORS ABOUT ENDANGERED BRAZILIAN CERRADO PLANT SPECIES

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ABSTRACT

The Cerrado is an important Brazilian biome due to the high levels of endemism and species diversity. As a result of anthropic actions and natural causes, the Cerrado also includes some plant species threatened with extinction. We conduct a bibliometric survey of scientific information on a set of threatened Cerrado plant species to answer two main questions: i) How much is known about endangered plant species endemic to Cerrado?; and ii) When, by whom and where were scientific papers published about plant species endemic to Cerrado? We identified and mapped a list of 117 endemic endangered species of Cerrado flora from 35 different families. A total of 151 articles were published with these species and indexed in the Scopus database. We found that even more than twenty years after the publication of Normative Instruction number 6 of September 23, 2008, little is known about these species from a scientific point of view.

Keywords: Endemism; Flora; Savanna; Scientometrics.

RESUMO

Uma visão geral dos indicadores bibliométricos sobre espécies de plantas ameaçadas de extinção do Cerrado brasileiro. O Cerrado é um importante bioma brasileiro devido aos altos níveis de endemismo e diversidade de espécies. Por ações antrópicas e causas naturais, o Cerrado também inclui algumas espécies de plantas ameaçadas de extinção. Realizamos um levantamento bibliométrico de informações científicas sobre um conjunto de espécies de plantas ameaçadas do Cerrado para responder a duas principais questões: i) Quanto se sabe sobre as espécies de plantas endêmicas do Cerrado ameaçadas de extinção?; e ii) Quando, por quem e onde foram publicados artigos científicos sobre plantas endêmicas do Cerrado ameaçadas de extinção? Identificamos e mapeamos uma lista de 117 espécies endêmicas da flora do Cerrado ameaçadas de extinção de 35 famílias diferentes. Um total de 151 artigos foram publicados com essas espécies e indexados na base de dados Scopus. Verificamos que mesmo após mais de vinte anos da publicação da Instrução Normativa number 6 of September 23, 2008, pouco se sabe sobre essas espécies do ponto de vista científico.

Palavras-chave: Cienciometria; Endemismo; Flora; Savana.

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INTRODUCTION

The Brazilian Cerrado (or Cerrado or Brazilian savannas) is an essential biome due to high levels of diversification and endemism. The Cerrado contains around 837 species of birds, 120 species of reptiles, 150 species of amphibians, and 1,200 species of fishes (WWF, 2020). The Cerrado vegetation comprises around 12,374 of Angiosperms species belonging to 1,661 genera and 186 families, making it the wealthiest savannah in the diversity of species in the world (Flora do Brasil 2020). About 7,342 species of plants that occur in the Cerrado (59,33%) are endemic to Brazil, and this is probably related to the great variety of phytophysiognomies and environments ranging from fields to humid seasonal forests (Flora do Brasil 2020). Due to the low population size and the constant advance of unsustainable human practices, the Cerrado also includes a large number of species at risk of extinction (Strassburg *et al.*, 2017)

According to the criteria published by IUCN (2001) and adopted by the Red Book of Flora of Brazil (Martinelli *et al.*, 2014) an species, to be considered endemic or threatened of extinction, it is necessary to present the following criteria: Loss in the population greater than or equal to 90% in the last ten years or the previous three generations with reversible causes; a fragmented geographic distribution or with an estimated occurrence of fewer than 100 km^2; a fragmented geographic distribution or with a likely presence of fewer than 100 km^2; an estimated population of less than 50 mature individuals and Quantitative analysis showing the probability of extinction in nature of at least 50% in 10 years or three generations.

In this sense, one of the initiatives of the government of Brazil was the publication of the Normative Instruction number 6 of September 23, 2008, from the Brazilian Environment Minister. This normative instruction aims to recognize a list of Brazilian flora species as being threatened with extinction or with data deficiency. The normative instruction takes into account the commitments assumed by Brazil in the Convention on Biological Diversity - CBD, ratified by Legislative Decree number 2, of February 8, 1994, and promulgated by Decree number 2,519, of March 16, 1998, and in the Convention on the International Trade in Species of Wild Flora and Fauna in Danger of Extinction - CITES, ratified by Legislative Decree number 54 of June 24, 1975, and promulgated by Decree number 92,446 of March 7, 1986.

The normative instruction number 6 of September 23, 2008, also says that action plans should be developed, with a view to the future removal of species from the list, elaborated and implemented under the coordination of specialized bodies and with the participation of governmental bodies, the scientific community and organized civil society, within a maximum period of five years, from the publication of this Normative Instruction. Considering that more than twenty years have passed since the publication of this regulation, a systematic search for the advancement of scientific knowledge with this list of species is still absent.

Due to this scenario, we perform a bibliometric survey of scientific information regarding a set of endangered Cerrado plant species to answer two main questions: i) How much is known about Brazilian endemic plant species in the Cerrado threatened with extinction?; and ii) When, by whom and where were scientific articles on endemic endangered Cerrado plants published? Furthermore, we analyze the current state of scientific knowledge regarding endangered Cerrado plant species listed in the Normative Instruction number 6 of September 23, 2008, from the Brazilian Environment Minister.

MATERIAL AND METHODS

We investigate the scientific production of about 117 plant species regarding 35 families of Brazilian Cerrado listed as endangered by the normative instruction number 6 of September 23, 2008 (Ministério do Meio Ambiente, 2008). This normative instruction list aims to recognize species of Brazilian flora threatened with extinction in addition to recognizing species with data deficiency. We confirm the scientific name and the biome of each species using the Reflora database.

We search for articles using the SCOPUS database. For each search, the scientific name of each species was used as keyword to retrieve bibliometric information. The keywords were searched for in the title, abstract, or articles' keyword. We include in this study original and review articles published between 1945 and 2020. Besides, we use the name of each species as keywords to retrieve information from the International Union for Conservation of Nature's Red List of Threatened Species database.

RESULTS AND DISCUSSION

How much is known about Brazilian endemic plant species in the Cerrado threatened with extinction?

We identified and mapped science to a list of 117 endemic endangered species of Cerrado flora from 35 different families. When the data survey was carried out, the list of threatened species of flora found and available that classified by Brazilian biome was Normative Instruction number 6 of September 23, 2008, but currently there are more updated lists without the classification by biome, such as: Official list of species of the Brazilian flora threatened of extinction by MMA ordinance number 148, of june 7, 2022; therefore, it is suggested that future studies consider the most current lists. A total of 151 articles were published with these species and indexed on the Scopus database (Table 1). The families that stand out in the number of species listed are Eriocaulaceae and Lythraceae, both with 9.4% (n= 11 species). Eriocaulaceae and Lythraceae species presented 18.8% of all publications with endemic plants from the Cerrado listed as endangered. The most studied species so far belong to the Asteraceae (48) and Rutaceae (47) families (Table 1). For 89 (76.06%) of the analyzed species, no scientific articles published according to the Scopus database were identified. We also identified that only Cactaceae, Fabaceae (only one species), Lauraceae, and Lentibulariaceae had information in the IUCN Red List database indicating data lack for the other species (Table 1).

The species of the Asteraceae family endemic to the Cerrado and which are under threat of extinction are popularly known and have a great interest in their biological activity compounds, such as insecticide, bactericides, and fungicides (Pinto *et al.*, 2002); *Lychnophora ericoides* (47) is characterized as a valuable genetic resource of the Cerrado and with economic value due to its analgesic, antioxidant, anti-inflammatory, antipyretic, antiedematogenic and antinociceptive properties (Semir *et al.*, 2011) *Pilocarpus microphyllus*, known as jaborandi (Rutaceae), is a species with importance for medicinal use (EMBRAPA, 2019), it was already expected to find many publications (45).

Considering the fact that they are endangered species, it is alarming the small number of published articles, on average 1.3 articles per species, since a higher number of studies tend to favor the preservation and awareness and respect for the critical situation in situations that are used. With a lack of information

and intense exploration, changes in habitat due to agribusiness and urban occupation help in the loss of genetic resources since accentuated natural degradation (Ribeiro *et al*,. 2016).

Table 1. Information about endangered Brazilian Cerrado plant species considering the Normative Instruction number 6 of September 23, 2008, from the Brazilian Environment Minister.

Family	Species	**IUCN Red List**	**Number of articles by species**	**Number of articles by family**
Acanthaceae	*Staurogyne warmingiana*	NA	0	1
	Stenandrium stenophyllum	NA	1	
Amaranthaceae	*Gomphrena hatschbachiana*	NA	0	
	Pfaffia argyrea	NA	0	2
	Pfaffia minarum	NA	0	
	Pfaffia townsendii	NA	2	
Apocynaceae	*Metastelma harleyi*	NA	0	0
Arecaceae	*Acanthococos emensis*	NA	0	
	Attalea barreirensis	NA	1	1
	Attalea brasiliensis	NA	0	
Aspleniaceae	*Asplenium schwackei*	NA	0	0
Asteraceae	*Anteremanthus hatschbachii*	NA	0	
	Aspilia pohlii	NA	0	
	Lychnophora ericoides	NA	47	48
	Viguiera aspilioides	NA	1	
	Viguiera corumbensis	NA	0	
	Viguiera hilairei	NA	0	
Bignoniaceae	*Jacaranda intricata*	NA	0	0
Cactaceae	*Arthrocereus melanurus ssp ondurus*	Vulnerable	1	
	Arthrocereus rondonianus	Least Concern	0	
	Cipocereus crassisepalus	Endangered	0	
	Pilosocereus aurisetus ssp. Aurilanatus	Least Concern	8	12
	Uebelmannia buiningii	Critically Endangered	1	
	Uebelmannia gummifera	Endangered	1	
	Uebelmannia pectinifera ssp. Pectinifera	Endangered	1	
Celastraceae	*Maytenus rupestris*	NA	1	1
Convolvulaceae	*Ipomoea macedoi*	NA	1	1
Cyperaceae	*Bulbostylis distichoides*	NA	0	0
	Bulbostylis smithii	NA	0	

Eriocaulaceae	*Actinocephalus cipoensis*	NA	1	
	Actinocephalus claussenianus	NA	0	
	Paepalanthus crinitus	NA	0	
	Paepalanthus extremensis	NA	0	
	Paepalanthus hydra	NA	0	
	Paepalanthus rhizomatosus	NA	0	11
	Paepalanthus scytophyllus	NA	0	
	Syngonanthus brasiliana	NA	0	
	Syngonanthus elegans	NA	9	
	Syngonanthus magnificus	NA	0	
	Syngonanthus suberosus	NA	1	
Fabaceae	*Dimorphandra wilsonii*	Critically Endangered	15	
	Mimosa heringeri	NA	0	15
	Mimosa humifusa	NA	0	
	Mimosa montiscarasae	NA	0	
	Mimosa pabstiana	NA	0	
Iridaceae	*Pseudotrimezia elegans*	NA	0	
	Pseudotrimezia synandra	NA	0	
	Pseudotrimezia gracilis	NA	0	0
	Pseudotrimezia tenuissima	NA	0	
	Trimezia fistulosa	NA	0	
	Trimezia pusilla	NA	0	
Lamiaceae	*Eriope machrisae*	NA	0	
	Hyptidendron claussenii	NA	0	
	Hyptis arenaria	NA	0	
	Hyptis frondosa	NA	0	
	Hyptis imbricatiformis	NA	0	1
	Hyptis pachyphylla	NA	1	
	Hyptis penaeoides	NA	0	
	Hyptis rhypidiophylla	NA	0	
	Hyptis tagetifolia	NA	0	
Lauraceae	*Ocotea langsdorffii*	Vulnerable	0	0
Lentibulariaceae	*Utricularia biovularioides*	Least Concern	0	0
Loganiaceae	*Spigelia aceifolia*	NA	0	0
	Spigelia cipoensis	NA	0	
Lycopodiaceae	*Huperzia aqualupiana*	NA	1	1
	Huperzia rubra	NA	0	

Lythraceae	*Cuphea adenophylla*	NA	0	
	Cuphea cipoensis	NA	0	
	Cuphea teleandra	NA	0	
	Diplusodon ericoides	NA	0	
	Diplusodon glaziovii	NA	0	
	Diplusodon gracilis	NA	0	0
	Diplusodon hatschbachii	NA	0	
	Diplusodon minasensis	NA	0	
	Diplusodon panniculatus	NA	0	
	Diplusodon retroimbricatus	NA	0	
	Diplusodon vidalii	NA	0	
Malpighiaceae	*Aspicarpa harleyi*	NA	0	0
Melastomataceae	*Cambessedesia hermogenesii*	NA	0	
	Lavoisiera itambana	NA	0	
	Marcetia oxycoccoides	NA	0	0
	Ossaea warmingiana	NA	0	
	Tibouchina bergiana	NA	0	
Orchidaceae	*Constantia cipoensis*	NA	1	
	Constantia microscópica	NA	0	
	Habenaria itacolumia	NA	0	
	Pseudolaelia cipoensis	NA	0	1
	Scuticaria itirapinensis	NA	0	
	Sophronitis brevipedunculata	NA	0	
	Sophronitis endsfeldzii	NA	0	
Passifloraceae	*Passiflora saccoi*	NA	0	0
Plantaginaceae	*Angelonia alternifólia*	NA	0	0
Poaceae	*Gymnopogon doellii*	NA	0	
	Panicum brachystachyum	NA	1	
	Paspalum biaristatum	NA	0	2
	Paspalum longiaristatum	NA	0	
	Paspalum niquelandiae	NA	1	
Polygalaceae	*Polygala franchetii*	NA	0	0
Pteridaceae	*Pellaea gleichenioides*	NA	0	0
Rubiaceae	*Galianthe souzae*	NA	0	
	Hindsia ibitipocensis	NA	1	2
	Mitracarpus rigidifolius	NA	0	
	Staelia hatschbachii	NA	1	
Rutaceae	*Pilocarpus microphyllus*	NA	45	47
	Pilocarpus trachylophus	NA	2	
Sapindaceae	*Talisia subalbens*	NA	2	2
Solanaceae	*Cestrum tubulosum*	NA	1	1
Verbenaceae	*Stachytarpheta procumbens*	NA	0	0
Vitaceae	*Cissus inundata*	NA	0	0

Xyridaceae	*Xyris cipoensis*	NA	2	
	Xyris coutensis	NA	0	
	Xyris hystrix	NA	0	
	Xyris nigricans	NA	0	2
	Xyris phaeocephala	NA	0	
	Xyris platystachya	NA	0	
	Xyris retrorsifimbriata	NA	0	
Total			151	151

As for species characteristics, after consulting the Reflora database, most threatened species are herbs (40%) (Figure 1), grow from the terrestrial substrate (82%) (Figure 2), from the phytogeographic domain rupestre (47 %) (Figure 3) and occurs in the southeastern region (59%) (Figure 4), with emphasis on the state of Minas Gerais. The largest amount of scientific production in Brazil occurs in the southeast region, with the State of Minas Gerais ranking third (Cross *et al.*, 2018), coupled with the fact that the Cerrado occurs in large part of the mining territory.

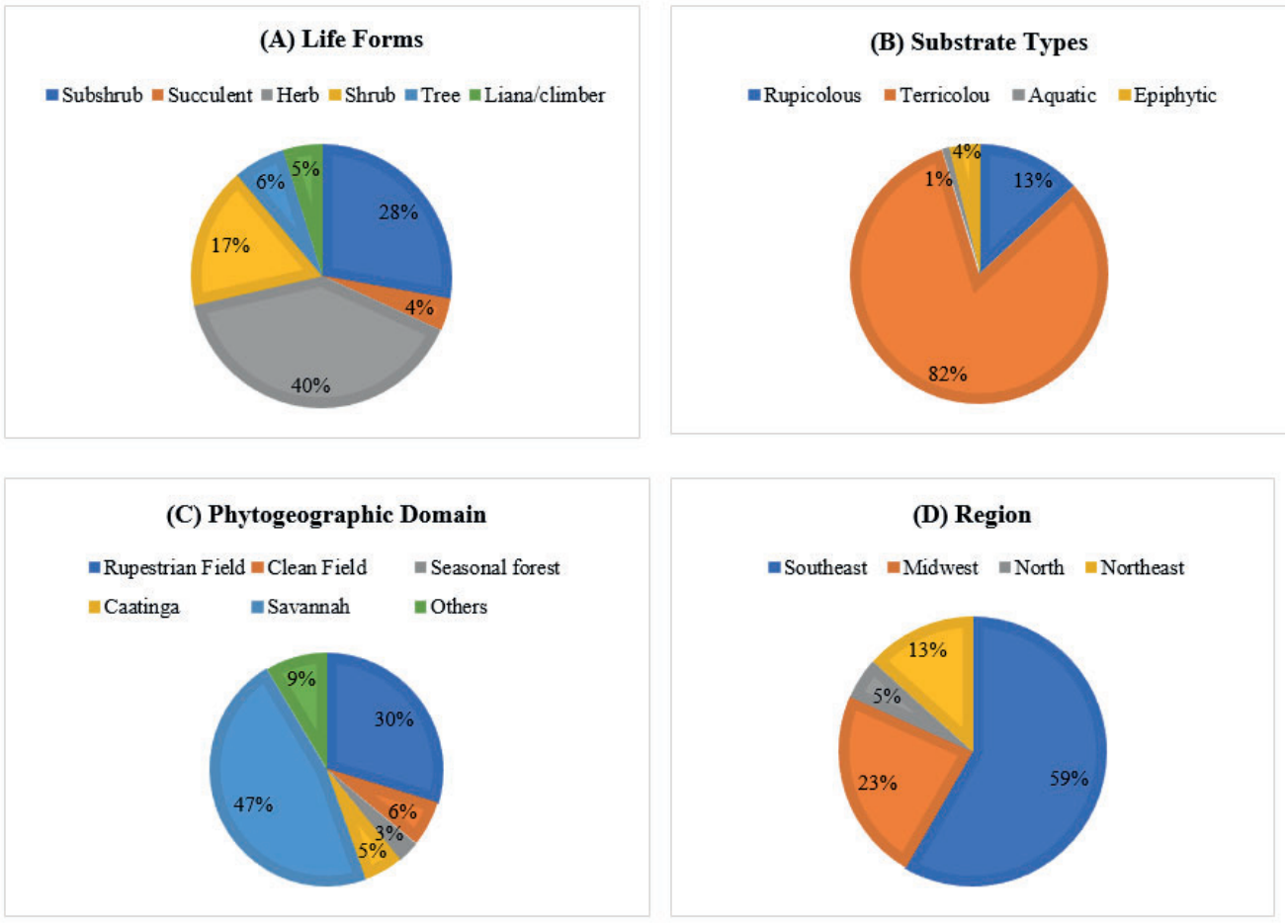

Figure 1. Life forms (A), substrate types (B), phytogeographic domain (C) and region (D) of threatened plant species in the Cerrado.

When, by whom, and where were scientific articles on endemic endangered Cerrado plants published?

As for the type of work, the majority (93%) of the articles found were original articles with only 1.3% of review articles, among the other 6% are the erratum, book chapter, letter, note, and conference

article. Review articles are characterized by being useful and widely used, contemplating a critical role to spread the information among scientists and to allow the information facilitated for other people. Also, review articles are of significant importance in comparing information from different sources, compressing existing knowledge, supporting bibliographic search, and directing research to new areas (Figueiredo, 1990). Therefore, these articles facilitate and contribute to researchers and scientists to update studies advancing in a particular area (Rother, 2007).

The most common original language of publication was English (81%), followed by Portuguese (17%). English is considered the official language of science, as it is a language known worldwide, which allows the communication of scientific knowledge at the international level between teaching and learning institutions (Finardi and Guimaraes, 2017). The importance of having a unifying language will continue to increase as the language has become essential in the scientific world, in the publication of scientific works and discoveries, researchers from all over the world try to use English usually. With that, a concern arises regarding proficiency in the English language in the academic environment in which they seek to optimize reading, comprehension, and writing in the language (Zambonato, 2019).

As expected, the country with the largest number of publications with these species was Brazil. Scientific production has increased in recent decades in Brazil; currently, the country occupies the 13th place in the world ranking of scientific production. This increase is due to the growth of universities and research institutions, training of new doctors and investments from the federal government, however, much still needs to be done to increase the impact of Brazilian research considering that the Brazilian innovation index remains low, despite the increase in production (Moreira, 2018).

The leading research institutions involved in the development of studies on endangered plant species in the normative instruction number 6 of September 23, 2008, are all destined for public universities in Brazil, among them: Universidade Federal de Lavras - Department of Biology (8), Universidade Estadual Paulista - Department of Physics and Chemistry (6), University of São Paulo - Faculty of Pharmaceutical Sciences of Ribeirão Preto (6), Federal University of Goiás - Department of Botany (5). Among the leading research promotion agencies, the Coordination for the Improvement of Higher Education Personnel (CAPES) and the National Council for Scientific and Technological Development (CNPq) stand out. CAPES has a fundamental role in the amplification and progress of postgraduate studies (master and doctorate) in all states of the Federation; besides, she is in charge of the leading national and international scholarships for Brazilian students at the postgraduate level (CAPES, 2020). CNPq's primary function is to promote scientific and technological research by providing training for Brazilian researchers, in addition to being responsible for postgraduate scholarships (CNPq, 2020). Thus, CAPES and CNPq are fundamental for technological, social, environmental, cultural and economic development to build a promising Brazilian future; however, the current situation for graduate education is critical, as well as for all higher education, more investment with public resources is essential in order to ensure the development of science and graduate education. Only with these changes will it be possible to achieve what was proposed in the National Education Plan regarding postgraduate studies (Jardim, 2020).

As shown in figure 2, the number of articles published per year has increased, although, in eight years, the publication of only one article with the researched species was observed. In 2017 there was a peak

in production, with 17 articles published. This growth in scientific production by universities and research institutions is probably related to the training of new doctors and the increase in investments by the Brazilian government in the country's education and science (Hilu and Gisi, 2011). Thus, it is also possible to associate the environmental movement, environmental laws, and agendas that Brazil signed in international agreements and the concept of sustainable development as recommended since the Brundtland Report. Besides, there has been a rise in environmental policies over the past few decades; however, this development is threatened thanks to government actions that intend to consolidate the Brazilian environmental policy by promoting the national and international exploitation of natural resources in opposition to article 225 of the Brazilian Constitution "Everyone has the right to an ecologically balanced environment, common use of the people and essential to a healthy quality of life, imposing on public authorities and the community the duty to defend and preserve it for present and future generations " (Silva *et al.*, 2019).

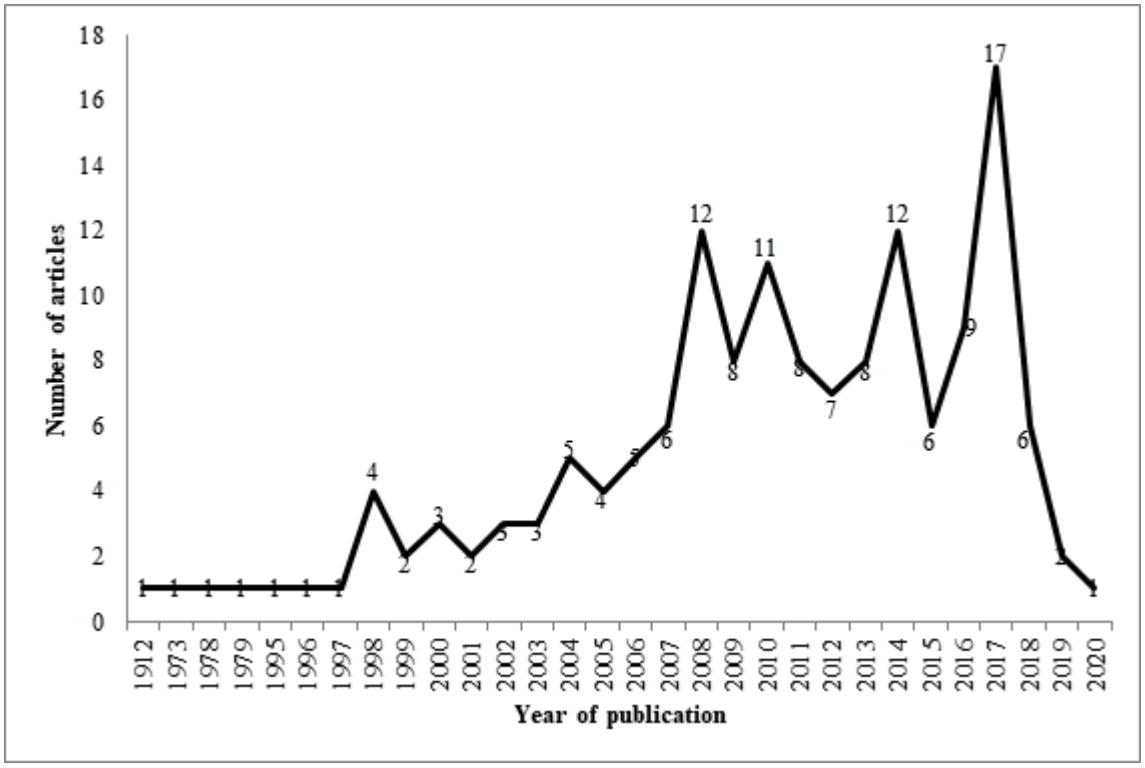

Figure 2. Number of articles by year related to endangered Brazilian Cerrado plant species.

The journals that stood out in publications with endangered Brazilian plant species were: Acta Botanica Brasilica (7), PLoS One (7), Biochemical Systematics and Ecology (5) and Revista Brasileira de Plantas Medicinais (5). According to Plos One itself, it is aimed at disseminating multidisciplinary and consistently interdisciplinary research, covering more than two hundred areas of science, engineering, medicine, social sciences, and humanities. Most publications (58%) had a low number of citations, that is, seven or fewer citations. Above ten citations, only 54 articles (36%) are observed (Figure 3). The impact factor of a journal or journal is related to the frequency with which articles are cited, revealing the quality of that journal (Ruiz *et al.*, 2009). The article with the highest number of citations, 81, addresses the use of medicinal plants in the region of the Cerrado biome and the use by the rural and urban population for herbal purposes, often linked to economic power.

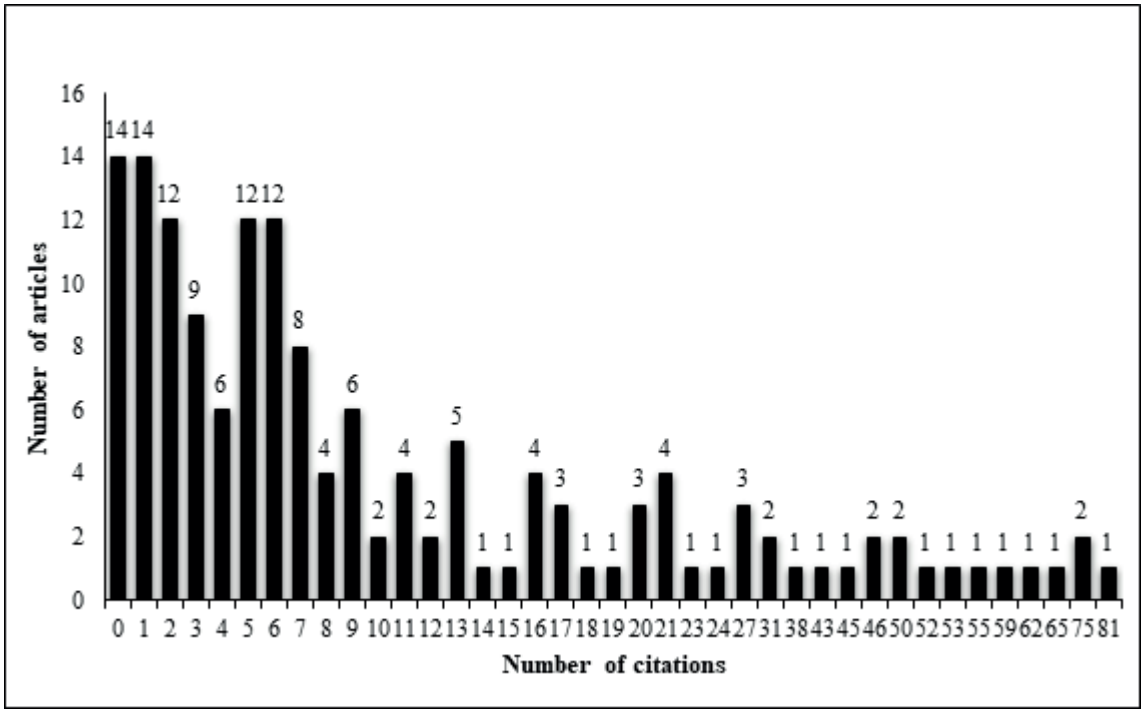

Figure 3. Distribution of the number of articles related to the number of citations in studies related to endangered Brazilian Cerrado plant species.

On average, the selected articles had 5.7 authors. Most articles (77%) have six or fewer authors (Figure 4). There is a trend towards an increase in the number of authors over the years (Table 3). Mattedi and Spiess (2017), found a significant association between the impact factor and the number of authors per article, and articles with a higher number of authors tend to receive more citations, corroborating this study (Table 3). Thus, there is a propensity to increase the number of citations according to a significant impact factor, in addition to demonstrating that over the years, there has been significant compliance with the impact factor of published journals. The Impact Factor is one of the mechanisms to assess the quality of a given journal, in addition to representing the link between the number of citations in a journal and its number of published articles. Therefore, in the academic environment, it becomes relevant to publish in high impact magazines aiming to certify performance indicators (Goldenberg, 2019).

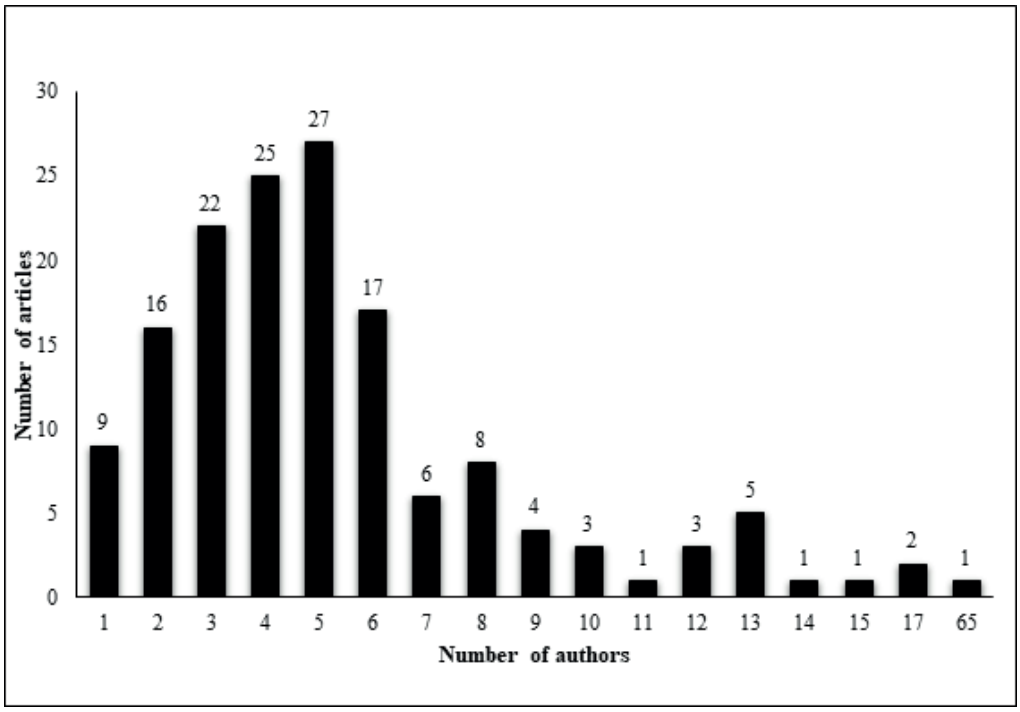

Figure 4. Distribution of the number of articles related to the number of authors that have published studies related to endangered Brazilian Cerrado plant species.

Table 3. Pairwise associations between the number of citations, number of authors, year of publication, and journals' impact factor that has published studies related to endangered Brazilian Cerrado plant species.

Associations	***r***	***p****
Number of citations x Year	-0,1309	0,1096
Number of citations x Impact factor	0,3628	<0,0001
Number of authors x Number of citations	0,0669	0,4143
Number of authors x Year	0,1940	0,0172
Number of authors x Impact factor	0,4135	<0,0001
Impact factor x Year	0,2163	0,0078

* Pearson's correlation

CONCLUSION

In this study, we evaluated the current state of scientific knowledge production for the list of plant species in the Cerrado that are threatened with extinction, which were listed as a priority for conservation in the normative instruction 6 of September 23, 2008. We found that even after more than twenty years of the publication of the normative instruction, little is known about these species from a scientific point of view. In this sense, research efforts and training of researchers specialized in these groups are still an essential demand for Brazil. We also found that review articles on these species are scarce and that the vast majority are not yet registered on the IUCN Red List. The results confirmed a trend of studies with a higher number of authors since this quantity is associated with a more significant number of citations and consequently, a high impact factor of the journals. Finally, there is a lack of scientific production with these species, which hinders the acquisition of knowledge about them and consequently, the development of

conservation strategies, since they are species threatened with extinction.

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