

# Trends and gaps of the scientific literature on the Cerrado biome: A scientometric analysis

## Tendências e lacunas da literatura científica sobre o bioma Cerrado: uma análise cienciométrica

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### Abstract

The Cerrado (Brazilian savanna) is the second largest Brazilian biome and is considered a biodiversity hotspot, for presenting high endemism and being under intense threat. This study aimed at highlighting publication trends on the Cerrado, detecting possible gaps and indicating future directions for scientific studies on this biome. We searched for articles between 1991 and 2012 in the journal database of the Institute for Scientific Information (ISI). We observed a significant increase in the number of articles throughout the years of the evaluated period ( $r=0.89$ ;  $P<0.001$ ), demonstrating an increasing interest of the scientific community in the Cerrado. Largely addressed issues were related to biodiversity (64.75%), followed by abiotic environment (13.38%) and agricultural crops (11.21%). In addition, 10.65% addressed both biodiversity and abiotic environment jointly. The most studied taxonomic group was plants (42%), followed by fungi (18%) and insects (12%). Fishes presented a lower number of studies (0.6%). The main gaps concern the few studies dealing with abiotic aspects and freshwater organisms, such as fishes, and also a low increment in the number of articles on invertebrates, except insects. Based on these gaps, we suggest that future studies must be especially directed towards aquatic environments and their biodiversity.

**Keywords:** biodiversity, hotspot, scientometrics.

### Resumo

O Cerrado (Savana brasileira) é o segundo maior bioma brasileiro, sendo considerado um *hotspot* de biodiversidade, pois apresenta elevado endemismo e está sob intensa ameaça. O objetivo deste trabalho foi destacar as tendências das publicações sobre o Cerrado, detectar possíveis lacunas e indicar direções futuras para trabalhos científicos nesse bioma. Foi realizada uma busca de artigos utilizando-se a base de periódicos do Institute for Scientific Information (ISI), entre os anos de 1991 a 2012. Foi observado um aumento significativo de artigos ao longo dos anos ( $r=0,89$ ;  $P<0,001$ ), demonstrando aumento de interesse da comunidade científica sobre o Cerrado. Grande parte dos trabalhos aborda assuntos relacionados à biodiversidade (64,75%), seguida do meio abiótico (13,38%) e de culturas agrícolas (11,21%). Além disso, 10,65% desses trabalhos abordam os temas biodiversidade e meio abiótico conjuntamente. O grupo taxonômico mais estudado foi o das plantas (42%), seguido de fungos (18%) e insetos (12%). Os peixes apresentaram um menor número de estudos (0,6%). As principais lacunas detectadas estiveram relacionadas a aspectos abióticos e organismos límnicos, como, por exemplo, peixes, bem como um baixo incremento no número de artigos enfocando invertebrados, excetuando-se os insetos. Assim, sugere-se que futuros estudos sejam direcionados principalmente aos ecossistemas aquáticos e sua biodiversidade.

**Palavras-chave:** biodiversidade, ciencimetria, *hotspot*.

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## Introduction

Among the world's important biomes, the Cerrado stands out for its high species diversity and endemism (Myers *et al.*, 2000), being considered the most diverse Savanna of the planet (Klink and Machado, 2005). It occupies an area of about 2,000,000 km<sup>2</sup> in Central Brazil (Oliveira and Marquis, 2002; Oliveira-Filho and Rater, 2002). This biome is constituted by a mosaic of physiognomies that vary from fields to forest formations (Ribeiro and Walter, 2008). It is the second largest biome of Brazil in terms of land surface, covering the states of Goiás, Tocantins, Mato Grosso, Minas Gerais, Mato Grosso do Sul, Bahia, Maranhão, Rondônia, Piauí, São Paulo, Ceará and Distrito Federal, besides enclaves in the states of Paraná, Amapá, Pará, Amazonas and Roraima (Cavalcanti and Joly, 2002; Oliveira-Filho and Rater, 2002; Ribeiro and Walter, 2008).

The Cerrado presents a high biodiversity, with about 33% of all life forms of Brazil (Aguiar *et al.*, 2004). The biome has about 837 species of birds (Myers *et al.*, 2000), 161 of mammals, 120 of reptiles, 150 of amphibians (Myers *et al.*, 2000), and about 67,000 of invertebrates (Aguiar *et al.*, 2004). Moreover, it has a high level of endemism: for example, among the Cerrado's plant species, about 44% are endemic (Myers *et al.*, 2000; Silva and Bates, 2002). Subjugated for long, so much so that it is not considered a National Patrimony site by the Federal Constitution of Brazil promulgated in 1988 (Coutinho, 2006), this biome has suffered accentuated conversion of natural vegetation into areas under cultivation. About 54 million hectares are already occupied by pastures and 21.5 million hectares by crops (Sano *et al.*, 2010).

No study dealing with the state of the art of the scientific literature about the Cerrado is known. The lack of understanding of what has been developed in the biome hinders future strategies

for its conservation difficulty. The assessment of the scientific production on a particular subject can highlight which the trends and gaps of knowledge are and, thus, guide future studies aiming at better understanding natural ecosystems and taxonomic groups, mainly those which got little attention from the scientific community (Nabout *et al.*, 2012). One of the assessment forms of scientific activity is scientometrics (Vanti, 2002), which can be defined as a quantitative or qualitative technique for evaluation of scientific or technological production (Vanti, 2002; Verbeek *et al.*, 2002).

Various knowledge areas carry out scientometric studies to diagnose the trends of the scientific literature, as, for example, studies on ecology (Pinto *et al.*, 2003; Bini *et al.*, 2005; Fazey *et al.*, 2005; Melo *et al.*, 2006), climate changes (Stanhill, 2001; Nabout *et al.*, 2012), organism groups (Carneiro *et al.*, 2008; Padial *et al.*, 2008; Nabout *et al.*, 2009), and genetic studies (Quixabeira *et al.*, 2010). Therefore, this study aimed at carrying out a scientometric analysis on the Cerrado, seeking to understand the publication trends in the period of 1991 to 2012, detecting the biases and indicating future directions for scientific studies on this biome. In this work, we attempted particularly: (i) to evaluate the temporal trend in the number of articles throughout the years; (ii) to verify which the main journals and the most cited studies are, (iii) to highlight the type of approach of the studies (i.e., biodiversity, agricultural crops or abiotic) and (iv) to verify which taxonomic groups are studied.

## Material and methods

Publications on the Cerrado biome between 1991 and 2012, indexed in the Web of Knowledge-Thomson Reuters platform were accessed through *Web of Science* (www.isiknowledge.com), which covers the main articles published in the world. Only that journal database was used due to its great im-

portance in academics. Moreover, the use of another database would generate article redundancy, since most documents captured in a database would be repeated in the other (e.g. Web of Science and Scopus). The database used has studies indexed since 1945, but summaries are available only from 1991 on, which justifies the choice of the period of analysis. The search was made by capturing articles with the words “*Brazilian Cerrado*” OR “*Brazilian Savanna*” OR “*Biome Cerrado*” OR “*Cerrado*” in their titles.

The variables analyzed from the title, keywords and abstract of each article, were: (i) year of publication; (ii) journal in which the text was published; (iii) number of citations of the article; (iv) approach of the article (biodiversity, agricultural crops or abiotic), and (v) taxonomic group studied (humans, mammals, amphibians, birds, reptiles, fish, insects, invertebrates, except insects, micro-organisms, plants and fungi). The name of the journal in which the article is published was obtained from the very data sheet generated by the platform. The articles were classified in the following categories: (i) biodiversity, when they dealt with living organisms, native or exotic, occurring in the Cerrado, (ii) agricultural crops, when related to crops for agricultural purposes in the Cerrado, and (iii) abiotic aspects, when they dealt with environmental variables, such as soil and climate, among other things. The following types of publications were analyzed: articles, notes or reviews. The other typologies of identified publications, i.e., letters and opinions, were ignored in this analysis for not fitting in the objective of the proposed study.

To verify whether there was an increase in the number of articles on the Cerrado throughout the years, we carried out a Pearson correlation ( $P < 0.05$ ) between the years and the number of articles. Correlations ( $r$ ) were also carried out for all investigated taxonomic groups (i.e., birds, mammals, etc.), in order to evaluate the temporal trend in the number of articles throughout the

years. Therefore, positive values of  $r$  indicate that the number of articles for a particular taxonomic group is increasing throughout the years, while negative values indicate a reduction in the number of articles. The taxonomic groups were thus evaluated between each other, considering the total number of articles and the temporal trend (Pearson's  $r$ ). Data analyses were carried out using software R (R Core Team, 2012).

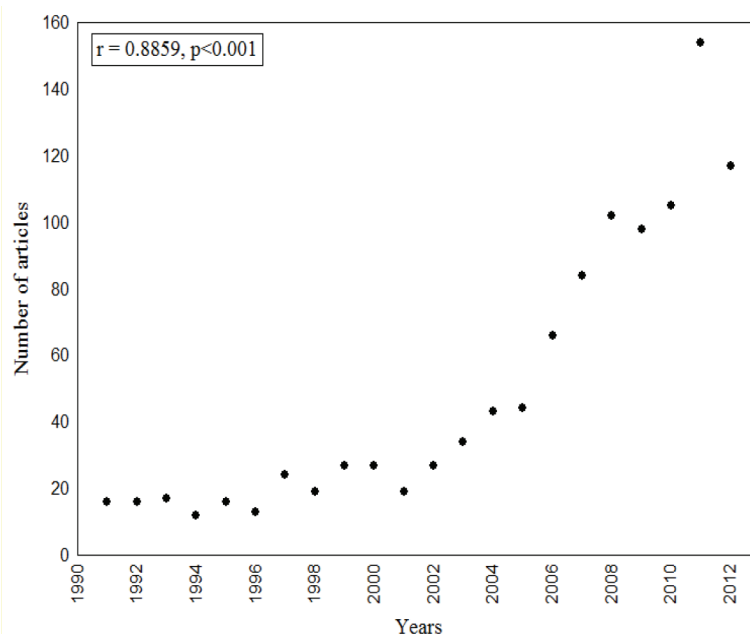
## Results

A total of 1,080 publications on the Cerrado biome was registered for the period 1991-2012. A significant increase in studies was detected for this period ( $r = 0.89$ ;  $P < 0.01$ ) (Figure 1).

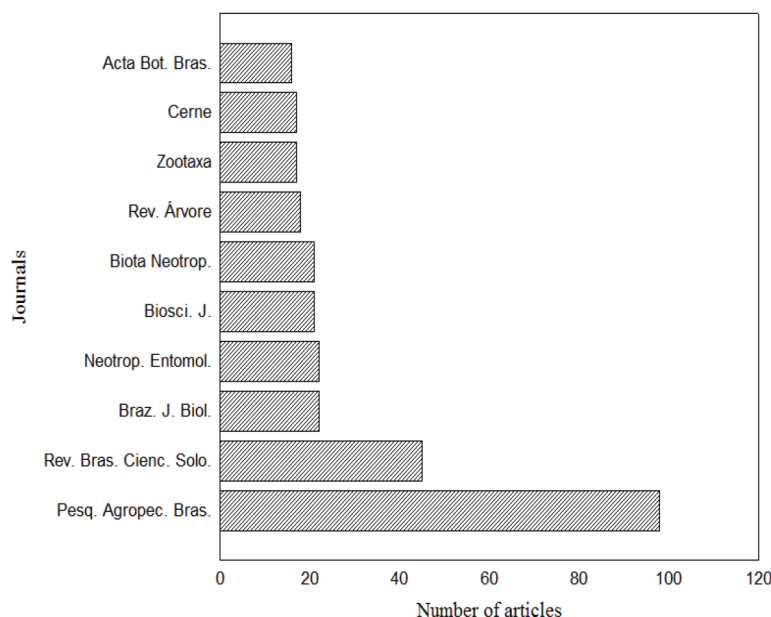
A total of 293 different journals with articles on the Cerrado were registered. The article distribution in these journals is asymmetric, given that 45% of all the article production is linked to only 19 journals. The majority of the articles on the Cerrado was published in Brazilian journals (57%), which also represent the 10 journals with the highest number of articles. The journal *Pesquisa Agropecuária Brasileira* (PAB) presented the highest number of articles (Figure 2), with a total of 98 articles (or 9.07% of the total).

The most cited publication of the set of sampled articles was the study of Ratter *et al.* (1997), followed by Klink and Machado (2005) (Table 1). It is important to highlight that these articles deal with biodiversity and conservation.

It was possible to classify the type of study for 1,061 of the total 1,080 articles. Most articles, 806 (64.75%), dealt with elements of the biodiversity of the Cerrado. Other 119 (11.21%) dealt with agricultural crops, 142 (13.38%) with the abiotic environment, and 113 (10.65%) covered both biodiversity and abiotic characteristics of the Cerrado. Only 27 have the word conservation in their title. They dealt with the most different aspects, biodiversity conservation being dealt with in most studies (15), in which birds (05),



**Figure 1.** Temporal trend of the total number of articles on the Cerrado published between 1991 and 2012 and indexed by the Thomson ISI journal database.



**Figure 2.** Scientific journals with the highest number of articles on the Cerrado published between 1991 and 2012 and indexed by the Thomson ISI journal database.

mammals (03), anurans (03), plants (01), ants (01) and vertebrates in general (02) are represented. Four articles dealt with aspects of genetic conservation and one with phylogenetic diver-

sity. The conservation of the Cerrado as a whole as well as the conservation of the soil are subjects of four articles. Effects of human development and exotic crops on biodiversity conservation

**Table 1.** Most cited articles on the Cerrado among those published between 1991 and 2012 and indexed by Thomson ISI journal database.

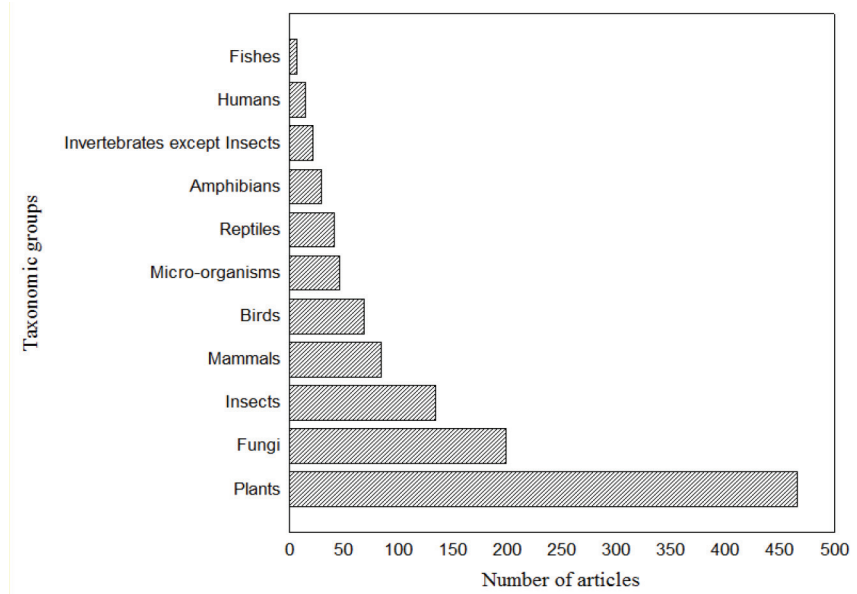
Journal	Title	Authors	Year	Citations
<i>Annals of Botany</i>	The Brazilian Cerrado vegetation and threats to its biodiversity	Ratter <i>et al.</i>	1997	244
<i>Conservation Biology</i>	Conservation of the Brazilian Cerrado	Klink and Machado	2005	211
<i>Journal of Geophysical Research-Atmospheres</i>	Smoke and fire characteristics for Cerrado and deforestation burns in Brazil - base-B experiment	Ward <i>et al.</i>	1992	171
<i>Journal of Ecology</i>	Relationships of fire, biomass and nutrient dynamics along a vegetation gradient in the Brazilian Cerrado	Kauffman <i>et al.</i>	1994	116
<i>Plant Cell And Environment</i>	Fluxes of carbon, water and energy over Brazilian Cerrado: An analysis using eddy covariance and stable isotopes	Miranda <i>et al.</i>	1997	105
<i>Journal of Herpetology</i>	An introduction to the ecology of Cerrado lizards	Vitt	1991	102
<i>Functional Ecology</i>	Atmospheric and hydraulic limitations on transpiration in Brazilian Cerrado woody species	Meinzer <i>et al.</i>	1999	98
<i>Tree Physiology</i>	Partitioning of soil water among tree species in a Brazilian Cerrado ecosystem	Jackson <i>et al.</i>	1999	80
<i>SOil &amp; Tillage Research</i>	Carbon sequestration in two Brazilian Cerrado soils under no-till	Bayer <i>et al.</i>	2003	77
<i>Geoderma</i>	Soil organic matter dynamics in density and particle size fractions as revealed by the (13)C/(12)C isotopic ratio in a Cerrado's oxisol	Roscoe <i>et al.</i>	2001	73

are subjects of one article each, and aspects related to climate instability and conservation of the Cerrado appears in one article only.

As regards the taxonomic group, there was a predominance of studies about plants (466), both native and exotic, corresponding to 42% of the total. We found 199 publications (18%) on fungi, 134 (12%) on insects, 84 (8%) on mammals, and 22 (2%) of invertebrates, except insects. The less studied group was that of fishes, with seven articles only (0.6%) (Figure 3). However, the time trend analysis of each taxonomic group (indicated by Pearson's  $r$ ) showed that the groups with the highest increase in the number of articles were birds ( $r = 0.82$ ), insects ( $r = 0.81$ ), mammals ( $r = 0.80$ ) and amphibians ( $r = 0.78$ ) (Figure 4).

## Discussion

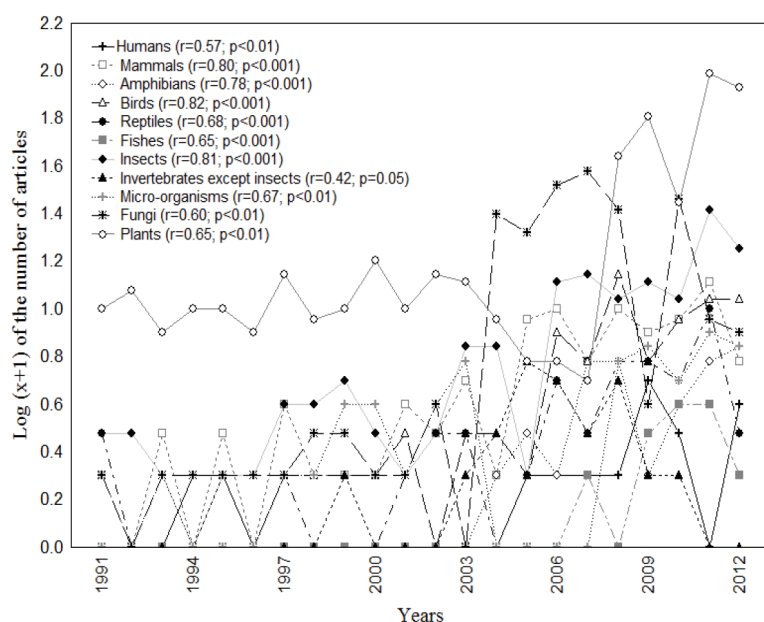
In this study, we verified that the number of articles on the Cerrado has been increased throughout the

**Figure 3.** Taxonomic groups registered in the scientific literature on the Brazilian Cerrado published between 1991 and 2012 and indexed by the Thomson ISI journal database.

years. It is important to point out that a similar increase is being constantly registered in scientometric studies on various knowledge areas (King, 2004;

Carneiro *et al.*, 2008; Nabout *et al.*, 2012). However, the Cerrado is given less attention than other biomes in the scientific literature. A search for titles





**Figure 4.** Temporal trend of the total number of articles on taxonomic groups occurring in the Cerrado published between 1991 and 2012 and indexed by the Thomson ISI journal database.

in ISI between 1991 and 2012 shows that Amazon had 6,456 articles (search terms: Amazon, OR “Amazon Forest”) and the Atlantic forest 1,352 articles (search terms “Atlantic Rainforest” OR “Atlantic Forest”). This shows that, despite the temporal increase in articles, the Cerrado is still in need of more studies on its natural resources.

An important bias characterizing the endogeneity of the articles on the Cerrado is the predominance of such articles in Brazilian journals. In fact, it is possible that the interest in studying the Cerrado comes from the local scientific community and that the results of such studies have more impact on the Brazilians themselves. However, the fear or even the very experience of a refusal from foreign journals can also lead researchers to submit their articles to national journals (Meneghini, 2010). Even taking into account the increase in the number of articles indexed in international databases (as Thompson-ISI; Leta and Chaimovich, 2002), Brazilian journals are still poorly aimed at internationally (Meneghini, 2010), a fact that is demonstrated by the low number of

citations. This is probably due to the large number of articles still published in Portuguese. Moreover, the subjects dealt with can be of high relevance in Brazil, but have a small impact on the international stage (Packer, 2011).

Two aspects presented in this study show the bias of the studies on the Cerrado in favor of conservation aspects, namely articles on conservation with high number of citations and predominance of studies characterizing biodiversity. Various factors have been pointed out as responsible for the number of citations of an article, among which the language of the study (Bornmann *et al.*, 2012), characteristics of the title (Jamali and Nikzad, 2011), scope of the study (Jabbour *et al.*, 2013), and quality of the article (Padial *et al.*, 2010). The two most cited articles in the period of this study, namely Ratter *et al.* (1997) and Klink and Machado (2005), deal with general subjects as characteristics of the Cerrado, biodiversity conservation and effects of agriculture. These are subjects of interest to researchers of various knowledge areas, which can contribute to a high number

of citations. Moreover, both studies were published in important international journals.

Another item that characterizes the bias in favor of conservation in the studies on the Cerrado is the concentration of studies analyzing the biodiversity of this biome. In fact, the lack of knowledge of the geographic distribution of the species (known as Wallacean shortfall) and even the ignorance of the existing species (known as Linnean shortfall) make the elaboration of conservation strategies difficult (see Bini *et al.*, 2006). Therefore, studies aiming at characterizing biodiversity describing ecological processes of taxonomic groups are essential in biomes like the Cerrado, i.e., with little scientific knowledge, with high biodiversity and highly impacted. The predominance of studies with plants, verified in the study period, can be explained by the high endemism and danger of extinction of this group (Myers *et al.*, 2000).

The predominance of studies related to biodiversity, in special for the group of plants, has already been highlighted in other scientometric studies (see Nabout *et al.*, 2012; Siqueira *et al.*, 2009 for global climate changes). This trend is confirmed for the Cerrado seeing that this biome has more than 10,000 species of plants, with predominance of various endemic species (Myers *et al.*, 2000). It is important to highlight that the concentration of studies dealing with some groups or the strong time trend of their growth rates cannot justify abandoning studies related to them. New environment problems keep occurring, such as impacts of global climate changes on ecosystems, and it is necessary to evaluate their consequences on biodiversity in general (see scientometrics in Nabout *et al.*, 2012). On the other hand, the scarcity of studies on a particular taxonomic group shows that it is necessary to extend the investigation on that group.

In addition to the studies on plants, there has been a significant increase

in studies dealing with other taxonomic groups in recent years. This can be a reflection of the researchers' interest in studying groups with high level of endemism and danger of extinction (Myers *et al.*, 2000). Some factors make the studies of aquatic ecosystems difficult and may have contributed to a low number of studies on fishes, as the lack of researchers and infrastructure on samplings (Agostinho *et al.*, 2005), which justifies the low representation of studies on this group of organisms.

## Concluding remarks

Scientometric research allows to infer the trends of scientific publications and contributes to determine their biases and gaps. The results of this study supply some indicators on the scientific production about the Cerrado, pointing out trends and gaps of the studies on that biome. Among the trends we may highlight the following: (i) increment in the number of articles throughout the years; (ii) most publications concentrated in Brazilian journals, and (iii) many studies dealing with aspects of biodiversity, mainly of plants. On the other hand, the main gaps concern the few studies dealing with abiotic aspects and freshwater organisms, such as fishes, and also a low increment in the number of articles on invertebrates, except insects.

Based on the above mentioned gaps, we suggest that future studies must be especially directed towards aquatic environments and their biodiversity. It is also important to extend studies related to the abiotic environment, but without abandoning aspects of the biome's biodiversity and ecosystems, beside studies on the conservation of this biome, which is very important for the maintenance of the natural resources of Brazil. Moreover, it would be important to extend the number of articles published in widely visible international journals and thus, indirectly, to increase the attention of the

world-wide scientific community for the species richness, the high levels of degradation and questions of handling and conservation of the Cerrado.

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