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TATIEL VENÂNCIO GONÇALVES

Unidades de Conservação Brasileiras: tendências espaço-temporais da literatura científica, distribuição geográfica e suficiência climática

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TATIEL VENÂNCIO GONÇALVES

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Tese apresentada ao Programa de Pós-Graduação *Stricto Sensu* em Recursos Naturais do Cerrado, da Universidade Estadual de Goiás para obtenção do título de Doutor em Recursos Naturais do Cerrado.

Orientador: Prof. Dr. João Carlos Nabout

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Nome Completo: Tatiel Venâncio Gonçalves

E-mail: tatiel.eco17@gmail.com

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ATA DE DEFESA PÚBLICA DE TESE Nº 92/2020

Aos 30 dias do mês de Setembro do ano de 2020, às 13h30min, reuniu-se no auditório do bloco IV do Câmpus Anápolis de Ciências Exatas e Tecnológicas - Henrique Santillo da UEG, a banca Examinadora composta pelos: Dr. João Carlos Nabout (UEG), Dr. Ludgero Cardoso Galli Vieira (Universidade de Brasília), Dr. Hasley Rodrigo Pereira (Secretaria da Educação do Estado de Goiás), Dr. Fabrício Barreto Teresa (Universidade Estadual de Goiás) e Dr. Rodrigo Assis de Carvalho (Universidade Estadual de Goiás) para sob a presidência do primeiro, procederem à "defesa de Doutorado" intitulada: "Unidades de Conservação Brasileiras: Tendências espaço-temporais da literatura científica, distribuição geográfica e suficiência climática, de Tatiel Venâncio Gonçalves, discente do PPG Recursos Naturais do Cerrado, nível doutorado. Foi realizada a avaliação oral no sistema de apresentação e defesa de tese de autoria do(a) discente. Terminada a avaliação oral, a Banca Examinadora reuniu-se emitindo os seguintes pareceres mediante as justificativas e sugestões abaixo:

Membro da Banca	Parecer (Aprovado/Reprovado)	Assinatura
Dr. João Carlos Nabout	APROVADO	
Dr. Ludgero Cardoso Galli Vieira	APROVADO	
Dr. Hasley Rodrigo Pereira	APROVADO	
Dr. Fabrício Barreto Teresa	APROVADO	
Dr. Rodrigo Assis de Carvalho	APROVADO	

Justificativas e sugestões: atender as sugestões da banca que foram apresentadas na defesa e no documento final.

Após avaliação, a referida candidata foi considerada aprovado na defesa de tese. Às 18 horas, o (a) Prof. Dr. João Carlos Nabout, presidente da Banca Examinadora deu por encerrada a sessão e, para constar, lavrou a presente Ata:

Prof. Dr. Ludgero Cardoso Galli Vieira

Prof. Dr. Hasley Cardoso Galli Vieira

Prof. Dr. Fabrício Barreto Teresa

Prof. Dr. Rodrigo Assis de Carvalho

Prof. Dr. João Carlos Nabout

Para Kelly, com todo amor e carinho.

E para o futuro doutor Luiz Miguel, que cresça com sabedoria e saúde.

Agradecimentos

Tenho a muitos por agradecer por ter chegado até aqui. Todos, de alguma forma, contribuíram para que este momento pudesse ser alcançado. Agradeço a minha família pelos incentivos e apoios a mim dedicados ao longo desses anos. Agradeço a minha esposa por toda nossa caminhada até aqui, por ter me dado forças e pela família que estamos formando, com nosso Luiz Miguel crescendo cada dia mais inteligente e esperto.

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Sumário

Resumo

Os impactos ambientais atingem diretamente a biodiversidade. A conservação se torna, portanto, fundamental para a manutenção das espécies e dos ciclos biológicos. As Unidades de Conservação (UC) se tornaram uma das ferramentas essenciais para esse objetivo. Entretanto, ainda sabemos pouco sobre as UCs brasileiras e, em especial, no bioma Cerrado. Nessa tesa apresento dois artigos que procuram avaliar diferentes aspectos das UCs no bioma Cerrado e no Brasil. No primeiro artigo, avaliamos a geografia histórica de criação das UCs, a representação bioclimática e dados infométricos sobre o bioma Cerrado. Nós identificamos baixa cobertura por UCs no bioma, alta sobreposição de UCs, falta de contemplação de todas as variáveis bioclimáticas e muitas UCs com poucos trabalhos ou busca na internet. No segundo artigo, usamos um mapeamento sistemático para espacializar a produção científica nas UCs brasileiras e analisar se alguns fatores explicam as divergências existentes. Verificamos que há muitas UCs sem artigo ou com poucos artigos publicados. Verificamos também que fatores como ter área maior, ser uma UC mais antiga e estar próximo de área urbana podem explicar uma UC ter mais artigos do que as outras. Portanto, apresentamos resultados que podem contribuir para o mapeamento científico, histórico e eficiência das UC brasileiras e, assim, tomar ações que melhorem o status da conservação da biodiversidade.

Palavras-chave: Cerrado, conservação, mapeamento sistemático, número e diversidade de artigos.

Abstract

Environmental impacts directly affect the biodiversity. Therefore, the conservation becomes essential for the maintenance of species and biological cycles. Protected Area (PA) become one of the essential tools for this purpose. However, we still have little knowledge about Brazilian PAs and, especially, the Cerrado biome. In this thesis I present two papers that seek to evaluate different aspects of PAs in the Cerrado biome and in Brazil. In the first paper, we evaluated the historical geography of creation of the UCs, the bioclimatic representation and infometric data about the PAs of Cerrado biome. We identified low coverage by PAs in the biome, high overlap of PAs, gap of contemplation of all bioclimatic variables and many PAs with few papers or search on the internet. In the second paper, it has developed a systematic mapping to spatialized the scientific production in Brazilian PAs and analyzes whether some factors explain how divergences exist. We found that there are many PAs with no paper or few published papers. We also found that PAs with more papers were larger, older and close to an urban area.

Therefore, we present results that can contribute to the scientific, historical and efficiency mapping of Brazilian UCs and, thus, take actions that improve the status of biodiversity conservation.

Keywords: Cerrado, conservation, systematic mapping, number and diversity of papers

Introdução geral

A conservação de biomas e espécies é um desafio global frente aos impactos ambientais causados pelo ser humano. Em oposição à superexploração ambiental, cientistas e organizações têm buscado alternativas para conciliar a conservação ambiental com o uso dos recursos naturais. Tais medidas envolvem avanços em pesquisas, acordos internacionais, conscientização da sociedade, divulgação científica e envolvimento político. Diante da escassez de recursos humanos e financeiros, muitos países buscam priorizar áreas para a conservação, com o intuito de usar o mínimo de recursos com maior eficácia na conservação.

O Brasil é um exemplo de país megadiverso que passa por uma crise ambiental sem precedentes. Por um lado, a produção agrícola é um dos maiores mantenedores da economia nacional. Por outro, a exploração desordenada coloca em risco a fauna e flora tão riquíssima que o país possui. As Unidades de Conservação (UC) se tornaram uma saída política e ambiental para tentar contornar esse problema. Entretanto, podemos enumerar muitos fatores que reduzem a eficiência das UCs brasileiras, tais como a falta de plano de manejo, a criação de uma UC dentro de outra preexistente, a falta de recursos para criação, manutenção e fiscalização nessas áreas e a necessidade de pesquisas dentro de cada área.

Para entender um pouco esse contexto, propomos nessa tese dois artigos. No primeiro, temos como foco o bioma Cerrado, por ser um bioma de grande biodiversidade, ocupar uma área relativamente grande do território nacional e que sofre constantemente por impactos como as queimadas e desmatamento. Intitulado como "The historical geography, bioclimatic, and informetric conditions of protected areas in the Brazilian Cerrado", esse artigo, na forma de artigo, foi submetido à JNC (Journal for Nature Conservation). Em síntese, avaliamos a geografia histórica de criação das UCs, a representação bioclimática e dados infométricos sobre o bioma. Dentre outros objetivos, analisamos fatores importantes relacionados às UCs, como a presença de plano de manejo e conselho gestor, se há tendência de criação de novas áreas, a sobreposição de UCs e a situação atual do bioma em termos de área protegida. Com a representação bioclimática, analisamos se a distribuição das UCs no Cerrado é suficiente para contemplar todas as condições climáticas existentes no bioma. Por fim, adicionamos uma análise informétrica, o que nos permitirá entender os vieses no número de artigos e seus acessos na internet entre as UCs. Portanto, é um artigo que aborda várias temáticas sobre o status de conservação no bioma Cerrado.

Já no segundo artigo, apresentamos o artigo intitulado "Brazilian protected areas that are larger, older, and closer to urban areas are more studied by scientists", submetido a Biological Conservation. Também com a temática de conservação e UCs, mas abrangendo todo o território nacional, usamos um mapeamento sistemático para espacializar a produção científica nas UCs brasileiras. Além disso, testamos alguns fatores que podem justificar as diferenças em publicações de uma UC para outra, como exemplo a área da UC, seu tempo de criação, sua proximidade com outra UC e com centros urbanos, dentre outros. Portanto, esse artigo fornecerá uma visão geral sobre a produção científica nas UCs brasileiras e o que pode influenciar as diferenças encontradas. Apresentamos a seguir, na íntegra, a submissão do texto principal de cada artigo.

Paper I - The historical geography, bioclimatic, and informetric conditions of protected areas in the Brazilian Cerrado

To: Journal for Nature Conservation

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The historical geography, bioclimatic, and informetric conditions of protected areas in the Brazilian Cerrado

Tatiel Venâncio Gonçalves[1,*], Marcos Aurélio de Amorim Gomes[1], João Carlos Nabout[1]
[1] Universidade Estadual de Goiás, Campus de Ciências Exatas e Tecnológicas, BR 153, n. 3105, Anápolis, Goiás, Brasil.

* Correspondent author: taticov17@hotmail.com

Abstract

Protected areas (PAs) are crucial to the conservation of biodiversity and ecosystem services. Moreover, the creation, management, and efficiency of PAs are associated with the historical geography (the type of PA and number of PAs over the years), bioclimatic sufficiency, and informetric factors (number of papers and number of hits on the internet). These variables vary across the PA network, and combining these factors can help to understand biases of PAs and the future direction to preserve the Brazilian Cerrado biodiversity. In this paper, we evaluated the historical geography, bioclimatic representation, and informetric factors of the Brazilian Cerrado PAs. Although the number of PAs and the cumulative area of PAs has increased significantly, we detected that some new PAs are overlapping other PAs. The overlapping was not idiosyncratic, where some PAs categorized overlapped more than others. The number of papers and hits of PAs on the internet showed a positive correlation and asymmetric distribution, where most PAs had few papers/hits. The bioclimatic variables registered in PAs did not contemplate all bioclimatic variabilities found in the Cerrado. Thus, new areas are fundamental to increase the sufficiency of the PA network and to conserve the Cerrado biome. Our summarized analysis revealed that some variables showed a positive correlation, for example, age, area, number of papers, number of hits, and some PA categories. Finally, our results indicated concordance of some biases, e.g., historical geography and informetric factors. Besides, we recommend the addition of new PAs to increase the sufficiency of the Cerrado PA network.

Keywords: Conservation unity; overlapping; sufficiency; number of papers.

Introduction

Overexploitation of natural resources and the advance of deforestation are among the factors that negatively affect biodiversity worldwide (Laurance, 2007). Even with technological and scientific advances in Conservation Biology and international political agreements, the current efforts are insufficient for containing the rapid rate of species extinction (Titterson *et al.* 2014). Presently, protected areas (PAs) are considered the most efficient policy tools for biodiversity conservation (Chape *et al.* 2005; Lockwood, 2010). However, the process of creating these areas goes through rigorous evaluation criteria (Drummond *et al.* 2009). Several social, political, and economic factors hinder the advancement in the creation of protected areas, such as the limited availability of human, technological, and financial resources (McShane *et al.* 2011).

The protection function of a PA is associated with its efficiency (Di Marco et al. 2019) and effectiveness (see Wiersma et al. 2009). A multidisciplinary approach is necessary to evaluate the current situation of PAs, and new PAs may be required for a complete effective network. Here, we used three groups of variables to evaluate the current scenario of the Brazilian Cerrado PAs: i) Historical geography; ii) Climatic and biodiversity (bioclimatic) representation of all biome; iii) Informetric data. Historical geography has been emerged as a fusion of subjects and has a potential application on conservation studies (e.g. Foster 2002). Besides, understanding the temporal change in number, geographic area, and management of PAs are fundamental for effective governance of protected areas (e.g. Dearden et al. 2005). The second group is associated with the geographic distribution of PAs and their representability of all climatic and biodiversity of the biome (e.g. Eklund et al. 2016). This group is associated with the sufficiency of PAs regarding the question: "How much is enough?" (sensu Di Marco et al. 2016), i.e., if the current PA network is "bioclimatically" representative for the biome. The PA network, if sufficient, can represent the climate, species, and ecosystem type of a region/biome (Pressey et al. 1993). Informetrics (third group) is associated with the scientific and popularity performance of a PA, and the number of papers and hits on the internet frequently are used in the informetric literature (see Gomes et al. 2019; Nabout et al. 2019; and more potential applications of informetrics in Moed 2017). Furthermore, this group is associated with the social and economic interests of PAs with sustainable use. Thus, characterizing simultaneous those three groups can help to understand the current situation of PAs and contribute to future management by public policies. Here, we created those groups only to indicate the multidisciplinary used in this paper. Therefore, our objective is not to summarize terms or set of variables that indicate the efficiency or effectiveness of PA.

In Brazil, PAs are regulated since 2000 (Brazilian Law number 9,985 – National System of Conservation Units – NSCU), although they have existed for over 70 years. The proposed implementation of a PA may come from different axes, such as NGOs (Non-Governmental Organizations), civil society, environmental entities, or political initiatives. However, in all cases, their creation and regulation will depend on political acceptance, whether at the state or federal level (Drummond *et al*. 2009). Brazil is megadiverse, and considering its biomes, the Cerrado is a global hotspot with a high number of endemic species and major impacts on its biodiversity (Myers *et al.* 2000). Initiatives to create PAs in the Brazilian Cerrado began in the late 1940s, strongly encouraged by political issues, with the creation of protected areas in lands with no economic advantages (Marquis, 2002; Diniz-Filho *et al.* 2008).

In the present paper, we evaluate the historical geography, bioclimatic representation, and informetric conditions of the Brazilian Cerrado PAs. Particularly for the historical geography, we ask the following questions: i) What are the temporal trends of the number of PAs and cumulative area of PAs over the years?; ii) How much of the Cerrado (in percentage) are in PAs?; iii) How many and where do PAs overlap (total or complementary)?; iv) What type of PAs overlap?; v) How many PAs have a management plan and council, and what is the relationship between these two variables? Concerning the bioclimatic factors, we evaluate (vi) if the number and geographic distribution of PAs are sufficient to contemplate all climatic conditions registered across the Cerrado. Finally, for informetric conditions, we investigate (vii) the biases in the number of papers and hits on the internet among PAs and evaluate the relationship among these variables. Thus, this paper aims to show a snapshot view of the Brazilian Cerrado PAs, which is essential for the management of these areas in the future.

Material and Methods

We evaluated the 268 Conservation Units present in the Cerrado biome (173 State and 95 Federal), registered among 1949 until 2014 in the National Registry of Conservation Units (CNUC, http://www.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs). For each PA, we obtained the following data: a) current area (km^2); b) year of creation; c) category of PA; d) PA overlap and which categories. For this, we classified the overlap considering two steps: d.1) In case of overlap among PAs, we categorized the type of overlap into complementary or complete; d.2) In case of complete overlap, we classified the position of overlap, where the external PA contains the internal PA (see figure 1); e) the presence of management plan and management council; f) bioclimatic conditions; g) the number of scientific papers and hits on the internet. All data are available in Supplementary Material SM1.

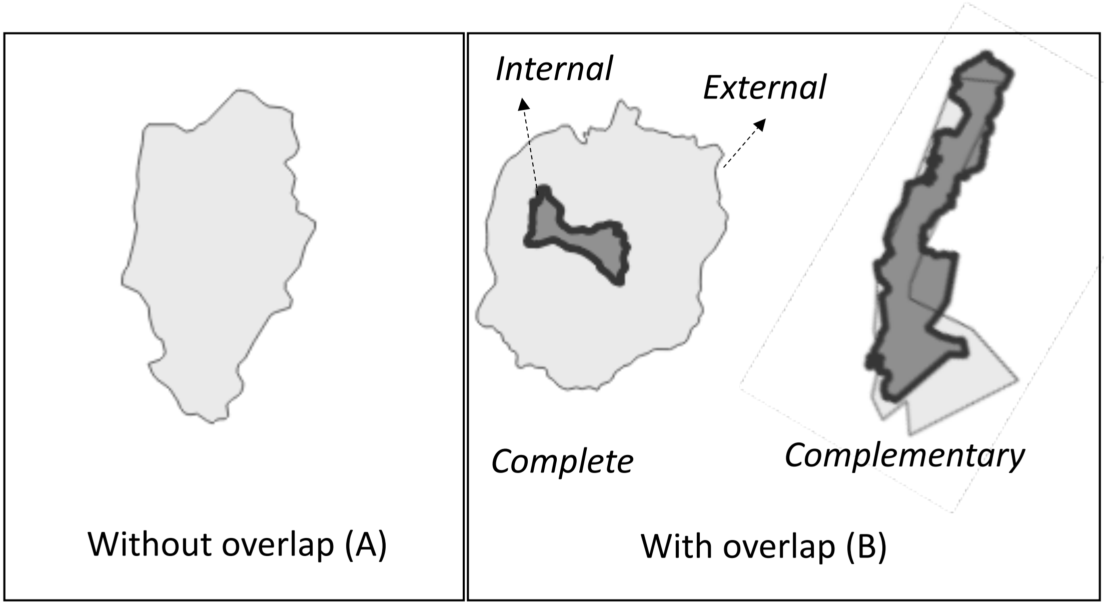

Figure 1 – Schematic representation of the overlap classification for each protected area in the Brazilian Cerrado. (A) Protected area without overlap. (B) Protected area with overlap. In this case, the overlap may be complementary (partial overlap) or complete (one protected area is completely inside another protected area). In the case of complete overlap, the protected area is classified as internal or external.

We calculated the current area of each PA using the ArcGIS software, based on the shapefile provided online by the Ministry of Environment (http://mapas.mma.gov.br/i3geo/datadownload.htm). The category of each PA was based on their management plan. According to the Brazilian legislation (NSCU), there are two groups of PAs: Strictly PA and Sustainable-Use PA. Furthemore, the NSCU has 12 PA categories (see Santos & Schiavetti 2014). However, the Cerrado biome comprises 11 different PA categories, Ecological Station (ES), Environmental Protection Area (EPA), Area of Ecological Interest (AEI), National Forest (Forest), Natural Monument (NM), National Park (Park), Biological Reserve (BR), Sustainable Development Reserve (SDR), Extractive Reserve (ER), Private Natural Heritage Reserve (PNHR), Wildlife Refuge (WR). ES, BR, Park, NM, WR are strictly PA, and AEI, PNHR, EPA, Forest, SDR, ER are PA with sustainable use. The Cerrado biome does not have any PA categorized as Faune Reserve.

Each PA was evaluated according to the overlap with another PA. Thus, PAs were classified in "without overlap" or "with overlap" (figure 1). In addition, PAs with overlap were posteriorly classified as complementary (partial overlap) or complete (PA overlapped entirely by another PA). In the case of complete overlap, we classified it as external or internal.

The bioclimatic condition of each PA was determined using all 19 bioclimatic variables available in the Worldclim database (wordclim.org). We used the current climate scenario with cell-grids of 5 arc-minutes spatial resolution (approximately 8 km^2) (bioclimatic data and resolution in Hijmans et al. 2005). Those variables were also obtained for the entire Cerrado biome and upscaled to a spatial resolution of 0.5 degrees, using the mean of bioclimatic values.

The number of scientific papers of each PA was obtained using the Google Scholar platform (scholar.google.com, searched in April 2020). Google Scholar has often been used as a tool in scientometric studies (e.g. Omar et al. 2017). Furthermore, we used the number of hits on the Google website (google.com) to indicate the popularity of PAs (searched in April 2020). The internet search (e.g. hits on Google) is frequently used to indicate popularity in Ecology studies (e.g. Gomes et al. 2019; Zmihorski et al. 2013).

Data analysis

The Pearson Correlation analysis was used to determine the correlation between two continuous variables. Specifically, we tested the correlation between (1) the cumulative number of PAs and year of creation; between (2) the cumulative area of PAs and the year of creation; and between (3) the number of papers and hits on the internet.

The correspondence among categorical variables was determined using a chi-squared test. Specifically, we tested the correlation between (1) PA categories and the presence or absence of overlap; between (2) PA categories and type of overlap; and (3) PA categories and position of overlap.

The bioclimatic conditions of PAs and Cerrado were compared using a Permutational Multivariate Analysis of Variance (PERMANOVA; Anderson 2014) to compare the mean values of both groups (PAs and entire Cerrado). Besides, we used a Permutation Analysis of Multivariate Dispersion (PERMDISP; Anderson 2006) to compare the climate variability between the two groups. Both tests were performed using Euclidean distance. The PERMANOVA evaluates if the mean bioclimatic conditions in PAs is similar to the bioclimatic conditions of the Cerrado. The PERMDISP evaluates if the variability of bioclimatic conditions is similar between PAs and the Cerrado. Both analyses are essential to evaluate if the climate aspects of the PAs represent the average and variability of all climate aspects of the Cerrado.

We performed a Principal Component Analysis (PCA) using the same distance matrix of the PERMANOVA to visualize the mean and dispersion of both groups (Cerrado and PA).

We summarize the following PA variables in the Principal Components Analysis: the presence of management council, presence of management plan, presence of overlap, presence of without overlap, axis 1 and 2 of PCA summarized bioclimatic variables, age of PAs, area of PAs, number of papers, number of hits on the internet, 11 different categories of PAs (dummy variables). The continuous variables area, age, number of papers, and number of hits on the internet were log-transformed (logX+1).

All analyses were performed using functions and packages of the R software (R Core Team, 2019). Pearson Correlation, Chi-squared, and PCA were performed using the functions *cor.test*, *chisq.test*, *prcomp* in the stats package. The PERMANOVA and PERMDISP were performed using the functions *adonis* and *betadisper* in the vegan package.

Results

The Brazilian Cerrado has 268 Protected Areas until 2014, distributed throughout the biome (figure 2). They comprise an area of 161,793.6 km^2, representing 7.94% of the biome area (2,036,448 km^2). The state level of PAs and the full protection category represent the most protected areas in the biome (Table 1).

The cumulative number of PAs (figure 3A, Pearson Correlation r=0.88; P<0.001) and the cumulative geographic area (figure 3B, Pearson Correlation r=0.87; P<0.001) increased over the years. However, these results do not consider overlapping PAs. In other words, there is redundancy since new PAs can occur in the same area of older PAs (see figure 1 for different types of overlap).

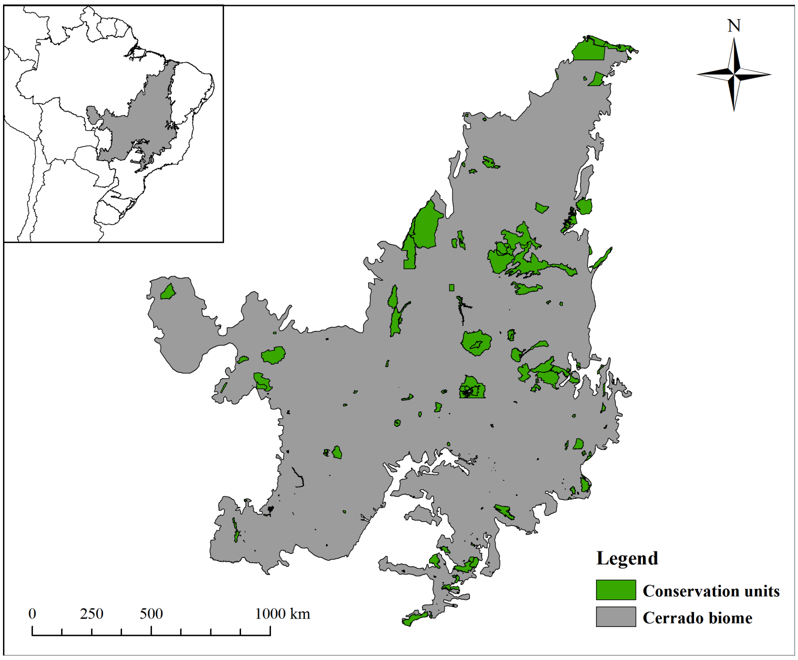

Figure 2 – Geographic distribution of all protected areas in the Brazilian Cerrado used in this paper.

Table 1. Distribution of protected areas in the Brazilian Cerrado according to their sphere and protection category (% of the total number of PAs).

Category	Autarchy			Total
	Municipal	State	Federal	
Integral Protection	5 (1.8%)	86 (32%)	22 (8.2%)	113 (42.2%)
Sustainable Use	2 (0.7%)	84 (31.3%)	69 (25.7%)	155 (57.8%)
Total	7 (2.6%)	170 (63.4%)	91 (33%)	268

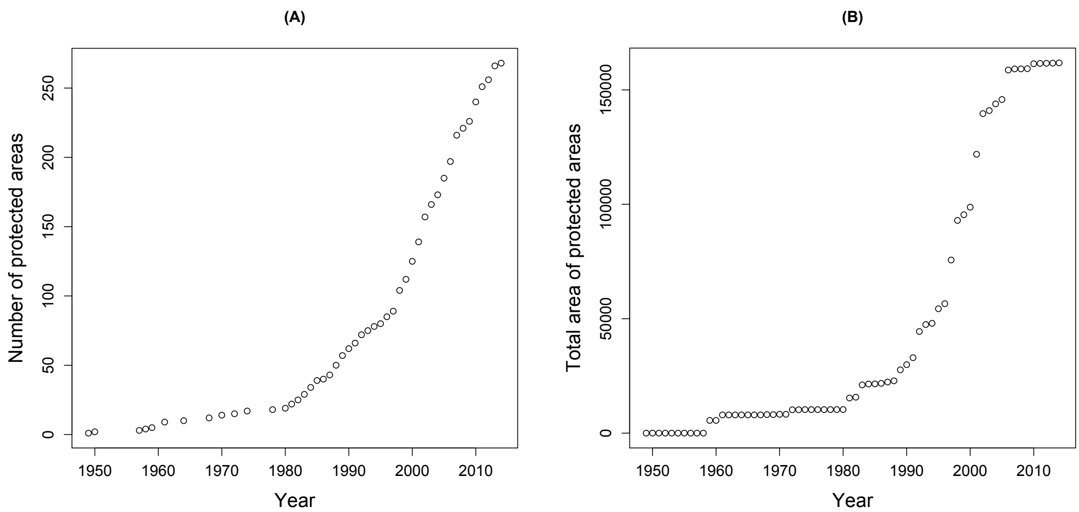

Figure. 3. Temporal trends of the number and area of PAs created in the Cerrado.

Among the 268 PAs, 107 had some level of overlap with other PAs. Considering only PAs with complete overlap, 64 PAs were completely within other PAs, representing 2677.81 km^2 or 1.6% of the Cerrado PAs. Furthermore, some PA categories had more frequency of overlaps (figure 4A, c^2=31.9; P<0.001), it was the case of AEI category. Among the overlapping PAs (total of 107), we observed that 83 had complete overlap, which corresponds to the sum of 64 internal and 19 external PAs. This difference (64 and 19) occurred because some external PAs had more than one internal PA. Moreover, we found correspondence between the PA categories and the type of overlap (figure 4B, c^2=30.5; P<0.001). Particularly, some PA categories were exclusively "complete" overlap, for example, AEI, BR, ER, Forest, and NM. Besides, the number of PNHR PAs with complete overlap is higher than with complementary overlap. Considering the complete overlap (total of 83 PAs), each PA was classified as internal or external (see figure 1). We observed that external PAs were EPA, and internal were predominantly AEI and PNHR. Thus, the overlap among PAs was not idiosyncratic but was dependent on the PA categories (figure 4C, c^2=51.03; P<0.001).

We found that 179 PAs (66.8%) of the Brazilian Cerrado has no management council or management plan, and only 23 (8.6%) have both management tools (Table 2). We emphasize that only PAs classified as PRNH (Private Reserve of Natural Heritage) are not required to have a management council. In addition, legislation requires both management tools to be deployed no later than five years after the PA creation. However, this legislation is mandatory only after the creation of NSCU in 2000, where many PAs used these tools before.

The popularity and scientific knowledge (as a surrogate for investment) of each PA were determined considering the number of hits in a research website (Google) and the number of papers published. Both variables showed asymmetrical patterns, where most PAs had fewer papers (Figure 5A) and fewer numbers of hits (figure 5B). The correlation between the number of papers and hits indicated that PAs with more papers are more popular on the internet (Pearson Correlation r=0.77; P<0.001). The PA with most papers and hits was the Brasilia National Park with 2560 papers and 301000 hits.

The PAs of the Brazilian Cerrado showed a wide geographic distribution in the Cerrado biome. Comparing the climatic variability of the Cerrado with the climatic variability among PAs, we observed a significant difference between the climate centroids (Cerrado and PA) (PERMANOVA, F= 2.84; P=0.04). Moreover, the climate registered in the PAs did not contemplate the entire climatic variability of the Cerrado biome (PERMDISP, F=15.21; P<0.001; Figure 6). Some regions of Cerrado, located on the positive axis 1 and negative axis 2, were not contemplated by PAs.

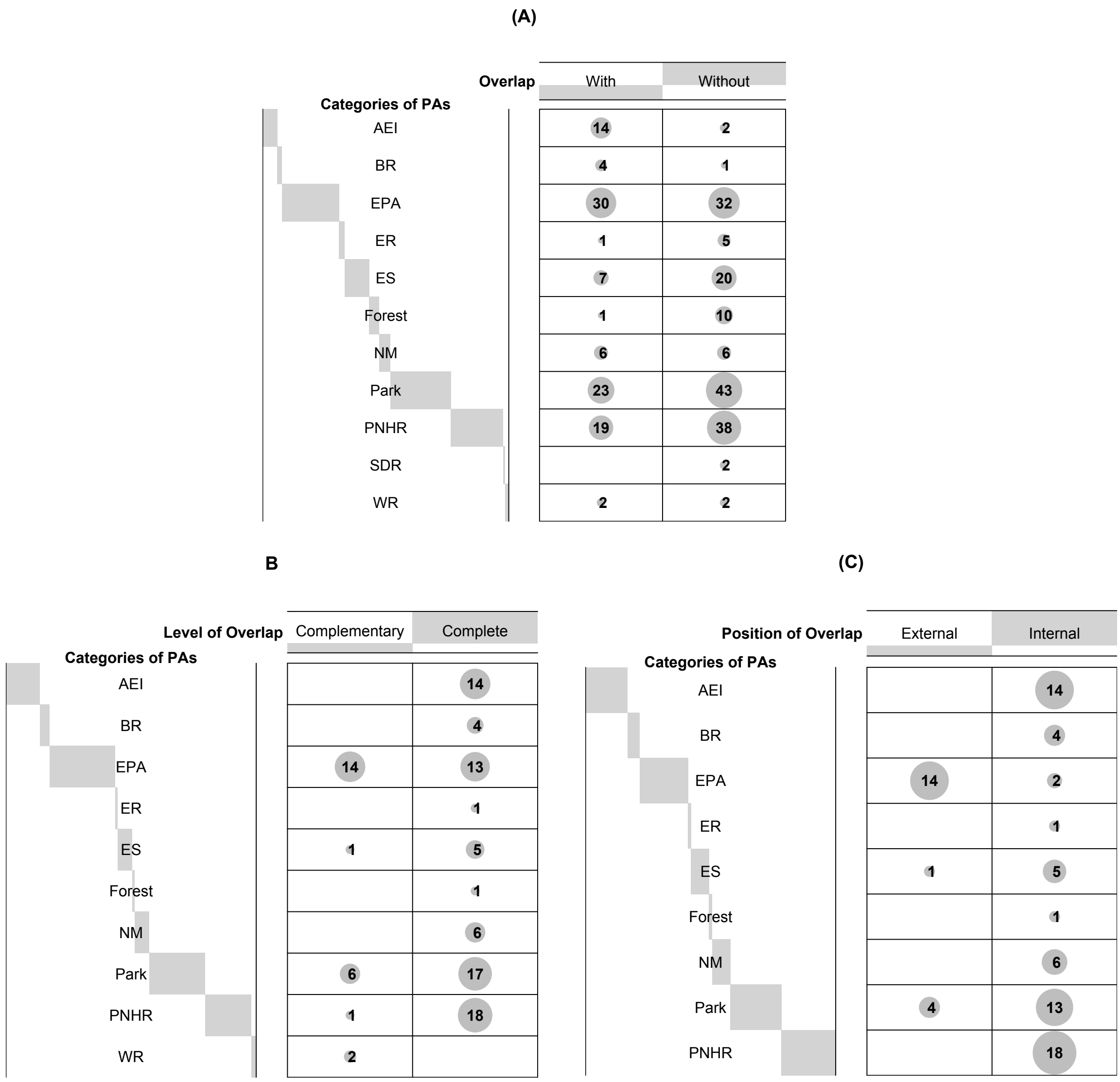

Figure 4 – Balloon Plot showing the relationship among the PA categories. With or without overlap (A), level of overlap (B) for overlapping PAs, and position of overlap (C) for completely overlapping PAs. AEI - Area of Ecological Interest; BR – Biological Reserve; EPA - Environmental Protection Area; ES – Ecological Station; Forest – National Forest; NM – Natural Monument; Park – National Park; PNHR – Private Natural Heritage Reserve; WR – Wildlife Refuge.

Table 2. Presence of management plan and council in the Brazilian Cerrado PAs (% of the total number of PAs).

Management plan	Management council		Total
	Yes	No	
Yes	23 (8.6%)	21 (7.8%)	44 (16.4%)
No	45 (16.8%)	179 (66.8%)	224 (83.6%)
Total	68 (25.4%)	200 (74.6%)	268

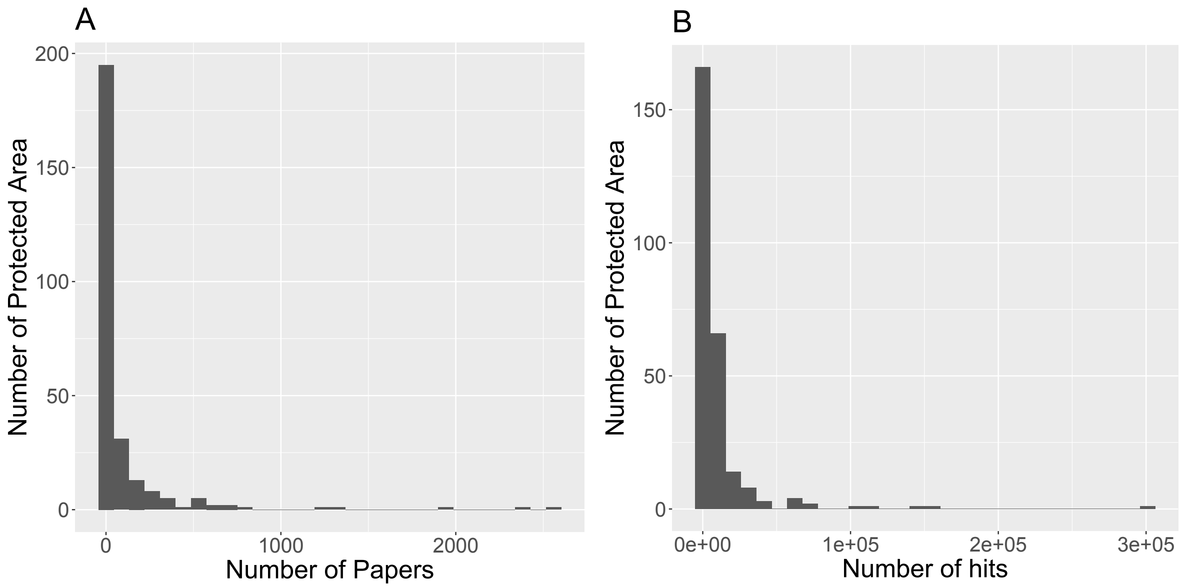

Figure 5. Histograms of the number of papers (A) and hits on the internet (B) for the protected areas of the Brazilian Cerrado.

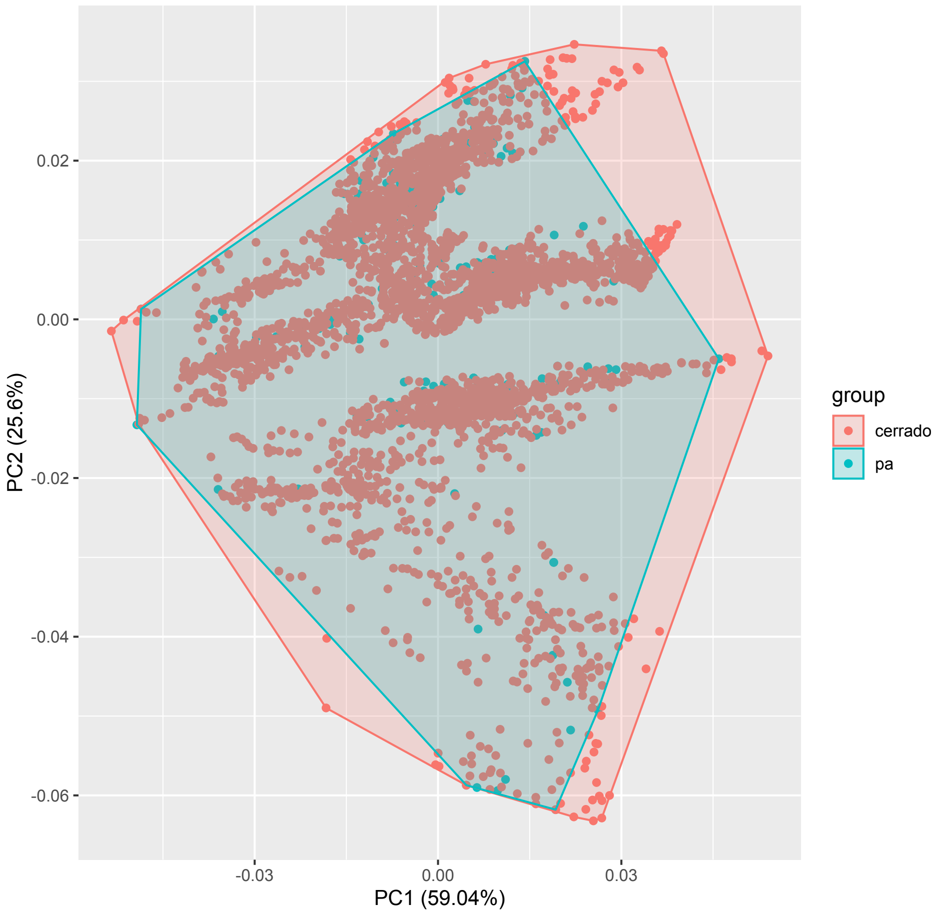

Figure 6 – Principal component analysis of 19 bioclimatic data of the entire Cerrado and protected areas.

All variables collected in the present study were summarized in the Principal Component Analysis (PCA; Figure 7). The two axis explain 29.3% of the total variability. In the first PCA axis, we observe positive correspondence among the number of papers published, the number of hits, geographic area, presence of management council and plan, age of PAs, and categories Park, ES, and EPA. Considering the correspondence among those variables, we highlight that PAs with more studies (number of paper and hits) were also larger, older, and had management council, management plan and with some categories of PAs. The non-correspondence in PCA of the number of papers and hits with climate variables indicated that PAs with more studies had different climatic conditions. The second axis divided PAs with overlap from PAs without overlap. In this situation, the climate was more similar in PAs with overlap, which is expected because the overlap is geographic, and consequently, the climate is similar.

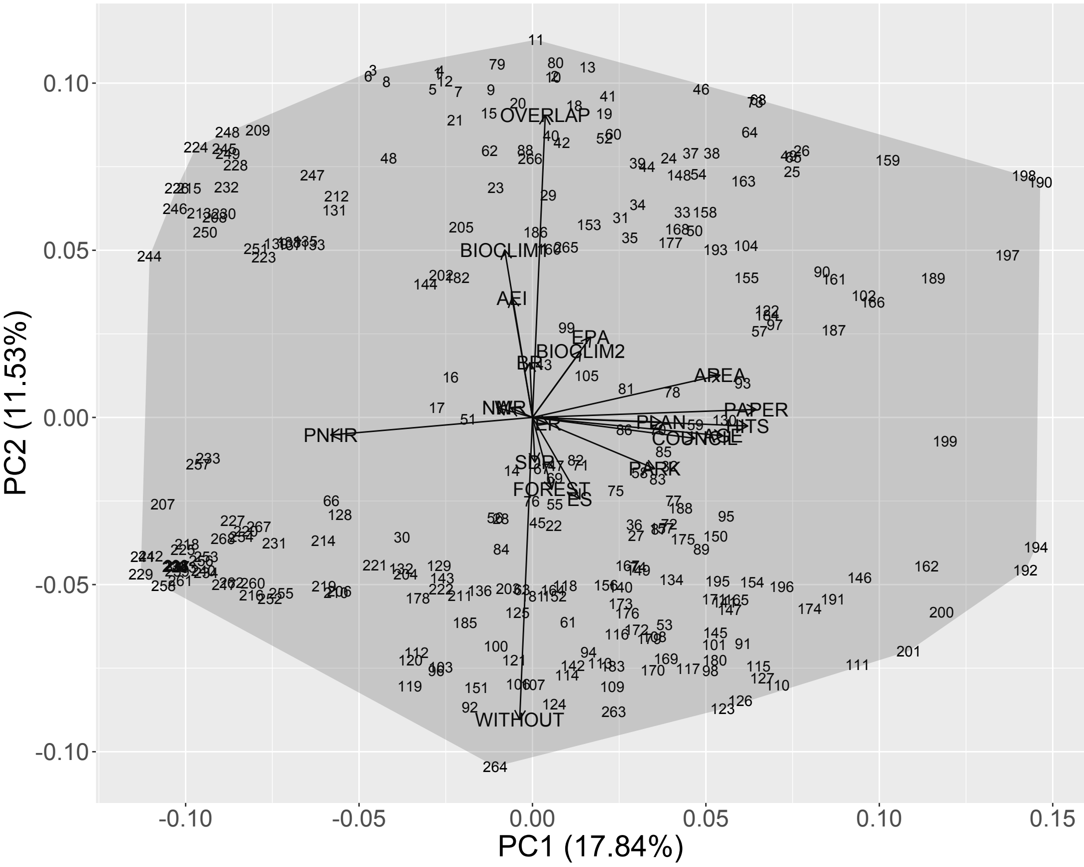

Figure 7 – Principal component analysis with all summarized variables collected in the present study per protected area. The numbers represent the protected areas and correspond to the identifier (ID) in MS1.

Discussion

In the present paper, we evaluated three sets of factors that were important to understand the scenario of the Brazilian Cerrado PAs. Besides, we performed a snapshot of historical geography, bioclimatic, and informetric factors of these PAs. Our main findings were: i) The number of PAs increase over the years, but also increase the overlap among PAs; ii) The overlap of PAs was not idiosyncratic, thus some PA categories are more likely to overlap; iii) Few PAs had most scientific papers and hits on the internet, in addition, these both variables were positively correlated; iv) The bioclimatic variability registered in the PAs did not represent the entire bioclimatic variability of the Cerrado.

The number of PAs has increased over the years in different Brazilian biomes (see Vieira et al. 2019) and globally (Jenkins & Joppa, 2009). However, this expansion does not necessarily indicate greater efficiency in conserving biodiversity and natural resources. The PA network and the total area protected are important for efficient and sufficient conservation. Approximately 54% of the Cerrado total area is still covered by native vegetation (MMA 2015, and see more in Sano et al. 2019), and our results were similar to other results, indicating that 7.94% of the Cerrado biome is under protection in PAs (but see Vieira et al. 2019 – 8.6% under PA; and Françoso et al. 2015 - 8.33% under PA and considering the overlapping). All results indicated that Brazil did not achieve the target 11 of the Aichi Biodiversity Targets, where it says "By 2020, at least 17% of terrestrial and inland water, and 10% of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes" (see Butchart et al. 2016).

The PA overlap has great variation among countries, and in Brazil, 93.2% of PAs did not overlap (Deguignet et al. 2017). Besides the absolute values, overlapping PAs can lead to several management conflicts, such as resource allocation and land use (Bruner *et al.* 2004; McShane *et al.* 2011). Furthermore, the overlap should not diminish the intention and efforts to create PAs in complementary areas of the Cerrado. Furthermore, we detected that overlaps were most frequent in PsA categorized as Area of Ecological Interest (AEI, as reported in figure 4B, C, and 7). Most AEI (14/16) were located within Environmental Protection Areas (EPA). Both categories are classified as sustainable use (according to Brazil legislation), and AEIs are small areas within EPAs with particular natural characteristics and without human occupation. Thus, coherence and concordance are necessary among management plans and councils of these two groups of PAs. Indeed, we identified a high absence of management plan and council in the

Cerrado PAs. That absence is not unique to this biome, but also other biomes in Brazil (Ganem *et al.* 2013). These two management tools are fundamental to regulate the allowed uses in each PA.

Most Brazilian Cerrado PAs have few studies, and this indicates a gap of knowledge about these PAs. Besides, we detected a study bias, where larger and older PAs were more studied, and as a consequence, smaller PAs in the Cerrado were more neglected. The lack of scientific papers can reflect a gap in biodiversity knowledge. Comparing to other Brazilian biomes (e.g. Atlantic Rainforest), the Cerrado PAs had the smallest sampling density of biodiversity (Oliveira et al. 2017). The number of papers is also a surrogate of investment since scientific research in Brazil is dependent on funding, mostly public (see Young 2005). Therefore, despite some financial resources being already officially destined for PA, the investment in PA knowledge is quite asymmetric. Research in PAs is critical for understanding the status of biodiversity and many biological processes (Laurance, 2013). However, some Brazilian PAs have a high investment in research and interest from the scientific community, while other PAs have never been studied yet (Bittencourt & Paula, 2012).

Here, we associated the bioclimatic data of PAs with the bioclimatic information for the entire Cerrado biome. The PA network bioclimatic data is a subset of all bioclimatic data of the Cerrado. However, some Cerrado areas showed bioclimatic characteristics not contemplated in the PAs. Thus, the number and current geographic distribution of the Cerrado PAs do not represent all climatic variability registered in the Cerrado. Therefore, creating PAs in new bioclimatic regions can increase the efficiency of the PA network. The insufficiency and inefficiency of PAs aggravate when considering that the PA network is located in unproductive and inaccessible areas (e.g. Vieira et al. 2019), and the impact of global climate change on biodiversity (see Velazco et al. 2019; Diniz-Filho et al. 2019).

The use of bioclimatic factors to evaluate the efficiency and sufficiency of PAs require caution because other factors associated with PAs are necessary to evaluate the efficiency and sufficiency of PAs. Factors such as geographic size, number of species, ecosystem services, endangered species, connectivity, and social context are important (e.g. Knight et al. 2009, Di Marco et al. 2016, Wei et al., 2020). The importance of those factors varies in geographic scale and purpose depending on the PA aim and is mandatory in Systematic Conservation Planning (see Margules & Pressey 2000). However, the bioclimatic variables used here are frequently used to estimate the species geographic distribution using Ecological Niche approaches, which are used in conservation studies (see, for example, Loyola et al. 2013; Velazco et al. 2019). Therefore, we do not recommend using only a bioclimatic approach to evaluate the complete efficiency of the PA network. The conservation of the Brazilian Cerrado depends on climatic, biological, socioeconomic factors, and political tradeoffs (Faleiro & Loyola 2013). Therefore, integrative studies with political and economic support are fundamental to develop efficient and sufficient conservation strategies for the Cerrado biome.

The Cerrado has undergone major landscape transformations with the expansion of agriculture and pasture (see Oliveira & Marquis 2002), which increased the pressure of biodiversity conservation (e.g. Lemes et al. 2020). Despite the efforts of scientists and lawmakers, there is always a constant need to reaffirm the importance of the Brazilian Cerrado PAs, mainly in a crisis scenario with cut of the budget for science and technology and depreciation of the institutions responsible for regulating and monitoring the PAs (e.g. Pereira et al. 2020). That is the current scenario in the ongoing Brazilian politics. Therefore, the present paper reinforces the importance of PAs, and that gaps still need to be fulfilled, such as PAs that lack research and even Cerrado areas that need PAs.

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References

Anderson, M. J. (2006). Distance-based tests for homogeneity of multivariate dispersions. *Biometrics*, *62*(1), 245-253.

Anderson, M. J. (2014). Permutational multivariate analysis of variance (PERMANOVA). *Wiley statsref: statistics reference online*, 1-15.

Bruner, A.G., Gullison, R.E. & Balmford, A. (2004). Financial costs and shortfalls of managing and expanding protected-area systems in developing countries. *AIBS Bulletin*, 54(12):1119-1126.

Chape, S., Harrison, J., Spalding, M. & Lysenko, I. (2005). Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 360(1454): 443-455.

Dearden, P., Bennett, M., & Johnston, J. (2005). Trends in global protected area governance, 1992–2002. *Environmental management*, *36*(1), 89-100.

Deguignet, M., Arnell, A., Juffe-Bignoli, D., Shi, Y., Bingham, H., MacSharry, B., & Kingston, N. (2017). Measuring the extent of overlaps in protected area designations. *PloS one*, *12*(11).

Di Marco, M., Watson, J. E., Venter, O., & Possingham, H. P. (2016). Global biodiversity targets require both sufficiency and efficiency. *Conservation Letters*, *9*(6), 395-397.

Diniz-Filho JAF, Bini LM, Vieira CM, Blamires D, Terribile LC, *et al.* 2008. Spatial patterns of terrestrial vertebrate species richness in the Brazilian Cerrado. *Zoological Studies*, 47:146-157.

Diniz-Filho, J. A. F., Barbosa, A. C. D. O. F., Chaves, L. J., e Souza, K. D. S., Dobrovolski, R., Rattis, L., Terribile, L.C., Lima-Ribeiro, M.S., Oliveira, G., Brum, F.T. & Loyola, R. (2018). Overcoming the worst of both worlds: integrating climate change and habitat loss into spatial conservation planning of genetic diversity in the Brazilian Cerrado. *Biodiversity and Conservation*, 1-16.

Drummond, J.A., Franco, J.L.A. & Ninis, A.B. (2009). Brazilian federal conservation units: a historical overview of their creation and of their current status. *Environment and History*, 15(4):463-491.

Eklund, J., Blanchet, F. G., Nyman, J., Rocha, R., Virtanen, T., & Cabeza, M. (2016). Contrasting spatial and temporal trends of protected area effectiveness in mitigating deforestation in Madagascar. *Biological Conservation*, *203*, 290-297.

Françoso, R. D., Brandão, R., Nogueira, C. C., Salmona, Y. B., Machado, R. B., & Colli, G. R. (2015). Habitat loss and the effectiveness of protected areas in the Cerrado Biodiversity Hotspot. *Natureza & Conservação*, *13*(1), 35-40.

Foster, D. R. (2002). Insights from Historical Geography to Ecology and Conservation: Lessons from the New England Landscape. *Journal of biogeography*, 1269-1275.

Ganem RS, Drummond JA & Franco JLDA, 2013. Conservation polices and control of habitat fragmentation in the Brazilian Cerrado biome. *Ambiente & Sociedade,* 16(3):99-118.

Gomes, M. A. A., Gonçalves, T. V., Teresa, F. B., da Cunha, H. F., Lima, F. P., & Nabout, J. C. (2019). High school students' knowledge of endangered fauna in the Brazilian Cerrado: A cross-species and spatial analysis. *PloS one*, *14*(4).

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G., & Jarvis, A. (2005). Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *25*(15), 1965-1978.

Oksanen J, F. Guillaume Blanchet, Michael Friendly, Roeland Kindt, Pierre Legendre, Dan McGlinn, Peter R. Minchin, R. B. O'Hara, Gavin L. Simpson, Peter Solymos, M. Henry H. Stevens, Eduard Szoecs and Helene Wagner (2019). vegan: Community Ecology Package. R package version 2.5-6. https://CRAN.R-project.org/package=vegan

Knight, A.T., Cowling, R.M., Possingham, H.P., Wilson, K.A. (2009) From theory to practice: designing and situating spatial prioritization approaches to better implement conservation action. In: Moilanen, A,, Wilson, K.A., Possingham, H.P. (eds) Spatial conservation prioritisation: quantitative methods and computational tools. Oxford University Press, Oxford, pp 249–259.

Laurance, W.F. (2007). Have we overstated the tropical biodiversity crisis?. *Trends in Ecology & Evolution,* 22(2):65-70.

Lemes, L., de Andrade, A.F.A., & Loyola, R. (2019). Spatial priorities for agricultural development in the Brazilian Cerrado: may economy and conservation coexist?. *Biodiversity and Conservation*, 1-18.

Lockwood, M. (2010). Good governance for terrestrial protected areas: a framework, principles and performance outcomes. *Journal of Environment Management,* 91(3):754-766.

Loyola, R. D., Lemes, P., Nabout, J. C., Trindade-Filho, J., Sagnori, M. D., Dobrovolski, R., & Diniz-Filho, J.A.F. (2013). A straightforward conceptual approach for evaluating spatial conservation priorities under climate change. *Biodiversity and Conservation*, *22*(2), 483-495.

Margules, C.R., Pressey, R.L. (2000) Systematic conservation planning. Nature 405:243–253.

Marquis RJ, 2002. *The cerrados of Brazil: ecology and natural history of a neotropical savanna*. Columbia University Press.

McShane, T.O., Hirsch, P.D., Trung, T.C., Songorwa, A.N., Kinzig, A, *et al.* (2011). Hard choices: making trade-offs between biodiversity conservation and human well-being. *Biological Conservation*, 144(3):966-972.

McShane, T.O., Hirsch, P.D., Trung, T.C., Songorwa, A.N., Kinzig, A., *et al.* (2011). Hard choices: making trade-offs between biodiversity conservation and human well-being. *Biological Conservation*, 144(3):966-972.

MMA 2015. Mapeamento do uso e cobertura do Cerrado: Projeto TerraClass Cerrado. Available at: http://www.mma.gov.br/images/arquivo/80049/Cerrado/publicacoes/Livro%20_EMBRAPA-WEB-1-TerraClass%20Cerrado.pdf, Accessed 02th Jun 2020.

Moed, H. F. (2017). Applied evaluative informetrics. Amsterdam: Springer International Publishing.

Nabout, J. C., Teresa, F. B., Machado, K. B., do Prado, V. H. M., Bini, L. M., & Diniz-Filho, J. A. F. (2018). Do traditional scientometric indicators predict social media activity on scientific knowledge? An analysis of the ecological literature. *Scientometrics*, *115*(2), 1007-1015.

Oliveira, P.S., Marquis, R.J. (2002) The Cerrados of Brazil: ecology and natural history of a neotropical Savanna. Columbia University Press, New York, NY

Oliveira, U., Soares-Filho, B. S., Paglia, A. P., Brescovit, A. D., De Carvalho, C. J., Silva, D. P., & Stehmann, J.R. (2017). Biodiversity conservation gaps in the Brazilian protected areas. *Scientific reports*, *7*(1), 1-9.

Omar, M., Mehmood, A., Choi, G. S., & Park, H. W. (2017). Global mapping of artificial intelligence in Google and Google Scholar. *Scientometrics*, *113*(3), 1269-1305.

Pereira, E. J. D. A. L., de Santana Ribeiro, L. C., da Silva Freitas, L. F., & de Barros Pereira, H. B. (2020). Brazilian policy and agribusiness damage the Amazon rainforest. *Land Use Policy*, *92*, 104491.

Pressey, R.L., Humphries, C.J., Margules, C.R., Vanewright, R.I., Williams, P.H. (1993) Beyond opportunism – key principles for systematic reserve selection. *Trends in Ecology and Evolution*, 8:124-128.

Sano, E. E., Rodrigues, A. A., Martins, E. S., Bettiol, G. M., Bustamante, M. M., Bezerra, A. S., ... & Bolfe, E. L. (2019). Cerrado ecoregions: A spatial framework to assess and prioritize Brazilian savanna environmental diversity for conservation. *Journal of environmental management*, *232*, 818-828.

Santos, C. Z., & Schiavetti, A. (2014). Spatial analysis of Protected Areas of the coastal/marine environment of Brazil. *Journal for nature conservation*, *22*(5), 453-461.

Tittensor, D.P., Walpole, M., Hill, S.L., Boyce, D.G., Britten, G.L., *et al.* (2014). A mid-term analysis of progress toward international biodiversity targets. *Science,* 346(6206):241-244.

Velazco, S.J.E., Villalobos, F., Galvão, F., & De Marco Júnior, P. (2019). A dark scenario for Cerrado plant species: Effects of future climate, land use and protected areas ineffectiveness. *Diversity and Distributions*, *25*(4), 660-673.

Vieira, R. R., Pressey, R. L., & Loyola, R. (2019). The residual nature of protected areas in Brazil. *Biological conservation*, *233*, 152-161.

Wei, F., Wang, S., Fu, B., & Liu, Y. (2020). Representation of biodiversity and ecosystem services in East Africa's protected area network. *Ambio*, 49(1), 245-257.

Wiersma, Y. F., & Nudds, T. D. (2009). Efficiency and effectiveness in representative reserve design in Canada: the contribution of existing protected areas. *Biological Conservation*, *142*(8), 1639-1646.

Young, C. E. F. (2005). Financial mechanisms for conservation in Brazil. *Conservation Biology*, *19*(3), 756-761.

Żmihorski, M., Dziarska-Pałac, J., Sparks, T. H., & Tryjanowski, P. (2013). Ecological correlates of the popularity of birds and butterflies in Internet information resources. *Oikos*, *122*(2), 183-190.

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Paper II - Brazilian protected areas that are larger, older, and closer to urban areas are more studied by scientists

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Brazilian protected areas that are larger, older, and closer to urban areas are more studied by scientists

Tatiel V Gonçalves[1]*, Micael R Parreira[2], João C Nabout[1]

[1] Universidade Estadual de Goiás, Campus de Ciências Exatas e Tecnológicas, BR 153, n. 3105, Anápolis, Goiás, Brazil.

[2] Universidade Federal de Goiás, Campus Samambaia, Av. Esperança, s/n, Goiânia, Goiás, Brazil.

* Corresponding authors: taticov17@hotmail.com; joao.nabout@ueg.br

Abstract

The Brazilian System of Conservation Units is a federal law that plays a crucial role in the conservation of the Brazilian biodiversity, by legally regulating the protected areas (PAs). Many scientific studies and theories have been developed in Brazilian PAs, addressing their environmental, economic, social, and scientific importance. In this study, we performed a systematic mapping to evaluate what factors affect the number of scientific papers developed in PAs. We selected the following factors: number of papers per PA, the subject category of papers, area and age of PAs, distance to urban areas, and distance to other PAs. We found 2,715 papers regarding 1,563 Brazilian PAs published between 1991 and 2017, with significant growth in the number of publications over the years. We found a geographic bias at a national scale, where PAs that are larger, older, and closer to urban areas have the greatest number and diversity of papers These variables driver the research in Brazilian PA, nonetheless, approximately 90% of all PAs had less than five papers indicated the great number of PA with few papers Therefore, more investment is necessary to reduce the geographic bias and increase the number and diversity of papers in Brazilian PAs.

Keywords: systematic mapping; conservation unity; number of papers; diversity of papers.

Introduction

In Brazil, the National System of Conservation Units (SNUC) is one of the most important governmental instruments for the conservation of Brazilian biodiversity and establishes the legally protected areas (PAs) of Brazil. PAs play important ecological (Lockwood, 2010), social (West et al., 2006), tourist (Jamal and Stronza, 2009), economic (e.g. Adams et al. 2008), and scientific roles. A great part of the knowledge produced in PAs is published in scientific papers, thus, the number of papers is a surrogate of scientific information about one region or PA in particular. Moreover, the paper's topic or journal's subject category can indicate the diversity of scientific information about PAs. These two variables (number and diversity of papers) are complementary and can help to understand the complete scientific knowledge about PAs.

The number and diversity of papers are not similar among all PAs. In fact, the scientific production about conservation biology (and other biological fields) varies among geographic areas (Roberts et al., 2016), taxonomic groups (Clark and May 2002), and other biases (Fazey et al., 2002). Thus, we expect that the number and diversity of papers produced about a particular PA can vary considering its size, age, distance to urban areas, and distance to other PAs. The PA's age is associated with the time of study, thus, older PAs have a longer research time and previous studies may facilitate future studies. Moreover, the age in the scientometric literature is often associated with more citations (e.g. Yu and Li 2007; Carneiro et al., 2008). The PA's size is associated with variability of information and environmental characteristics, thus, larger PAs have more diverse ecosystems, and more environmental and social diversity (Nóbrega and De Marco Jr, 2011). The geographic distance is associated with the logistics and costs for researches in PAs (e.g. Parreira et al., 2018). More isolated PAs difficult the access of scientists, requiring more investments to perform samplings or experiments. In summary, time, diversity of ecosystems and low costs are crucial factors that motivate the scientific studies in Brazilian PAs.

In this study, we aim to evaluate what factors drive the number and diversity of papers among terrestrial Brazilian PAs. We obtained the number and diversity of papers published for terrestrial PAs and the following predictors: area and age of PAs, distance to urban areas, and distance to other PAs. We hypothesize that larger and older PAs, as well as closer to urban areas and other PAs have more papers and diversity of papers. This may occur because low costs, more facilities, and diversity of ecosystems facilitate the actions of Brazilian scientists and drive the research for some PAs. Moreover, we evaluate the temporal trends of the number of papers in PAs and the spatial structure of the number and diversity of papers in Brazilian PAs. The propose of the present paper was not detect witch PAs were more studies and neither what has studies, our propose was a snapshot of paper produced in PAs considering one global scientific database, and investigate what factors drive this spatial pattern.

Material and Methods

We conducted a systematic mapping to evaluate the scientific production in Brazilian PAs. For this, we selected all papers published in the *Clarivate Analytics* Web of Science (WoS) database (www.webofknowledge.com) between 1991 and 2017. We selected only papers since 1991 because only starting this year the WoS database provides the paper's abstract. We based on different categories of PAs commonly used in scientific literature and searched used differents PA categories (see Table 1 of MS1 and exactly terms used in search) on the topic (title, abstract, and keywords) of papers. We searched these terms in English and Portuguese, considering their variations (e.g. plural). We obtained a total of 45,794 papers, which were later refined for papers produced only in terrestrial Brazilian PAs. For this, we retained only papers with "Brazil*" or "Brasil*" terms in their titles, abstracts or keywords (total of 3,019). Moreover, we removed the papers that, based on the titles and abstracts, were not produced in Brazilian PAs, and paper that use marine PA. We adopted to excluded marine PA because we uniformized the comparation among terrestrial PAs. After all refining processes, we ended up with a total of 2,715 papers.

We evaluated the temporal trends of the number of papers produced in PAs over the years, using the number of papers and the year of publication. We also evaluated the relative contribution of Brazilian papers regarding PAs on all papers about protected area in the world. For this, we used the output of first search in WoS (total of 45,794 papers), and first filter (second search with 3,079 papers), respectively represented global papers and Brazilian papers about PA. Thus, the relative contribution of Brazil on global protected area was estimated by dividing to each year the Brazilian number of papers regarding PAs by the global number of papers published about PAs.

The Brazilian PAs was obtained in Ministry of the Environment (MMA) website (http://mapas.mma.gov.br/i3geo/datadownload.htm) and for each PA listed we obtained the following data: the number of papers, the number of subject categories of each paper, area (km^2), year of creation, distance to the closest urban area (city), and distance to the closest PA. According MMA the Brazil has 1,944 PAs, however, after exclude marine or incomplete data we utilized 1,563 PAs, represented 80% of total PAs of Brazil. The subject category was obtained in the WoS database, which classifies each journal with one or more of the 253 different categories (https://images.webofknowledge.com/images/help/WOS/hp_subject_category_terms_tasca.html).

We calculated the PA's size (Km^2) in QGIS software version 3.4.4 (Qgis Development Team, 2018), using the shape of Brazilian PAs available in the MMA website (http://mapas.mma.gov.br/i3geo/datadownload.htm). We calculated the centroid of each PA and through these coordinates we calculated the straight distances from each PA to the closest urban area and PA, using the INPE's "geographic calculator" tool (National Institute for Space Research, http://www.dpi.inpe.br/calcula/). We obtained the coordinates of each city's centroid through the IBGE city map (Brazilian Institute of Geography and Statistics, http://www.ibge.gov.br/home/geociencias/geografia/default.shtm).

The temporal trends of the number of papers and the representation were evaluated using the Pearson correlation. The spatial structure of the number of papers and subject categories of Brazilian PAs were evaluated using the Moran's I correlogram (see Legendre & Legendre 2012). The effect of age, area, distances (to the closest urban area and PA) on the number of papers of each PA was modeled using different regression models. We used the Ordinary-Least Squares (OLS), Poisson, Zero-Inflated Negative Binomial (ZINB), and Zero-Inflated Poisson (ZIP) models. We considered using the Zero-Inflated approaches because of the great number of PAs without papers, thus, the response variables presented many zeros (44% of PAs with no papers). We compared the models using the Akaike Information Criterion (AIC; Burnham and Anderson 2002), where the best model was the one with the lowest AIC value. The explanatory variables were log-transformed (logX+1) and standardized, which scales the mean to zero and standard deviation to one. We also evaluated the collinearity of predictor variables using the Variance Inflation Factor (VIF), and all variables were posteriorly used in the regression models because they had VIF values less than two. In a cross-spatial analysis, the absence of spatial independence can increase the type I error. Thus, we evaluated the assumptions of spatial independence by investigating the spatial structure of residuals from the best regression model (see Hawkins et al. 2007).

All analyses were performed using several functions and packages of the R software (R Core Team, 2019). The OLS model, Poisson model, and AIC analysis were performed using the *lm* (linear model), *glm* and *AIC* functions in stats package. The zero-inflated models (ZIP and ZINB) were performed using the function *zeroinfl* in pscl package (Zeileis et al. 2008). The Moran's I correlograms were performed using the function *correlog* in ncf package (Ottar & Bjornstad 2018).

Results

We found 2,715 scientific papers produced on Brazilian PAs between 1991 and 2017, and these papers were published in journals with 82 different subject categories. The spatial distribution of the number of papers and subject categories by PAs is idiosyncratic, with no spatial structure (Figure 1). The number of subject categories showed similar patterns (see in Figure 1 of MS2). Besides, approximately 88% of all PAs had less than two papers and subject categories (see Figure 2 of MS2). The Moran's I correlogram did not indicate any spatial structure, i.e., nearby PAs don't have a similar number of papers or subject categories (see correlograms in Figure 3 of MS2).

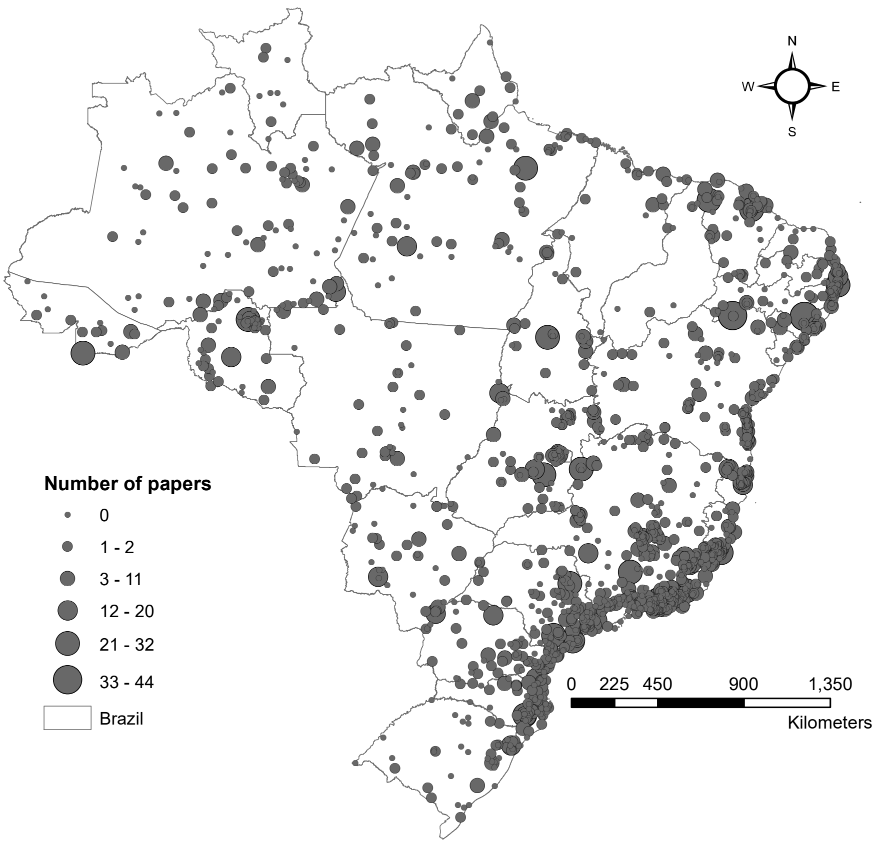

Figure 1. Spatial distribution of the number of papers registered in each Brazilian protected area.

The number of papers published increased significantly over the years ($r = 0.95$, $df = 25$, $p < 0.001$, Figure 2A), and similarity, the relative contribution of PA papers also increased over the years ($r = 0.96$, $df = 25$, $p < 0.001$, Figure 2B). Both results (mainly relative contribution), demonstrating the increment of Brazil science about protected area along the years. In fact, in the early of years 90s nearby 1% of global papers about PA were developed in Brazil, more recently (e.g. 2017) this relative contribution raised to 9%.

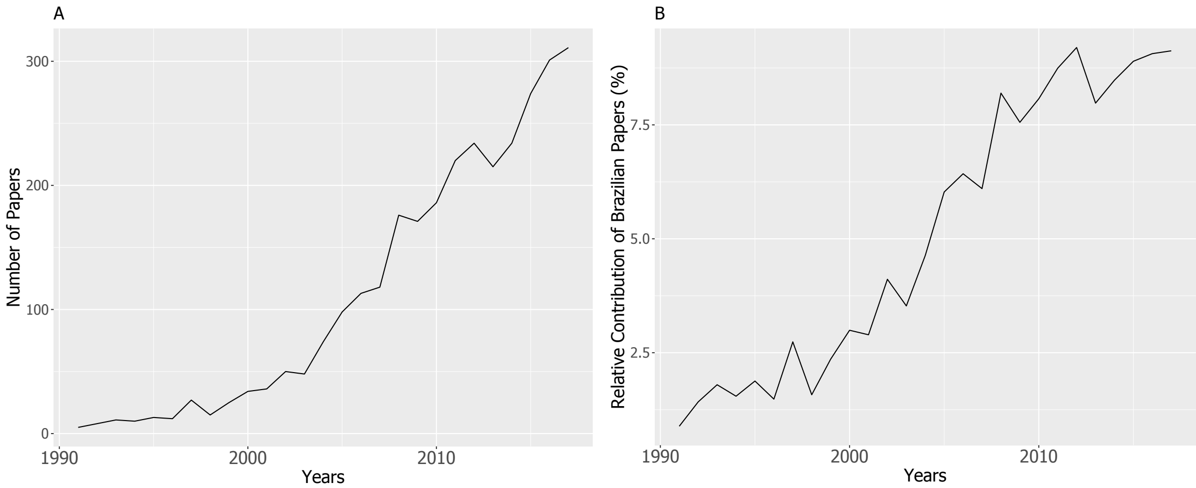

Figure 2. Number of published in Brazilian Protected Area (A), and relative contribution of Brazilian paper on all papers about Protect Area in the world, considering the period from 1991 to 2017.

We generated four different models to evaluate the influence of area, age, and distances to the closest urban area (city) and PA on the number of papers produced in Brazilian PA. We found similar results among the models, yet the OLS model had the lowest AIC value and thus, was the best model. We also found that older and larger PAs, as well as closer to cities have more papers. The distance to another PA was not a significant variable for any model. The number of subject categories showed similar results (see Table 1 in MS2). The OLS regression was a good model with R^2=0.47, with no spatial correlation in the residuals.

Discussion

The number of papers is an important indicator of scientific knowledge and reveals differences among scientific fields (Parish et al., 2018), countries (King, 2004) and can indicate priority areas for future investment in Science & Technology (Rabiei et al., 2017). Here, we detected that distance, size, and age of PAs were important drivers of scientific production. This result associated with the geographic distribution of the scientific production in Brazilian PAs can contribute to select PAs for future studies and reduce the asymmetry of scientific production among PAs. Other studies have found different biases in studies of conservation biology, such as taxonomic (e.g. Clark and May 2002, Fazey et al., 2005), with more papers with birds and mammals, and geographic biases (Griffiths and Dos Santos, 2012), with more papers in developed countries. Here, we detected other geographic biases, but at a national scale.

The bias in the number of papers and subject categories of Brazilian PAs was determined considering three predictors: age, area, and distance of PAs to the closest city. This result corroborates in part our initial hypothesis, where only the distance to the closest PA was not significant to explain the number and diversity of papers. We found that larger and older PAs, as well as closer to cities had a greater number of papers and subject categories. The age indicated the time of the study, and, regions with more time are more probably increase number of papers. The larger the PA, the greater the diversity of ecosystems and species (e.g. Nóbrega & De Marco Jr, 2011), which allows the study of species with a larger living area, such as many mammals (Morato et al., 2014). The PAs closest to urban areas have more papers published than the most distant ones. Although proximity to urban areas reduces the conservation efficiency of PAs (McDonald et al., 2008), it contributes to the accessibility of researchers in the field and reduce research costs.

Although Brazil has a wide geographic extension and biodiversity (Joly et al., 2019), it lacks in biodiversity conservation funding, particularly nowadays due to reductions in research and development (Magnusson et al., 2018). This limits the action of Brazilian scientists, which contributes to geographic bias in scientific production. Moreover, although some PAs were more studied than others, they still lack in conservation studies, mainly those regarding some taxonomic groups, such as reptiles, amphibians, and fishes (Clark and May, 2002). Nonetheless, the most critical observation in our paper is the great number of PAs without any scientific production. In fact, 50% of Brazilian PAs is not registered at least one species occurrence (Oliveira et al. 2017). The absence of scientific studies can limit the management and conservation of PAs because they are key instruments for addressing issues and gaps, as well as the financial needs of protected areas (Bruner et al., 2004; Chiaravalloti et al., 2015).

The number of papers about Brazilian PAs has increased over the years, indicating a constant interest in this topic by researchers. Brazil is a megadiverse country with devastating impacts on its biodiversity (e.g. Scarano and Ceotto, 2015), which are aggravating due to the current political agenda for biodiversity conservation (e.g. Hope, 2019). Nonetheless, the area of biological conservation has become more prominent, with an increase in the number of biodiversity and conservation societies and graduate courses. Finally, our results indicated that many PAs still need to be investigated and recognized, and the slowdown or interruption in the current Brazilian scientific grown can generate tremendous negative impacts on studies of conservation biology in Brazil.

Finally this paper produced the state of art of scientific literature about Brazilian PAs, and this synthesis generated relevant results to oriented new investment and public policy (Milner-Gulland et al., 2009). The Brazilian PAs need more investment to reduce geographic bias and increase the number and diversity of papers. Therefore, future investments should be directed toward other geographic areas in Brazil and different scientific fields, increasing the diversity of scientists and reducing geographic bias.

Acknowledgment

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References

Adams, C., da Motta, R.S., Ortiz, R. A., Reid, J., Aznar, C. E., de Almeida Sinisgalli, P.A., 2008. The use of contingent valuation for evaluating protected areas in the developing world: Economic valuation of Morro do Diabo State Park, Atlantic Rainforest, São Paulo State (Brazil). Ecological Economics 66, 359-370.

Bruner, A.G., Gullison, R.E., Balmford, A., 2004. Financial Costs and Shortfalls of Managing and Expanding Protected-Area Systems in Developing Countries. Bioscience 54, 1119–1126.

Bjornstad, O.N., 2018. ncf: Spatial Covariance Functions. R package version 1.2-6. https://CRAN.R-project.org/package=ncf

Carneiro, F.M., Nabout, J.C., Bini, L.M., 2008. Trends in the scientific literature on phytoplankton. Limnology 9, 153-158.

Clark, J.A., May, R.M., 2002. Taxonomic bias in conservation research. Science 297, 191-192.

Chiaravalloti, R. M., Delelis, C., Tofoli, C., Padua, C. V., Ribeiro, K. T., & Menezes, G. A. (2015). Federal protected areas management strategies in Brazil: sustainable financing, staffing, and local development. *Natureza & Conservação*, *13*(1), 30-34.

Fazey, I., Fischer, J., Lindenmayer, D.B., 2005. What do conservation biologists publish?. Biological Conservation 124, 63-73.

Griffiths, R.A., Dos Santos, M., 2012. Trends in conservation biology: Progress or procrastination in a new millennium? Biological Conservation 153, 153-158.

Hawkins, B.A., Diniz-Filho, J.A.F., Bini, L.M., De Marco, P., Blackburn, T.M., 2007. Red herrings revisited: spatial autocorrelation and parameter estimation in geographical ecology. Ecography 30, 375-384.

Hope, M., 2019. The Brazilian development agenda driving Amazon devastation. The Lancet Planetary Health 3, e409-e411.

Jamal, T., Stronza, A., 2009. Collaboration theory and tourism practice in protected areas: Stakeholders, structuring and sustainability. Journal of Sustainable Tourism 17, 169-189.

Joly, C.A., Scarano, F.R., Bustamante, M., Gadda, T.M.C., Metzger, J.P.W., Seixas, C.S., Ometto, J.P.H.B., Pires, A.P.F., Boesing, A.L., Sousa, F.D.R., Quintão, J.M.B., Gonçalves, L.R., Padgurschi, M. de C.G., Aquino, M.F. dos S. de, Castro, P.F.D. de, Santos, I.L. dos, 2019. Brazilian assessment on biodiversity and ecosystem services: summary for policy makers. Biota Neotrop. 19, e20190865

King, D.A., 2004. The scientific impact of nations. Nature 430, 311–316.

Lockwood M, 2010. Good governance for terrestrial protected areas: a framework, principles and performance outcomes. *Journal of environmental management*, 91(3): 754-766.

Magnusson, W.E., Grelle, C.E. V., Marques, M.C.M., Rocha, C.F.D., Dias, B., Fontana, C.S., Bergallo, H., Overbeck, G.E., Vale, M.M., Tomas, W.M., Cerqueira, R., Collevatti, R., Pillar, V.D., Malabarba, L.R., Lins-e-Silva, A.C., Neckel-Oliveira, S., Martinelli, B., Akama, A., Rodrigues, D., Silveira, L.F., Scariot, A., Fernandes, G.W., 2018. Effects of Brazil's Political Crisis on the Science Needed for Biodiversity Conservation. Front. Ecol. Evol. 6, 1–5.

McDonald, R.I., Kareiva, P., Forman, R.T., 2008. The implications of current and future urbanization for global protected areas and biodiversity conservation. Biological conservation 141, 1695-1703.

Milner-Gulland, E.J., Fisher, M., Browne, S., Redford, K. H., Spencer, M., Sutherland, W. J., 2010. Do we need to develop a more relevant conservation literature?. Oryx 44, 1-2.

Morato, R.G., Barros, K.M.P.M., Paula, R.C., Campos, C.B., 2014. Identification of priority conservation areas and potential corridors for jaguars in the Caatinga biome, Brazil. PloS ONE 9, e92950.

Nóbrega, C.C., De Marco Jr. P., 2011. Unprotecting the rare species: a niche-based gap analysis for odonates in a core Cerrado area. Diversity and Distributions 17, 491-505.

Oliveira, U., Soares-Filho, B. S., Paglia, A.P., et al., 2017. Biodiversity conservation gaps in the Brazilian protected areas. Scientific reports 7, 1-9.

Parish, A.J., Boyack, K.W., Ioannidis, J.P.A., 2018. Dynamics of co-authorship and productivity across different fields of scientific research. PLoS One 13, e0189742. https://doi.org/10.1371/journal.pone.0189742

Parreira, M. R., Machado, K. B., Logares, R., Diniz-Filho, J. A. F., Nabout, J.C., 2017. The roles of geographic distance and socioeconomic factors on international collaboration among ecologists. Scientometrics 113, 1539-1550.

Qgis Development Team, 2018. QGIS Geographic Information System. Open Source Geospatial Foundation Project.

R Core Team, 2019. A language and environment for statistical computing. R Foundation for Statistical Computing.

Rabiei, M., Hosseini-Motlagh, S.-M., Haeri, A., 2017. Using text mining techniques for identifying research gaps and priorities: a case study of the environmental science in Iran. Scientometrics 110, 815–842.

Roberts, B. E., Harris, W. E., Hilton, G. M., Marsden, S. J., 2016. Taxonomic and geographic bias in conservation biology research: a systematic review of wildfowl demography studies. PloS One 11, 1-12.

Scarano, F.R., Ceotto, P., 2015. Brazilian Atlantic forest: impact, vulnerability, and adaptation to climate change. Biodiversity and Conservation 24, 2319-2331.

West P, Igoe, J., Brockington, D., 2006. Parks and peoples: the social impact of protected areas. *Annu. Rev. Anthropol.* 35, 251-277.

Yu, G., Li, Y.J., 2007. Parameter identification of the observed citation distribution. Scientometrics 71, 339–348.

Zeileis, A., Kleiber, C., Jackman, S., 2008. Regression Models for Count Data in R. Journal of Statistical Software 27, 1-25.

Supplementary Material

MS1

Table 1. List of terms searched in the Web of Science database.

Portuguese terms	English terms
“estaç* ecológica*”	OR “ecological station*”
“reserva* biológica*”	OR “biological reserve*”
“parque* naciona*” OR “parque* estadual”	OR “national park*” OR “state park*”
“monumento* natura*”	OR “natural monument*”
“refúgio* de vida silvestre”	OR “wildlife refuge*”
“área* de relevante interesse ecológico”	OR “area* of relevant ecological interest”
“reserva* particular* do patrimônio natural”	OR “private reserve* of natural heritage”
“area* de proteção ambiental”	OR “environmental protection area*”
“floresta* naciona*”	OR “national forest*”
“reserva* de fauna”	OR “wildlife reserve*”
“reserva* de desenvolvimento sustentável”	OR “sustainable development reserve*”
“reserva* extrativista*”	OR “extractive reserve*”

Bellow we presented the exacted terms searched in Web of Science database, returned a total of 3,079 papers used in presented papers. The output of papers were filtered removed papers not associated with the topic of the paper (see details in Material and methods):

TS=(“estaç* ecológica*” OR “ecological station*” OR “reserva* biológica*” OR “biological reserve*” OR “parque* naciona*” OR “parque* estadual” OR “national park*” OR “state park*” OR “monumento* natura*” OR “natural monument*” OR “refúgio* de vida silvestre” OR “wildlife refuge*” OR “área* de relevante interesse ecológico” OR “area* of relevant ecological interest” OR “reserva* particular* do patrimônio natural” OR “private reserve* of natural heritage” OR “area* de proteção ambiental” OR “environmental protection area*” OR “floresta* naciona*” OR “national forest*” OR “reserva* de fauna” OR “wildlife reserve*” OR “reserva* de desenvolvimento sustentável” OR “sustainable development reserve*” OR “reserva* extrativista*” OR “extractive reserve*”) AND TS=(Brazil* OR Brasil*)
Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Timespan=1991-2017

MS2

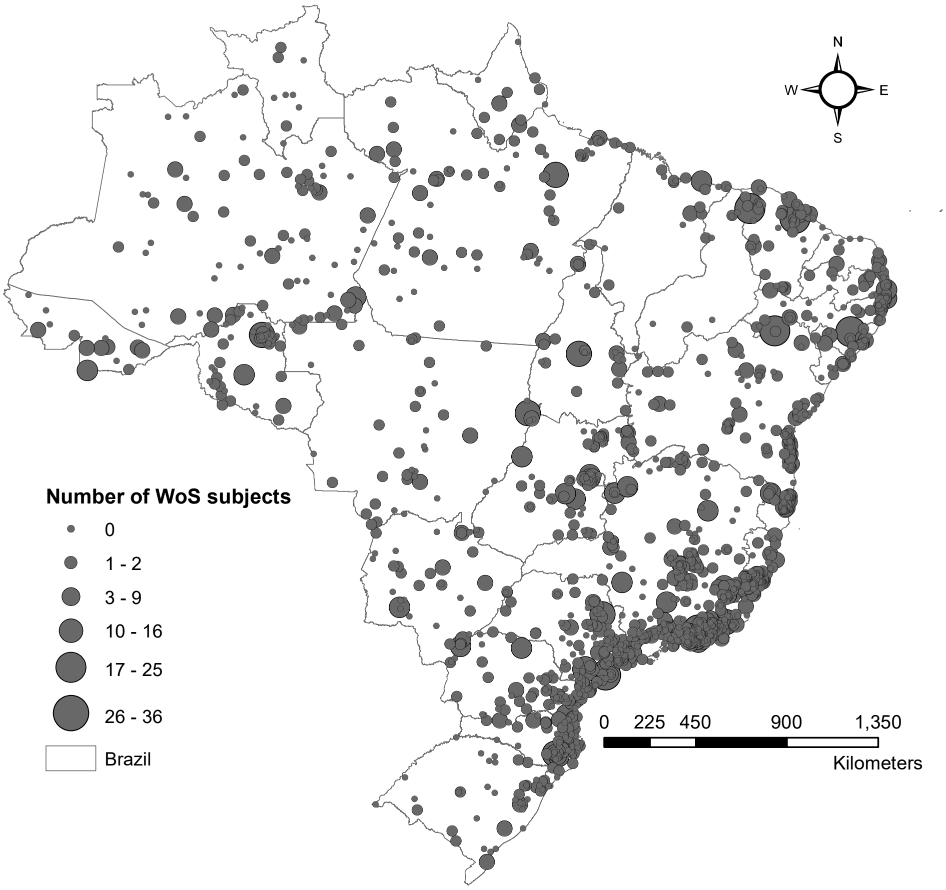

Figure 1. Spatial distribution of number of subjected category registered in each Brazilian Protected Area.

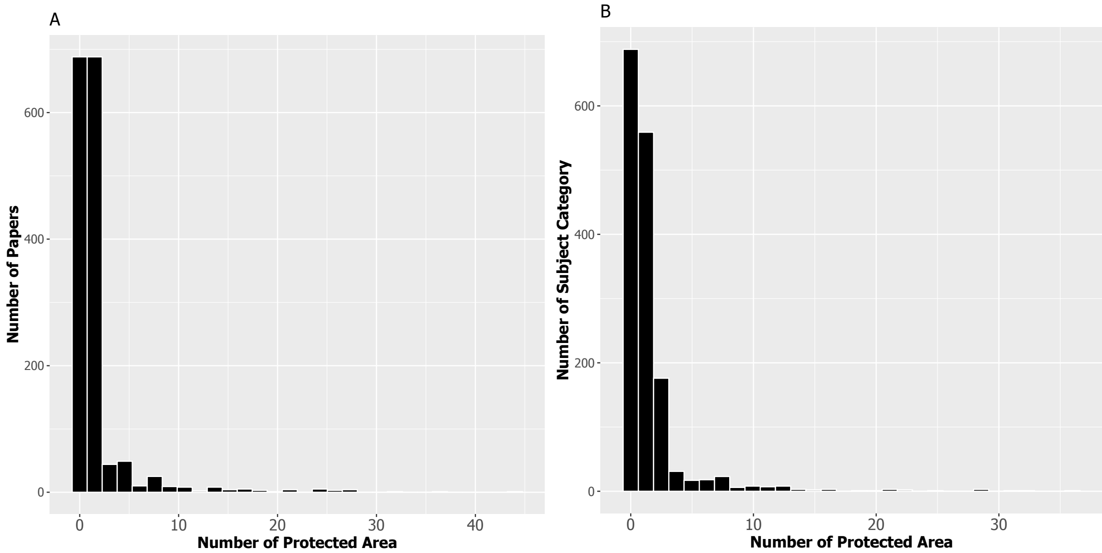

Figure 2 – Histogram of number of paper (A) and number of subject category (B) by Conservation units.

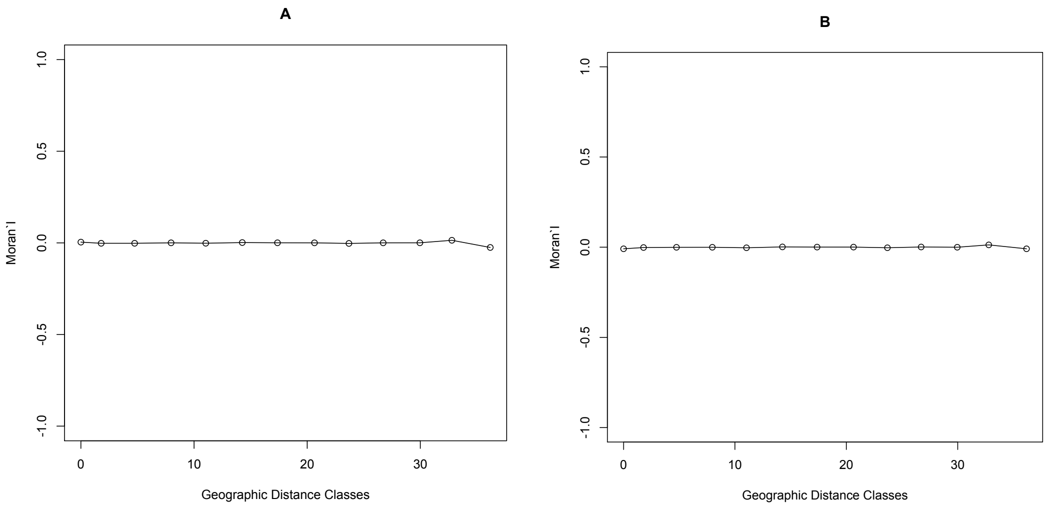

Figure 3 Moran' I Correlogram of number of paper (A) and number of subject category (B).

Table 1. Statistical results of four different models for number of subjected category published in Brazilian Protected area. The models utilized were linear (OLS), Zero Inflated Binomial (ZIBN), Zero Inflated Poisson (ZIP), Poisson.

	OLS		ZIBN		ZIP		Poisson	
	St Coeff.	P	St Coeff.	P	St Coeff.	P	St Coeff.	P
Area	0.400	<0.001	0.611	<0.001	0.595	<0.001	0.595	<0.001
Age	0.401	<0.001	0.787	<0.001	0.852	<0.001	0.848	<0.001
Distance PA	-0.014	0.509	0.030	0.839	0.047	0.0623	0.043	0.0829
Distance City	-0.184	<0.001	-0.208	<0.001	-0.181	<0.001	-0.195	<0.001
R2	0.45		0.49		0.51		0.5	
AIC	3493.67		3972.15		4373.65		4383.13	

Conclusão geral

Apresentamos dois artigos que abordaram, de forma multidisciplinar, análises sobre a situação da conservação numa escala mais regional (bioma Cerrado) e numa escala nacional. Buscamos trazer inovações ao conhecimento científico brasileiro, usando diferentes análises e apresentando dados até então não levantados ou pouco estudados. Dessa forma, identificamos alguns resultados de destaque, tais como: (i) a baixa cobertura por UCs no bioma Cerrado; (ii) a grande sobreposição de UCs; (iii) a falta de contemplação de todas as variáveis bioclimáticas do bioma Cerrado; (iv) muitas UCs sem sequer um artigo publicado; (v) UCs maiores, mais antigas e mais próximas de áreas urbanas possuem mais artigos publicados.

Sem dúvidas, melhorar o status de conservação do país é um grande desafio. Para tal missão, sugerimos uma série de ações que inclui: (i) criação de UCs em áreas com pouca presença de ações de conservação, que possuem importante biodiversidade e que no momento não está sendo preservada; (ii) uma melhor gestão das UCs existentes, com ausência de conflitos de interesse e elaboração de planos de manejos condizentes com a realidade; (iii) melhor aquisição e uso dos recursos disponíveis; (iv) a criação de leis mais rígidas para os crimes ambientais, com aumento da fiscalização; (v) incentivo de pesquisas em UCs pouco exploradas ou pouco conhecidas; (vi) formação de uma base de dados contendo os artigos e projetos realizados em cada UC. Com essas e outras ações, poderemos melhorar a atual situação de conservação, garantindo a existência da biodiversidade atual para as próximas gerações.