RESEARCH STATUS AND TRENDS IN THE PANTANAL: A BIBLIOMETRIC REVIEW

Panorama e Tendências da Pesquisa no Pantanal: uma revisão bibliométrica

Statut et Tendances de la Recherche dans le Pantanal: une revue bibliométrique

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Abstract: The Pantanal, the largest tropical wetland in the world, is renowned for its biodiversity and ecological services, including water storage and purification, which significantly impact the socio-economic life of the region. The recent occurrence of large-scale fires, exacerbated by climate change, underscores the urgent need for comprehensive studies. This research aimed to investigate the trends and current state of scholarship on the Pantanal through a bibliometric analysis. We utilized Web of Science and VOSviewer to analyze 926 publications from 1988 to 2023, mapping the primary authors, collaborations, and predominant research areas, with a focus on Environmental Sciences, Ecology, and Zoology. The results highlight Brazil's leading role in Pantanal research and identify the most influential researchers, as well as the main themes and gaps for future investigation. This analysis offers a thorough overview of scientific production related to

Introduction

The Pantanal covers land in Brazil, Paraguay, and Bolivia, in the center of South America. Its ecosystem is the most extensive (150,500 km²) tropical wetland in the world and is widely known for its contrasting landscape and rich biodiversity (Alho *et al.*, 2019). It is located in the Upper Paraguay Basin, which in Brazil is divided into two zones: the Pantanal plain, with

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the Pantanal, thereby supporting the development of effective conservation policies and strategies.

Keywords: Literature Review, Scientific Collaboration, Wetlands.

Resumo: O Pantanal, a maior área úmida tropical do mundo, destaca-se por sua biodiversidade e pelos serviços ecológicos, como o armazenamento e purificação da água, que impactam significativamente a vida socioeconômica da região. A ocorrência recente de incêndios em larga escala, intensificada pelas mudanças climáticas, enfatizou a necessidade de estudos abrangentes. Este estudo teve como objetivo investigar as tendências e o estado atual da pesquisa sobre o Pantanal por meio de uma análise bibliométrica. Utilizamos o Web of Science e o VOSviewer para analisar 926 publicações de 1988 a 2023, mapeando os principais autores, colaborações e áreas de pesquisa predominantes — com destaque para Ciências Ambientais, Ecologia e Zoologia. Os resultados evidenciam o protagonismo do Brasil nos estudos sobre o Pantanal e identificam os pesquisadores mais influentes, bem como os principais temas e lacunas para futuras investigações. Essa análise fornece uma visão abrangente da produção científica sobre o Pantanal, apoiando o desenvolvimento de políticas e estratégias de conservação.

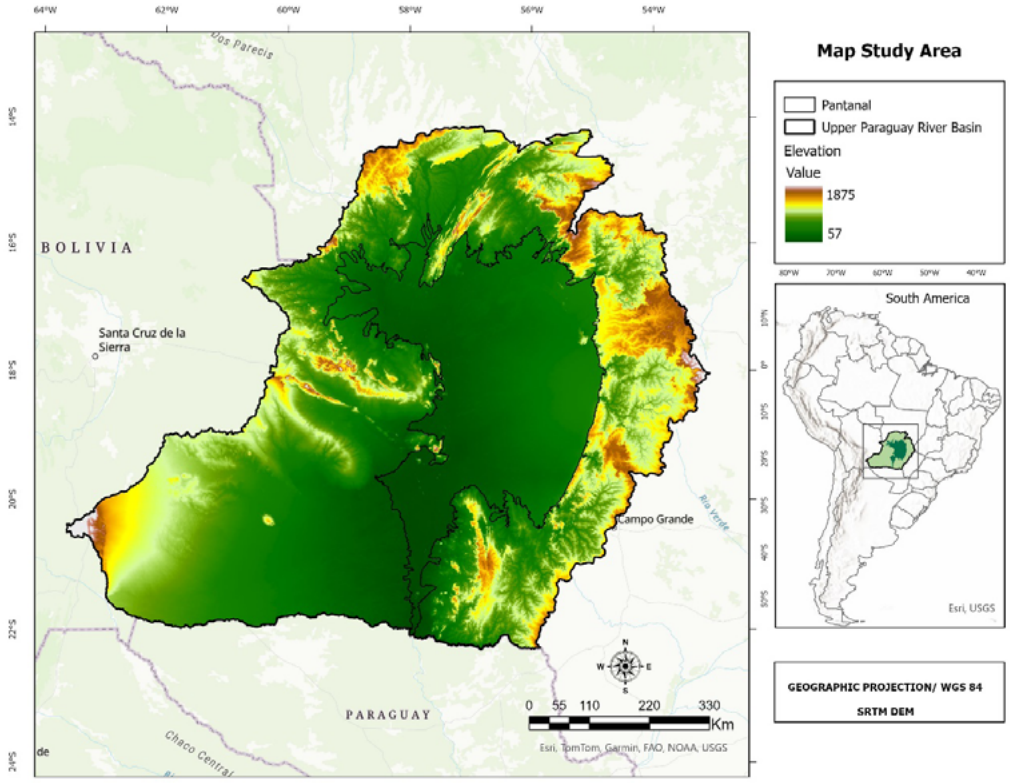
Palavras-chave: Revisão da literatura, Colaboração científica, Zonas húmidas.

Resumen: El Pantanal, el mayor humedal tropical del mundo, se distingue por su biodiversidad y sus servicios ecosistémicos, como el almacenamiento y la depuración del agua, que tienen un impacto significativo en la vida socioeconómica de la región. La reciente aparición de incendios a gran escala, exacerbados por el cambio climático, ha puesto de manifiesto la necesidad de llevar a cabo estudios exhaustivos. Este estudio tiene como objetivo investigar las tendencias y el estado actual de la investigación sobre el Pantanal mediante un análisis bibliométrico. Utilizamos Web of Science y VOSviewer para analizar 926 publicaciones desde 1988 hasta 2023, mapeando a los principales autores, colaboraciones y áreas de investigación predominantes, con énfasis en Ciencias Ambientales, Ecología y Zoología. Los resultados destacan el papel preponderante de Brasil en los estudios sobre el Pantanal e identifican a los investigadores más influyentes, así como los principales temas y vacíos para futuras investigaciones. Este análisis proporciona una visión integral de la producción científica sobre el Pantanal, apoyando el desarrollo de políticas y estrategias de conservación.

Palabras clave: Análisis bibliométrico, Colaboración científica, Humedales.

147,629 km², and the plateau, with 211,963 km². These zones have two distinct geomorphological aspects. While the watercourses on the plateau act as tributaries, they are transformed (Souza *et al.*,1998; Miranda *et al.*, 2018). The Upper Paraguay River Basin is situated between latitudes 14º06′ - 22º30′ S and longitudes 53º06′ - 59º42′ W. The lowland region has an elevation ranging from 80 to 200 meters, while the plateau varies from 200 to 925 meters (Alvares, 2005) (Figure 1). Human occupation in the Upper Paraguay River Basin (BAP) remains low in density; however, economic activities extend beyond livestock farming (Assine; Soares, 2004). In the highland areas, mining—particularly limestone extraction—constitutes a significant economic sector. Furthermore, agriculture has experienced notable expansion since 2015, with an increase in grain and sugarcane cultivation. While these activities enhance the local economy, they also raise significant environmental concerns for the region (Coutinho *et al.*, 2016).

Figure 1: Location Map of the Study Area with Altimetry Data for the Upper Paraguay River Basin and the Pantanal



Source: Upper Paraguay Drainage River Basin Digital Elevation Model (SRTM3 DEM) from NASA's Shuttle Radar Topography Mission (SRTM) for South America, ~90m resolution, WGS84 datum, acquired in February 2000. Map created by the authors in ArcGIS Pro in March 2024.

As a significant wetland in the Upper Paraguay River Basin, the Pantanal has increasingly attracted the attention of the scientific community due to its unique ecological and hydrological characteristics. The region experiences intense seasonal flooding, which is essential for maintaining its biodiversity and ecosystem services. The Pantanal supports a variety of habitats, including aquatic, wetland, and terrestrial environments, all of which contribute to its rich biodiversity. However, it faces numerous environmental threats, such as deforestation, the construction of hydroelectric dams, and pollution from agriculture and mining. These challenges have prompted scientists and environmentalists to advocate for enhanced protection and sustainable management strategies (Lázaro *et al.*, 2020). One such initiative is the development of a comprehensive master plan for the sustainable development and protection of the Pantanal and other Brazilian wetlands (Junk; Da Cunha, 2018).

The Pantanal has long been the subject of research, attracting the interest of naturalists and explorers since the 18th and 19th centuries. One of the first reports on the region was by the French naturalist Auguste de Saint-Hilaire, who traveled through Brazil in the 1820s, documenting the local flora and fauna (BIBLIOTECA NACIONAL DA FRANÇA). In the 20th century, researchers such as Edgard Roquette-Pinto and Rodolpho von Ihering continued to explore and study the Pantanal, contributing significantly to scientific knowledge of the region. Roquette-Pinto's pioneering work in the 1910s highlighted the ecological importance of the Pantanal, while Ihering's expeditions in the 1930s and 1940s deepened understanding of the local biodiversity (Keuller, 2019). These early initiatives laid the foundations for the wide range of scientific studies that continue to be carried out today, focusing on the preservation and sustainable management of the Pantanal (Kauffman, 2015).

Wetlands provide numerous services for society, fauna, and flora, such as water storage, river discharge buffering, groundwater recharge, sediment retention, water and microclimate regulation, among others (Junk *et al*., 2014). By joining the convention in 1993, Brazil committed itself to collecting data on biodiversity, classifying wetlands, conducting studies for their protection, and providing the country with support for research, defining priorities, and more (D'Ascenzo *et al*., 2024).

The flooding process in the Pantanal plays a crucial role in the daily living conditions of the people who, over the years, have had to adapt to the regular oscillations of floods and ebbs. During the rainy season, natural pastures are revitalized, benefiting the raising of cattle and other herbivores. The periodicity of the floods also favors the rejuvenation of birds and fish. Apart from its rich biodiversity, the Pantanal is home to a unique culture known as Pantanal culture (Alho, 2008). This society is characterized by its remoteness from urban centers, often in isolation, adapting to necessary technologies while maintaining the livestock tradition, in the rearing of cattle for meat production (Girard; Vargas, 2008).

The conservation and sustainable use of wetlands have been the focus of research and intergovernmental agreements (Ramsar, 2016). Developing guidelines for environmental assessments in regions that impact the quality and dynamics of these areas is a priority for environmental organizations, both national and international (Abdon *et al*., 2005). In this context, the purpose of this article is to conduct a bibliometric study, which involves a comprehensive analysis of research and publications related to the Pantanal. The study aims to highlight the main trends, discoveries, and gaps in the accumulated knowledge about this unique ecosystem. Through bibliometric analysis, we will quantify and evaluate the volume and impact of scientific publications in this field of study.

Bibliometrics can be defined as the application of mathematical and statistical methods to books and other media to measure the impact and dissemination of scientific information (Pritchard, 1969). It is a statistical and quantitative technique used analyze information on publications and citations in a specific field. It mainly involves a bibliographic review of scientific studies and also highlights publications that are frequently (Ebrahim *et al*., 2020).

Scientometrics is an extension of bibliometrics, which involves quantitative methods of research into the development of science as an information process (Nalimov; Mulchenko, 1971). It evaluates scientific and technological impact, collaboration between researchers, and the development of technologies. Bibliometric and scientometric analyses, therefore, converge with the common objective of examining publications in the scientific literature from various perspectives (Moresi *et al*., 2021).

According to Moresi *et al*. (2021), to comprehend the outcomes of previous research, scholars traditionally utilize two methodologies: the qualitative approach for systematic literature reviews and the quantitative approach for as described by Schmidt (2008). The third method, introduced by Zupic; Čater (2015) is referred to as scientific mapping. This method is based on the quantitative approach of bibliometric research methods, which includes analyses of citations, co-citations, bibliographic coupling, co-occurrence of words, and co-authorship. Scientific mapping is increasingly employed to track the structure and evolution of scientific fields and disciplines. It will be utilized in this study.

Bibliometric analyses are a valuable tool for researchers and professionals, providing information on trends and recent developments in specific fields of research (Donthu *et al*., 2021). They help identify gaps in the literature and guide future research directions. They still have significant value, especially when focused on specific research questions (D'Ascenzo *et al*., 2024). It is believed that, when well planned, these reviews can complement traditional narrative reviews and enrich our understanding of the current state of studies in priority conservation areas such as the Pantanal.

Materials and Methods

Materials

The research was conducted using the Web of Science (WoS) and VOSviewer platforms, accessible at *https://www.webofscience.com/* and *https://www.vosviewer.com/*, respectively. These are useful tools for bibliometric analysis and visualization

of scientific networks. The Web of Science is a database that offers a vast repository of scientific articles and bibliographic information. VOSviewer, on the other hand, is mainly used to build and visualize co-authorship networks, citations, keywords, and other elements based on data extracted from scientific publications (Van Eck; Waltman, 2021).

Several studies have highlighted the combined application of Web of Science and VOSviewer for bibliometric analysis. Shah et al., (2020), in their work titled Prosumption: "Bibliometric Analysis using HistCite and VOSviewer", conducted a systematic review of the literature on prosumption, focusing on marketing-related research. This study utilized bibliographic coupling and mapping analysis on two decades of data extracted from the Web of Science. Similarly, Van Eck and Waltman (2017), in "Citation-based Clustering of Publications using CitNetExplorer and VOSviewer," demonstrated the potential of CitNetExplorer and VOSviewer for clustering publications and analyzing clustering solutions based on Web of Science data. Ahmad e Batcha (2019) further employed this methodology in "Mapping of Publications Productivity on Journal of Documentation 1989-2018," examining three decades of research productivity in the Journal of Documentation and visualizing their findings with VOSviewer. Lastly, Kirby (2023), in "Exploratory Bibliometrics: Using VOSviewer as a Preliminary Research Tool," explored VOSviewer's utility in conjunction with Web of Science data for conducting preliminary research and identifying novel research directions. Collectively, these works showcase the versatility of Web of Science and VOSviewer in facilitating in-depth bibliometric analysis.

The Web of Science (WoS) platform is a multidisciplinary database covering various areas of knowledge, such as the sciences, social sciences, arts, and humanities, indexing a variety of formats including journals and conferences. It is essential for researchers, academics, and students looking to access and keep up to date with recent scientific literature (Birkle *et al*., 2020). WoS also offers advanced functionalities, such as citation tracking, which helps assess the impact of articles in their respective fields, as well as allowing detailed searches by keywords, authors, and titles, with tools to refine and filter results. Access is generally available through subscriptions to academic institutions (Adams; Testa, 2011).

The Web of Science employs the Journal Impact Factor (JIF) as a primary metric for evaluating the impact of academic journals. The JIF is calculated as the ratio of the number of citations received by a journal's articles in a specific year to the total number of articles published by that journal in the preceding two years. This metric, provided by the Journal Citation Reports (JCR), enables

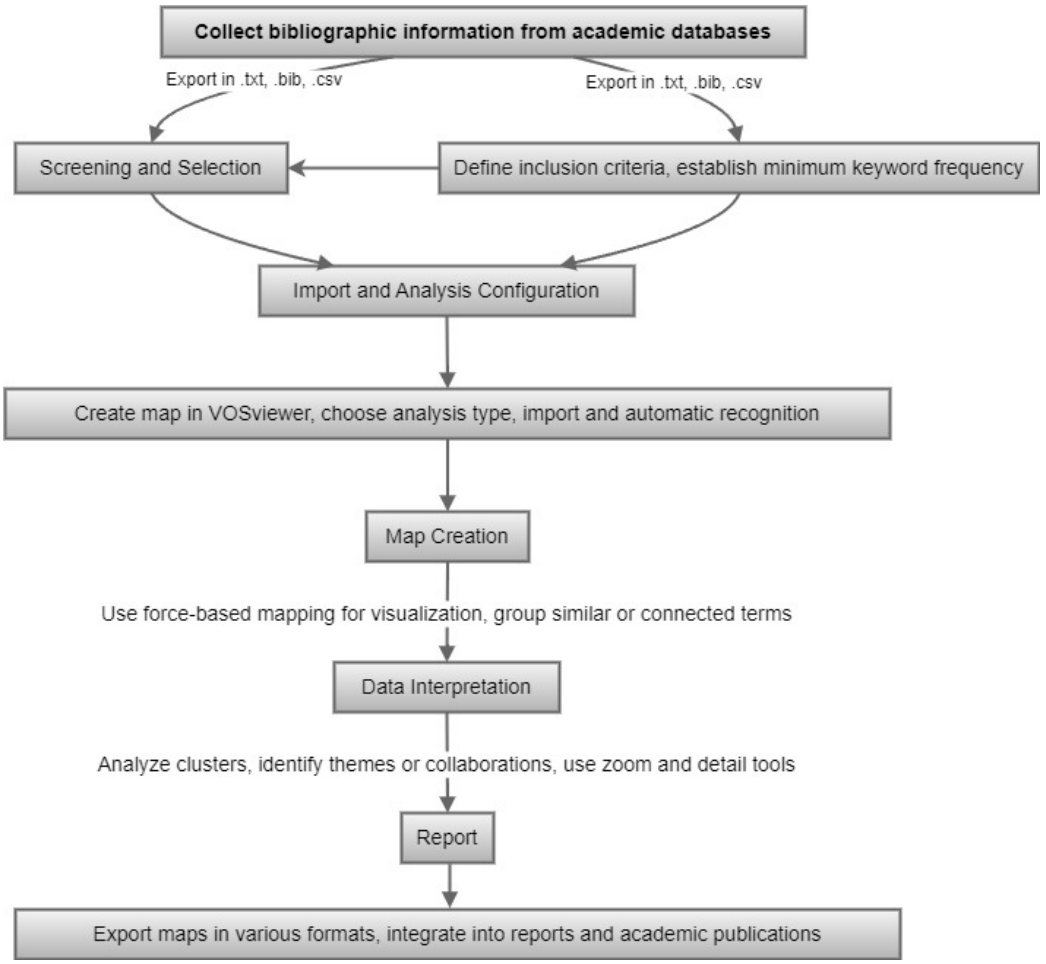
the assessment of journals' relevance within their respective fields (Clarivate Analytics, 2023).

Methodological Processes

The structured search on the Web of Science (WoS) platform, provided by Clarivate, was conducted using the keywords. We accessed the platform at *https://www.webofscience.com/* and logged in using either an institutional or personal account. The search encompassed the period from 1988 to 2023, with the inclusion of publications from the entire historical series available on Web of Science to ensure a comprehensive overview of studies in this field. Filters were applied to limit the results to original research and review articles that are fully accessible in English or Portuguese. After executing the search, the results were analyzed and exported for further examination.

VOSviewer, a software tool widely used to visualize and analyze competition networks of keywords, authors, journals, and other entities in bibliographic datasets, was utilized to enhance the visualization of the research conducted on this topic. The software is frequently employed in bibliometric and scientometric studies to map trends, collaborations, and research topics in specific fields or datasets. The methodology employed to utilize this platform was based on the steps illustrated in the figure 2 below.

Figure 2: Data collection steps in the VOSviewer Software



Source: Created by the authors using *Draw.io* by *diagrams.net*. (2024).

Using VOSviewer, we conducted co-authorship, co-citation, keyword co-occurrence, network and cluster analyses, overlay mapping, temporal analysis, interactive visualizations, and data exports. The tool's interactive visualizations and data export features offered a deeper understanding and interpretation of the collected information.

During the data export stage, we reviewed and filtered the first ten authors to prevent duplication. To standardize author names, we modified entries in the *thesaurus_authors.txt* file within the VOSviewer database. In this file, we utilized the "label" function to indicate the name of the duplicated author, along with the "replace by" function to specify the standardized author name. Each corrected name was entered next to the duplicate by pressing the "tab" key to

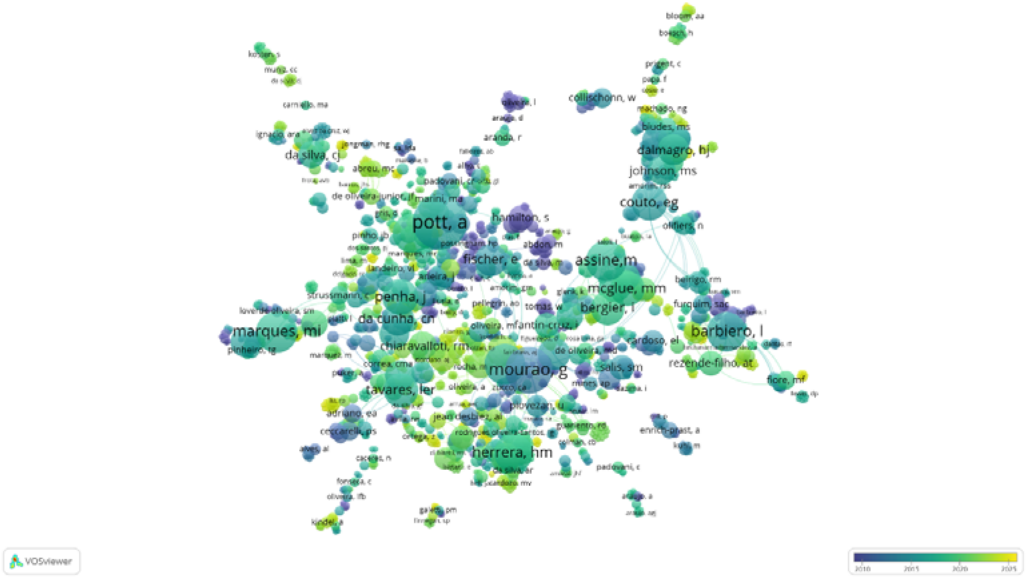
ensure proper alignment. This modified *thesaurus_authors.txt* file was then incorporated into the map creation stage, facilitating accurate author selection and minimizing duplication errors.

This systematic approach ensured that the maps generated by VOSviewer accurately represented authorship without redundancies, facilitating a reliable analysis of co-authorship networks, citation patterns, and keyword co-occurrence.

Results

In this descriptive bibliometric analysis of the number of articles published on the Pantanal between 1988 and 2024, 926 publications were found, initially involving 2,963 authors. However, after correcting for duplicate authorships, this number was adjusted to 2,689 authors. Figure 3 below shows the bibliometric map generated after this analysis.

Figure 3: Data collection steps in the VOSviewer Software



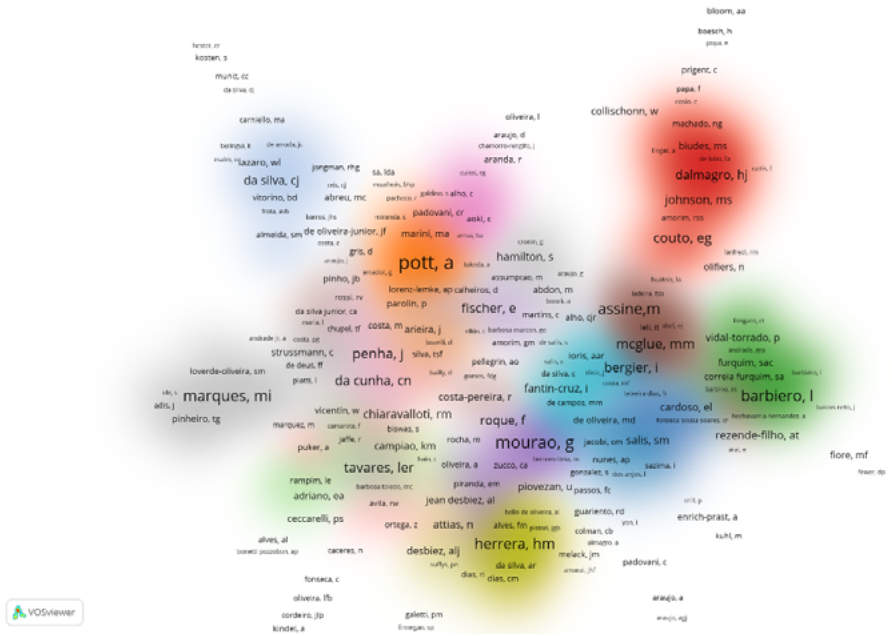
Source: VOSviewer (2024).

In the center of the map, you can see larger nodes such as "pott, a" and "mourao, g", indicating that these authors have a high productivity in publications on the Pantanal. The lines "pott, a" to other authors, such "fischer, e" and "chiavalloti, rm" show that these authors have significant collaborations with each other. In terms, of time distribution, looking at colors of the nodes, it is possible

to see those authors such "assine, ml", "barbeiro, l" have published more recently (greender and more yellow nodes), "pott, a" and "tavares, ler" have a distribution of publications over a longer period.

In the density map below (Figure 4), nodes are organized into color-coded clusters, with each color indicating a group of authors who frequently collaborate. Further details on the top 10 authors are provided in Table 10. These groupings indicate sub-areas of research or collaboration networks. The closer the nodes are, the more frequent the collaboration between authors. This map allows for the assessment of the cohesion of research networks and the identification of the leaders of each cluster, who are authors with the highest number of publications and connections.

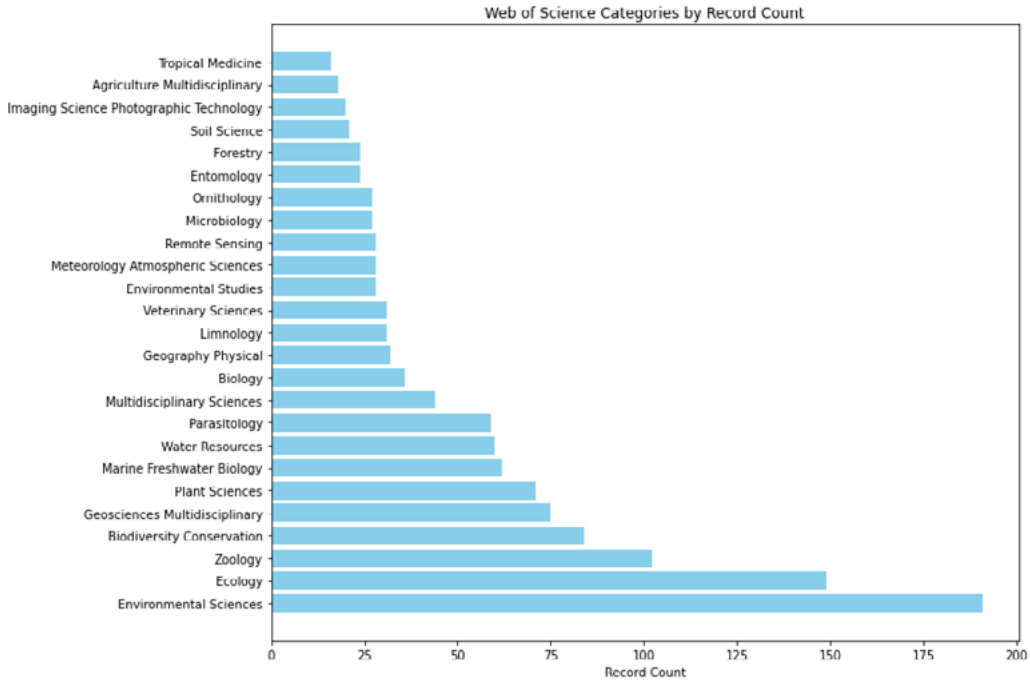
Figure 4: Bibliometric Map of Collaborations and Scientific Production on the Pantanal



Source: VOSviewer (2024).

In addition, there are many different categories of scientific research, which can be visualized by the number of records found in each category in the graph (Figure 5) below:

Figure 5: Distribution of Record Counts Across Web of Science Categories



Source: Created by the authors in *Spyder* (2024).

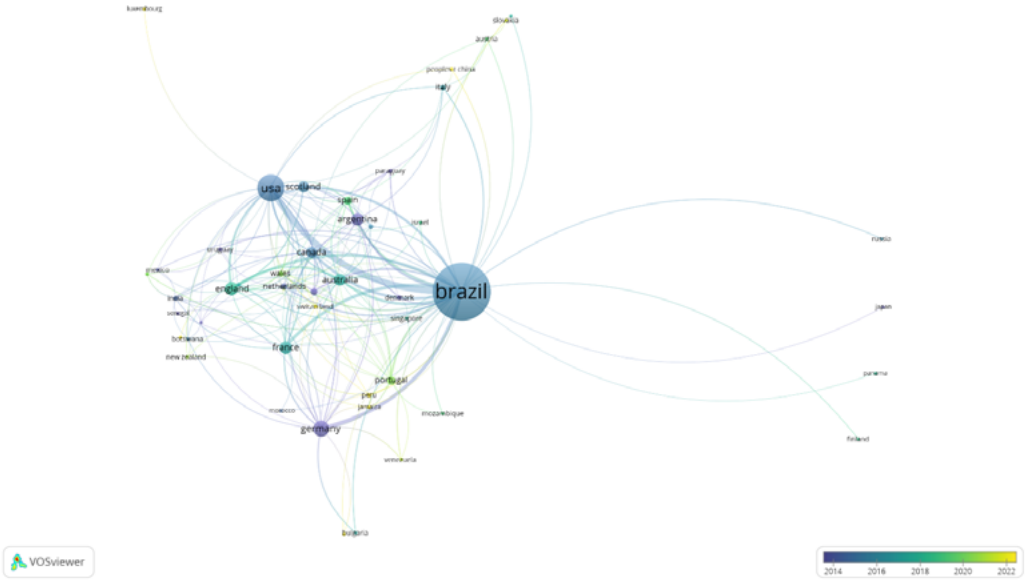
The environmental sciences category has the highest record count, with 191 publications, representing approximately 20.7% of the total 926 records. This indicates a strong interest and volume of research in this area. Ecology is the second largest category, with 149 publications, corresponding to 16.1% of the total. Zoology, with 102 publications (11.1% of the total), is another notable area. The percentage of publications in each category follows a downward trend, reflecting the distribution of interest and volume of research across different fields. Other relevant categories in the Pantanal include Biodiversity Conservation, Multidisciplinary Geosciences, and Plant Sciences, each with a significant number of publications ranging from 71 to 84 records, representing percentages between 7.7% and 9.1%, respectively.

The categories with the fewest publications include Tropical Medicine, Multidisciplinary Agriculture, and Imaging Science and Photographic Technology, each with fewer than 20 records, representing less than 2 percent of the total. These areas may have less competition and potentially offer more opportunities for new studies and significant contributions.

In terms of conducted in the Pantanal (Figure 6), Brazil leads the way, followed by other countries with fewer research activities, as shown by the green

dots on the map. The distribution of nodes in the bibliometric network indicates that Brazil serves as the primary center for production and collaboration. Research encompasses a range of interconnected topics, including and Each colored cluster represents groups of topics and authors who frequently collaborate, highlighting the areas of greatest focus and connectivity within the field of study.

Figure 6: Density Map of Country Collaborations in Pantanal Research



Source: VOSviewer (2024).

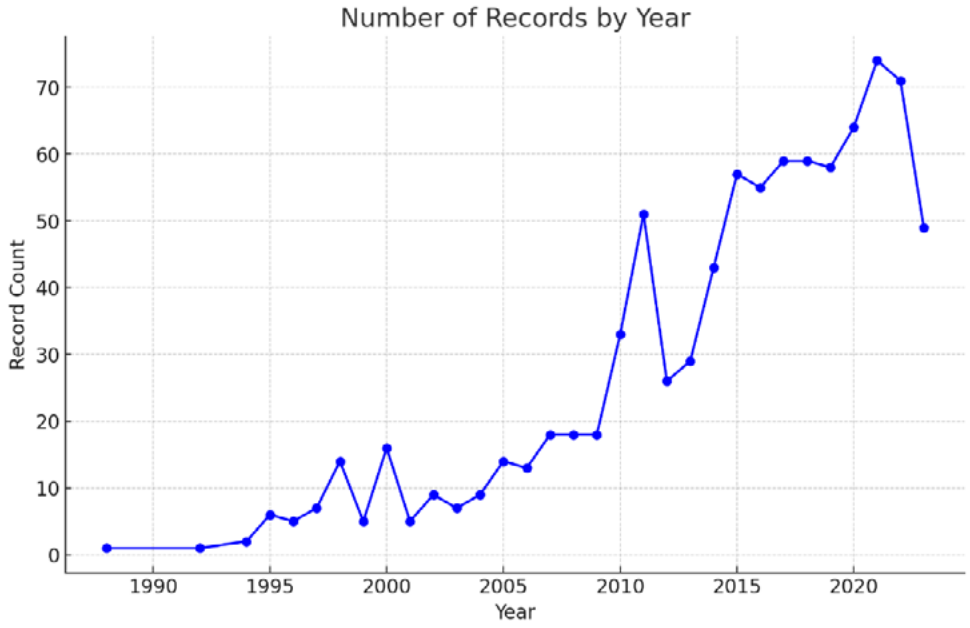
Analyzing the annual record counts of publications in the Web of Science provides valuable insights into research trends, the growth of academic knowledge, and shifts in research priorities over time (Melo; Trinca; Maricato, 2021). The article "Software Survey: VOSviewer, a Computer Program presents VOSviewer" as a tool for constructing and visualizing bibliometric maps, emphasizing its graphical representation capabilities. The authors utilize the Web of Science to gather co-citation data and analyze patterns in scientific publications, organizing extensive bibliometric datasets. VOSviewer's interactive functionality, which includes zoom and detailed exploration features, is particularly beneficial for examining clusters and relationships within large datasets, facilitating the analysis of research trends and the structures of scientific knowledge (Van Eck; Waltman, 2010).

In analyzing annual publication trends using the Web of Science database, Chen (2006) employed CiteSpace II as a robust methodological tool to enhance the understanding of research dynamics, intellectual growth, and shifting priorities

over time. According to the author, CiteSpace II facilitated the detection and visualization of emerging research trends by utilizing snapshots and clusters to map research fronts and intellectual foundations across various scientific fields. By concentrating on key articles and co-citation patterns, CiteSpace II allowed for a detailed exploration of research trends, assisting researchers and policymakers in identifying evolving scientific themes and effectively aligning strategies with the most impactful research directions.

The analysis demonstrates the evolution of publication volume over the years, highlighting periods of significant growth. While Figure 7 illustrates these growth trends, identifying the factors that influence these changes necessitates a more detailed analysis and supplementary support from various sources. Potential influences may include increased funding in specific research areas, shifts in academic priorities, or technological advancements that have heightened scientific interest. However, these assumptions require further exploration based on additional contextual data.

Figure 7: Annual Record Counts in Web of Science Publications (1988-2024)



Source: created by the authors in *Spyder* (2024).

From 1988 to 2005, the number of publications was relatively low, often below 20 per year, indicating limited research output or fewer indexed publications in the Web of Science for the given field or topic. Starting around 2005, there is a noticeable increase in publications, possibly due to growing interest in the

field, increased research funding, or improved indexing practices. The increase in funding for specific scientific areas is directly correlated with the growth in academic output. In the context of the Pantanal, located in the Central-West region of Brazil, research incentive policies implemented around 2005 significantly contributed to this growth. For instance, Embrapa Pantanal, situated in Corumbá, Mato Grosso do Sul, launched a research program for 2006/2007 that encompassed 61 research and development projects. Many of these projects received funding from sources beyond Embrapa itself, indicating a rise in financial support for research in the region (Embrapa, 2006). This enhanced financial backing has facilitated increased academic production and advances in scientific knowledge about the Pantanal.

Between 2010 and 2020, there is a sharp rise in publications, peaking around 2014-2020, representing the most prolific years in terms of research output (Figure 7). The article in Brazil by Clarivate Analytics, produced for CAPES, confirms a significant expansion of scientific production in Brazil over the past few decades. This growth reflects the impact of public investment in research and development (R&D), particularly within higher education institutions. Between 2011 and 2016, the number of Brazilian publications indexed in the Web of Science increased substantially, aligning with a national strategy designed to enhance scientific productivity and foster international collaborations, especially in strategic sectors such as clinical medicine, agricultural sciences, and industrial technology. This analysis indicates that the rise in annual publication counts is linked to funding policies targeting specific areas, demonstrating an expansion of knowledge and a shift in research priorities (Cross *et al.,* 2017).

The peak in publications in 2021 was likely driven by the accumulation of research completed and published during that period, as well as specific events that heightened interest in certain areas of study. Conversely, the decline observed between 2022 and 2024 may be attributed to changes in research funding, global events such as the COVID-19 pandemic, or shifts in scientific priorities. In the Brazilian context, as discussed by Cross *et al*. (2017), the pandemic prompted a reorganization of research priorities, with many efforts redirected toward public health topics. This redirection has resulted in a significant increase in high-impact publications in the fields of health and infectiology, while also fostering international collaboration, which is essential for addressing the health crisis and strengthening global cooperation networks. Despite these fluctuations, the overall trend from 1988 to 2023 shows a significant increase in the number of publications, indicating a growing body of research and expanding knowledge in the field.

The descriptive analysis also identified the number of publications and their impact. The number of documents indicates the productivity of the authors in terms of articles published on the Pantanal. Authors such as "pott, a" and "damasceno-junior, ga" are the most productive authors in the period analyzed (Table 1).

Table 1: Document and Citation Counts by Author

Authors	Documents	Citations
pott, a	36	174
mourao, g	31	138
marques, mi	23	105
assine, ml	24	102
tomas, wm	27	168
barbiero, l	21	135
damasceno-junior, ga	28	181
herrera, hm	20	162
couto, eg	18	109
penha, j	19	81

Source: created by the authors in *Spyder* (2024).

In relation to productivity versus impact, authors such as "pott, a" have high productivity (36 documents) and also a high number of citations (174), suggesting that their publications are widely recognized. However, when compared with "damasceno-junior, ga", they have a lower number of documents (28) but a higher number of citations (181), indicating that, despite publishing less, their research may have an even greater impact.

To analyze the impact of publications, the methodology employed in this study focused on evaluating gross productivity and citation metrics, rather than relying on the traditional Journal Impact Factor (JIF) calculated by Journal Citation Reports (JCR). Specifically, we examined recognition trends by assessing the number of citations each author received in relation to the total number of documents published. This approach enabled us to explore the visibility and recognition of each author's work independently of the JIF, which applies exclusively to journals. By analyzing the proportion of citations relative to publications, our aim was to gather insights about the impact of individual researchers on the broader scientific community. Although this method does not correlate directly with the JCR impact factor, it provides a complementary metric for understanding academic influence at the author level.

It is important to emphasize that this analysis focused on gross productivity and citation metrics, rather than the Impact Factor as formally calculated by the Journal Citation Reports (JCR). The aim was to observe trends in recognition,

measured by the number of citations, in relation to the volume of production, indicated by the number of documents authored by each individual. Although this study did not directly utilize the JCR Impact Factor—which is calculated for journals rather than individual authors—the ratio of citations to publications provides a complementary metric of impact, despite its limited direct correlation with the JCR.

As highlighted by Sheng *et al.* (2024), citation impact can be influenced by team composition factors, such as age diversity, which is positively associated with higher citation counts across various disciplines. This underscores the notion that while citation metrics may reflect visibility and impact, they do not solely indicate scientific quality, as they can also capture broader collaborative dynamics.

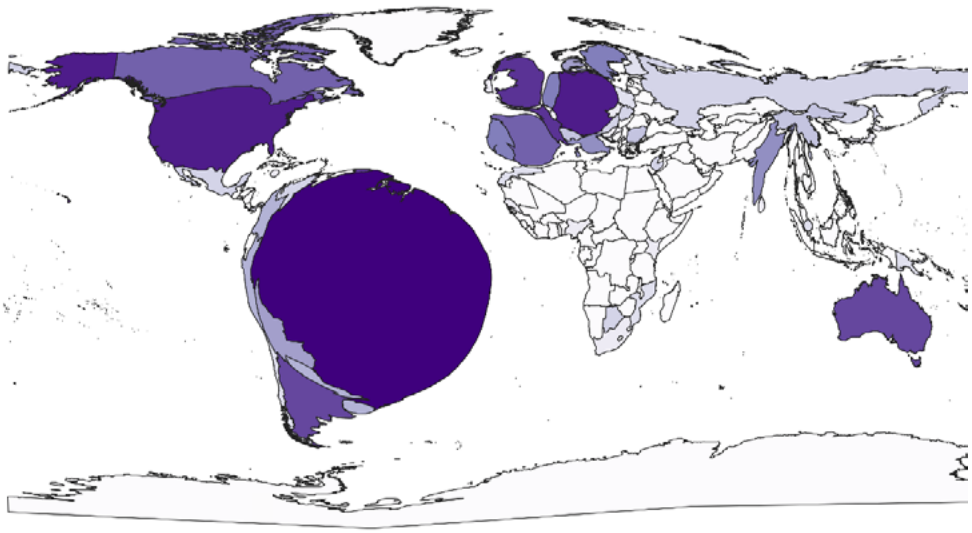
As noted by Wang *et al*. (2024), citation metrics can be significantly influenced by factors such as international collaboration and home country networks. The country effect, for example, leads to research receiving a higher number of citations domestically or from collaborating countries, which can inflate citation counts regardless of the scientific merit of the work. This observation reinforces the notion that citation counts are complex metrics, shaped by visibility and network reach rather than quality alone.

Regarding the quality of research, it is essential to emphasize that metrics such as the number of citations or downloads do not necessarily reflect the scientific merit of a work. An author with numerous publications but few citations may indicate that the research is less utilized or referenced; however, this does not inherently imply a low-quality assessment. Conversely, an author with few publications but many citations may suggest that their contributions are widely recognized, although this recognition could arise for various reasons, such as contextual relevance or even controversies within the field. Thus, while citations reflect the impact and visibility of research, they do not guarantee a superior scientific evaluation, as highly cited articles can also exemplify errors or refuted ideas. By cross-referencing citation data with the bibliometric map, it becomes possible to identify authors who frequently collaborate. For instance, if authors like Pott, A. and Mourao, G. have many publications and citations, analyzing their collaborative networks could reveal strong scientific partnerships.

The distribution of article production across countries reveals significant disparities in academic output. Brazil leads with 832 articles, demonstrating its dominant role in research activities. The USA follows with 185 articles, while Germany, England, and France contribute 64, 46, and 42 articles respectively. Other notable contributors include Argentina (38), Australia (36), and Canada and Scotland, both with 31 articles. Spain, Portugal, and Sweden also make

notable contributions, albeit on a smaller scale. Many countries, particularly in Asia and Africa, demonstrate limited research output on this topic, with Kenya, Nigeria, and Sri Lanka each contributing only a single article. This uneven distribution highlights the concentration of academic research in regions with established research infrastructure and greater financial resources. Although countries with lower output may experience growth through investments in research infrastructure and education, this does not necessarily indicate a latent potential for increased scientific production. The number of publications alone does not fully reflect a country's capacity or interest in producing research on this topic, as various socio-economic and structural factors significantly influence these outcomes. The anamorphosis map below (FIGURE 8) visually emphasizes these disparities, with country sizes proportional to their article counts, vividly illustrating the global imbalance in research production.

Figure 8: Global Distribution of Publications on Pantanal Wetlands



Source: Created by the authors using QGIS with the Compute Cartogram plugin and ArcGIS Pro (2024).

The anamorphosis map (Figure 8) illustrates the global distribution of publications on the Pantanal, revealing significant discrepancies in research contributions across different regions. Brazil emerges as the primary contributor, underscoring its central role in Pantanal studies, likely due to its geographical proximity and national interest in the biome. Countries such as the United States and several European nations, including Germany, England, and France, also play a prominent role, indicating substantial international collaboration, which

is probably facilitated by greater financial resources and advanced research infrastructure. In contrast, the regions of Asia, Africa, and Oceania are less represented, reflecting a lower number of publications and potentially limited resources allocated for environmental research. It is important to emphasize that the number of publications does not necessarily indicate a country's potential to contribute to Pantanal science, as factors such as investment in infrastructure, education, and academic networks directly influence scientific output. Consequently, the map represents the current landscape of access to and allocation of research resources rather than an assessment of the intrinsic potential of these regions.

According to Alho (2011), one of the primary challenges of conducting research in the Pantanal is the logistical difficulty associated with such a remote and expansive area. Researchers must often rely on boats or helicopters to reach their study sites, significantly increasing the complexity and expense of fieldwork. These conditions limit the participation of researchers from distant regions with fewer resources, contributing to disparities in research output.

Cunha, Buermann and Marengo, (2024)the overarching research question is to explore whether compound drought-heat events (CDHEs analyze changes in compound drought and heat events in the Brazilian Pantanal using remote sensing data and various drought indicators. The study discusses significant logistical and environmental challenges faced by researchers, including a scarcity of local meteorological data and a reliance on global datasets due to the low density of weather stations in central Brazil. This situation hinders effective monitoring of climatic extremes. Furthermore, extreme drought and heat conditions increase fire risks, which adversely affect biodiversity preservation and limit field research due to restricted access and mobility in the region. It is suggested that this aspect serves as a limiting factor in the advancement of research, particularly research that necessitates fieldwork by both national and international researchers, due to the logistical requirements that entail significant investments.

Conclusion

This work made it possible to identify the most influential and productive researchers in the field of Pantanal studies, map the collaboration networks, and understand how research groups are formed and interact. It is also noteworthy that through this analysis, it is possible to detect temporal trends in research, such as the increase or decrease in publications on the Pantanal over the years.

This data can be used to identify the main experts in the field of study of the Pantanal, which is useful for collaborative networks, peer review, or even for advice and guidance on new research projects. Analyzing the most cited authors and their specific areas of study offers valuable insights into the primary lines of research and emerging themes related to the Pantanal. However, rather than solely directing future research towards high-impact topics or collaborations with prominent authors, this approach can help identify critical gaps and underexplored areas that require further investigation. Consequently, this bibliometric analysis enhances our understanding of scientific production focused on the Pantanal and highlights opportunities to strengthen knowledge about the biome, aligning research efforts with the environmental and social needs of the region and the challenges it faces.

As for the collaboration maps, they provide a detailed overview of scientific collaboration networks in the Pantanal. These maps illustrate the key researchers, the temporal evolution of collaborations, and the structure of research networks. By presenting this information, the maps enable researchers to make strategic decisions regarding future collaborations and to identify areas of study that could yield a greater scientific impact, as well as contribute to the understanding and conservation of the Pantanal.

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Supplementary Material

Supplementary material can be found at the following link: https://link.ufms.br/geopan37.

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