SPATIAL AND TEMPORAL DISTRIBUTION OF FIRE SPOTS IN THE PANTANAL BIOME

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ABSTRACT

This study investigated the spatial and temporal dynamics of fire spots in the Pantanal Biome from August 2013 to June 2024 using data from burned areas generated by the National Institute for Space Research (INPE). Temporal and spatial analyses produced detailed maps of fire spot occurrence across different intervals of times (08/2013 to 07/2015, 08/2015 to 07/2017, 08/2017 to 07/2019, 08/2019 to 07/2021, 08/2021 to 07/2023 and 08/2023 to 03/2024), offering insights into sub-regional trends. Findings indicate lower fire spot occurrence from 2013 to 2019, with concentrations in the central (Paiaguás and Nhecolândia), southwestern (Nabileque), and northeastern (Barão de Melgaço) regions. The 2019-2021 period saw peaks in the northeast (Poconé and Paraguai), mostly due to extreme drought. This trend intensified from 2021 to 2023, especially in the west and southwest. In 2023-2024, fire spots neared peak levels, notably in Poconé and Paraguai. These findings underscore the Pantanal's vulnerability to climate-induced drought and fires, stressing the urgency of effective mitigation strategies.

Keywords: Pantanal biome, fure spots, temporal analysis, spatial analysis

1. INTRODUCTION

The Pantanal biome is one of the largest continuous wetland areas on the planet. Although it is the smallest biome in terms of territorial extent in Brazil, its importance is remarkable due to its lush biodiversity. With an approximate area of 150,355 km², the Pantanal covers about 1.76% of the national territory [1]. This alluvial plain is influenced by rivers that drain the Upper Paraguay Basin. The Pantanal is directly influenced by three major Brazilian biomes: the Amazon, the Cerrado, and the Atlantic Forest. Its unique ecological characteristics make it a vital area for wildlife conservation and ecosystem services, playing a crucial role in regional climate regulation.

Despite its classification as a humid region, the Pantanal has been facing significant climatic challenges, particularly a prolonged drought that began in 2019. This severe drought has had devastating effects on the region, notably contributing to widespread wildfires that have destroyed hundreds of thousands of hectares across the biome [2]. The drought and subsequent fires highlight the vulnerability of the Pantanal to climate change and human activities, underscoring the need for effective management strategies to mitigate these impacts.

Thus, the Pantanal has emerged as a critical area for conservation and monitoring. There is a pressing need for information regarding areas with recent increases in fire spots, as these indicate wildfire risks. This study aims to analyze the temporal dynamics of fire spots in the Pantanal Biome over during 2013 – 2024. By analyzing temporal and spatial patterns, as well as intensity trends across 11 physiographic sub-regions, we offer preliminary insights into the evolving fire dynamics within the biome. These findings can inform the development of testable hypotheses for future studies aimed at deepening our understanding of fire behavior in the Pantanal.

2. MATERIAL E METHODS

This study was conducted using the boundaries of the Pantanal Biome in Brazil. It is a predominantly flat region, inserted in the Upper Paraguay River Basin, and covers parts of the states of Mato Grosso and Mato Grosso do Sul. In the national context, it is delimited by the limits with Bolivia and Paraguay [1].

Fire spots were acquired from Queimadas Program [3], developed by the National Institute for Space Research (INPE) to monitor and assess forest fires and wildfires. The Queimadas Program offers geoservices for monitoring and modeling the occurrence, propagation, and classification of active fires in vegetation, providing daily updates on fire spots throughout the country. These data are used to evaluate the geographical distribution of fire events.

We selected the fire spots from the VIIRS sensor (NPP-375 platform) with spatial resolution of 375 m, for the entire Pantanal biome. This data was collected from the Queimadas Program portal. The dataset was selected for the period from August 1, 2013, to March 31, 2024.

The biome was analyzed considering two interpretation scales:

1) Considering the 11 physiographic sub-regions of Pantanal [4] delimited by the Brazilian Agricultural Research Corporation (Embrapa). This data is based on flooding aspects, relief, soil, and vegetation, and was used to improve the understanding of the fire spot dynamic in different natural contexts within Pantanal.

2) Considering a grid of 10 km × 10 km, to allow the analyses of several elements, within the same cell, in space and time, also enabling statistical analyses of each cell with its neighbors [5], which can be useful for the future development

of this study.

For both cases, we counted how many fire spots occurred within the limits of the delimited area (10 km × 10 km grid cell and sub-region limit).

All fire spots from 2013 to 2024 were gathered, covering the past decade of vegetation suppression mapping and the current year (2024). These spots were analyzed into 6 sets, each spanning 2 years, except 2023-2024: 08/2013 to 07/2015, 08/2015 to 07/2017, 08/2017 to 07/2019, 08/2019 to 07/2021, and 08/2021 to 07/2023. These data were aggregated to simplify the analysis of previous trends. The last period covers data from 08/2023 to 03/2024, which is the most recent. Note that the last period encompasses only one year whereas the other ones cover two years. This difference must be acknowledged for the interpretation of results. The fire spot distribution over time and space were then presented as choropleth maps.

3. RESULTS

Figure 1 illustrates the variation of the spatial distribution of the total number of fire spots in the 11 sub-regions of the Biome. The Nhecolândia region showed a high number of fire spots only for 2013 –2015 (a), whereas Poconé presented the highest numbers for 2019-2021 (d) and 2023-2024 (f). Porto Murtinho and Aquidauana showed the lowest amounts of fire spots throughout the decade.

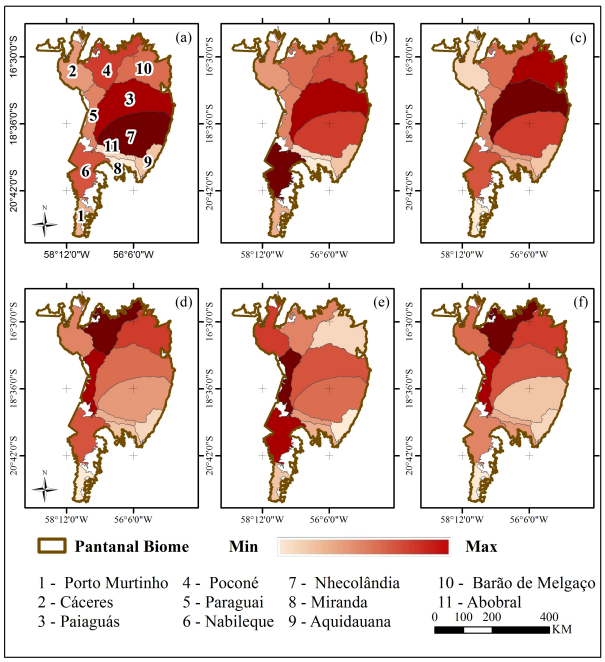


Figure 1: Choropleth maps presenting the total sum of fire spots in each subregion over the periods.

Figure 2 illustrates the spatiotemporal occurrence of fire spots for each period of interest within the grid. The northwestern region of the biome stands out with areas of high fire spot density, particularly during periods 2013–2015 (a), 2019–2021 (d), 2021 – 2023 (e), and 2023–2024 (f). The southwestern region of the biome exhibits density levels ranging from moderate to high throughout all periods, except during the period 2023–2024 (f). During the period of 2019–2021 (d) a high concentration of fire spots were registered in the northwest of the biome. The period of 2021–2023 (d) registered record-breaking numbers of fire spots in the series analyzed in this study, and the number of fire spots in the shorter period analyzed, 2023-2024 (f), presents more than the double of fire spots registered in the periods 2015 – 2017 and 2017 – 2019.

Figure 3 summarizes the total number of fire spots per subregion for each period. Notably, the 2019-2021 biennium recorded the highest peak in the majority of sub-regions (except in Porto Murtinho, Miranda, and Abobral). After the period of highest intensity (2019 to 2021), the sub-regions of Cáceres, Nabileque, Nhecolândia, and Aquidauana experienced a reduction in the occurrence of fire spots in 2021-2023.

Analyzing the most recent period, from 2023 to 2024, which, unlike the others, corresponds to only one year of fire spot occurrence, it is evident that the sub-regions of Paiaguás, Poconé, Paraguai, and Barão de Melgaço witnessed an increase in occurrence compared to the biennium from 2021 to 2023. Furthermore, the time interval from 2023 to 2024, despite being less than one year, already shows higher fire spot rates than those observed across the time interval of analysis.

4. DISCUSSIONS

Our results, although exploratory in nature, show an increase in the number of fire spots over time in the Pantanal. This is most notable in seven months between 08/2023 and 03/2024, with 927 registered fire spots, which corresponds to 75% of the occurrences in the 24 months of 2019—2021 and 65% of the occurrences in the 24 months of 2021–2023.

Our analysis of fire spot occurrence by sub-region indicates differences in fire spot rates between 2021–2023 and 2023–2024 across the Pantanal biome, with higher rates in the sub-regions of Paiaguás, Poconé, Paraguai, and Barão de Melgaço. This analysis could help to delimitate priority areas for immediate action.

The analysis using a grid allowed the understanding, spatially, of the most burned areas in the biome, in the last 13 years, showing its increase over time. The results show that the northwest and southwest regions of Pantanal tend to exhibit a higher recurrence of fire spots, especially for the periods from 2019-2021 and the most recent one, from 2023 to 2024. The significant increase of fire spots in these periods is attributed to extensive burned areas, which marked the highest index since 2001 [6]. These results can subsidize more advanced studies, such as analyses correlating the occurrence of fire spots and land cover proportion in each cell of the grid, which in turn would help us to understand how land use changes influence fire occurrence and so how public policies could help to combat and prevent fires [7].

For the Pantanal, higher rates of fire spots can have far-reaching consequences. For instance, a catastrophic wildfire swept through nearly one-third of the Pantanal in 2020. Its occurrence was attributed to the water deficit in the region

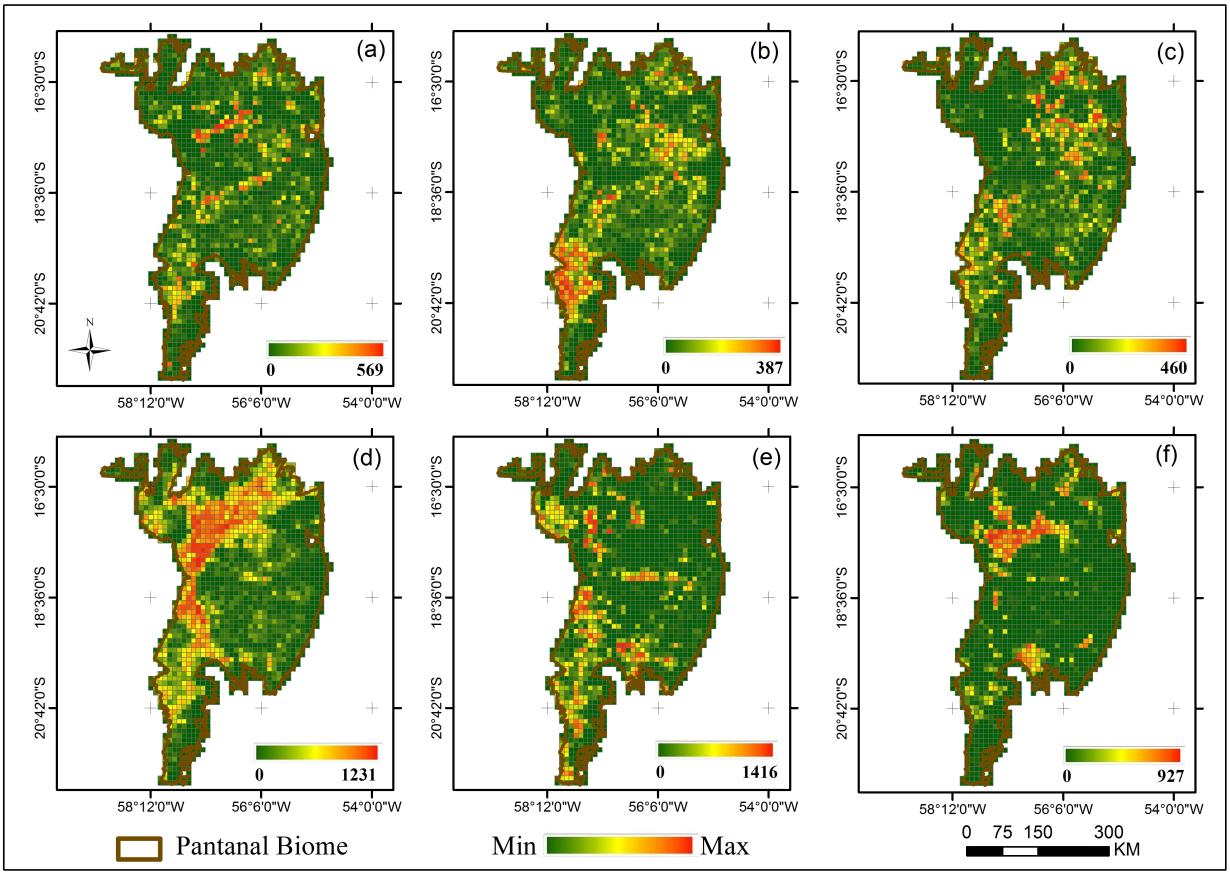


Figure 2: Total number of fire spots in each 10km x 10km grid cell for the periods of 2013 -2015 (a), 2015-2017 (b), 2017-2019 (c), 2019-2021 (d), 2021-2023 (e) and 2023-2024 (f).

[2] resulting in extensive ecological damage. The smoke generated from this fire traveled thousands of kilometers, eventually contributing to "black rain" events in other parts of Brazil [8]. This situation emphasizes the urgent need for robust fire management and conservation efforts in the region to protect its unique biodiversity and ecosystem services.

Understanding the complex interactions between climate variables, land use, and fire occurrence is essential for developing effective conservation strategies in the Pantanal. Current research has shown that climate change exacerbates the frequency and intensity of wildfires, making it crucial to implement adaptive management practices that enhance the resilience of this vital ecosystem [9, 10]. Our results facilitate the identification of priority areas for fire prevention and control measures, particularly by correlating historical trends (2013–2021) with current data (2023—2024). Furthermore, they indicate that future studies, such as those analyzing the behavior of fires within the context of extreme climate events, could benefit from analyses stratified in different physiographic contexts.

5. CONCLUSIONS

The maps developed in this study enabled the analysis of spatiotemporal variations in the intensity of fire spots occurrence over the past years, which were compared with the current scenario. Using the 10 km x 10 km grid, we observed that the northwest and southwest regions of Pantanal tend to exhibit a higher recurrence of fire spots, especially for the periods from 2019-2021 and the most recent one, from 2023 to 2024.

In the maps showing the occurrences of fire spots by the regions of Pantanal, we could observe that Paiaguás, Poconé, Paraguai, and Barão de Melgaço experienced an increase from 2023 to 2024 compared to the biennium from 2021 to 2023, even though the difference in the temporal scale used in the analysis. The most recent period, from 2023 to 2024, despite consisting of less than one year of observation, already shows a number of fire spots surpassing the total observed in each of the initial three periods (2013 to 2019). Future studies should address what these regions have in common that explain their higher flammability.

Although preliminarily, this study can inform public policies aimed at fire mitigation, especially through the results by sub-regions, which allows a better understanding of wildfires in different physiographic contexts.

6. ACKNOWLEDGEMENTS

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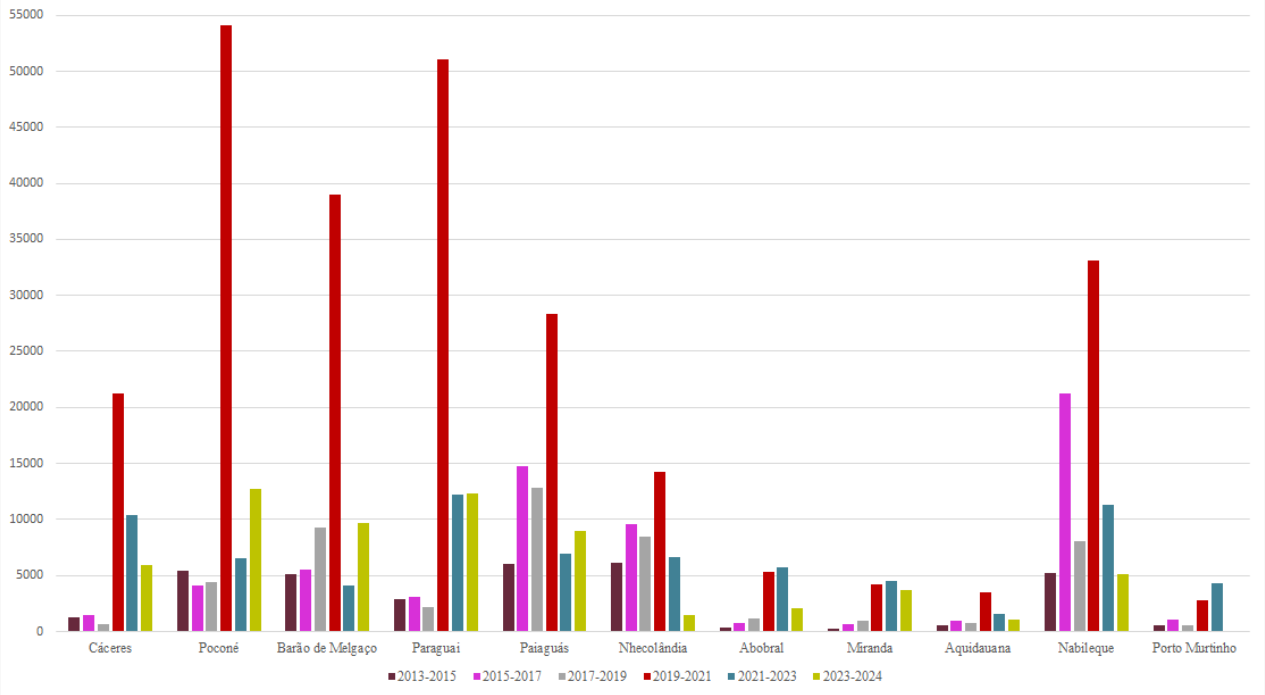


Figure 3: Temporal distribution of the fire spots in the last 10 years.

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