Spatial and temporal distribution of heat spots in the Pantanal biome

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1. Introduction

The Pantanal biome is the largest tropical wetland area on the planet, covering 150,355 km² in the Brazilian states of Mato Grosso and Mato Grosso do Sul, extending into Bolivia and Paraguay. Despite being a humid area, Pantanal has been subjected to a prolonged drought since 2019, with significant negative impacts for the region: mainly subsequent fires that consumed hundreds of thousands of hectares across the biome (Marengo et al., 2021). In 2020, an extensive wildfire occurred in the area, affecting nearly one-third of the biome. The resulting smoke spread over thousands of kilometers, leading to the phenomenon known as 'black rain' in other parts of the country (Libonati et al., 2020).

Given these events, Pantanal emerged as a critical area of conservation and control, and information about areas with recent increases in the occurrence of heat spots is needed. This study aims to analyze the temporal dynamics of heat spots in the Pantanal Biome over the past decade (2013-2024). This will be achieved by identifying seasonal patterns and intensity trends across 11 physiographic sub-regions. The analysis will facilitate the identification of priority areas for fire prevention and control measures, particularly by correlating historical trends with current data (2023-2024).

2. Material and Methods

This study was conducted using the boundaries of the Pantanal Biome. It is a predominantly flat and depressed 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 (IBGE and Ambientais, 2019).

Heat spots were acquired through the Queimadas Program (INPE, 2024), 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 hot spots throughout the country. These data are used for evaluating the geographical distribution of fire events.

We selected the heat spots from the VIIRS sensor (NPP-375 platform) for the entire Pantanal biome through the Queimadas Program portal. The dataset were selected for the period from August 1, 2013, to March 31, 2024.

The biome was analyzed considering two interpretation scales: 1) a grid of 10 km $\times$ 10 km, that allows for the detailed visualization of variations of heat spots occurrence in time and space, and 2) considering the 11 physiographic sub-regions of Pantanal (Silva and Moura Abdon, 1998) 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 heat spot dynamic in different natural contexts within the biome.

For both cases, we counted how many heat spots occurred within the limits of the delimited area (cell of grid or sub-region limit). All heat 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: 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. Note that the last period encompasses only one year whereas the other ones cover two years.

Choropleth maps were created to show heat spot distribution over time and space. It is worth noting that the 11 sub-regions do not cover the entire biome.

3. Results and discussions

Figure 1 illustrates the spatiotemporal occurrence of heat spots for each period of interest within the grid. The northwestern region of the biome stands out with areas of high heat spot density, particularly during periods 2013 -2015 (a), 2019-2021 (d), 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). Period 2019-2021 (d) registered record-breaking numbers of heat spots since the start of the monitoring, mainly in 2020, attributed to the water deficit in the region.

Figure 2 illustrates the variation of the spatial distribution of the total number of heat spots in the 11 sub-regions of the Biome. The Nhecolândia region showed a high number of heat 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 numbers of heat spots throughout the decade.

Figure 3 summarizes the total number of heat spots per sub-region for each period. Notably, the 2019-2021 biennium recorded the highest peak, with the exception of the regions of Porto Murtinho, Miranda, and Abobral. This significant increase is attributed to extensive burned areas in 2020, which marked the highest index since 2001 (Reis et al., 2023).

When conducting a quantitative analysis focused exclusively on the absolute values of heat spots, the first three analyzed periods exhibited lower values compared to the subsequent ones.

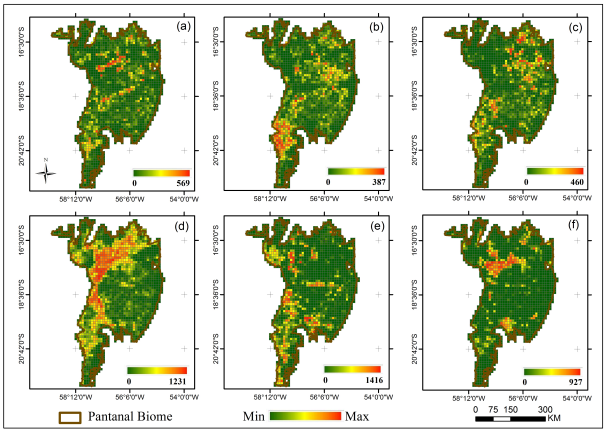

Figure 1. Total number of heat spots in each 10km grid for the periods of 2013 -2015 (a), 2015-2017 (b), 2017-2019 (c), 2019-2021 (d), 2021-2023 (e) and 2023-2024 (f).

The time interval from 2023 to 2024 (f), despite being only one year, already shows rates superior to those observed in the initial years. 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 heat spots in 2021-2023.

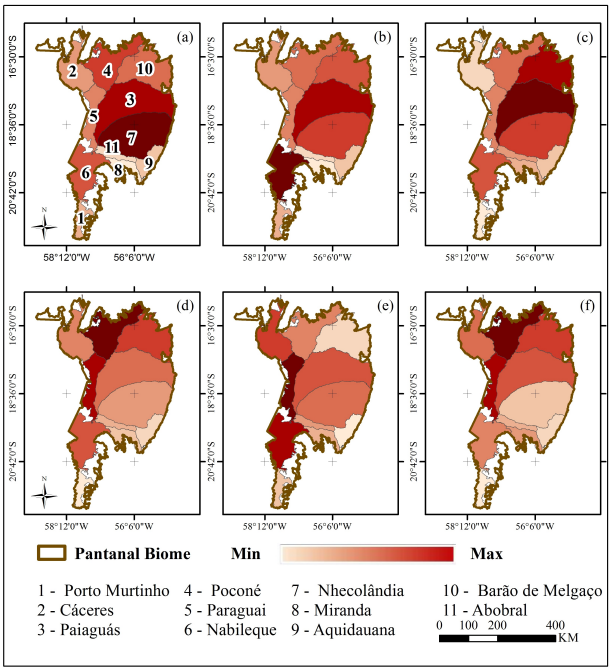

Figure 2. Choropleth maps presenting the total sum of heat spots in each subregion over the time periods.

Analyzing the most recent period, from 2023 to 2024, which, unlike the others, corresponds to only one year of heat 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. This suggests a trend of increasing burned areas for the current period.

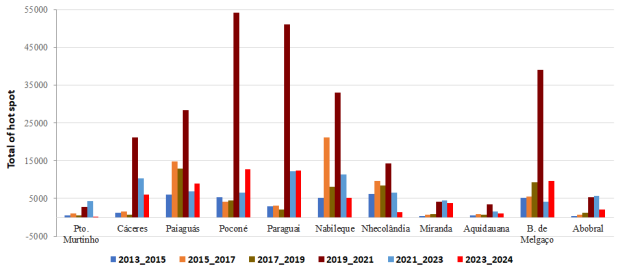

Figure 3. Temporal distribution of the heat spots in the last 10 years.

4. Final remarks

The maps developed in this study enabled the analysis of spatio-temporal variations in the intensity of heat spots occurrence over the past years and compare them with the current scenario. The northwest and southwest regions exhibit a higher recurrence of heat spots, especially for the periods from 2019 to 2021 and the most recent one, from 2023 to 2024. Paiaguás, Poconé, Paraguai, and Barão de Melgaço experienced an increase from 2023 to 2024 compared to the biennium from 2021 to 2023. The most recent period, from 2023 to 2024, despite consisting of only one year of observation, already shows a number of heat spots surpassing the total observed in the initial three periods (2013 to 2019). The research can support public policies aimed at fire mitigation, including the analysis of the results by sub-regions, which allows for understanding the advancement of wildfires in different physiographic contexts.

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