

**MONITORING OF FIRE OUTBREAKS IN THE LEGAL AMAZON REGION OF
MARANHÃO IN THE MUNICIPALITIES OF THE PINDARÉ-MA VALLEY**

**MONITORIZAÇÃO DAS OCORRÊNCIAS DE FOCOS DE INCÊNDIOS DA AMAZÔNIA
LEGAL MARANHENSE NOS MUNICÍPIOS DO VALE DO PINDARÉ-MA**

**MONITOREO DE LOS INCENDIOS FORESTALES EN LA AMAZONIA LEGAL DE
MARANHÃO EN LOS MUNICIPIOS DEL VALLE DEL PINDARÉ-MA**



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ABSTRACT

The Microregion of the Pindaré Valley comprises 22 municipalities and is named after one of the longest and most important rivers in Maranhão, the Pindaré River. This study aimed to analyze the occurrence of wildfires in the municipalities of the Pindaré Valley that are part of the Legal Amazon. The adopted methodology involved collecting information from the Meteorology Database - BDMEP, National Institute for Space Research - INPE, Brazilian Institute of Geography and Statistics - IBGE, Institute of Applied Economics - IPEA, Center for Weather Forecasting and Climate Studies - CPTEC for the period 2018-2022. The BDQueimadas and Environmental Information Bank (BDiA) verified that the municipalities of Santa Luzia, Buriticupu, and Bom Jardim had the highest number of fire outbreaks, due to their phytoecological characteristics and the predominance of Dense Ombrophilous Forest. Meanwhile, the municipalities of Tufilândia and Pindaré Mirim recorded the lowest number of outbreaks, reflecting a region predominantly composed of Open Ombrophilous Forest. It was

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observed that most municipalities engage in agropastoral activities and use fire to clear pastures due to its low cost. The analysis also revealed that the first semester has higher average rainfall and lower temperatures, whereas in the second semester the situation is reversed. Therefore, the variables temperature, rainfall, vegetation cover, and agropastoral activities may significantly influence the increase in fire outbreaks. Implementing environmental control and fire prevention measures is essential for sustainable development and the ecological balance of these communities.

Keywords: Burnings. Analysis. Legal Amazon. Pindaré Valley.

RESUMO

A Microrregião do Vale do Pindaré possui 22 municípios, este nome é dado a um dos mais extensos e importantes rios do Maranhão, o Pindaré. Este estudo teve como objetivo analisar as ocorrências de queimadas nos municípios do Vale do Pindaré que fazem parte da Amazônia Legal. A metodologia adotada, optou-se pela coleta de informações nas bases de dados: Banco de dados de Meteorologia - BDMEP, Instituto Nacional de Pesquisas Espaciais - INPE, Instituto Brasileiro de Geografia Estatística - IBGE, Instituto de Pesquisa Aplicada - IPEA, Centro de Previsão de Tempo e Estudos Climáticos - CPTEC no período de 2018-2022. Verificou-se no BDQueimadas e Banco de Informações Ambientais - BDIA que os municípios Santa Luzia, Buriticupu e Bom Jardim tiveram o maior número de focos de incêndio, devido às características fitoecológicas e a predominância de Floresta Ombrófila Densa. Já os municípios de Tufilândia e Pindaré Mirim apresentaram menores focos, exibindo uma região predominante de Floresta Ombrófila Aberta. Observou-se que a maioria dos municípios possuem atividades agropastoris e utilizam o fogo para limpar os pastos devido ao seu baixo custo. Verificou-se que no primeiro semestre há uma maior precipitação média e temperaturas médias mais baixas e no segundo semestre, isso se inverte. Portanto, as variáveis temperatura, precipitação pluviométrica, cobertura vegetal e atividades agropastoris podem influenciar significativamente no aumento de focos de incêndio. Implementar ações de controle ambiental e prevenção dos focos de incêndio é necessário para o desenvolvimento sustentável e equilíbrio ecológico dessas comunidades.

Palavras-chave: Queimadas. Análise. Amazônia Legal. Vale do Pindaré.

RESUMEN

La Microrregión del Valle del Pindaré está compuesta por 22 municipios y recibe este nombre por uno de los ríos más extensos e importantes de Maranhão, el río Pindaré. Este estudio tuvo como objetivo analizar la ocurrencia de quemas en los municipios del Valle del Pindaré que forman parte de la Amazonia Legal. La metodología adoptada consistió en la recopilación de información en las bases de datos Base de datos meteorológica (BDMEP), Instituto Nacional de Investigaciones Espaciales (INPE), Instituto Brasileño de Geografía y Estadística (IBGE), Instituto de Investigación Aplicada (IPEA), Centro de Predicción del Tiempo y Estudios Climáticos (CPTEC) en el período 2018-2022. Se verificó en la BDQueimadas y en la Base de Datos Ambientales (BDIA) que los municipios de Santa Luzia, Buriticupu y Bom Jardim presentaron el mayor número de focos de incendio, debido a sus características fitoclimáticas y a la predominancia de Bosque Ombrófilo Denso. Por otro lado, los municipios de Tufilândia y Pindaré Mirim registraron los menores focos, exhibiendo una región predominantemente de Bosque Ombrófilo Abierto. Se observó que la mayoría de los municipios desarrollan actividades agropecuarias y utilizan el fuego para limpiar los pastos debido a su bajo costo. Además, se constató que en el primer semestre ocurre una mayor precipitación media y temperaturas más bajas, mientras que en el segundo semestre esta

situación se invierte. Por lo tanto, las variables temperatura, precipitación pluvial, cobertura vegetal y actividades agropecuarias pueden influir significativamente en el aumento de los focos de incendio. Implementar acciones de control ambiental y prevención de incendios es esencial para el desarrollo sostenible y el equilibrio ecológico de estas comunidades.

Palabras clave: Quemas. Análisis. Amazonia Legal. Valle del Pindaré.

1 INTRODUCTION

One of the biggest challenges in our country is related to the population growth resulting from the accelerated process of urbanization of cities and ends up also affecting the populations of rural areas, because according to data from the Brazilian Agricultural Research Corporation - Embrapa, the areas considered urban in Brazil represent less than 1% of the national territory and concentrate 160 million people, that is, 84.3% of the Brazilian population (Faria *et al.*, 2017). This population growth, which has occurred in the last forty years, has produced significant impacts on the population and especially on the environment, reducing the quality of life and degrading natural resources.

With the population growth, several agricultural areas are being exploited for the cultivation of food products and, consequently, they are deforested and some use burning to remove the material from the site. Some fires are controlled and others are done anyway. In addition, other natural factors also cause fires due to the dry climate, and accidental ones that are caused by the population itself that disposes of waste in these environments, such as: glass, cigarette butts or flammable materials that cause fires in these places.

According to INPE (2024), in 2024, Maranhão was the 6th Brazilian state with the highest number of fire outbreaks, and in 2023 it occupied the 2nd place, due to the prolonged drought, dry grass becomes a good fuel for forest fires. The flames reach up to four meters high and advance quickly, bringing destruction to the fauna, flora and inhabitants of these places who suffer from the smoke that enters their homes, causing respiratory problems.

Vale do Pindaré has 22 municipalities with 666,083 inhabitants in an area of 36,000.996 km², and a population density of 18.6 inhabitants/km² (IBGE, 2023). The municipalities, due to their agricultural and extractive potential, suffer from land grabbing, illegal extraction of materials in these areas, expansion of agricultural and pastoral areas, invasion of Indigenous Lands (TIs) and Environmental Preservation Areas (APAs), and consequently deforestation and fires arise in these places.

In view of the facts reported about the incidence of fire outbreaks in these locations, this study aimed to analyze and evaluate the occurrences of fires in the municipalities of the Pindaré Valley that are part of the Maranhão Legal Amazon in the periods from 2018 to 2022. In addition, a survey of the occurrences of fires was carried out using the databases of INPE, IPEA, IBGE, Portal da Amazônia, BDMEP, CPTEC in the last five years. Soon after, the physical variables related to the danger of forest fires were characterized. For this, georeferencing and location tools were used, such as *Google Maps*⁸, *Ambiental Geo*⁹ and

⁸ www.google.com/maps

⁹ <https://geosgb.sgb.gov.br/>

*Forest-gis*¹⁰, to identify areas prone to fire outbreaks. Then, an evaluation and comparison of the data from the hazard maps provided by the institutional bodies was carried out.

2 THEORETICAL FRAMEWORK

Man's relationship with fire went through three distinct stages: production by man, maintenance through the use of fires, and the use of resins, so that it would not go out so easily when the lit torches were carried. Israeli archaeologists have discovered the oldest evidence of a bonfire produced 790 thousand years ago, on the banks of the Jordan River, between Israel and Jordan (FIO CRUZ, 2023). This resource has several uses such as food preparation, production of any material for industries, space heating and also in agriculture. After that, fire was necessary even in the agricultural sector, because at no cost, it would be efficient and affordable. However, the indiscriminate use and intensity of fires to open areas for agriculture has become a serious environmental problem.

Biomes, especially those most fragile in their physical, chemical and biological aspects, in recent decades have suffered from anthropic actions, which associated with natural causes, have been causing serious risks to the maintenance of the balance of the environment. Inherent to these factors, we can highlight forest fires, whose action impacts environmental systems, causing damage to the sustainability of the environment.

Forest fire is the occurrence of fire in any vegetative form without control and can be caused by several ways, both natural and also by anthropic actions. These actions can be of a criminal, accidental or unexpected nature. The main causes related are: climatic variables, combustible material characteristic of the area, relief, lightning strikes or excessive heat; arsonists; agricultural or forestry burning; hunters, fishermen and tourists; opening of roads; among others (INBRAEP, 2023). Thus, concerns regarding prevention arise, especially for those who work in front of commercial plantation projects using controlled burning and in conservation units (Nogueira *et al.*, 2002).

Controlled burning is the scientific application of fire in fuels, both in its natural state and altered under certain conditions, in such a way that it is confined to a predetermined area and produces the intensity of heat and the rate of propagation to favor certain management objectives, that is, controlled burning is the use of fire in a planned way to achieve a certain objective such as, for example: clearing a pasture; reduction of combustible material; improvement of habitat for fauna; control of undesirable species and reduction of the risk of fire propagation (INBRAEP, 2023).

On the other hand, the intervention in firefighting is divided into six steps, according to

¹⁰ <https://forest-gis.com/>

Tetto, Soares and Batista (2001) (apud Silva, 2021, p. 5):

1. Detection: time elapsed between the ignition or start of the fire and the moment it is seen by someone;
2. Communication: time between the detection of the fire and the receipt of information by the person responsible for the combat action;
3. Mobilization: time spent between receiving information about the existence of the fire and leaving the personnel for combat;
4. Displacement: time between the departure of the combat personnel and the arrival of the first group at the scene of the fire;
5. Planning for combat: Time spent by the person responsible for the combat to evaluate the behavior of the fire and plan the combat strategy;
6. Firefighting: time consumed in the operation of fighting or definitively eliminating the fire, including the aftermath.

Following the steps for a good intervention in fighting fires in forest areas, it would have much less damage to the environment. In Maranhão, it was observed that the territorial extension of the Maranhão Legal Amazon increased in 2021, and included several municipalities in Maranhão, totaling an area of 5,015,067.86 km², corresponding to about 58.93% of the Brazilian territory, and 56% of the Brazilian indigenous population resides in it (IBGE, 2021).

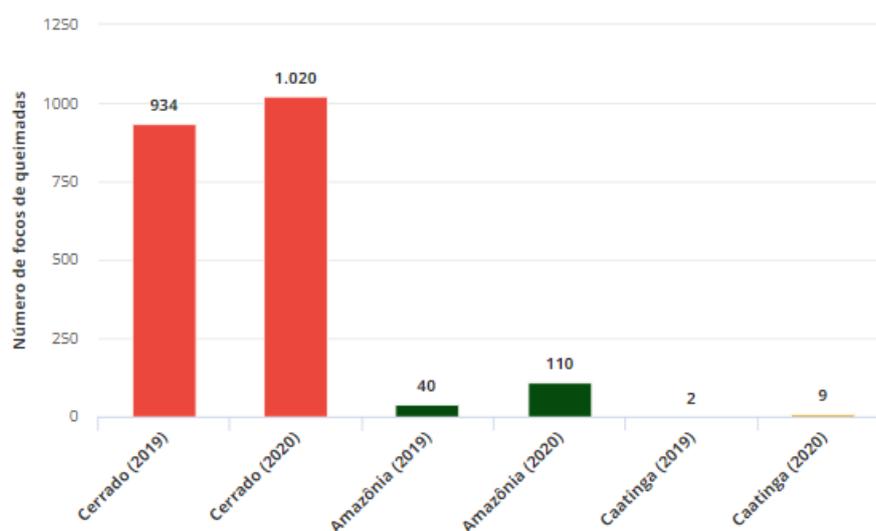
The concept of the Legal Amazon was instituted in 1953 and its territorial limits derive from the need to plan the economic development of the region and, therefore, are not limited to the humid jungle ecosystem, which occupies 49% of the national territory and also extends over the territory of eight neighboring countries. The boundaries of the Legal Amazon have been altered several times as a result of changes in the country's political division, and the Sustainable Amazon Plan (PAS) was launched by the federal government, which fully considers the State of Maranhão as part of the Brazilian Amazon (IPEA, 2008). But according to the census carried out by the IBGE in 2021, Maranhão is the state with the largest number of municipalities belonging to the Legal Amazon with 181 of the 217, that is, 79.3% of its territory (IBGE, 2021).

With the increase in the extension of the Legal Amazon in Maranhão, public agencies must intensify the provision of projects to reduce the environmental impacts in these areas. Because most of these areas have natural resources in abundance, and the mismanagement of these resources can bring several damages to the environment, such as deforestation, invasion of indigenous and quilombola areas, advance of agriculture and fires.

In 2020, the region most affected by fires was the south of Maranhão, where the agricultural sector predominates. But it is clear that other municipalities that make up the legal Amazon of Maranhão also suffer from forest fires, there was an increase from 40 outbreaks in 2019 to 110 outbreaks in 2020 (INPE, 2023), in addition to natural factors, anthropic actions also favor this increase, such as: the expansion of farming, livestock, real estate, further aggravating the environment (Figure 1).

Figure 1

Fire outbreaks between March 20 and July 1, 2020



Source: INPE, 2023.

To prevent and combat fire outbreaks in these areas, technologies can represent an advance in reducing these incidents. And also the information by teams trained in passing on to small, medium and large farmers the good ways to do controlled burning, because many of these farmers do not know the technique and end up causing large fires.

Assis and his collaborators (2014) presented in their article that geotechnologies are an important resource in assisting in the detection of fires, locating the foci and quantifying and analyzing the areas where fires occur. Therefore, with the great advancement of science in technology, especially in aerospace knowledge and georeferencing. Meanwhile, Tomzhinski, Coura and Couto (2011), portrays several ways that these technologies can be exploited to detect these fire outbreaks, such as terrestrial surveillance, observation post or satellite image monitoring.

When fires are provoked, they generate impacts on the environment and provide penalties to offenders. The Environmental Crimes Law, Law No. 9,605, of February 12, 1998, establishes penalties for damages caused by forest fires (Brasil, 1998), states that:

Article 41 – Causing a fire in a forest or forest: Penalty – imprisonment, from two to four years, and a fine. Sole Paragraph. If the crime is culpable, the penalty is imprisonment from six months to one year, and a fine.

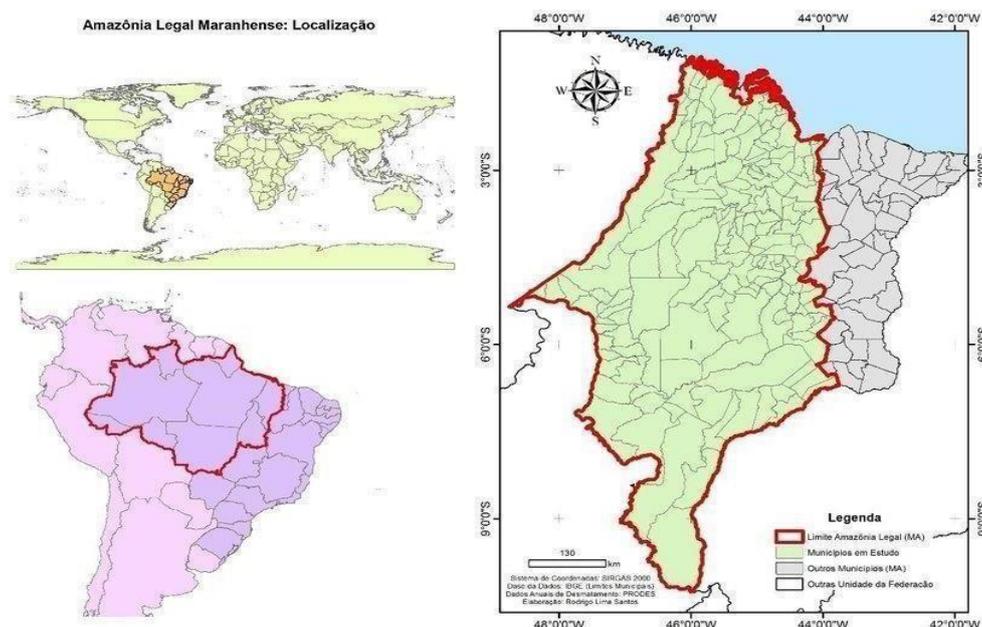
In addition to the Environmental Crimes Law, the Brazilian penal code also determines in article 250 "that causing fire, exposing the life, physical integrity or property of others to danger is considered a crime of common danger, with a penalty - imprisonment, from 03 to 06 years, and a fine. In item II of paragraph 1, it requires an increase in the penalty by one third if the fire is in a crop, pasture, forest or forest" (Brasil, 1940).

3 METHODOLOGY

The study area is the Microregion of Vale do Pindaré, which is part of the Legal Amazon of Maranhão. In 2017, as shown in Figure 2, there were 170 cities, and currently 11 more have been incorporated, totaling 181 municipalities that are part of this region (IBGE, 2023). The Pindaré Planning Region is one of the 32 administrative regions of the State of Maranhão, Brazil, being the largest in number of municipalities and one of the largest in territorial extension. Despite this, it is the twentieth most densely populated and takes its name from one of the most extensive and important rivers in Maranhão, the Pindaré (SEPLAN, 2008).

Figure 2

Location Map of the Legal Amazon of Maranhão, with emphasis on its 170 municipalities



Source: Santos; Nunes, 2017.

Initially, a descriptive search was carried out in the main databases on fires in the Brazilian Legal Amazon with a focus on the Maranhão region based on bibliographic fearology found in books, articles, monographs, dissertations, theses and journals in the databases of Capes Journals, *Scielo*, *Google Scholar*, *Web of Science*. And in the specific magazines, the following terms were used: "burning", "fire", "legal Amazon", "Maranhão biomes", "deforestation". However, the following exclusion criteria were established: publications from annals of events, conferences, duplicate studies and that do not adequately relate to the objective of the study in relation to its contribution.

To evaluate and analyze the fire outbreaks in the region, a qualitative and quantitative exploratory research was carried out based on the Meteorological Database of Education and Research, National Institute of Meteorology (INMET), Fire Database of the Post of Weather Forecasts and Climate Studies, National Institute of Space Research, Brazilian Institute of Statistical Geography of Brazil, Institute for Applied Economic Research and in the Amazon Portal, in the form of a *shapefile* (common vector file format used by Geographic Information Systems - GIS, containing geospatial data) in the period from 2018 to 2022, the number of fire outbreaks, month of occurrence, annual distribution of fires, causes of occurrences were analyzed. The physical variables of forest fire danger in the Pindaré Valley region were collected: Land use and vegetation cover using images from the ResourceSat satellite, "LIS3" sensor, Polar Heliosynchronous orbit; Rainfall, Temperature. For the analysis of the data on hot spots, satellite images provided by the INPE website were studied.

The collected data were evaluated through descriptive statistical analysis in a spreadsheet of the Microsoft Office program EXCEL 2013, and the procedure of interpretation of the information began.

4 RESULTS AND DISCUSSIONS

According to the Humanitas Unisinos Institute (2023), ¹¹in Maranhão, there was an increase of almost 22% from 2021 to 2022, with more than 3 thousand outbreaks reported last year. During the month of December alone, 617 fire outbreaks were recorded.

From the analysis of the results collected in INPE's Fire Database (2023), it was found that among the Municipalities of the Pindaré Valley that are part of the Legal Amazon: Santa Luzia, Buriticupu and Bom Jardim had the highest numbers of fire outbreaks between the years 2018 and 2022. As shown in Table 1.

¹¹ <https://ihu.unisinos.br/categorias/>

Table 1

Annual fire outbreaks in the Municipalities of the Pindaré Valley that are part of the legal Amazon of Maranhão

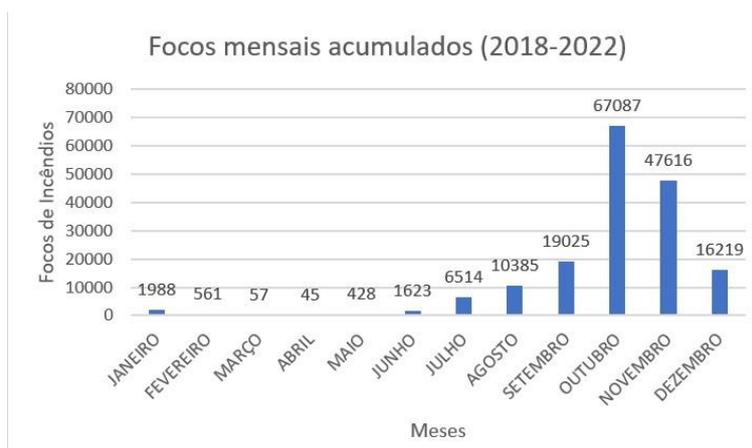
Municipalities	2018	2019	2020	2021	2022
Altamira do Maranhão	399	725	693	239	531
Alto Alegre do Pindaré	884	2008	1738	1326	1953
Bom Jardim	2070	5305	5614	3876	6849
Bom Jesus das Selvas	1650	3583	3027	1914	4501
Sand Swamp	750	1881	925	1169	1683
Buriticupu	2956	4247	4344	6548	6039
Governor Newton Bello	372	754	1008	400	606
Lagoa Grande do Maranhão	1085	1417	371	1389	2121
Stone Lake	1205	2025	1428	1500	1774
Maharaja of the Seine	1872	3451	1950	2457	4249
Nova Olinda do Maranhão	230	561	1617	396	609
Pindaré-Mirim	64	164	260	121	215
President Médici	222	600	414	321	387
Saint Agnes	234	410	718	316	324
Santa Luzia	3945	6648	4101	5011	7634
Santa Luzia do Paruá	287	723	483	234	445
São João do Carú	347	727	711	304	512
Tufilândia	121	157	240	128	148
Vitorino Freire	303	1138	862	503	911
Zé Doca	434	1748	2302	1136	2064

Source: INPE, 2023.

The city of Santa Luzia leads the ranking with a total of 27,339 fire outbreaks, Buriticupu with 24,134 and Bom Jardim with 23,714. The three municipalities together correspond to 43.82% of the outbreaks of all 22 municipalities that are part of the legal Amazon in the Pindaré Valley, with a total of 171,548 fire outbreaks in the five-year period (2018-2022). The average number of fires per km² was calculated and it was observed that the municipality of Buriticupu had the highest average value, with 9.48 fires/km², Santa Luzia with 5.65 fires/km² and Bom Jardim with 3.60 fires/km². In addition, it was noted that the incidence of hot spots increases considerably from the month of July, peaking in October, as shown in Figure 3.

Figure 3

Monthly fires accumulated in the period 2018-2022



Source: INPE, 2023.

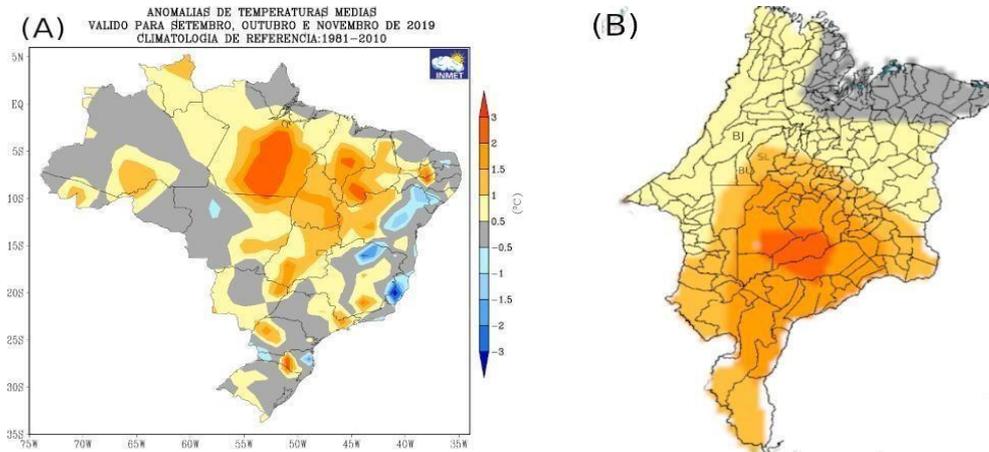
According to the Action Plan for the Prevention and Control of Deforestation and Fires in the State of Maranhão - PPCD/MA (2011), in the Maranhão Legal Amazon, deforestation is linked to illicit activities and/or unsustainable practices from primary economic sectors (livestock, agriculture, plant extractivism and mining) and secondary economic sectors (steel, timber, civil construction and others).

As shown in Figure 4, the monthly maps of mean temperature anomalies from the INMET Temperature Monitoring database were analyzed. It was noticed that during these five years, the average temperature is considerably higher in the second semester (in the months of August to December) in all municipalities of the Pindaré Valley. The climate of the region, according to the Köppen classification (Köppen; Geiger, 1928), is of the Af type (humid tropical) with a rainy summer and dry winter, with an average rainfall of at least 60 mm in each month. Average annual temperatures are above 22 °C and the average for the coldest month is above 18 °C.

According to the studies by Corrêa et al. (2023) on the Köppen classification, they updated the climate classification and climatological water balance in the State of Maranhão, where the Tropical Climate obtained the following characteristics: Megathermal climates, average annual temperature in the coldest month, with 18 °C; Absent winter season, with higher annual precipitation and evapotranspiration in the tropical climate. In code "f" with humid climate, precipitation occurs in all months of the year, inexistence of a defined dry season and precipitation in the driest month with more than 60 mm and rainfall in autumn and winter, with dry summer.

Figure 4

(A) Average temperature anomalies for the months of September, October and November 2019 in Brazil. (B) Cut of Maranhão with overlapping of the municipal grid of Maranhão (approximate)

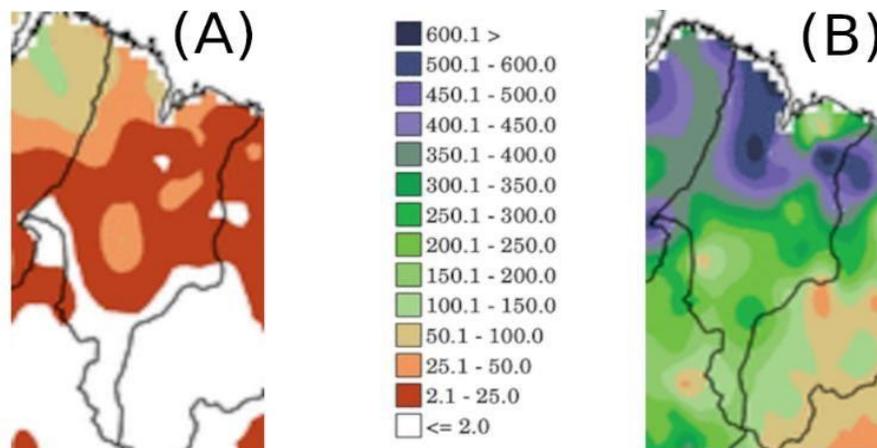


Source: INMET, 2024.

Therefore, the second half of the year is warmer and is characterized by little rain and strong winds that contribute to fire outbreaks turning into fires and burnings. It was also observed that the dry grass and the amount of winds that occur during this period, the flames can reach up to four meters in height and advance quickly, bringing destruction to the biome of this place. The population is more vulnerable to fires due to the increase in respiratory problems that increase in the same period. The data analyzed from CPTEC (2024) on the rainfall maps in Brazil, it was noticed that the months of December to May have on average considerably higher rainfall when compared to the other six months of the year from June to November, and this pattern is repeated during the five years analyzed. As shown in Figure 5.

Figure 5

(A) Rainfall in August/2022, (B) Rainfall in March/2022

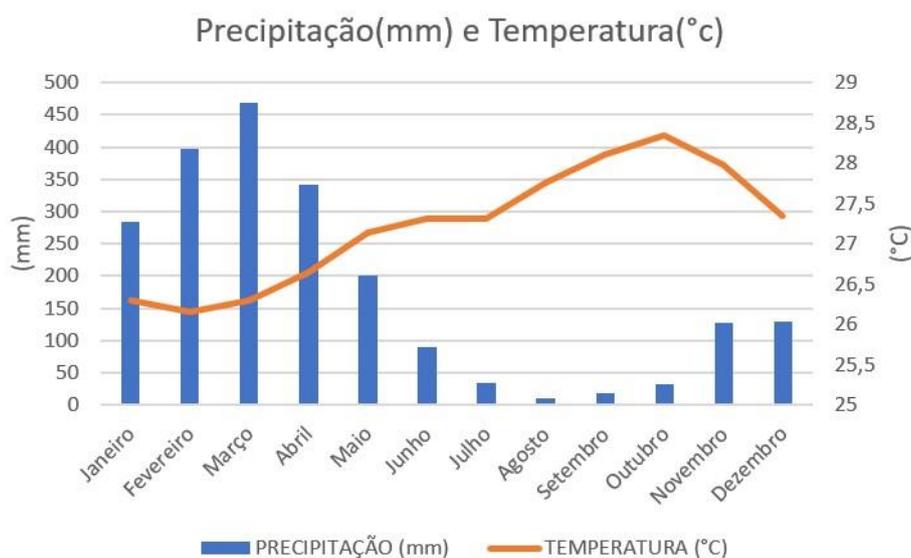


Source: CPTEC, 2024.

The months with the highest rainfall, mentioned above, are also the months with low temperature and low numbers of fire outbreaks, in addition, it was observed that the month of March concentrates the highest average rainfall and October the highest average temperature. It can be corroborated by the collection of climatological data from the only conventional station in the Pindaré Valley, station ZE DOCA - World Meteorological Organization Code - WMO:82376 (INMET, 2024) as shown in Figure 6.

Figure 6

Rainfall and average monthly temperatures in the period 2018-2022



Source: INMET, 2024.

In addition, it is important to highlight that Silva et al. (2016) analyzed in their work:

Regarding temperature, the behavior is homogeneous, that is, all stations recorded the upward trend, in an intense and statistically significant way. Regarding precipitation, the Zé Doca station in the Amazon biome and the Carolina station in the Cerrado biome showed downward trends in precipitation in the dry season.

The dry period in the Amazon region and in the adjacent Cerrado region is usually related to El Niño events and/or warmer than normal sea surface temperatures in the Tropical North Atlantic. These ocean temperature increases favor the occurrence of anomalous regional water deficits, warmer temperatures, and intense fire seasons. This was the case of the exceptional droughts in the Amazon in 2005, 2010, 2015, 2016 (Aragão *et al.*, 2007) and in the Pantanal 2019–2020 (Jimeinez *et al.*, 2021).

According to Marengo *et al.* (2022), the long-term trends of air temperature and evaporation variables show that dry conditions have intensified during the last two decades,

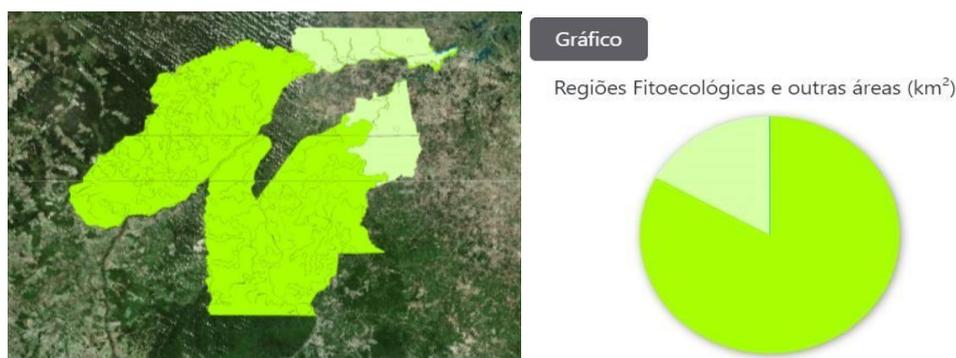
suggesting increased water stress in vegetation. The dry and dry-wet seasons in the eastern Maranhão Amazon are becoming increasingly longer, hotter, and drier.

Since 1992, the IBGE has estimated the extent of vegetation types in Brazil, classified into phytocological regions and vegetation areas. Then, the type of vegetation present in the Pindaré Valley was verified in the Environmental Database and Information of this agency. Phytocological regions are defined by a floristic of typical genera and characteristic biological forms that are repeated within the same climate, and may occur in terrains of varied lithology, but with well-marked relief.

The municipalities with the highest number of fire outbreaks were Santa Luzia, Buriticupu and Bom Jardim, and these are mostly composed of Dense Ombrophilous Forest of moss green and part of light green (Figure 7).

Figure 7

Phytocological regions in the municipalities with the highest number of fire outbreaks: Santa Luzia, Buriticupu and Bom Jardim



Source: IBGE, 2023.

The phytocological region is basically composed of macro and mesophanerophytes, as well as lianas and epiphytes, characterized by a thermal shoulder climate, with practically no biologically dry period, with rainfall above 2,300 mm and average annual temperatures between 22 °C and 25° C in the north of the country (IBGE, 2023). This type of dense and closed forest provides a milder microclimate, and the fuels have a higher and more stable content than a forest with little vegetation and open.

When fires occur in these forests, some conditions prevent the detection of fires, such as fire only on the ground in this type of dense vegetation, without affecting the tree canopy. However, these characteristics do not favor the high number of outbreaks presented by the municipalities, possibly other factors may be related to the increase in the number of fire outbreaks, such as logging, agricultural and real estate activities that occur in these regions.

On the other hand, the municipalities with the lowest fire outbreaks, Tufilândia and Pindaré Mirim, are mostly made up of open ombrophilous forest (Figure 8) of light green color and a much smaller part of dense ombrophilous forest of moss green color and some rivers present in this region, especially the Pindaré River.

Figure 8

Phytoecological regions in the municipalities with the lowest number of fire outbreaks: Tufilândia and Pindaré Mirim



Source: IBGE, 2023.

The phytoecological region located in the ombrophilous climate range, however, presenting a short dry period, of two to three months, and dominance of biological forms of rosulate phanerophytes and woody lianas (IBGE, 2023). These characteristics of the type of forest and vegetation areas are more favorable to the increase of fire outbreaks in the region, but in practice they are not observed. However, these two municipalities also have a significant part of the water body, which is a possible variable that favors the low number of fire outbreaks, compared to the other municipalities in Maranhão.

In addition, agropastoral activities may have contributed to the high numbers of fire outbreaks, in 2020, data from Municipal Livestock show a growth in the main herds in these 5 municipalities: Santa Luzia, Buriticupu, Bom Jardim, Tufilândia and Pindaré Mirim (IBGE, 2023). As shown in Table 2.

It was observed that the municipalities of Bom Jardim, Buriticupu and Santa Luzia, which have the highest number of fire outbreaks, have as their main herd the raising of cattle, animals that need pastures to be fed. Considering that "In agriculture, fire is used to clean and regrow pastures and combat pests and diseases" (Manual for the Prevention and Control of Fires in the State of Maranhão, 2020). Therefore, the creation of this type of herd can have a direct or indirect influence on the high number of fire outbreaks in these municipalities, due to the possible type of cleaning that is carried out in a pasture, usually using fire, due to its low cost.

Table 2*Herd Number*

Municipalities	Variable - Effect of herds (head) in 2020								
	Herd Type								
	Beef	Buffalo	Equine	Total pig	Swine - swine breeders	Goat	Sheep	Chickens - total	Chickens - chickens
BomJardim	159123	821	2567	2527	790	3321	2455	23578	6550
Buriticupu	143789	118	998	2600	788	1200	1087	32457	8500
Pindaré Mirim	14586	-	439	631	201	237	409	740031	1550
Santa Luzia	249087	121	3345	2412	654	2786	3022	32456	12367
Tufilândia	17240	-	274	589	146	377	237	3786	800

Source: Adapted from IBGE data - Municipal Livestock Survey, 2023.

In addition, in Maranhão it is still quite common to use burning in the preparation of the land for small plantations that contribute to the increase of particulate matter released into the atmosphere. The effects of this particulate emitted by fires on human health mainly affect the elderly and children. However, it is clear that the dry season favors the increase in fire outbreaks in the state. The second half of the year corresponds to the dry season in Maranhão, with negative impacts such as devastation of existing flora, extinction of animals, respiratory complications in the health of residents, toxic gases that can increase the temperature of the greenhouse effect.

According to Marengo *et al.* (2022) studied the consequences of agricultural expansion in the Eastern Amazon-Cerrado transition zone and evidenced the increase in temperature, vapor pressure deficit, subsidence, frequency of dry days, and decrease in precipitation, humidity, and evaporation, in addition to a delay in the onset of the rainy season, inducing a greater risk of fire during the dry-to-rainy transition season.

Bezerra *et al.* (2018, p. 6) highlight that,

The main socio-environmental impacts arising from prolonged drought events in Maranhão can be summarized as difficulty in accessing water, losses in agricultural activities, loss of material goods, risk to human life and potential damage to biodiversity in Maranhão's biomes and ecosystems (due to the action of fires).

An impact of drought events that deserves to be highlighted in the territory of Maranhão are fires, since these can be modulated by events of droughts and/or prolonged droughts in Maranhão, as well as a consequence of anthropogenic forms of land use and cover (IMESC, 2017).

According to Zalles *et al.* (2021) portrays that "humans have markedly altered environments through the conversion of natural vegetation pastures, crops, and other land

uses, as well as the degradation of natural vegetation through logging, fire, and other types of disturbance."

Thus, it is perceived that "forest fires are one of the most degrading forms of tropical forests due to the predominance of agropastoral activities, where they still use fire to clean these areas, causing an increase in flammability in these places for the practice of intensive logging, fragmentation and climate change" (Barlow *et al.*, 2012).

Therefore, prevention actions are needed together with public agencies and the population in order to minimize and combat fire outbreaks in the Pindaré Microregion.

5 CONCLUSION

According to the survey carried out in the databases of INPE, INMET and IBGE, it was observed that the municipalities that are part of the Maranhão Legal Amazon belonging to the Pindaré Microregion, the cities of Bom Jardim, Buriticupu and Santa Luzia stand out with the highest number of fire outbreaks and Tufilândia and Pindaré Mirim with the lowest numbers.

From the data collected on the increase in fire outbreaks in the municipalities of the Pindaré Valley, some factors were listed that may supposedly be related: logging, farming, real estate activities, and perhaps the lack of training and misinformation of farmers when they use burning to clean these places.

Other important factors that can significantly influence the number of fire outbreaks are the variables: average temperature (in the hottest and driest period in the region), rainfall (scarcity of rainfall) and phytoecological regions (types of vegetation cover). It was found mainly in regions that predominate the Dense Ombrophilous Forest tend to have greater fire outbreaks.

The increases in the number of fire outbreaks can bring environmental damage to the flora, fauna and population that reside in these locations. With the increase in respiratory problems caused by the smoke that mainly affects the elderly and children. Promote actions and/or recommendations for the prevention and combat of fires and try to sensitize the authorities and the population about the importance of preserving the environment.

In addition, the promotion of specific awareness campaigns for local communities on safe practices and fire prevention could reduce the number of fires in these locations. Promote sustainable agricultural practices that reduce reliance on fires, such as using cultivation techniques that do not involve burning vegetation. And also establish and maintain firefighting bases in strategic areas, especially in the municipalities with the largest fire outbreaks Santa Luzia, Bom Jardim and Buriticupu.

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