The effects of forest fires on hospital admissions for respiratory diseases

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Abstract

Objectives

To analyze the effect of spatially exposure to fire risk on the occurrence of respiratory diseases in the municipalities of the State of Mato Grosso do Sul (MS), Brazil.

Methods

This was an ecological study of spatial prevalence of hospitalization for respiratory diseases and fire risk using Monte Alegre index. This methodology reduces the risk as precipitation occurs, where the volume of rain (in mm) is considered as danger lane changer. The empirical Bayesian method and a multiple regression spatial response variable were used to model the prevalence of hospitalization for respiratory diseases, and the exposure variable fire hazard. For calibration, the proxies of fire outbreaks and surface ozone concentration, precipitation and humidity were used.

Results

We observed statistically significant associations between the prevalence of hospitalization for respiratory diseases and the risk of fire.

Conclusions

fire risks triggering fires are highly related to the prevalence of hospitalizations for respiratory diseases in vulnerable sub populations in the municipalities of the State of Mato Grosso.

1. Introduction

Few studies have been carried out to evaluate the effects produced by burning biomass (any material of plant or animal origin used as an energy source). In 1985, a bulletin from the World Health Organization (WHO) questioned the severity and extent of the damage caused by air pollution as a result of combustion of biomass in rural areas of developing countries (Koning et al., 1985).

Biomass incineration is the largest domestic source of energy in developing countries, approximately half of the planet's population, and more than 90% of households in rural developing countries remain using energy from burning biomass, in the form of wood, coal, animal manure or agricultural waste, which produces high levels of air pollution.

Despite the great technological advances, the deliberate or accidental burning of vegetation is often uncontrolled, reaching large expanses of forests, savannas or other less dense vegetation. Fire is a

growing problem due to the remains of burned forests and savannahs, and pollutions resulting from smoke, and has a substantial impact on the health of the exposed populations. This impact includes increased mortality, hospital admissions, emergency visits and medication use, due to respiratory and cardiovascular diseases, in addition to decreased lung function (Bruce et al., 2000).

In Mato Grosso do Sul (MS), the main causes of fires are: lightning, agricultural burninig of cultivated fields before sowing new crop, forest operations, rural fires, smokers and arsonists.Unscheduled and uncontrolled fires have different consequences at different scales, however do not influence meteorological systems (Caúla et al., 2015) and the phases of El Niño-Oscilação Sul (ENOS) - (Oliveira-Júnior et al., 2020), ranging from risk to populations to environmental degradation,, contributing to air pollution and worsening air quality. However, the extent and intensity of the fires are related to several factors, including the type, quantity and state of the combustible vegetation.

Children in Brazil are affected annually by smoke from forest fires, many of them in the Midwest and North with the burning of the Pantanal and the Amazon rainforest. The increase in forest fires in recent years suggests that this at-risk population has only grown. In parts of Brazil, up to 20% of the fine particulate material (PM) (2.5 and 10μm) to which children are exposed results from forest fires. Due to the warming of our climate, exposure to smoke from forest fires is likely to increase and to expose more children to smoke from forest fires as the century progresses (Mills et al., 2018).

Smoke from fire can cause a range of health problems in adults. According to a systematic review from 2015 on the effects of forest fire smoke on the general population, most of the epidemiological research has focused on different respiratory outcomes, some on mortality asa well as other outcomes (Liu et al, 2015). Hospitalizations and emergency visits for respiratory diseases increased consistently with exposure to fire smoke in adults, although estimates of the effect size vary both in how they are reported and in their magnitude (Shusterman et al, 1993; Liuetal, 2015 ; Alman et al, 2016; Black et al, 20170. There have been mixed results for cardiovascular outcomes (Black et al, 2017, Cascio, 2018). All-cause mortality is also associated with exposure to fire smoke in adults (Cascio, 2018). Doubleday, et al, 2020 tested the association between exposure to forest fire smoke and mortality in the western United States. The probability of mortality at all ages with exposure on the same day was 1.0% (95% CI: − 1.0–4.0%) higher on days of fire smoke compared to days of smoke without fire, and the previous day's exposure was associated with a 2.0% increase (95% CI: 0.0–5.0%). When stratified because of mortality, the chances of respiratory mortality on the same day increased by 9.0% (95% CI: 0.0–18.0%), while the chances of mortality from COPD on the same day increased by 14, 0% (95% CI: 2.0–26.0%). In subgroup analyzes, they observed a 35.0% increase (95% CI: 9.0–67.0%) in the chances of respiratory mortality on the same day for adults aged 45–64.

In a problematic way, few studies have intentionally focused on pediatric populations as a target population or subpopulation (Liu et al, 2015). Children are an especially vulnerable population because they are more exposed. Children tend to spend more time outdoors, breathe more air in relation to their body weight and are still growing and developing. They also have less nasal particle deposition, which

means that a larger proportion of particles can penetrate deep into the lungs (Bennett et al, 2007). In addition, adverse effects on childhood developing lungs have been shown to have lifelong health effects (Miller and Marty, 2010).

The selection of MS for this study is due to its geographical location. Its borders are the states of Goiás, Minas Gerais, Mato Grosso (), Paraná () and São Paulo (to the northeast, east, north, south and southeast, respectively), as well as the countries of Bolivia and Paraguay, to the west and southwest, respectively. It has an area of 358,124,962 km², with a population of approximately 2,360,498 inhabitants, with 79 municipalities and predominance in primary activities according to the population estimates of the IBGE for the year 2009, The state of MS has one of the largest cattle herds in the country, and its economy is based on rural production (animal, plant extraction and rural industry), industry, mineral extraction, tourism and service provision.

This study aims to analyze the joint spatial distribution of an air pollution indicator and the prevalence of hospitalizations for respiratory diseases in sensitive population groups in the different municipalities comprising the state of MS.

2. Methodology

2.1 Study area

The State of MS is located between latitudes 17º13´40” and 19º27´47” S; and longitudes of 50º56´06” and 53º42´18” W. Figure 1 presents the spatial distribution of the meteorological stations used in this study.

2.2 Hospitalization Data

In is a spatio-temporal and ecological study, the trend of the respiratory disease coefficient for the State of MS was analysed. Data on hospital admissions for respiratory causes (Chapter X - Diseases of the respiratory system comprising categories J00 to J99 of the International Classification of Diseases - ICD 10) by municipality residency were obtained from the computerized databases of the Ministry of Health via Hospitalization Authorizations (AIH) of the Unified Health System (SUS) for the years 2015–2020 (DATASUS).

The hospital incidence coefficient is defined by Eq. (1):

$$C = \left(\frac{I}{POP}\right) \times 100 \qquad (1)$$

Where, *I* represents the number of ambulatory admissions in a municipality in a given season, and *POP* stands for the population of this municipality on the date corresponding to the season (Laurenti et al., 1985).

2.3 Fire Risk Index

The Monte Alegre Formula (FMA) considers the risk of forest fire based on two meteorological variables: relative humidity (%) of 13 hours and daily rain (in mm). FMA is cumulative, that is, the longer the sequence of days with low relative humidity and without rain, the greater the fire risk (Soares, 1972). It is worth mentioning that there is a relationship between FMA and the intensity of the rainfall, as shown in Table 1 (Antunes, 2000). FMA risk is based on Table 2 (Antunes, 2000).

The FMA is describes by Eq. (2):

$$FMA = \sum_{i=1}^{n}\left(\frac{100}{H_i}\right) \quad (2)$$

where FMA is the Monte Alegre Formula (daily Forest fire danger index), H is therelative air humidity (%)at 1 PM and n is the number of *i* days without rain.

Table 1
Monte Alegre index in relation to daily rainfall

Daily rain (in mm)	Modification in Calculation
≤ 2,4	No
2,5 a 4,9	Cull 30% in the FMA calculated the day before and add ($^{100}/H$) of the day.
5,0 a 9,9	Cull 60% in the FMA calculated the day before and add ($^{100}/H$) of the day.
10,0 a 12,9	Cull 80% in the FMA calculated the day before and add ($^{100}/H$) of the day.
≥ 12,9	Stop the calculation (FMA = 0) and restart the sum the next day.
Source: Antunes, 2000	

Table 2
Fire risk scale

FMA VALUE	DEGREE OF DANGER
≤ 1,0	Too small
1,1 a 3,0	Small
3,1 a 8,0	Average
8,1 a 20,0	High
≥ 20	Very high
Source: Antunes, 2000	

The relative humidity daily rain data were collected from the Climate and Hydrology Monitoring Center of the State of Mato Grosso do Sul-CEMTEC, and were used to produce maps of the observed and estimated respiratory disease distributions and residual errors. Likewise, a map illustrating the spatial distribution of the fire risk was constructed.

The respiratory diseases used in the analysis were extracted from the SUS Hospital Information System (DATASUS) for the period from January 1, 2015 to December 31, 2020. The total number of hospitalizations for respiratory diseases was 148,849. From the diseases catalog of the International Coding of Diseases (ICD 9th and 10th revisions) as in the Diseases of the respiratory system (460–496 and J00-J99 respectively), it was found that the highest daily averages of hospitalizations were due to influenza (flu) and pneumonia (480–487 and J10-J18) representing 52.3% of total hospitalizations. The second most popular respiratory diseases were chronic lower airway diseases, such as chronic bronchitis, simple and mucous-purulent bronchitis, emphysema, asthma, asthmatic disease and bronchectasis (490–496 and J40-J47), with 19.3%. Thirdly, with 11.3% and an average of 5.2 daily hospitalizations were the other diseases of the upper airways (470–478 and J30-J39), such as allergic and vasomotor rhinitis, rhinitis, chronic nasopharyngitis and pharyngitis, chronic sinusitis, nasal polyp, other disorders of the nose and paranasal sinuses, chronic diseases of the tonsils and adenoids, chronic laryngitis and laryngotracheitis. Other acute infections of the lower airways (466 and J20-J22), such as acute bronchitis and bronchitis, had a daily average of 2.8 hospitalizations and represented 6% of the total hospitalizations. Finally, acute infections of the upper airways (460–465 and J00-J06) represented 4.3% of total hospitalizations, with an average of 2.0 daily hospitalizations. Among these diseases are the acute nasopharyngitis (common cold), sinusitis, pharyngitis, tonsillitis, laryngitis, obstructive laryngitis, epiglottitis and tracheitis. Other diseases of the respiratory system did not reach the average of 2.0 daily admissions and showed a very low percentage - except for the group of unspecified diseases (508 and J95-J99), which represented 4.9% of the total hospitalizations and a daily average of 2 hospitalizations. However, this group, as the name indicates, represents unspecified diseases and, therefore, it is impossible to recognize the real cause of these hospitalizations.

To characterize the distribution of respiratory diseases in Mato Grosso do Sul, several models were developed. By using the multiple linear regression, one can assess a given problem by analyzing the degree of relationship between one or more variables.

In this study, an univariate exploratory analysis of spatial data was carried out to investigate the spatial autocorrelation of Bayesian estimates of hospitalizations for respiratory diseases, and of the fire risk indicator in the municipalities of MS. We chose to build Bayesian estimates for hospitalizations, aiming to minimize the instability of prevalence, by eliminating the random fluctuation present in small areas (Bailey and Gatrell AC, 1985), using the empirical spatial Bayesian method proposed by Marsha, 1991, in which the prevalence of each municipality is adjusted by considering the prevalence of its neighbors.

In the multiple analysis, the direction and magnitude of the associations between the independent variables were first evaluated through a correlation matrix. Next, multiple spatial regression analysis was

used. This type of analysis has the same assumptions as traditional linear regression, but takes into account the spatial trends or correlations of the data, and in case spatial autocorrelation is found, certain parameters are incorporated to enable the removal of these effects. The quality of the fit of the spatial regression model is similar to that of the traditional multiple regression model, being verified through the analysis of residues.

The data of hot spots was obtained from the Burn Database (BDQueimadas) from the Weather Forecast and Climate Studies Center (CPTEC) of the National Institute of Meteorology (INMET) /: <http: //queimadas.dgi.inpe .br / burned / bdqueimadas />. It is worth mentioning that the data have already been used in a study in the State of MS (Oliveira Júnior et al., 2020) and in Brazil (Caúla et al., 2015).

3. Results And Discussion

The results for the years 2015 to 2020 obtained by the model, which included respiratory system diseases owing to their high fire risk, were R^2 = 0.76, r = 0.87 and p = 0.0000. The model displayed a direct relationship between the the distribution of respiratory diseases and fire risk, such that the greater the increase in respiratory diseases cases. This relationship coincides with reality, suggesting that the emission of highly toxic gases into the atmosphere directly interferes with human health, thus causing an increase in respiratory diseases.

It is worth mentioning that the statistical model also revealed that children under the age of four years of age are the most vulnerable group to respiratory diseases (Fig. 2). This corresponds to a previous study carried out in Brazil, where the main cause of death among children was respiratory diseases (Sigaud, 2003).

Fires, which can be of natural origin or, more often in the Midwest Region, of anthropic origin (Caúla et al., 2015; Oliveira-Júnior et al., 2020), releases carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), particulate matter (PM), nitrogen oxides (NO2) and ozone (O3); the latter air pollutant is generated by the action of sunlight on nitrogen compounds. In addition to these pollutants, fires release aldehydes, hydrocarbons, inorganic acids and polycyclic aromatic hydrocarbons that can produce important clinical manifestations in adults and children (Souza et al., 2020a, Souza et al., 2000b). It is worth mentioning that fires represent more than 70% of the Brazilian carbon emissions (C) (Silva et al., 2009). The state of MS is among the states known to have the highest rates of heat sources (Caúla et al., 2015), with 42,840 quantified fire loci from 2015 to 2020Oliveira-Júnior et al., 2020).

The economy in the state of MS region is based on extensive breeding of beef cattle and agriculture of staple foods, mainly soy (Silva Junior et al., 2018; Silva Junior et al., 2019). Recently, there has been an intensive cultivation of corn and soybeans (economic drivers) and an increase in the mining and the industry sectors. Given the base of its economy and its large extent, the state of MS has been continuously using deforestation to meet the demands of its growing economy (Silva Junior et al., 2018; Silva Junior et al., 2019). Burning is a cheap, fast and common practice in the region forsoil cleaning and

pasture renewal (Franca and Setzer 2001; Caúla et al., 2015). Soy is the main contributor to the increase in the deforestation problem in the region, due to the need to increase their productivity (Chuvieco et al., 2008; Silva Junior et al., 2018; IBGE, 2020).

The total number of hot spots observed in the MS during the studied period was highly variable (Fig. 3). This variability can be attributed to the expansion of the agricultural frontier (crops or land of family agriculture) in the state in the last two decades, encouraged by the Federal Government. This development was followed by rudimentary practices of planting and harvesting, deforestation, arson and, ultimately, intra-seasonal and inter-annual variability of production systems and rain inhibitors in the state (Caúla et al., 2015; Oliveira-Júnior et al., 2020). The dynamics of hot spots distribution within the different regions of MS are strongly linked to the prevailing climatic conditions and human activities characterize within each region.

Despite the variable climate in the state of MS, we aim to evaluate the seasonality change of hot spots. Spring and winter had the highest fire frequencies, with 53% and 29% of the total outbreaks, respectively. In autumn and summer, a much lesser degree of fire frequencies were found, of about 9% each (Fig. 3), similarly to the results obtained by Caúla et al. (2015). The highest fire frequencies identified in the MS and its biomes were from August to October, corresponding to the most susceptible months to the occurrence of hot spots in the state, due to the low precipitation and high temperatures during this time (Oliveira-Júnior et al., 2020).

The frequency and distribution of fires in the MS are strongly associated with climatic conditions. These conditions and detection by environmental satellites are important tools in monitoring and providing information on fires on a regional scale (Lima et al., 2020). Spatial dynamics are conditioned by biomes, land use and occupation, agricultural practices, deforestation and public policies, among others.

Figure 3 shows the density of the hot spots in the existing biomes in the state of Mato Grosso do Sul. The municipalities of Corumbá and Porto Murtinho stand out with the highest occurrences of hot spots, with the Pantanal biome encompassing 55% of hot spots. In the Cerrado biome, 36% of the hot spots were located, where the municipalities Campo Grande and Ribas do Rio Pardo stood out with the highest occurrence of hot spots. Lastly, 9% of the hot spots were identified within the Atlantic Forest biome, where, the of Rio Brilhante and Ponta Porã municipalities presented somewhat higher incidence.

The model generated can also be explained by an earlier study carried out in Curitiba-PR, where the effects of air pollution on morbidity due to respiratory diseases in children were investigated. In this study, data on respiratory diseases in children were related to several variables such as the levels of particulate matter, smoke, nitrogen dioxide and ozone, inferring that all the investigated pollutants had effects on respiratory diseases in children (Bakonyi et al., 2007).

Other studies, carried out in Brazil, have investigated the patterns of morbidity distribution using spatial analysis techniques; few, however, have evaluated the morbidity of respiratory diseases related to exposure to the pollutant (fire risk).However, these were mostly time series analysis ecological studies,

which did not use Geographic Information Systems (GIS) (Junger and Leon, 2007; Bakonyi et al., 2004; Cançado et al., 2006).

The exposure variable was chosen for modelling in the present study since it is currently considered to be the one most strongly factor produced by air pollutants associated with the morbidity. Fire outbreaks, produced by fire hazards, release particles that are capable of reaching the deepest regions of the respiratory system, triggering inflammatory processes in the pulmonary interstitium (Donaldson et al., 2001). The deposition of these particles, when crossing the alveolar epithelium barrier, induces the release of chemical mediators that lead to both local (hypoventilation, obstruction, inflammation and pulmonary infection) and systemic responses, due to the transport of these mediators through the circulation, even acting directly in cardiac cells (Shi et al., 1996).

A large portion of the vulnerable groups included in the study (children and the elderly, Fig. 2), showed the highest incidence of respiratory diseases and have occurred in the municipalities belonging to the "Pantanal" region, which is characterized by large deforested areas and high concentrations of fire risks (Fig. 3).

Regarding the age groups, several authors state that the most sensitive groups to air pollutants exposure are children under five years old, elderly and individuals with respiratory diseases (Fig. 2) - (Organización Panamericana de la Salud, 2005; Rumchev et al., 2007; Medina-Ramo et al., 2006). However, other risk factors linked to socio-sanitary conditions are also associated with a broader development of respiratory diseases in childhood, especially during the first year of a child’s life (Macedo et al., 2007; Caldeira et al., 2005).

The spatial distribution of respiratory diseases by percentage displayed a well-defined pattern, where the Pantanal municipalities of the State had the highest concentrations of fire risk and, consequently, a greater number of fire outbreaks (Figure, 4). Artaxo et al. (2005) reported that the air quality in some regions of the Amazon is strongly affected during the burning season, thus possibly worsening the air parameters recorded in the urban city center of São Paulo, and similarly in the Pantanal. Such spatial pattern was also assessed by Freitas et al. (2005), who described the emissions from fires in South American ecosystems and observed the highest occurrence in the State of MSl, which is mainly associated with agricultural expansion and land preparation for pasture planting.

The analysis of the multiple spatial regression models showed statistically significant associations with the prevalence of hospitalizations for respiratory system diseases and fire risks. Lopes and Ribeiro (2006) mapped hospital admissions for respiratory issues and assessed the association of this morbidity to human exposure to the products of burning sugarcane straw in some municipalities in the State of São Paulo. By implementing spatial correlations analysis, they observed a higher occurrence of respiratory diseases in regions where burning activity was higher. Ignotti et al, 2007 conducted a study on hospital morbidity and mortality from acute respiratory disease in children under the age of five years in Mato Grosso, where the highest morbidities were found in regions notorious for their high concentrations of pollutants originating from burning biomass.

In the State of MS there are several small municipalities, where health care services are still precarious, and most of them do not have a hospital. This indicator allowed a better representation of supply and demand in relation to traditional health indicators, originally built for larger municipalities, with a minimum satisfactory capacity for installed care. However, Scatena (2000) warned that there is a certain compromise in the hospital assistance system in certain municipalities in the region, where stagnation, in terms of health policies, has been reported in recent years. This stagnation may reflect deficiencies in health prevention activities, which, consequently, could lead to a greater demand for hospital care in some municipalities, not necessarily related to the high concentrations of air pollutants.

In the study, the risk of fire was correlated with the number of hospitalizations. It was observed that certain municipalities with a high fire risk did not present high concentrations of hospitalizations. This can be partially explained by the time interval between the fire risk, which has its greatest intensity during the period from April to July, and the fire phase that mainly occurs during August to October. Freitas et al, 2005 pointed out that the estimates of biomass burning and the emission amount of a given chemical compound, depends on the amount of biomass burned, and are different for the cerrado, a tropical forest, from secondary and primary forests. In addition, the winds bring masses of air from the ocean, which transport emissions from the burning area to the south (Freitas et al., 2005). Therefore, the smoke emitted by fires in the Amazon region of the State of MT is transported to further south regions, and consequently increasing the chronic exposure to smoke in an unrelated Amazon biome region and contribute to the higher smoke concentrations to municipalities with typically minor fire (Artaxo et al., 2005). The State of MS presents a climate characterized by a dry winter (July, August and September), when the continental tropical air mass is stationed in the region and a rainy summer (January, February and March), when the continental equatorial air mass predominates throughout the state (Botelho et al., 2003), most, if not all, of the fires occur in the dry season. In this study, it was not possible to consider seasonality. However, the inclusion in the model of the variable number of fires per municipality can be considered as an indirect adjustment, since this number is associated with the longer or shorter duration of rain absence in the municipalities of the State of Mato Grosso do Sul.

Here, the prevalence of hospitalizations for diseases of the respiratory system was used. (Bittencurt et al., 2006) highlight that the Hospital Information System (SIH), from which the data is obtained, uses the Hospitalization Authorization (AIH) as the unit of analysis and not the sick individual, meaning that the same individual may be hospitalized more than once or even not admitted at all, although ill, due to limitations in the hospital structure. Hence, the use of hospitalizations as an approximation of the number of disease cases is fragile. However, hospitalizations datahas been pointed out as one of the best indicators of injuries and respiratory diseases. On the other hand, the participation of the supplementary health system is not relevant for the MS state or cities where DATASUS is responsible for 100% of the outpatient and hospital care, allowing the data used in this study to have good population coverage.

Alves and Rodrigues (2005) study on health determinants in elderly people in the city of São Paulo, reported that the level of education, among other socioeconomic variables, was highly associated with

the perception of health, and age had a significant influence. Perhaps the level of education contributes to the elderly and / or their families to perceive with greater clarity certain health conditions that require medical attention, which would be reflected in the greater use of health services in certain municipalities. It is important to highlight the difficulty of the Pantanal rural populations to access health services. Studies that have investigated the availability of the health services and their geographic accessibility show that the use of health services is reduced as the distance between the people in need for health care and health services increases (Alves and Rodrigues, 2005). Therefore, the actual situation must be even worse than the scenario verified through SUS morbidity data, which considers only the cases that managed to reach medical care - possibly the most serious cases.

Meteorological variables were not analyzed independently, which can be considered a limitation of this study as there is a very close relationship between them to the original air pollution. Likewise, it was not possible to include other air pollution indicators, due to the unavailability of data for all municipalities in the state. This inclusion would be important, since MS is an agricultural state, with large areas planted with sugar cane and, thus, characterizes a pressure of local exposures to several other air pollutants, and its failure to consider it in the analysis could have led to the observation of spurious associations between the exposure variable used and the prevalence of hospitalizations for respiratory disease in sensitive groups.

When the data indicates counts by areas, the size of the population at risk can vary considerably between the areas under study. The spatial spread of the risk of an event (for example, illness, death, etc.) is usually shown via rate incidence maps. The purpose of the mapping is to infer the geographic distribution of the rates and then to identify the areas where a greater or lesser incidence appeared, while looking for a spatial pattern. When autocorrelation is utilized, nearby regions tend to have the same pattern of the event of interest occurrence, whereas distant regions will present dissimilar patterns. Coefficient C showed that the levels of health and socioeconomic development of a given area, being considered one of the most important epidemiological indicators used (Laurenti et al., 1985), and has also been used as one of the main indicators of the quality of life of a population (DATASUS, 2012). The rate is given by the relationship between the number of hospitalizations for respiratory diseases and the total population of the municipality, at a particular place over a specific period of time, was calculated on the basis of one thousand. (C) is an important indicator, because it reflects the quality of health care, in addition to indicating a concern for reducing disparities in the social pyramid.

Contextual characteristics as socioeconomic status and education, among others, have been considered as a central determinants of health status (Bittencourt et al, 2006), being one of the motivations that led us to the selection of the multiple spatial regression method. Additionally, it made it possible to minimize random fluctuations in the prevalence of hospitalizations in small areas, allowing a better visualization of their spatial distribution. The disadvantage of using this method, however, consists in the fact that it can cause overestimation of the autocorrelation coefficients in areas comprising a small number of events, where smoothing the values of the municipality's variables towards the average of its neighbors is more accentuated. Even so, the option of Bayesian estimates was chosen, as it is understood that, in smaller

municipalities, the inconsistencies of the information records could produce a large variance in the outcome variable, and a consequential decrease in the accuracy and validity of the analysis.

Figure 5 depicts the values of disease cases observed in the years, along with the estimated values, which were obtained by the model, and their residues. According to Fig. 5b, the majority of municipalities in MS had high values of respiratory diseases cases and still coincide with the observed data (Fig. 5a). Figure 5c indicates the residues resulting from the difference between the observed and the estimated values. All selected variables were directly related to the distribution of respiratory diseases.

In the eastern region of the state, an area that coincided with the presence of coal mining industries, the direct relationship between population and cases of respiratory diseases indicated people's vulnerability, since the industries are concentrated in the Rural Zone. In the northern region of the state, the model presented similar factors, which is probably due to the origin of the CO emission and is not derived from the carboniferous region.

It was also observed that despite the high values of respiratory diseases cases, they are still underestimated. The variable rural and child populations (one to four years old) were directly related to respiratory diseases, with the exception of the accumulated precipitation variable, which registered an indirect association, that is, the lower the rainfall the greater the fire risk, fires and respiratory diseases incidences. This fact pointed to the observed relationship between climatic conditions and the deterioration of respiratory diseases, which, in this case, were greater during periods of drought. This relationship is further confirmed by a study carried out in the municipality of Presidente Prudente-SP, located in the western region, which analyzed the influence of climatic factors on the case incidence of respiratory system diseases. The results suggested that during periods of prolonged drought there is an increase in the number of hospitalization for respiratory diseases (Souza and Neto, 2008).

The selection of variables in the model generated is justified by the improved explanation of the respiratory diseases case incidence. Environmental and socioeconomic variables that were removed from the model, but had a strong association with the selected variables, can also be used as risk factors for the occurrence of new cases of diseases. Among the socioeconomic variables, employment ties in the manufacturing industry, urban population and population aged 65 years or over were highly correlated with the population aged 1 to 4 years, which remained in the final model.

The results of the southern portion showed low values of the FMA index and fire risk during the rainy season (Fig. 5), as the rates of both precipitation and humidity in this region were higher. The FMA values varied between 10.37 to 15.25, and in the dry period the values ranged from 14.65 to 22.55 (Fig. 4). The minimum, maximum and average fire risks values were1.50, 49.0 and 9.1, respectively (Fig. 6), during the dry season, reaching a very high degree of danger (values ≥20) and an annual average values with a high degree of danger (8.1 to 20.0). The annual average values of the FMA index ranged from 14 to 23, reaching 23 to 28 during the dry, representing a high fire risk for the state of MS (Antunes, 2000).

One must also consider the type of vegetation, since some can encourage fire as fuel, and in case the of cerrado to the east, Pantanal to the west, tropical forest to the south, the vegetation, has fire-friendly properties. The properties of fuels involve the type, diameter, weight and humidity, among which the moisture content is the most important in fire control (Beutling et al, 2005). The annual map (Fig. 6), similar the former maps, present lower values of the average fire risk in the east, increasing towards the west.

In the eastern part, the values ranged from 13.61 to 19.07, and are considered low, although they cannot be compared with the results of previous years, and to better identify the areas at risk of fire, the annual map was constructed fire risk values (Fig. 6).

4. Conclusion

The study shows the importance of spatial assessment of the morbidity of respiratory diseases and their relationship with the risk of fire resulting from biomass burning in the Cerrado and Pantanal biomes. The study also indicates priorities for health service managers in the region, in order to reinforce an effective diagnosis of respiratory diseases in vulnerable population groups. It is believed that the increase in the severity of respiratory diseases can be determined by the interaction of climatic variables, together with inadequate environmental conditions and low socioeconomic status.

It is interesting to note that, among the models generated from multiple linear regression, there was a coincidence in the selection of some variables. The concentration of O_3 pollutant, the precipitation and the sub-populations presented by the models, indicates that these factors are relevant for the ideal conditions of respiratory diseases in Mato Grosso do Sul.

The study also indicated that it is necessary to give special attention to the rural population, since they are more vulnerable to the risk of becoming ill than the resident in urban areas. It is believed that in the eastern region of the state, an area that coincides with the presence of coal mining industries, the direct relationship between the rural population and cases of respiratory diseases indicates their vulnerability, since the industries are concentrated in the rural area. In the northern region of the state, the research points to similar factors, except that the origin of the ozone emission is probably from fire outbreaks.

This type of study can be useful for the health surveillance services of the before mentioned exposed populations, as it points to environmental and socioeconomic factors that determine the distribution of health problems. Therefore, better urban planning is proposed, aiming at the life quality of the population. For the purpose of atmospheric pollution control and reduction, it is necessary to take some preventive measures, together with the public and private sectors, that assist in reducing the emission of toxic gases, prioritizing the health of the population.

This study sets up a platform to test and to estimate the risk of fire in the state of Mato Grosso do Sul and its association to respiratory diseases ratio. To this end, we integrated methods for predicting cumulative fire risk indices and map production according to the results of the applied index.

The climatic variability (relative average of the air measured at 1 pm and daily precipitation) was recorded monthly, and was applied within the Monte Alegre formula, thus obtaining information on more susceptible areas to the occurrence of fires and respiratory diseases. The importance of carrying out this work is that through the production of thematic maps, it is possible to identify when and where the risk of fire is the greatest, therefore being able to invest most effectively in a system in order to fight fires and their unfortunate link to respiratory diseases.

The system used to determine the specific daily diagnosis for the risk of fire and respiratory diseases is satisfactory. However, it is suggested that some efforts should be made for increasing the accuracy of fire risk estimation, such as the use of a more extensive and accurate historical database of fire outbreak occurrences to have a more robust relationship between index values fire risk.

Declarations

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Conflicts of Interest:

The authors declare no conflicts of interest.

Database declaration / Data availability:

The climate database is in the public domain and is available at: https://www.cemtec.ms.gov.br/ and the hospital admissions database is available at http://www2.datasus.gov.br/DATASUS/index.php?area=02

Ethical Considerations

The present study is based on secondary, publicly available data, which do not constrain groups of populations and / or individuals in the presentation of the results found, ensuring the confidentiality of the information collected. Thus, the ethical aspects of research with human beings were respected, according to Resolution no. 466/2012

Authors' participation

All authors participated in the preparation of the review and writing of the project, data collection, data analysis and writing of the article, review and writing of the article and review of the article.

References

Alman BL, Pfister G, Hao H, Stowell J, Hu X, Liu Y, et al. The association of wildfire smoke with respiratory and cardiovascular emergency department visits in Colorado in 2012: a case crossover study. Environ Health. 2016;15:64.

Alves L, Rodrigues RN. Determinantes da autopercepção de saúde entre idosos do Município de São Paulo, Brasil. Rev Panam Salud Publica 2005; 17(5/6): 333-41.

Antunes M.A.H. Uso de satélites para detecção de queimadas e para avaliação do risco de fogo. Revista do Departamento de Eng. Florestal UFPR. Curitiba, n.25, 2000.

Artaxo P, Gatti LV, Leal Amc, Longo Km, Freitas Sr, Lara LL. Química atmosférica na Amazônia: A floresta e as emissões de queimadas controlando a composição da atmosfera amazônica. Acta Amazônica 2005; 35(2): 185-96.

Bailey TC & Gatrell AC. Interactive Spatial Data Analysis. Editora Essex: Longman; 1995.

Bakonyi SMC, Danni-Oliveira IM, Martins LC, Braga ALF. Poluição atmosférica e doenças respiratórias em crianças na cidade de Curitiba, PR. Rev. Saúde Pública. 2004; 38(5): 695-700.

Bennett WD, Zeman KL, Jarabek AM. Nasal contribution to breathing and fine particle deposition in children versus adults. J Toxicol Environ Health A. 2007; 71:227–37.

Beutling A.; Batista, A.C.; Soares R. V. Quantificação de material combustível superficial em reflorestamentos de araucária angustifólia. Revista do Departamento de Eng. Florestal UFPR. n. 27, 2005.

Bittencourt AS Camacho LB, Leal MC. O Sistema de Informação Hospitalar e sua aplicação na saúde coletiva. Cad Saúde Pública 2006; 22(1): 19-30.

Black C, Tesfaigzi Y, Bassein JA, Miller LA. Wildfire smoke exposure and human health: significant gaps in research for a growing public health issue. Environ Toxicol Pharmacol. 2017; 55:186–95.

Botelho C, Correia AL, DA Silva AMC, Macedo AG, Soares Silva COS. Fatores ambientais e hospitalizações em crianças menores de cinco anos com infecção respiratória aguda. Cad Saúde Pública 2003; 19(6): 1771-80.

Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull. WHO 2000; 78: 1078-92.

Caldeira A P, Françab E, Perpétuoc IHO, Goulartd, Andrade EM. Evolução da mortalidade infantil por causas evitáveis, Belo Horizonte, 1984-1998. Rev Saúde Pública 2005; 39(1): 67-74.

Cançado Jed, Saldiva PHN, Pereira LAA, Lara, Lbls, Artaxo P, Martinelli La . The Impact of sugar Cane-Burning Emissions on the Respiratory System of Children and the Elderly. Environ Health Perspect 2006; 14(5): 725-9.

Cascio WE. Wildland fire smoke and human health. Sci Total Environ. 2018; 624:586–95.

Caúla, R. H.; Oliveira-Júnior, J. F.; Lyra, G. B.; Delgado, R.C. ; Heilbron Filho, P.F.L. Overview of fire foci causes and locations in Brazil based on meteorological satellite data from 1998 to 2011. Environmental Earth Sciences (Print), v. 74, p. 1497-1508, 2015. https://doi.org/10.1007/s12665-015-4142-z

CEMTEC-MS/AGRAER- Centro de Monitoramento de Tempo, do Clima e dos Recursos Hídricos de Mato Grosso do Sul.

Chuvieco E, Opazo S, Sione W, Del Valle H, Anaya J, Di Bella C, Cruz I, Manzo L, Lopez G, Mari N, Gonzalez-Alonso F, Morelli F, Setzer A, Csiszar I, Kanpandegi JA, Bastarrika A, Libonati R (2008) Global burned-land estimation in Latin-America using MODIS composite data. Ecol Appl 18:64–79

DATASUS. Informações em Saúde. Disponível em http:// w3.datasus.gov.br/datasus/ datasus.

DATASUS. Sistemas e Aplicativos. Disponível em http:// www.datasus.gov.br/cid10/.

DE Koning HW, Smith KR, Last JM, Biomass fuel combustion and health. Bull. WHO 1985; 63:11-26.

Donaldson K, Stone V, Clouter A, Macnee W. Ultrafine Particles. Occup Environ Med 2001; 58: 211-6.

Doubleday A, Schulte J, Sheppard L, Kadlec M, Dhammapala R, Fox J, et al. Mortality associated with wildfire smoke exposure in Washington state, 2006–2017: a case-crossover study. Environ Health. 2020; 19:4.

França H, Setzer A (2001) AVHRR analysis of a savanna site through a fire season in Brazil. Int J Remote Sens 22:2449–2461

Freitas SR, Longo Km, Silva Dias Maf, Silva Dias PL. Emissões de queimadas em ecossistemas da América do Sul. Estudos Avançados 2005; 19(53): 167-85.

IBGE—Instituto Brasileiro de Geografia e Estatıstica (2020) Area Territorial Oficial. http://www.ibge.gov.br/home/geociencias/cartografia/default_territ_area.shtm

Ignotti E, Hacon S, Silva AMC, Junger Wl, Castro HA. Efeitos das queimadas na Amazônia: método de seleção de municípios segundo indicadores de saúde. Rev Bras Epidemiol 2007; 10: 453-64.

Junger Wl, Leon Ap, Poluição do ar e baixo peso ao nascer no Município do Rio de Janeiro, Brasil, 2002. Cad Saúde Pública 2007; 23(4S): 588 -98.

Laurenti R, Jorge MHP, Lebrão Ml, Gotlieb SLD. Estatísticas de saúde. São Paulo: EPU/Edusp; 1985.

Lima, M.; Vale, J. C. E. ; Costa, G. M. ; Santos, R. C. ; Correia Filho, W. L. F. ; Gois, G. ; Oliveira Júnior, J. F., Teodoro, P. E. ; Rossi, F. S.; Silva Junior, C. A. The Forests in the Indigenous Lands in Brazil in Peril. Land Use Policy, v. 90, p. 1-3, 2020.

Liu JC, Pereira G, Uhl SA, Bravo MA, Bell ML. A systematic review of the physical health impacts from non-occupational exposure to wildfire smoke. Environ Res. 2015; 136:120–32.

Lopes Fs, Ribeiro H. Mapeamento de internações hospitalares por problemas respiratórios e possíveis associações à exposição humana aos produtos da queima da palha de cana-de-açúcar no estado de São Paulo. Rev Bras Epidemiol 2006; 9(2): 215-25.

Macedo SEC, Menezes AMB, Albernaz E, Post P, Knorst M. Fatores de risco para internação por doença respiratória aguda em crianças até um ano de idade. Rev Saúde Pública 2007; 41(3): 351-8.

Marshall RJ. Mapping disease and mortality rates using empirical Bayes estimators. Applied Statistics 1991; 40: 283-94.

Medina-Ramo M, Zanobetti1 A, Schwartz J. The Effect of Ozone and PM10 on Hospital Admissions for Pneumonia and Chronic Obstructive Pulmonary Disease: A National Multicity Study. Am J Epid 2006; 163(6): 579-88.

Miller MD, Marty MA. Impact of environmental chemicals on lung development. Environ Health Perspect. 2010; 118:1155–64.

Mills D, Jones R, Wobus C, Ekstrom J, Jantarasami L, St. Juliana A, et al. Projecting age-stratified risk of exposure to inland flooding and wildfire smoke in the united states under two climate scenarios. Environ Health Perspect. 2018; 126:047007.

Oliveira-Júnior, J. F.; Teodoro, P. E.; Silva Junior, C. A.; Baio, F. H. R.; Gava, R. ; Capristo-Silva, G. F. ; Gois, G. ; Correia Filho, W.L.F. ; Lima, M. G.; Santiago, D. B.; Freitas, W. K.; Santos, P. J. ; Costa, M. Fire foci related to rainfall and biomes of the state of Mato Grosso do Sul, Brazil. Agricultural and Forest Meteorology, v. 282-283, p. 1-13, 2020. https://doi.org/10.1016/j.agrformet.2019.107861

Organización panamericana de la salud. Evaluación de los efectos de la contaminación del aire en la salud América Latina y el Caribe. Washington, D.C.: OPS; 2005.

Rumchev K, Spickett J T, Brown HL, Mkhweli B. Indoor air pollution from biomass combustion and respiratory symptoms of women and children in a Zimbabwean village. Indoor Air 2007; 17: 468-74.

Scatena JHG. Avaliação da descentralização da Assistência à Saúde no Estado de Mato Grosso [tese de Doutorado]. Faculdade de Saúde Pública - Universidade de São Paulo; 2000.

Shi, MM, Godleski JJ, Paulauskis JD. Regulation of macrophage inflammatory protein-1 mRNA by oxidative stress. J Biol Chem 1996; 271: 5878-83.

Shusterman D, Kaplan JZ, Canabarro C. Immediate health effects of an urban wildfire. West J Med. 1993; 158:133–8.

Sigaud CHS. Concepções e práticas maternas relacionadas à criança com pneumonia: estudo realizado no município de São Paulo [tese]. São Paulo (SP): Universidade de São Paulo; 2003.

Silva Junior, C. A., Costa, G. M., Rossi, F. S., Vale, J. C. E., Lima, R. B., Lima, M., et al. (2019). Remote sensing for updating the boundaries between the Brazilian Cerrado-Amazonia biomes. Environmental Science & Policy, 1, 1–10. https://doi.org/10.1016/j.envsci.2019.04.006.

Silva Junior, C. A., Nanni, M., Shakir, M., Teodoro, P.E., Oliveira Júnior, J. F., Cezar, E. ; Gois, G. ; Lima, M. G. ; Wojciechowski, J. C.; Shiratscuhi, L. S. Soybean varieties discrimination using non-imaging hyperspectral sensor. Infrared Physics & Technology, v. 89, p. 338-350, 2018. https://doi.org/10.1016/j.infrared.2018.01.027

Silva PR, Rosa AM, Hacon SS, Ignotti E. Hospitalization of children for asthma in the Brazilian Amazon: trend and spatial distribution. J Pediatr (Rio J). 2009;85:541-6.

Soares R.V. Índice de Perigo de Incêndio. Revista do Departamento de Eng. Florestal UFPR. Curitiba, n. 13, 1972.

Souza CG, Neto JLS. Ritmo climático e doenças respiratórias: interações e paradoxos. Revista Brasileira de Climatologia. 2008; 65-82.

Souza, A.; Abreu, M. C.; Oliveira-Júnior, J.F.; Santos, C.M.; Pobocikova, I.; Fernandes, W.A.; Torsen, E.; Silva, E.B.; Mbaga, Y.V. Study Of Aerosol Optical Depth Climatology Using Modis Remote Sensing Data. European Chemical Bulletin, V. 9, P. 291, 2020.

Souza, A.; Andrade, F.A.; Oguntunde, Pelumi E. ; Arsic, Milica ; Silva, Debora A.S. Climate Indicators And The Impact On Morbidity And Mortality Of Acute Respiratory Infections. Advanced Studies In Medical Sciences., V. 6, P. 5-20, 2018a.

Souza, A.; Aristone, F.; Andrade, F. A. ; Pavao, Hamilton G ; Fernandes, W.A; Silva Santos, D. A.; Oguntunde, P.E.; Arsic, M.; Sabah, I. The Effects Of Climate On Hospitalization For Respiratory Diseases By Age Group. Advanced Studies In Medical Sciences., V. 6, P. 21-35, 2018b.

Souza, A.; Santos, D. A. S, Oliveira-Júnior, J. F.; Oliveira, A.P.G.; Silva, E. B.. Modeling Of Hospital Admissions For Respiratory Diseases As A Function Of Probability Distribution Functions. Research, Society And Development, V. 9, P. E869986501, 2020a.

Souza, A.; Santos, D. A. S. Vulnerabilidade do Risco de Doenças Respiratórias em Função da Temperatura Média Horária. Research, Society And Development, V. 9, P. E121985412, 2020b.

Figures

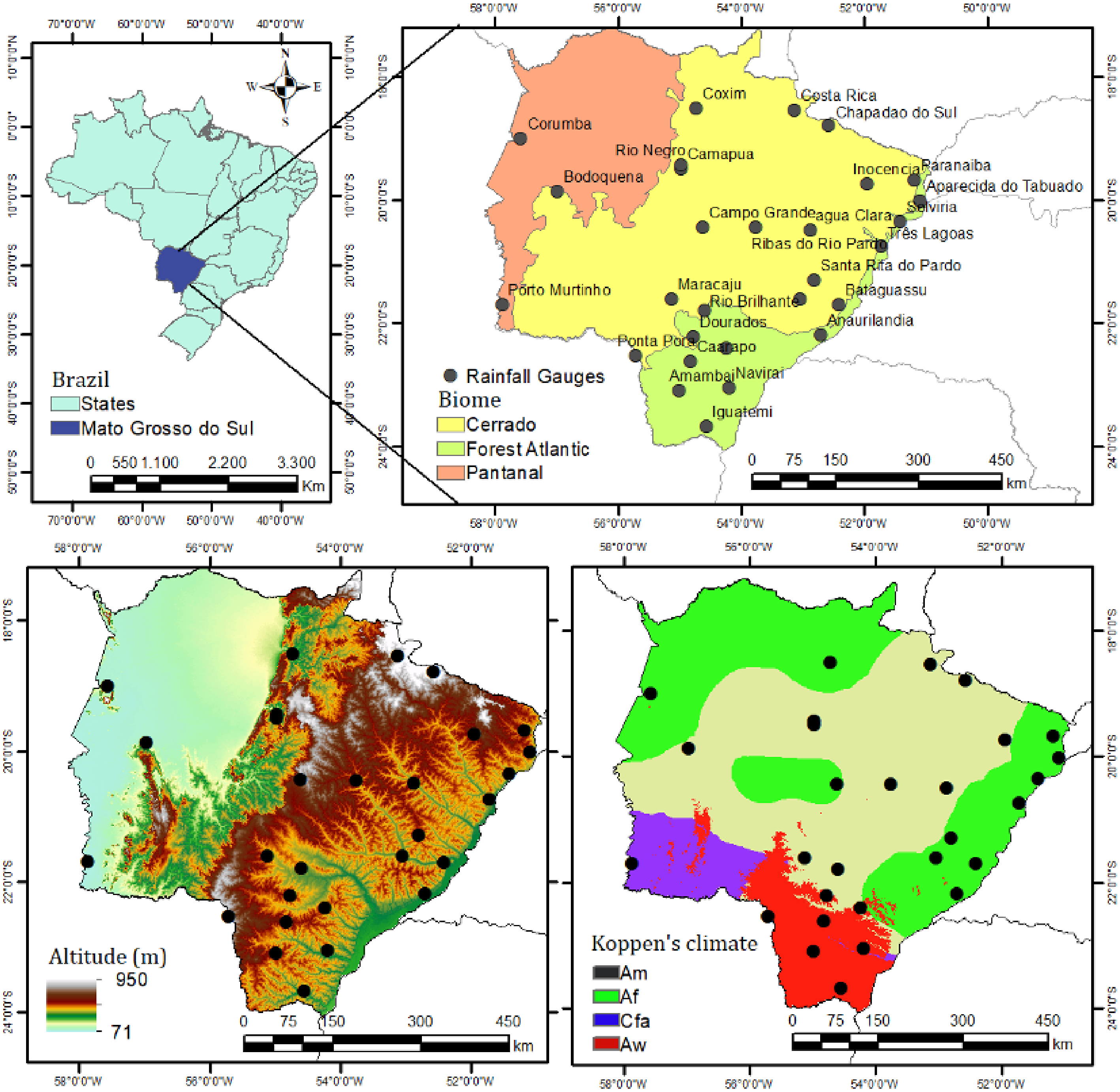

Figure 1

Left-upper: The location of the state of Mato Grosso do Sul in Brazil; right-upper: the boundaries of the three Mato Grosso do Sul biomes (Cerrado, Atlantic Forest and Pantanal), the maps of altitude (left-lower) and climatic classification (right-lower) including the location of weather stations. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

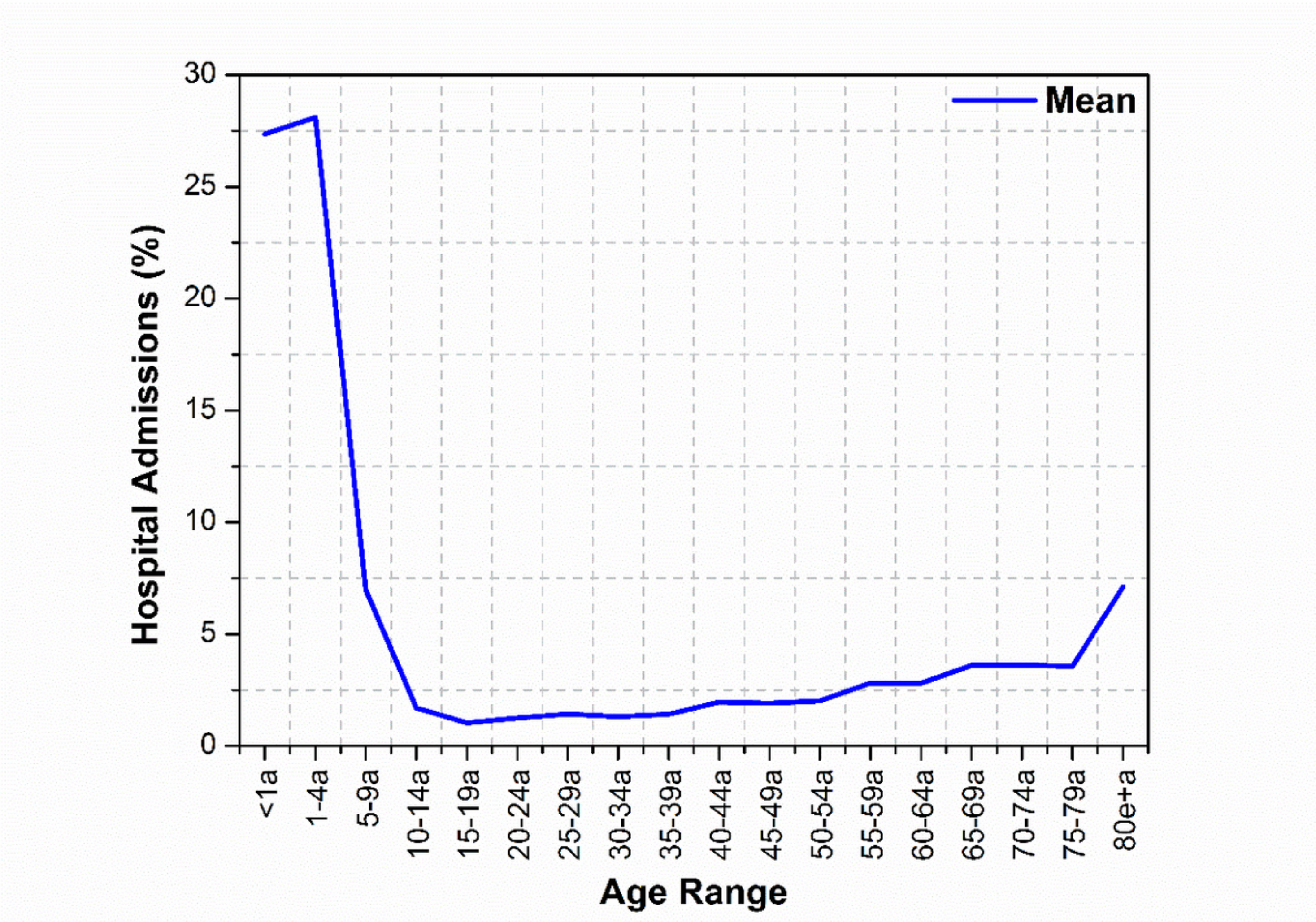

Figure 2

Percentage (%) of the number of hospitalizations for respiratory diseases by age group in the state of Mato Grosso do Sul, from 2015 to2020.

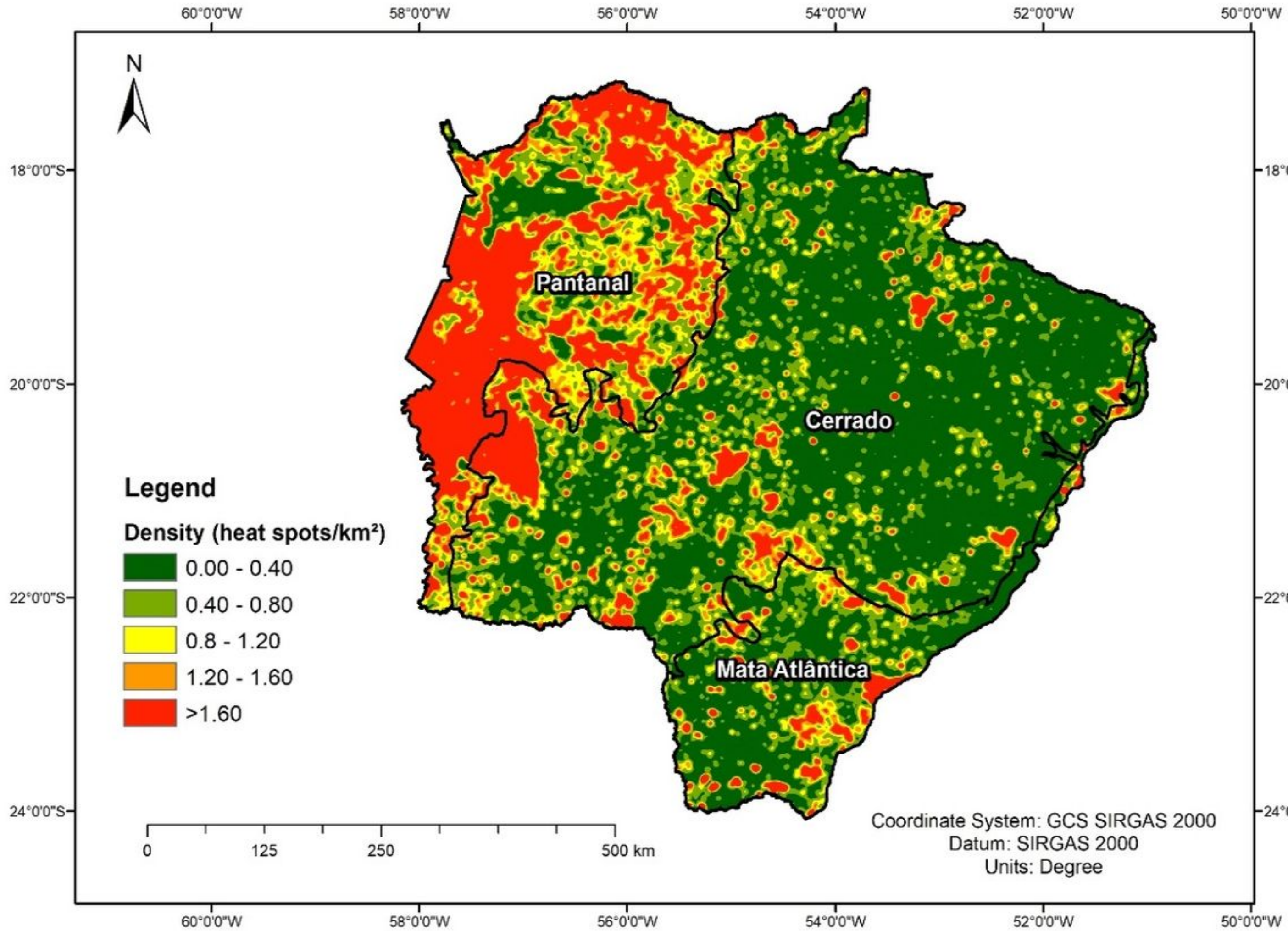

Figure 3

Kernel density map of heat sources for the biomes of Mato Grosso do Sul between 2015 and 2020. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

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Figure 4

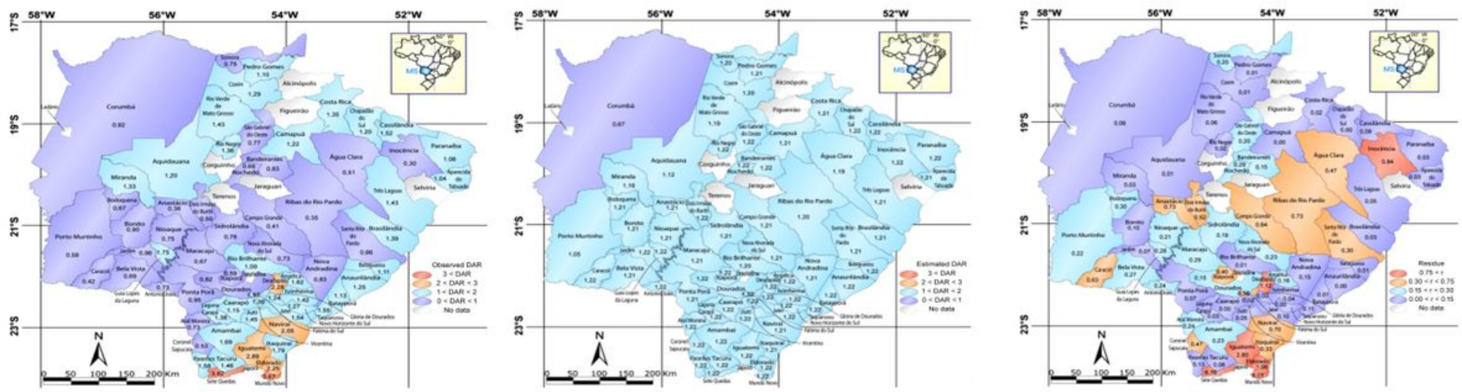

Figure 5

Results generated by the regression model, based on data on respiratory disease (DAR) for the years 2015 to 2020: (a) observed (b) estimated and (c) residues. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

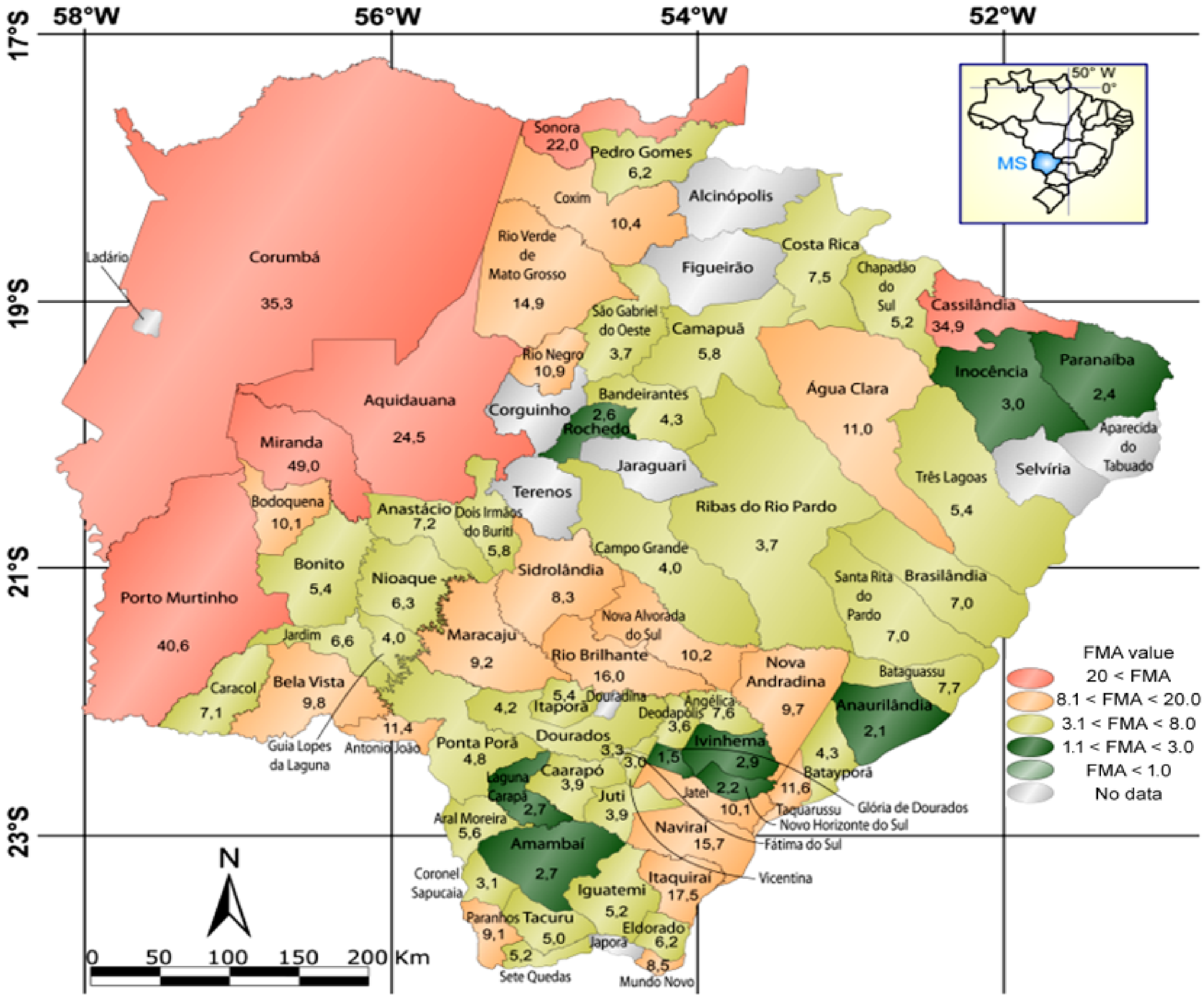

Figure 6

The average fire risk class spatially distributio for the State of Mato Grosso do Sul, in the period from 2015 to 2020. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.