saúde EM DEBATE

ORIGINAL ARTICLE

Cardiorespiratory hospitalization costs due to air pollution from biomass burning and wildfires in the Legal Amazon and Northern Cerrado regions (2010-2021)

Custos das hospitalizações como impacto da poluição atmosférica por queimadas e incêndios florestais na Amazônia Legal e Cerrado setentrional no Brasil (2010-2021)

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ABSTRACT This study estimated the financial costs to the Brazilian Unified Health System (SUS) from hospitalizations due to cardiorespiratory diseases associated with exposure to fine particulate matter (PM2.5) emitted by biomass burning in cities of the Legal Amazon and northern Cerrado from 2010 to 2021. This retrospective ecological study used data from the SUS Hospital Information System (SIH) and applied the methodology recommended by the World Health Organization to calculate attributable fractions. The results indicate an average annual impact on the SUS of approximately BRL 17.6 million. The highest hospitalization costs were concentrated in municipalities within the Deforestation Arc, where exposure to pollution from biomass burning is most intense. The study highlighted the effects of environmental degradation on health, guiding public policy decision-makers toward more sustainable development.

KEYWORDS Particulate matter. Air pollution. Hospital costs. Cardiorespiratory diseases. Amazon.

RESUMO *A pesquisa estimou os custos das internações hospitalares no Sistema Único de Saúde (SUS) associadas a doenças cardiorrespiratórias decorrentes da exposição ao Material Particulado fino (PM2,5) proveniente da queima de biomassa na Amazônia Legal e no Cerrado setentrional, entre 2010 e 2021. Trata-se de um estudo ecológico retrospectivo, no qual foram utilizados dados do Sistema de Informações Hospitalares do SUS e foi aplicada metodologia recomendada pela Organização Mundial da Saúde para cálculo de frações atribuíveis. Identificou-se um impacto financeiro médio anual de aproximadamente R$ 17,6 milhões. Os maiores custos foram registrados nos municípios do Arco do Desmatamento, onde a exposição à poluição atmosférica por queima de biomassa é mais intensa. Este estudo destacou os efeitos da degradação ambiental na saúde, orientando os decisores de políticas públicas para um desenvolvimento mais sustentável.*

PALAVRAS-CHAVE *Material particulado. Poluição do ar. Custos hospitalares. Doenças cardiorrespiratórias. Amazônia.*

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Introduction

Data from the National Institute for Space Research (INPE) Fire Program, available in the BDQueimadas database on the TerraBrasilis portal, show a high number of forest fires in the Amazon region in recent years. These fires, combined with environmental deregulation by the federal government, are likely to have serious consequences for the environment and Public Health.

Many heat sources have been detected in the region known as the Deforestation Arc, which includes the southern edge of the Brazilian Amazon, mainly from uncontrolled fires driven by human activities and extensive deforestation to expand agriculture and illegal logging[1,2]. According to ISA (Instituto Socioambiental) estimates from 2018, this area accounts for about 75% of the deforestation in the Amazon, highlighting the need for a comprehensive understanding of the socio-environmental impacts in the Amazon and Cerrado regions.

When instigators do not mitigate environmental degradation, negative externalities arise. These impose costs on third parties without compensation. As a result, economic activities may disregard environmental impacts, encouraging consumption patterns that do not reflect true costs. This results in a natural capital exploitation model where users benefit without bearing the costs, which fall on marginalized or excluded groups[3].

Biomass burning in the Legal Amazon and northern Cerrado regions emits substantial amounts of trace gases and aerosol particles into the atmosphere, affecting the regional climate, ecology, water cycle, and human activities[4]. These negative externalities result in direct costs, such as costs to agricultural production and forest resource losses, as well as broader societal externalities, including those related to CO2 emissions and human health impacts[5].

The Legal Amazon is an administrative region created by the Brazilian government. It aims to promote Amazonian socioeconomic development. The region covers Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia, Roraima, and Tocantins. It represents about 59% of the Brazilian territory and has an estimated population of 28 million inhabitants[6,7].

Numerous studies have highlighted the relationship between climatic seasonality and respiratory disease morbidity and mortality, particularly during drought periods in the Amazon region. These periods are associated with increased hospitalizations and deaths from respiratory conditions, exacerbated by heightened exposure to air pollutants from biomass burning[8–10]. However, there is a need for a deeper understanding of how deforestation and biomass burning affect human health, especially in showing the whole burden on the Public Health system. This is particularly important in a region that is already financially vulnerable and has limited access to essential healthcare services[11,12].

Environmental economic valuation aims to quantify, in monetary terms, the impacts that changes in natural resources impose on human well-being. This valuation is essential for integrating environmental costs into economic analyses, informing public policy, and supporting decision-making processes related to environmental conservation[13].

In the Amazon region, biomass burning results in substantial emissions of fine Particulate Matter (PM2.5), whose adverse effects on human health have been extensively documented in the scientific literature. It is estimated that exposure to PM2.5, combined with air pollution from the combustion of fuels for household heating and cooking, as well as ground-level ozone, contributes to approximately 40% of deaths from chronic obstructive pulmonary disease and up to 30% of cases of less severe respiratory infections[14]. However, the costs associated with these externalities, such as hospitalizations for cardiorespiratory diseases financed by the Brazilian Unified Health System (SUS),

are often not incorporated into conventional economic assessments.

Air quality affects cardiorespiratory health in the Legal Amazon and Northern Cerrado. Declining air quality, especially higher PM2.5, can worsen health among local populations. This leads to more disease and higher hospitalization costs for cardiopulmonary conditions. Recent evidence from the Brazilian Amazon finds that one standard deviation rise in PM2.5 causes a 1.5% increase in monthly hospitalizations for respiratory diseases[15].

A strong theoretical base is essential for estimating these costs using environmental economic valuation methods. This reveals the financial burden environmental degradation places on Public Health and supports more effective, equitable health and environmental policies.

Assessing the costs incurred by the SUS is crucial to enhancing the understanding of the biomass burning economic impacts through the valuation of these externalities. Comprehending these costs is essential for formulating public policies to reduce air pollution and mitigate its economic effects, and for advancing research on the impacts on Public Health and state expenditures.

This study aims to quantify the financial cost to the SUS from hospitalizations related to cardiorespiratory diseases caused by exposure to fine PM2.5 emitted by biomass burning in cities within the Legal Amazon and northern Cerrado regions from 2010 to 2021.

Material and methods

This study's methodology intends to assess the environmental valuation of hospitalization costs due to cardiorespiratory diseases related to air pollution exposure in the Legal Amazon and northern Cerrado regions.

This work applies environmental economic valuation using the substitute goods market method. Here, the health status variable Z is hard to measure directly. Substitute good variables help to estimate its value[3].

The theoretical foundation builds on the premise that hospitalization costs for cardiorespiratory diseases, as financed by the SUS, can serve as a proxy for valuing air quality. Thus, the health production function is specified as:

$$Z = F(X, E + S) \quad (1)$$

Where:

Z denotes the level of human health;

X is a vector of inputs composed of private goods and services;

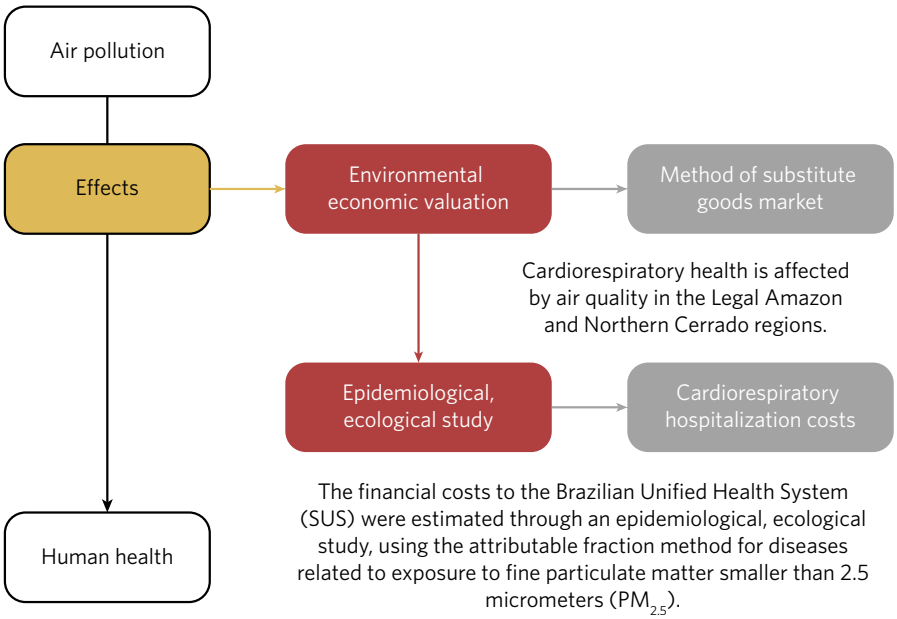
E refers to air quality;

S represents the number of hospitalizations due to cardiorespiratory conditions recorded by SUS.

This study estimated SUS financial costs through an ecological epidemiological study. It used the Attributable Fraction (AF) method for diseases linked to PM2.5 exposure. This approach provides a strong way to estimate the health impacts of air pollution[16].

Figure 1 shows the study's methodological framework for assessing air pollution's health impacts through economic valuation with the substitute-good markets approach. This analysis estimates hospitalization costs for cardiorespiratory diseases using an ecological epidemiological study.

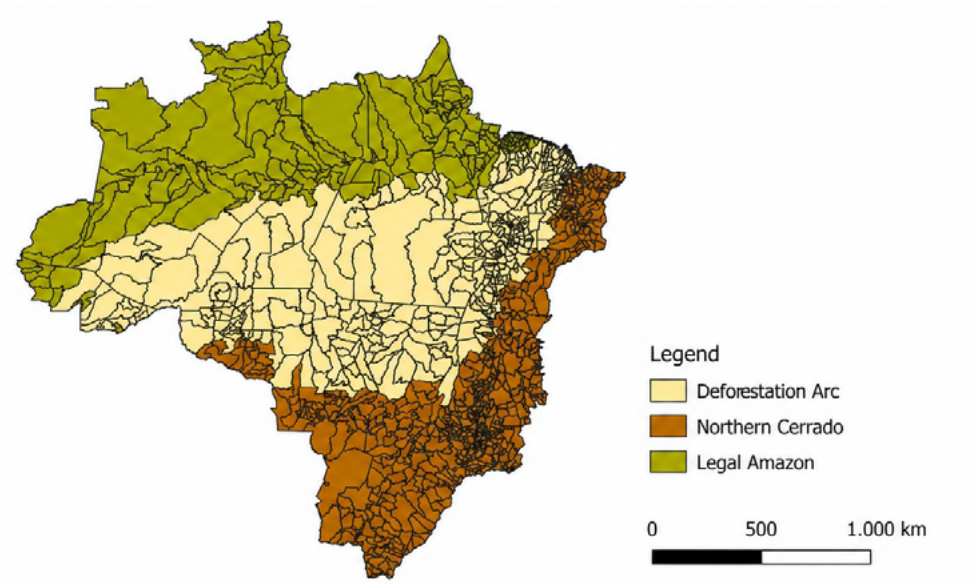
Figure 1. Methodological framework



Source: Prepared by the authors.

This study covers the Legal Amazon and northern Cerrado. It includes Acre, Amazonas, Amapá, the Federal District, Goiás, Maranhão, Mato Grosso, Mato Grosso do Sul, Pará, Rondônia, Roraima, and Tocantins. The study period is 2010 to 2021 (*figure 2*).

Figure 2. Groups of municipalities



Source: Prepared by the authors.

Data sources

Hospitalization data was retrieved from the Brazilian Hospital Information System (SIH). It is provided by the Department of Informatics of the Brazilian Unified Health System (DATASUS). The data analyzed were daily hospitalizations for cardiorespiratory diseases from SUS, covering all ages and those aged 30 and over.

Cardiorespiratory hospitalizations were classified under ICD-10 Chapters IX (I00-I99) and X (J00-J99)[17]. Data was sourced from the 'Microdatasus' Library in R (version 4.1.1)[18]. Daily hospitalization data were obtained and summed by year from 2010 to 2021, grouped by municipalities in the Legal Amazon and surrounding areas.

Data on PM2.5 exposure were sourced from the Copernicus Atmosphere Monitoring Service (CAMS Global Reanalysis). Daily air pollution data from 1,134 municipalities in the Legal Amazon and its surrounding areas were obtained, and then the annual averages from 2010 to 2021 were calculated.

Population data were extracted from the Ministry of Health/SVS/DASNT/CGIAE databases. The population of Brazilian municipalities was based on the Population Estimates Study by Municipality, Age, and Sex. It includes all ages and those over 30 in 1,134 municipalities of the Legal Amazon and surrounding areas from 2010 to 2021.

Attributable fraction calculation

Using the collected data, the AF of hospitalizations related to cardiorespiratory diseases attributable to PM2.5 exposure in the Legal Amazon and northern Cerrado regions was estimated.

The calculation was based on the method described by Ostro[16], developed as 'methodological guidance' for measuring the AF of diseases related to exposure to PM2.5. To calculate the number of hospitalizations related to PM2.5 exposure in a specific municipality, four assumptions defined by the methodology were used[16]:

1. Data on exposure to PM2.5, as indicated in the previous section 'Data Sources'.

2. The target population here is defined as adults aged 30 and over, as specified in the previous section 'Data Sources'.

3. Additionally, the methodology requires identifying the specific health outcomes studied, focusing on the ICD-10 chapters 'IX – Diseases of the Circulatory System' and 'X – Diseases of the Respiratory System'.

4. Concentration-Response functions (CR) derived from epidemiological literature. The CR function is used to estimate the magnitude and shape of the relationship between PM2.5 exposure and health impacts.

Based on these assumptions, the AF was calculated. It represents the proportion of cardiorespiratory hospitalization that can be attributed to PM2.5 exposure in the Legal Amazon and northern Cerrado regions.

For the calculation of the expected annual number of hospitalizations due to cardiorespiratory diseases attributed to chronic exposure to PM2.5, first, the relative risk for each of the 1,134 municipalities (i) was calculated according to equation (2):

$$RR_i = e^{CR * \Delta C_{PM_{2.5}i}} \quad (2)$$

Where:

$$CR = \frac{ln\ 1.06}{10} \quad (3)$$

$$\Delta C_{PM_{2.5}i} = \overline{PM_{2.5}}_i - 7.5$$

$$\Delta C_{PM_{2.5}i} \quad (4)$$

CR is the concentration-response function based on the literature[15] and $\Delta C_{PM_{2.5}i}$ is the variation between the municipality's annual average of PM2.5 and a baseline value of 7.5 ×g/m³. Finally, to calculate the annual AF for each municipality, equation (5) was used:

$$AF_i = \frac{RR_i - 1}{RR_i} \quad (5)$$

Additionally, to calculate the expected annual number of hospitalizations attributable to chronic exposure to PM2.5, the AF was applied to the total annual number of hospitalizations. So, for each year, the equation (6) was applied:

$$E_i = T_i * I_i * AF_i \quad (6)$$

Where:

Ei is the expected number of hospitalizations due to PM2.5 exposure in the municipality i;

Ii is the population incidence of cardiorespiratory disease in the municipality i (i.e., the hospitalization rate of the population over 30 for cardiorespiratory outcomes per thousand inhabitants);

Ti is the exposed population size of individuals aged 30 and over in the municipality i.

Calculation of hospitalization costs

Based on the AF of cardiorespiratory diseases caused by exposure to PM2.5 in the Legal Amazon and northern Cerrado regions, the costs to the SUS were calculated. Data on the number of hospitalizations due to cardiorespiratory outcomes at the SUS, the total amount paid for these hospitalizations based on Hospitalization Authorizations (AIHs), and the patients' length of stay were considered. The costs were obtained by multiplying the annual total of amounts paid for hospitalizations (V) by the AF:

$$E_i = T_i * I_i * AF_i \quad (7)$$

As a result, the hospitalization costs were verified at current prices. The Implicit GDP Deflator[19], an index that measures the average annual variation in the Brazilian Gross Domestic Product (GDP), was adopted to compile the costs for analysis at constant 2021 prices. The annual hospitalization costs, expressed in constant prices (VFA), were updated by multiplying them by the corresponding Implicit GDP Deflator (D):

$$DV_i = VFA_i * D_i \quad (8)$$

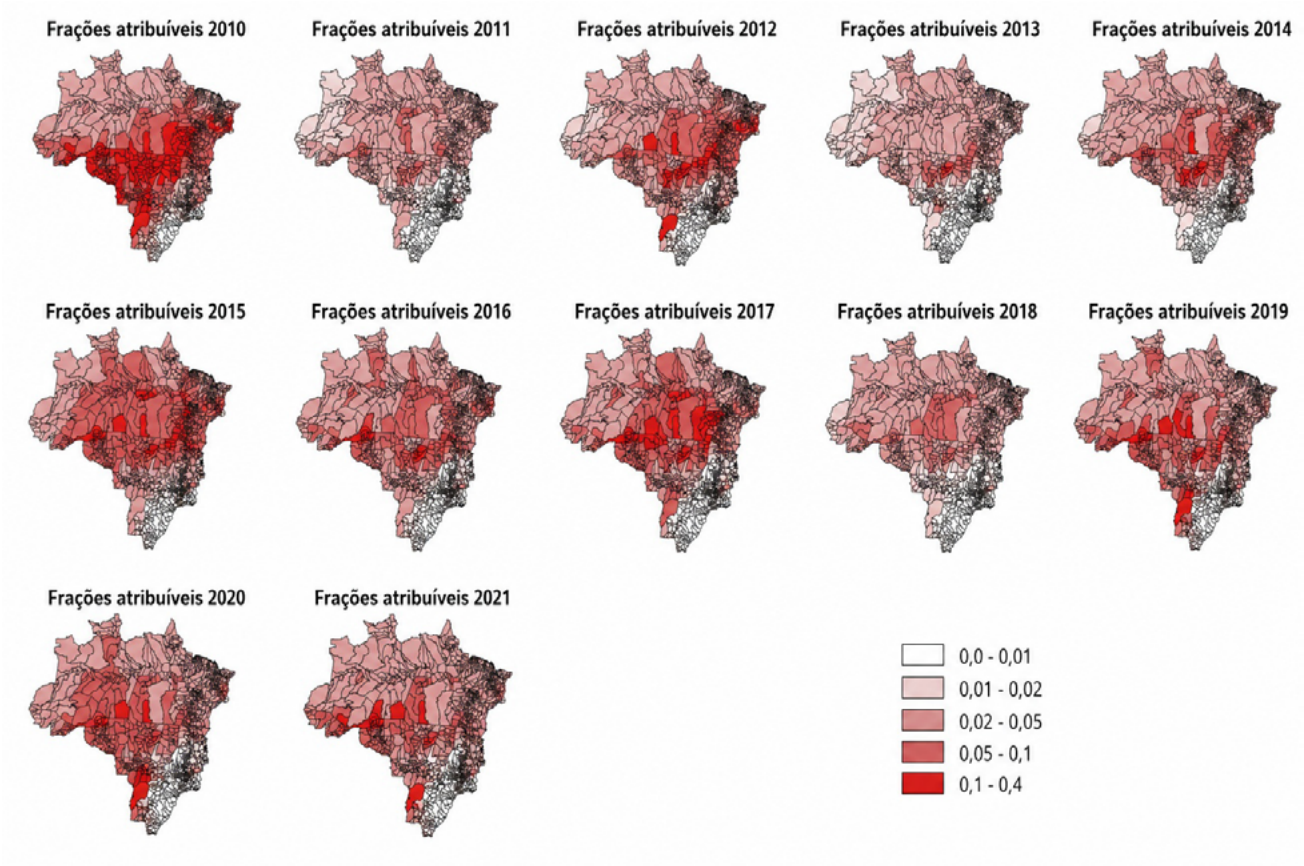
Results

Using the described methodology, we obtained AFs and estimates of hospitalization costs associated with exposure to fine PM2.5 in the Amazon region, at current prices, for all 1,134 municipalities analyzed.

Attributable fractions analysis

In 2010, the highest AFs in the entire series were recorded, with 18.5% of municipalities showing percentages above 10%. These municipalities were primarily located within the 'Deforestation Arc'. Notably, 211 municipalities had AFs of 10% or more, distributed across the states of Mato Grosso, Pará, Tocantins, Rondônia, Acre, Maranhão, Mato Grosso do Sul, and Amazonas. The municipalities with the highest AFs were Vila Rica/MT with 35%, Santana do Araguaia (PA) with 34.9%, Confresa/MT with 33.5%, Porto Alegre do Norte/MT with 32.9%, and Canabrava do Norte/MT with 32% (*figure 3*).

Figure 3. Proportion of Attributable Fractions of Hospitalizations for Cardiorespiratory Diseases Caused by Exposure to PM2.5 in the Amazon Region by State within the Legal Amazon and Cerrado from 2010 to 2021



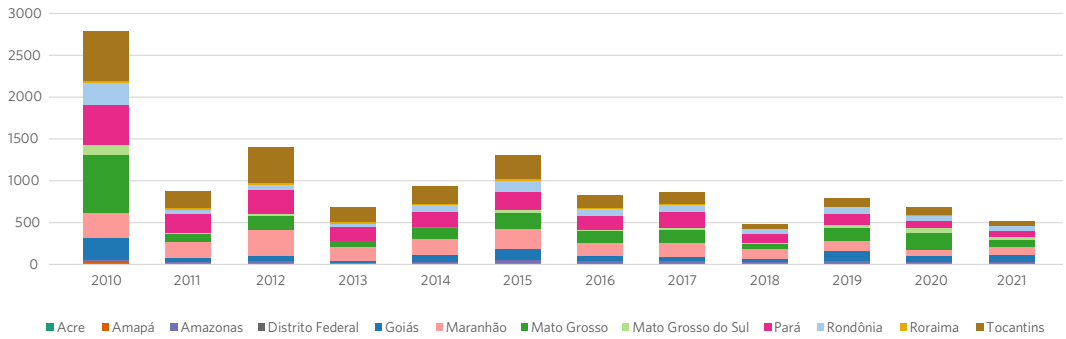
Source: Prepared by the authors.

Additionally, the number of hospitalizations due to cardiorespiratory diseases attributable to PM2.5 exposure was analyzed by state. In 2010, the highest number of fire outbreaks and exposure to PM2.5 occurred, resulting in the highest number of attributable hospitalizations in the Legal Amazon and northern Cerrado regions.

Analysis of the cost to SUS

Regarding the costs of hospitalizations due to cardiorespiratory disease attributable to PM2.5 exposure (*graph 1*), we should underscore that 2010 had higher values than other years, mainly due to elevated costs in the states of Pará, Mato Grosso, and Mato Grosso do Sul. Additionally, throughout the analyzed period, the state of Pará consistently ranked among the states with the highest costs attributable to PM2.5 exposure.

Graph 1. Attributable per capita value for hospitalizations due to cardiorespiratory diseases (ICD-10 chapters IX and X) caused by PM2.5 exposure for populations over 30, at 2021 constant prices, 2010-2021



Source: Prepared by the authors.

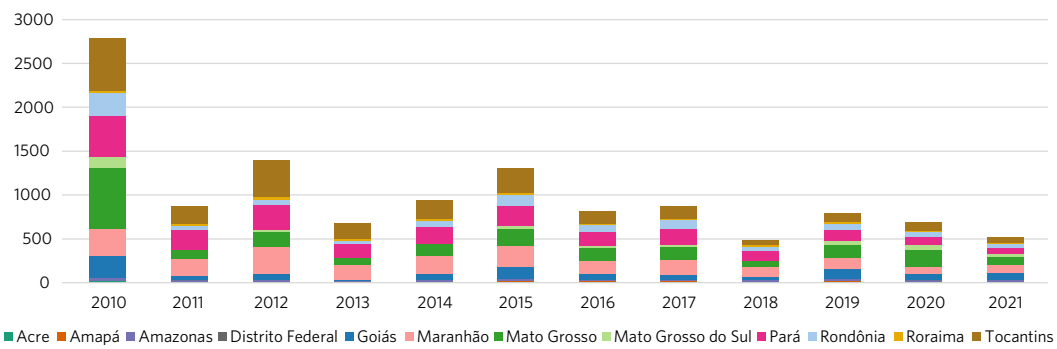
Subsequently, fluctuations in attributable hospitalization costs persisted through 2015, followed by a decline in costs associated with PM2.5 exposure in the region. However, a new rise was observed in 2019, closely linked to the increase in forest fires that year.

Although 2020 and 2021 showed a decrease in the total attributable costs of the analyzed states, we observed an increase in attributable costs in Mato Grosso in 2020, as well as successive increases in 2018, 2019, and 2021 for the Federal District (*graph 1*).

There is a strong connection between the Deforestation Arc region and total costs, with a high concentration of municipalities among those with the highest total costs attributable to PM2.5 exposure. The state of Pará had the highest total cost during the period, accounting for about 27% of hospitalizations related to cardiorespiratory outcomes caused by PM2.5 exposure from 2010 to 2021.

The municipality of Porto Velho/RO, located in the Deforestation Arc, stands out as one of the 10 municipalities with the highest total cost in the historical series, recording the highest comparative cost among municipalities in 2017. In terms of per capita attributable costs by state, we observed a similar trend to the total attributable values, with the highest per capita values reported in Tocantins, followed by Mato Grosso (*graph 2*).

Graph 2. Attributable per capita value for hospitalizations due to cardiorespiratory diseases (ICD-10 chapters IX and X) caused by PM2.5 exposure for populations over 30, at 2021 constant prices, 2010-2021



Source: Prepared by the authors.

Discussion

The analysis revealed a significant number of hospitalizations for cardiorespiratory diseases attributable to exposure to PM2.5, primarily originating from biomass burning in the Legal Amazon. Significant AFs were also identified across all states within the region throughout the study period. Additionally, the number of hospitalizations attributable to PM2.5 exposure increased significantly during periods and in areas with higher fire incidence, highlighting the strong association between biomass burning and adverse health outcomes in these regions, as well as the increased financial cost to the Public Health system.

In 2010, the cost of attributable hospitalizations amounted to approximately BRL 37.5 million, with the highest figures in Mato Grosso (BRL 9.3 million), followed by Pará (BRL 8.6 million). In 2011, we observed a significant reduction in heat-related sources, in air pollution from PM2.5, and in hospitalizations due to cardiorespiratory causes. Consequently, there was a notable decrease in costs to the SUS attributed to pollution exposure, with the highest costs being in the state of Pará (BRL 5.2 million), reflecting the financial impact on SUS stemming from biomass burning in the Legal Amazon and northern Cerrado.

Latorre[20] highlights an intense anomaly in rainfall patterns in 2010, influenced by El Niño, which, together with an increase in sea surface temperatures in the North Atlantic Ocean, led to a rise in temperatures in the Amazon region. This event is identified as a potential intensifier of wildfire impacts in the region.

Notably, in 2010 and 2011, the impacts were limited in the states of Amazonas and Roraima. However, from 2012 onwards, the effects of biomass burning exposure expanded in the state of Amazonas. Over the following years, this spread extended to other municipalities in Amazonas, and by 2015, it had also reached the state of Roraima. This geographic expansion of health impacts aligns with the increasing frequency of wildfires in these regions, underscoring the need for sustained monitoring and intervention to mitigate environmental degradation and its associated Public Health burdens.

According to data from the INPE, in 2017, Brazil recorded the highest number of wildfires since the beginning of INPE's historical series in 1999, with the Amazon biome suffering the greatest share of total hectares destroyed[21]. The Cerrado biome, which accounted for the second-largest area impacted, also recorded the highest occurrence of fire hotspots within federal conservation units, reflecting the increase in the number of hospitalizations attributable to PM2.5 exposure that year.

In 2018, approximately 8% more deforested areas were observed in the Legal Amazon region compared to the previous year, alongside a 39% reduction in the number of fire hotspots. In 2019, we observed a sharp rise in the deforested area, with a 34% increase compared to the previous year. The number of fires also rose, with a 39% increase in hotspots compared to the previous year[22,23].

A particular event occurred on August 10, 2019, known as the 'Day of Fire', when a series of coordinated forest fires was initiated in the Novo Progresso region (PA), leading to an estimated 300% increase in fire outbreaks in a single day. This event severely impacted air quality across various Brazilian states, even reaching states such as São Paulo, located nearly 2,000 kilometers away[24].

The high number of hotspots in the Legal Amazon region in 2019 can be associated with the same level of attributable hospitalizations as in 2017, with a 48% increase compared to the previous year. Total attributable costs also rose by about 50% when compared to 2018. The state of Pará had the highest attributable cost (BRL 3.7 million), followed by Rondônia (BRL 2.17 million) and Mato Grosso (BRL 2.15 million).

As previously noted, the deforested area in the Legal Amazon showed an upward trend

from 2019 onwards, with a 7.1% increase in deforested areas and a 20% rise in the number of fire outbreaks that year. In 2020, there was a 26% reduction in hospitalizations attributable to air pollution from biomass burning in the Legal Amazon and northern Cerrado compared to the previous year.

However, 2020 also witnessed large-scale forest fires in the Pantanal biome, which likely contributed to the increased hospital costs in Mato Grosso. More than 3,500 fire outbreaks were identified, representing an over 300% increase compared to the 2012-2019 period, devastating about one-third of the biome's territory[25,26].

In 2020, the World Health Organization (WHO) declared the coronavirus outbreak a Public Health Emergency of International Concern (PHEIC), and in March 2020, it was classified as a pandemic. As a result of COVID-19, cases of severe acute respiratory syndrome were detected, with around 7.6 million cases diagnosed in 2020[27,28].

A 2023 study identified a correlation between air pollution from particulate matter and the incidence, mortality, and severity of COVID-19 in five states of the Brazilian Amazon. The study explored the possibility that particulate matter produced by forest fires nearly doubled the risk of infection, death, and COVID-19 severity among individuals exposed to high concentrations of PM2.5[29].

Notably, this study used hospitalization data from the SUS, which may reflect distortions caused by the difficulty in diagnosing respiratory diseases due to COVID-19, which began in 2020[30].

In 2021, we observed a significant increase in deforested areas in the Legal Amazon, with approximately 20% more vegetation loss than in the previous year, while the number of fire outbreaks fell by about 32% compared to 2020. In conclusion, biomass burning in the Legal Amazon region has a significant social and economic impact on the municipalities analyzed. The results presented align with the studies referenced in this work, underscoring the importance of addressing this Public Health issue.

The restraint of illegal deforestation depends directly on the enforcement capacity of public entities, with the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) serving as the primary agent. In this regard, the institution's environmental enforcement efforts require allocating financial resources for various purposes. However, we should underscore that, in recent years, IBAMA's budget has been constrained due to fiscal restrictions under the Temer government, driven by the economic recession, and later by severe budget cuts to fire prevention and firefighting under the Bolsonaro government[31,32].

Historically, the Deforestation Arc has experienced high deforestation rates, requiring targeted enforcement and control measures from the Brazilian government. In recent years, the radius of devastation has expanded into new municipalities, prompting a reassessment of the territory in 2019[33,34].

This progressive devastation strongly interacts with Public Health and well-being indicators. The findings of this study reveal that exposure to particulate matter from biomass burning in the Legal Amazon and its surroundings has a significant impact on the number of hospitalizations for cardiorespiratory diseases in the region.

We collected hospitalization data for cardiorespiratory causes for the resident population of the Legal Amazon and northern Cerrado to analyze the impacts of air pollution from biomass burning on human health. For this purpose, we employed secondary data provided by the DATASUS. Notably, many Brazilian municipalities lack sufficient infrastructure within the SUS to treat cardiorespiratory diseases, which leads the population to migrate to municipalities with better Public Health infrastructure. Therefore, this study's analysis was conducted based on the municipality of residence rather than the hospitalization location.

Morbidity due to cardiorespiratory conditions increases the demand for care within SUS networks, with a greater impact on municipalities with fewer health facilities. This can also affect the treatment of other diseases and place additional strain on the overall health system.

Biomass burning can have unequal effects on affected communities, especially regarding the availability of health resources. Budget cuts further reduce the availability and quality of public services, exacerbating the impacts on those who depend on the Public Health network[35].

Environmental economic valuation aims to assess the impacts that changes in natural resources monetarily have on human well-being through specific indicators[36]. We should highlight, however, that the methodology employed in this work likely underestimates the total health-related costs of exposure to particulate matter, as it considers only hospitalization expenses covered by the SUS due to cardiorespiratory conditions. This analysis did not include other significant costs, such as productivity losses resulting from impaired health.

One limitation of this study is the inability to distinguish pollutants within fine particulate matter smaller than 2.5 micrometers. It is widely known that the largest source of aerosol emissions in South America's atmosphere derives from forest and savanna fires, especially during the dry season between August and October[37]. However, the analysis cannot disregard the impact of other pollutants on human health, particularly in more urbanized areas. Thus, a deeper understanding of pollutant distribution allows for a more refined comprehension of the impacts of biomass burning in the region.

Another significant limitation concerns the use of secondary data from the DATASUS to analyze hospitalizations due to cardiorespiratory causes. These data may reflect underreporting, as the use of secondary data depends on the quality of information recorded within the various SUS health facilities. Our approach did not include results or discussion of the cumulative effects of long-term exposure, particularly in vulnerable populations. It is linked to chronic respiratory diseases, stunted lung growth, and increased prevalence and severity of conditions like asthma, as presented by the Brazilian Ministry of Health[38].

Additionally, we should recognize that limitations in differentiating specific causes might be particularly relevant from 2020 onward due to the COVID-19 pandemic. Nevertheless, it is important to stress that the data used allow for extensive territorial coverage from a unified database, following consistent parameters for AIHs.

Lastly, we should mention that the Ostro methodology was developed to calculate the number of deaths attributable to exposure to airborne particulate matter with particles smaller than 10 micrometers or 2.5 micrometers and has been adapted for this study. However, the complex interactions among environmental, health, and social variables suggests the need for continued, targeted studies on the topic, particularly through epidemiological research and analyses of the region's socioenvironmental dynamics.

The study also reflects the outcomes of discussions between Brazilian academia and the Pan American Health Organization, contributing to the development of an integrated framework and to the use of recognized methodologies. As a result, the work expands the literature on environmental valuation by integrating health and environmental perspectives, introducing new discussions on the subject.

Thus, our analysis offers deeper insights into the costs of biomass burning in the Legal Amazon and northern Cerrado regions, focusing on Public Health costs associated with hospitalizations due to cardiorespiratory diseases in SUS facilities.

In conclusion, there was a substantial impact of exposure to PM2.5 resulting from biomass burning in the Legal Amazon and northern Cerrado regions on hospitalization

rates for cardiorespiratory diseases, representing an average annual cost of approximately 2.5 billion reais to the SUS.

Additionally, a direct relationship was observed between the increase in deforested areas and the occurrence of hotspots, contributing to a significant rise in hospitalization costs during years of greater intensity of these events, such as in 2010 and 2019.

Therefore, our proposed cost analysis of hospitalizations may help to gauge the effects of environmental degradation, guiding public policy decision-makers towards a more sustainable development.

Ensuring the right to clean air requires more than the development of technical tools and the generation of data; it necessitates a robust legal and institutional framework. In 2024, Brazil enacted its National Policy for Air Quality (PNQA) and formally established national air quality standards aligned with the World Health Organization guidelines, through a national resolution[39,40].

This study emphasizes the need for public policies related to environmental management, land use planning, and health surveillance to work together in a coordinated way, fostering prevention, monitoring, and response strategies for risks caused by vegetation loss and poor air quality. Only effective coordination between health and the environment can support government actions that protect life and promote long-term sustainability.

Authorship contributions

Correa MGC (0000-0003-2965-7228)* contributed to data analysis and interpretation, manuscript drafting, final approval of the version to be published, and responsibility for all aspects of the work in ensuring the accuracy and integrity of any part of the study. Ignotti E (0000-0002-9743-1856)* contributed to study conception and design, critical revision of the entire manuscript, final approval of the version to be published, and responsibility for all aspects of the work in ensuring the accuracy and integrity of any part of the study. Oliveira BFA (0000-0003-0103-3309)* contributed to study conception and design, critical revision of the entire manuscript, final approval of the version to be published, and accountability for all aspects of the work, ensuring the accuracy and integrity of any part of the study. Jacobson LSV (0000-0002-6698-4431)* contributed to study conception and design, critical revision of the entire manuscript, final approval of the version to be published, and responsibility for all aspects of the work in ensuring the accuracy and integrity of any part of the study. Young CEF (0000-0002-4225-4936)* contributed to Study conception and design, critical revision of the entire manuscript, final approval of the version to be published, and responsibility for all aspects of the work in ensuring the accuracy and integrity of any part of the study.■

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