INFLUENCE OF RAINFALL AND RELATIVE HUMIDITY ON MORTALITY FROM RESPIRATORY DISEASES: A CASE STUDY FOR THE MUNICIPALITY OF SÃO LUÍS – MA

INFLUÊNCIA DO ÍNDICE PLUVIOMÉTRICO E DA UMIDADE RELATIVA NA MORTALIDADE POR DOENÇAS RESPIRATÓRIAS: UM ESTUDO DE CASO PARA O MUNICÍPIO DE SÃO LUÍS – MA

INFLUENCIA DE LAS PRECIPITACIONES Y LA HUMEDAD RELATIVA EN LA MORTALIDAD POR ENFERMEDADES RESPIRATORIAS: UN ESTUDIO DE CASO PARA EL MUNICIPIO DE SÃO LUÍS – MA

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ABSTRACT

This study aims to analyze the influence of rainfall and relative humidity on mortality from respiratory diseases in São Luís, Maranhão, between July 2021 and June 2024. The research is based on concepts from biometeorology and research on the effects of climate change on public health, which indicate that atmospheric variables can aggravate respiratory diseases in vulnerable groups. This is an exploratory quantitative study based on data on deaths from Respiratory Tract Diseases obtained from the Death Verification Service (SVO), correlated with meteorological information from the Maranhão State University Station. Statistical analysis was performed using Pearson's correlation and polynomial adjustment. The results reveal no statistically significant association between climate variables and mortality in the general population. However, when specifically focusing on the elderly population (60+), a direct correlation was identified between these climate variables and the increase in deaths. The research reinforces the importance of integrating meteorological data and public health policies, especially during seasonal transitions. This research, with its intersectional approach to climate and urban health, contributes to public policy and prevention strategies.

Keywords: Respiratory Diseases. Relative Humidity. Rainfall. Public Health. Biometeorology.

RESUMO

Este estudo tem como objetivo analisar a influência da precipitação pluviométrica e da umidade relativa do ar na mortalidade por doenças respiratórias em São Luís (MA), entre julho de 2021 e junho de 2024. A pesquisa fundamenta-se em conceitos da biometeorologia e investigações sobre os efeitos das mudanças climáticas na saúde coletiva, os quais

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indicam que variáveis atmosféricas podem agravar doenças respiratórias em grupos vulneráveis. Trata-se de um estudo quantitativo exploratório, baseado em dados de óbitos por Doenças do Aparelho Respiratório obtidos junto ao Serviço de Verificação de Óbitos (SVO), correlacionados com informações meteorológicas da Estação da Universidade Estadual do Maranhão. A análise estatística foi realizada por meio da correlação de Pearson e ajuste polinomial. Os resultados revelam ausência de associação estatística significativa entre as variáveis climáticas e a mortalidade na população geral. Contudo, ao realizar um recorte específico para a população idosa (60+), foi identificada uma correlação direta entre essas variáveis climáticas e o aumento de óbitos. A investigação reforça a importância da integração entre dados meteorológicos e políticas públicas de saúde, especialmente nos períodos de transição sazonal. A pesquisa com abordagem interseccional entre clima e saúde urbana, contribui com subsídios para políticas públicas e estratégias de prevenção.

Palavras-chave: Doenças Respiratórias. Umidade Relativa. Índice Pluviométrico. Saúde Pública. Biometeorologia.

RESUMEN

Este estudio tiene como objetivo analizar la influencia de las precipitaciones y la humedad relativa en la mortalidad por enfermedades respiratorias en São Luís, Maranhão, entre julio de 2021 y junio de 2024. La investigación se basa en conceptos de biometeorología e investigaciones sobre los efectos del cambio climático en la salud pública, que indican que las variables atmosféricas pueden agravar las enfermedades respiratorias en grupos vulnerables. Se trata de un estudio cuantitativo exploratorio basado en datos sobre muertes por Enfermedades del Tracto Respiratorio obtenidos del Servicio de Verificación de Muertes (SVO), correlacionados con información meteorológica de la Estación de la Universidad Estatal de Maranhão. El análisis estadístico se realizó mediante correlación de Pearson y ajuste polinomial. Los resultados no revelan una asociación estadísticamente significativa entre las variables climáticas y la mortalidad en la población general. Sin embargo, al centrarse específicamente en la población de edad avanzada (60+), se identificó una correlación directa entre estas variables climáticas y el aumento de muertes. La investigación refuerza la importancia de integrar los datos meteorológicos y las políticas de salud pública, especialmente durante las transiciones estacionales. Esta investigación, con su enfoque interseccional sobre el clima y la salud urbana, contribuye a las políticas públicas y las estrategias de prevención.

Palabras clave: Enfermedades Respiratorias. Humedad Relativa. Precipitaciones. Salud Pública. Biometeorología.

1 INTRODUCTION

The impact of climate change has become increasingly evident, with extreme phenomena such as floods, droughts, and heat waves affecting populations around the world. As a result, the climate debate has gained increasing importance in public policy agendas and in the current social agenda.

The alternation of weather conditions and weather patterns has an impact on environmental dynamics and human physiology. According to Cirrus (2010), biometeorology studies how atmospheric conditions directly and indirectly affect humans and other organisms. According to Tromp (1979), human biometeorology studies the interactions between meteorological factors and the human body, investigating how factors such as temperature, humidity, atmospheric pressure and air pollution affect the human body.

Climate variations, among other factors, can lead to the manifestation of certain diseases, due to characteristics such as temperature, relative humidity, precipitation, atmospheric pressure and winds, which interfere with people's well-being (PAHO, 2008).

Climate change is causing an increase in floods, storms, droughts, and changes in temperature and, consequently, increasing exposure to contaminants, also resulting in respiratory problems (BRASIL, 2024). Diseases of the respiratory system, between 2013 and 2017, are the second leading reason for hospital admissions in Brazil, with a total of 5,928,712 hospitalizations for this period (ALEXANDRINO et al., 2022).

According to the Government of the State of Maranhão (2025), in 2024, Maranhão recorded 2,902 cases of Severe Acute Respiratory Syndrome (SARS), with emphasis on the region of São Luís, with 648 cases. By May 2025, Maranhão has already registered, this year, 1,776 cases of Severe Acute Respiratory Syndrome (SARS), with 100 confirmed deaths (G1 MA, 2025).

In urban areas, the effects of air pollution are especially intensified among the most vulnerable groups, which include children under five years of age and individuals over 65 years of age, especially when climate change occurs, especially thermal inversions (PAHO, 2018). Thus, it is necessary to carry out studies that address the effects of climate variations on the health of the population.

According to infectious disease doctor Antônio Augusto, in an interview with G1 MA (2025), the peaks of Severe Acute Respiratory Syndrome (SARS) are recorded seasonally, mainly between the months of March and May. This period corresponds to the heaviest rainy season in the state of Maranhão, which increases the risk of developing pneumonia.

Through this research, the objective is to analyze the relationship between the rainfall index and relative humidity with morbidity resulting from Respiratory System Diseases (RSD), for the period between July 2021 and June 2024, in the municipality of São Luís - MA.

2 THEORETICAL FRAMEWORK

The relationship between climate and public health has attracted increasing attention in scientific production, especially in view of the impacts of climate change on vulnerable populations. Environmental and social factors combine to define health risks, and it is essential to understand how atmospheric variables, such as humidity and precipitation, influence the Tables of respiratory diseases (NASCIMENTO and BERALDO, 2024).

According to the United Nations, climate change refers to statistically significant variations in precipitation patterns, temperature, winds, and other meteorological phenomena over an extended period (UNITED NATIONS, 2024). These changes are mostly attributed to anthropogenic activities, especially the emission of greenhouse gases (GHG). Among the impacts observed are the increase in the average global temperature, the melting of the polar ice caps, the rise in sea level, and the intensification of extreme weather events and natural disasters, with significant consequences on ecosystems, biodiversity, cultures, and societies (IPCC, 2023).

In the urban context, the Intergovernmental Panel on Climate Change (IPCC, 2023) highlights the negative impacts on human health, livelihoods, infrastructure, food and water security. There is an increase in the incidence of diarrheal and vector-borne diseases, worsening of respiratory diseases associated with air pollution, in addition to a greater occurrence of conflicts, injuries and deaths resulting from exposure to extreme weather conditions, such as droughts and heat waves. These impacts tend to be more intense among vulnerable groups considering initial and final age groups (children and the elderly, respectively) and socially marginalized populations.

Climate change can have an impact on human health in different ways. On a direct level, they include events such as heat waves, floods, and hurricanes. Indirectly, they promote changes in ecosystems and biogeochemical cycles, which can favor the incidence of infectious diseases, but also of non-communicable conditions, such as malnutrition and mental disorders (PAHO, 2018).

In consonance, Confalonieri (2005) argues that the impacts of the climate crisis go beyond the environmental field, profoundly affecting public health. The author emphasizes that changes in temperature and precipitation patterns have been associated with the intensification of respiratory, infectious, and cardiovascular diseases, requiring intersectoral approaches in public policy planning.

The empirical literature points to several studies that show the effects of variables such as relative humidity and precipitation on respiratory diseases. In Presidente Prudente (SP), Grosso de Souza and Lima Sant'Anna Neto (2008) observed that periods with humidity below 60% were correlated with peaks in hospitalizations for respiratory problems, indicating that "atmospheric weather oscillations cause or aggravate a tangle of symptoms and diseases". Vasconcelos *et al.* (2011) also demonstrated that high humidity, combined with poor air quality, contributes to the worsening of asthma and bronchitis tables, especially in urban environments.

Given the multiplicity of effects caused by climate change on human health, it is essential to integrate scientific evidence into the development of resilient and intersectoral public policies. It is necessary to strengthen prevention and adaptation actions, prioritizing the most vulnerable groups and promoting healthier and more sustainable urban environments.

3 METHODOLOGY

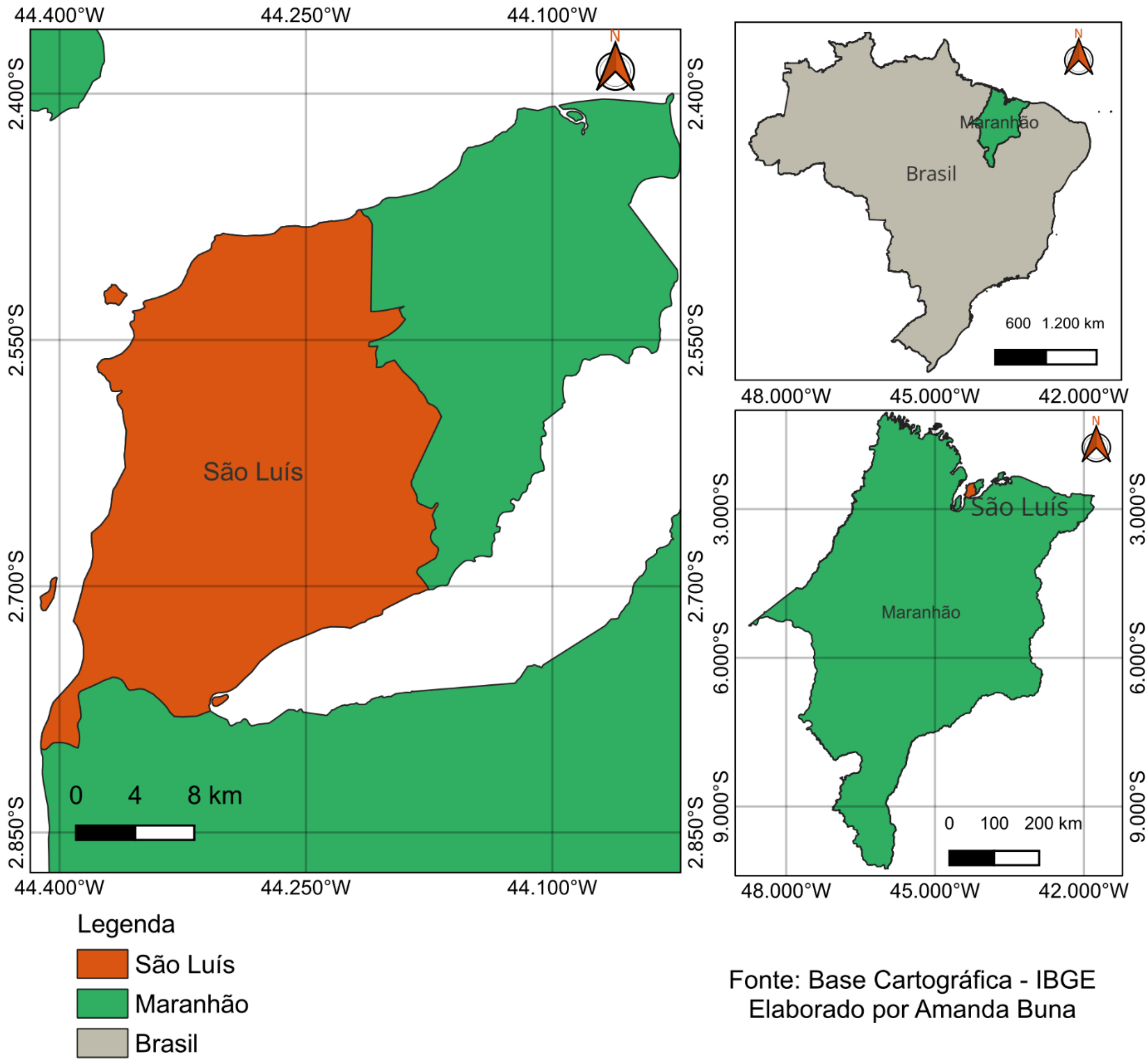
3.1 FIELD OF STUDY

The research was carried out in the municipality of São Luís, capital of the state of Maranhão, located in the Northeast Region. The city is located in the western portion of the island of São Luís, with geographic coordinates 02°28.21" and 02°39.34", south latitude and 44°07.49" and 44°20'59" west longitude. It is bordered to the north by the Atlantic Ocean, to the east by the city of São José de Ribamar, to the west by the Bay of São Marcos and to the south by the Mosquito Strait.

São Luís occupies about 57% of the total area of the island of São Luís, while the rest of the territory is shared by the municipalities of São José de Ribamar, Paço do Lumiar and Raposa, which are part of the Metropolitan Region of São Luís (SÃO LUÍS, 2011), as shown in Figure 1.

Figure 1

Location map of the study area: São Luís - MA



Source: Authors (2025).

Based on information from the last IBGE Demographic Census (2022), São Luís had a population of 1,037,775 inhabitants, with a demographic density of 1,779.87 inhabitants/km² (inhabitants per square kilometer). The municipality is located in the North Maranhense mesoregion and in the Urban Agglomeration of São Luís microregion, covering a territorial area of 583,063 km² (IBGE, 2022).

According to the IBGE climate classification (2002), the climate of São Luís - MA is of the Tropical Hot Equatorial Zone type, with an average temperature above 18ºC during all months of the year and with a semi-humid water regime, with 4 to 5 dry months. According to information from the National Environmental Data Organization System (SONDA, 2019), the climate is influenced by its proximity to the Intertropical Convergence Zone (ITCZ), with a rainy season that occurs from January to June and a dry season from July to December.

The city has a high annual rainfall, with significant variations in monthly totals. The peak of precipitation occurs in April, with values that reach approximately 475mm, while the months of July to December register low indexes, with values between 0mm and 50mm (SONDA, 2019).

According to this same agency, the minimum relative humidity reaches its maximum value in April, around 90%, and, from July to December, in the dry season, the relative humidity of the air presents its minimum. The average annual temperature is around 26°C, with a monthly minimum close to 22°C in July and a maximum close to 31°C in November.

3.2 METHODOLOGICAL PROCEDURES

3.2.1 Mortality data

The sample universe was characterized based on data from death records available at a public health institution – Death Verification Service (SVO) – and was stratified according to the variables of interest. The target population was composed of individuals who had deaths related to respiratory diseases (pneumonia, bronchopneumonia, lung disease, and tuberculosis) in the city of São Luís, MA.

Monthly information on mortality from respiratory diseases between July 2021 and June 2024 was analyzed, considering variables such as age, sex, and place of death.

3.2.2 Meteorological Data

In this research, two meteorological variables were analyzed: rainfall (mm) and relative humidity (%). The data were obtained from the Meteorological Station of the State University of Maranhão, whose Data Collection Platform is installed in the municipality of São Luís – MA, at the geographic coordinates 2º35' S and 44º12' W, with 62m and identified by the code ID 32003.

The historical series used comprises the period from July 2021 to June 2024, considering the values of maximum precipitation and minimum relative humidity. The choice of this time interval is in line with the records of deaths from respiratory diseases included in the survey. To ensure statistical consistency and due to the need to use data referring to the full water year, the months with missing data (NaN), corresponding to the beginning of 2021

(January to June) and the second half of 2024 (July to December), were disregarded, totaling a period with 3 full water years, from July 2021 to June 2024.

3.2.3 Data Analysis

The data were treated with descriptive, quantitative and exploratory statistical techniques, with the objective of analyzing the relationship between deaths from respiratory diseases and the meteorological variables addressed in the research.

For tabulation, organization and processing of data, *Microsoft Excel software* was used. Using the same program, the sum of rainfall and average relative humidity was calculated for the months under study. This information was organized in graphs and tables, in order to allow a detailed visualization of the data over the months analyzed.

Subsequently, statistical correlation analysis was performed in order to identify the degree of association between meteorological variables and death records. For this, Pearson's correlation (R) and coefficient of determination (R^2) were applied using the *Microsoft Excel software,* according to formula (1):

$$\boldsymbol{r} = \frac{\boldsymbol{n} \times \sum_{i=1}^{n} \boldsymbol{x_i} \times \boldsymbol{y_i} - \sum_{i=1}^{n} \boldsymbol{x_i} \times \sum_{i=1}^{n} \boldsymbol{y_i}}{\sqrt{\boldsymbol{n} \times \sum_{i=1}^{n} \boldsymbol{x_i^2} - \left(\sum_{i=1}^{n} \boldsymbol{x_i}\right)^2} \times \sqrt{\boldsymbol{n} \times \sum_{i=1}^{n} \boldsymbol{y_i^2} - \left(\sum_{i=1}^{n} \boldsymbol{y_i}\right)^2}} \qquad (\mathbf{1})$$

Where:

R: linear correlation coefficient for a sample;
N: number of data pairs;
X: independent variables;
Y: dependent variable.

Although widely used, the interpretation of correlation coefficients does not have universal consensus. What is observed in the literature are guiding recommendations, which may vary according to the context of the research and the nature of the data. For this study, the classification criteria proposed by Rumsey (2023), presented in Table 1, were adopted

Table 1

Pearson's correlation coefficient classification (r)

r	Classification

Exactly -1	**Perfect Downward Linear Ratio (Negative)**
-0,70	**strong downward linear ratio (negative)**
-0,50	**moderate (negative) linear downward relationship**
-0,30	**Weak Linear Downward Ratio (Negative)**
0	**absence of linear relationship**
+0,30	**weak upward linear ratio (positive)**
+0,50	**moderate upward linear ratio (positive)**
+0,70	**strong upward linear ratio (positive)**
Exactly +1	**Perfect Upward Linear Ratio (Positive)**

Source: Adapted by the authors (2025).

4 RESULTS AND DISCUSSION

4.1 PRECIPITATION AND MINIMUM RELATIVE HUMIDITY DATA

Analysis of precipitation and minimum relative humidity data between July 2021 and June 2024 revealed well-defined seasonal patterns, with important implications for public health.

The rainfall regime shows a concentration of intense rainfall in the first months of the year, especially between February and April, highlighting the peaks of March 2023 (577.8 mm) and February 2024 (488 mm). In the period from July to December, there was a sharp reduction in rainfall, with minimum values recorded in September 2023 (0.2 mm) and September 2021 (3.91 mm), as shown in Table 2.

Table 2

Precipitation Data (July/2021 to June/2024)

Month	2021	2022	2023	2024
January	Nan	183,4	370,2	259,4
February	Nan	262,1	258,4	488
March	Nan	327	577,8	460,2
April	Nan	276,8	461,4	289,6
May	Nan	239,4	210,8	255,26
June	Nan	142,2	213,6	148,51
July	132,6	153,2	89,6	Nan
August	18,40	73	17,4	Nan
September	3,91	10,4	0,2	Nan
October	7,78	7,78	7,78	Nan
November	16,56	49	16,56	Nan
December	44,54	116	16,8	Nan

Source: Authors (2025).

These oscillations can directly influence health indicators. Intense and concentrated precipitation can cause floods, putting pressure on drainage systems and hospital infrastructure. In addition, during the rainy season, there is an increase in the relative humidity of the air, which favors the emergence of mycoses, dermatitis and lung diseases caused by fungi.

Another critical point is the growth of arboviruses, such as dengue, *Zika* and *Chikungunya*, due to the proliferation of vectors. Waterborne diseases, such as leptospirosis, hepatitis A, and gastroenteritis, also occur more frequently, as a result of water contamination by infectious agents.

On the other hand, the scarcity of rainfall in the final months of the year, combined with low relative humidity, tends to aggravate respiratory and cardiovascular problems. For this period, the minimum relative humidity also presented relevant changes, with low indices recorded between February and April in the years 2023 and 2024, with a highlight to March 2024 (40.32%). The highest values occurred in May and June 2024, reaching 74.84% and 91.13%, respectively, as described in Table 3.

Table 3

Minimum Relative Humidity Data (July/2021 to June/2024)

Month	2021	2022	2023	2024
January	Nan	65,7775	54,38	53,23
February	Nan	72,09941	49,29	44,28
March	Nan	73,28267	47,94	40,32
April	Nan	57,13	48,13	47,13
May	Nan	47,71	46,97	74,84
June	Nan	56,8	54,47	91,13
July	66	46,71	74	Nan
August	59,319	67	59,3194	Nan
September	56,802	50,73	56,8024	Nan
October	55,537	40,32	57,68	Nan
November	57,201	53	53,53	Nan
December	59,931	62,9	56,45	Nan

Source: Authors (2025).

These spikes can indicate exposure to critical factors such as extreme heat, increased pollutants, or environmental infectious events. The absence of water particles in the atmosphere makes the air drier, favoring the emergence of diseases such as rhinitis, asthma, bronchitis, colds and flu, in addition to affecting other systems of the human body. This reinforces the importance of integration between meteorological data and public health strategies.

4.2 NUMBER OF DEATHS

The correlation between climatic conditions and urban health is evidenced by mortality data. Between March and June 2024, the highest rates of deaths from respiratory diseases were recorded, with emphasis on April (226 cases) and May (211 cases). These months coincide with periods of greater concentration of rainfall, composing an environment conducive to respiratory outbreaks. The interval between June and September 2022 presented values below average, suggesting that milder climatic variations may contribute to reducing the incidence of these diseases.

Table 4

Number of Deaths from Respiratory Diseases (July/2021 to June/2024)

Month	2021	2022	2023	2024
January	Nan	292	176	174
February	Nan	148	161	187
March	Nan	176	174	205
April	Nan	167	162	226
May	Nan	192	176	211
June	Nan	182	204	156
July	178	201	197	Nan
August	154	145	171	Nan
September	151	139	193	Nan
October	186	178	188	Nan
November	170	157	156	Nan
December	165	164	166	Nan

Source: Authors (2025).

The response capacity of health units is also directly influenced by climate variations. Peaks in demand for care, hospitalizations, and specialized treatments in critical periods require efficient planning, adequate allocation of resources, and integration of epidemiological data with meteorological information. In this sense, it is essential that public health strategies consider environmental variables as tools for predicting outbreaks, defining prevention policies, and strengthening epidemiological surveillance.

4.3 CORRELATION OF PRECIPITATION AND RELATIVE HUMIDITY WITH CASES OF DEATHS FROM RESPIRATORY DISEASES

The analysis focuses on the relationship between rainfall, relative humidity and the number of monthly deaths in the city of São Luís (MA), from July 2021 to June 2024. The data reveal that there is no direct and consistent correlation between climate indices and urban mortality patterns, as shown in Tables 4 and 5, Graphs 1 and 2, and Tables 2 and 3.

Still, there is evidence that climatic conditions especially influence cases of respiratory diseases.

Table 5

Precipitation X Number of Deaths

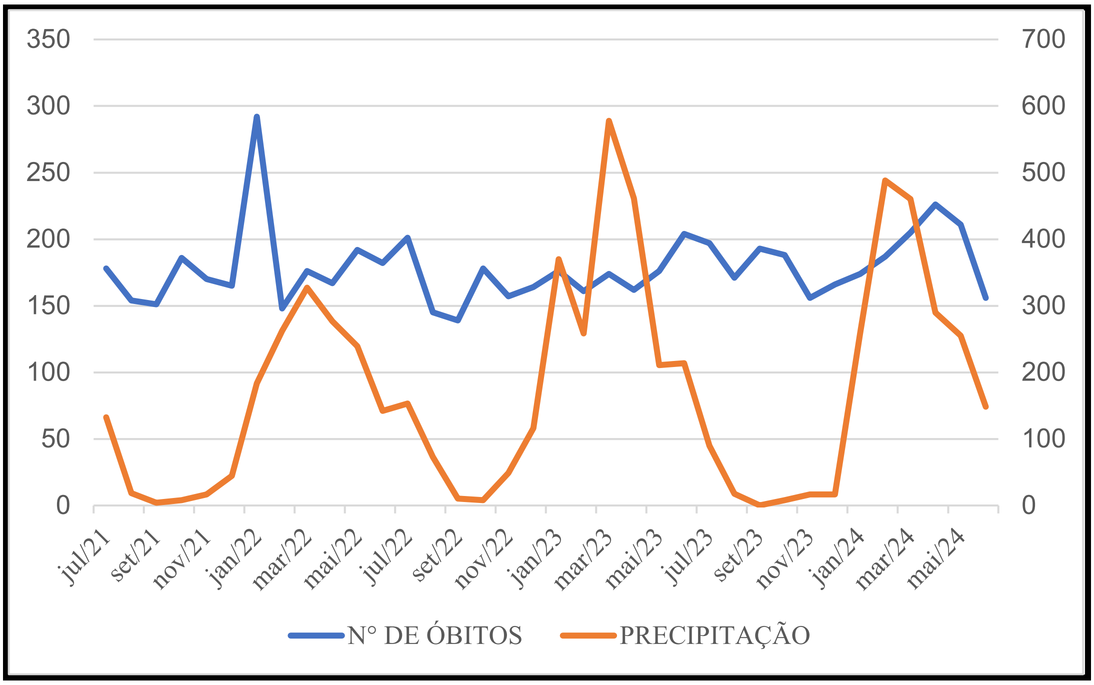
	2021		2022		2023		2024	
Month	**Precipitation**	**Number of Deaths**	**Precipitation**	**Number of Deaths**	**Precipitation**	**Number of Deaths**	**Precipitation**	**Number of Deaths**
January	**Nan**	**Nan**	**183,4**	**292**	**370,2**	**176**	**259,4**	**174**
February	**Nan**	**Nan**	**262,1**	**148**	**258,4**	**161**	**488**	**187**
March	**Nan**	**Nan**	**327**	**176**	**577,8**	**174**	**460,2**	**205**
April	**Nan**	**Nan**	**276,8**	**167**	**461,4**	**162**	**289,6**	**226**
May	**Nan**	**Nan**	**239,4**	**192**	**210,8**	**176**	**255,26**	**211**
June	**Nan**	**Nan**	**142,2**	**182**	**213,6**	**204**	**148,51**	**156**
July	**132,6**	**178**	**153,2**	**201**	**89,6**	**197**	**Nan**	**Nan**
August	**18,40**	**154**	**73**	**145**	**17,4**	**171**	**Nan**	**Nan**
September	**3,91**	**151**	**10,4**	**139**	**0,2**	**193**	**Nan**	**Nan**
October	**7,78**	**186**	**7,78**	**178**	**7,78**	**188**	**Nan**	**Nan**
November	**16,56**	**170**	**49**	**157**	**16,56**	**156**	**Nan**	**Nan**
December	**44,54**	**165**	**116**	**164**	**16,8**	**166**	**Nan**	**Nan**
Correlation	**0,36**		**0,22**		**-0,19**		**0,36**	

Source: Authors (2025).

Table 4 presents the monthly data on precipitation and number of deaths. It is observed that, even in months with high rainfall, such as March 2023 (577.8 mm), the number of deaths was similar to that of less rainy months. On the other hand, September 2023, with only 0.2 mm of rain, recorded a high number of deaths (193). This alternation suggests that the relationship between rainfall and mortality is multifactorial. Through Figure 2 it is noticeable that there is no direct correlation between the two variables.

Figure 2

Number of Deaths x Precipitation



Source: Authors (2025).

Table 2 shows the results of the statistical correlations between precipitation and the number of deaths, per year.

Table 6

Statistical Correlation by Year

Year	Correlation between precipitation and deaths	Interpretation
2021	0,36	moderate upward linear ratio (positive)
2022	0,22	absence of linear relationship
2023	-0,19	absence of linear relationship
2024	0,36	moderate upward linear ratio (positive)

Source: Authors (2025).

The correlation between these two variables fluctuated significantly from one year to another. In 2021 and 2024 it showed a moderate upward linear relationship, in which increases in precipitation coincide with increases in deaths in some months. Heavy rains can favor the increase of vector-borne diseases, such as dengue or seasonal viruses.

In 2022, according to the information in Table 6, the classification of the results based on the values presented by Rumsey (2023), suggests no linear relationship or weak linear relationship. The low correlation suggests that factors other than climate may have influenced mortality patterns that year.

For the year 2023, a negative correlation was observed and that, according to the classification of the results based on the values presented by Rumsey (2023), classified as the absence of a linear relationship, the trend indicates that drier months were associated with a higher number of deaths, showing that the decrease in precipitation can impact health through air dryness, the concentration of pollutants and greater transmissibility of respiratory diseases.

The alternation between positive and negative correlation over the years reveals that the relationship between rainfall and deaths is multifactorial and sensitive to secondary conditions, such as relative humidity level, average temperature, public policies, and preventive campaigns, for example.

Table 7 presents the monthly data on relative humidity and number of deaths. The relationship between these variables has also fluctuated over the years. In 2022, for example, humidity ranged from 40.32% to 73.28%, but the highest number of deaths occurred in January (292), with humidity of 65.78%.

Table 7

Relative Humidity X Number of Deaths

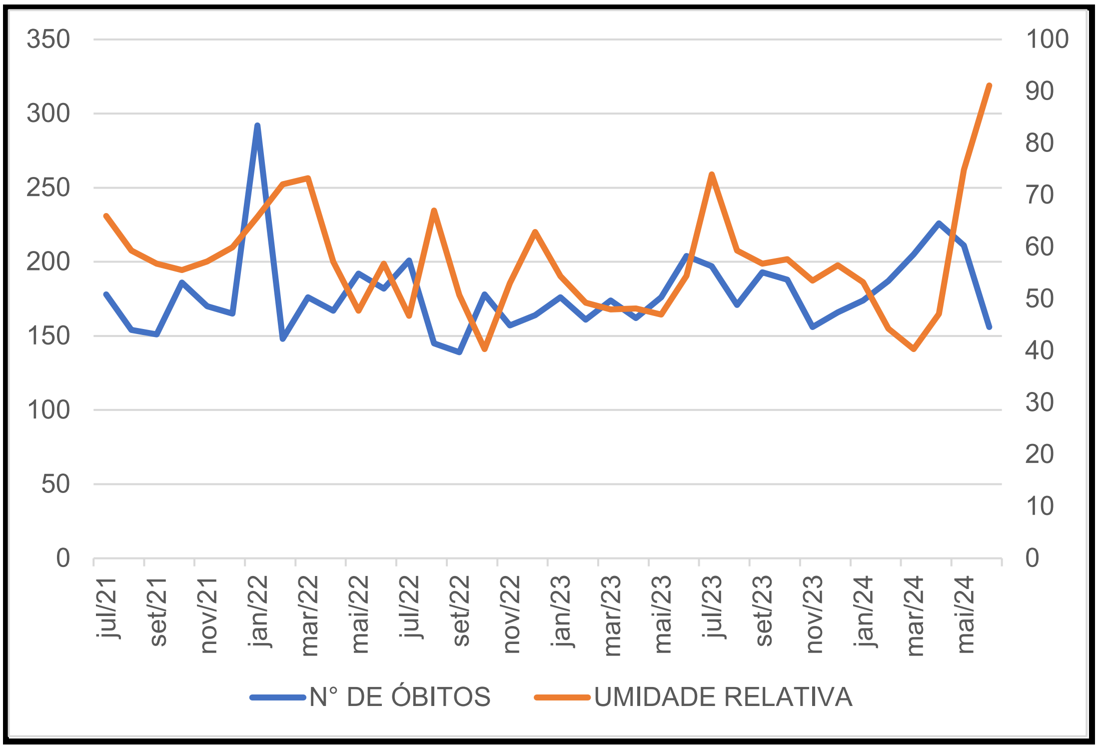
	2021		2022		2023		2024	
Month	**Relative humidity**	**Number of Deaths**	**Relative humidity**	**Number of Deaths**	**Relative humidity**	**Number of Deaths**	**Relative humidity**	**Number of Deaths**
January	**Nan**	**Nan**	**65,78**	**292**	**54,38**	**176**	**53,23**	**174**
February	**Nan**	**Nan**	**72,1**	**148**	**49,29**	**161**	**44,28**	**187**
March	**Nan**	**Nan**	**73,28**	**176**	**47,94**	**174**	**40,32**	**205**
April	**Nan**	**Nan**	**57,13**	**167**	**48,13**	**162**	**47,13**	**226**
May	**Nan**	**Nan**	**47,71**	**192**	**46,97**	**176**	**74,84**	**211**
June	**Nan**	**Nan**	**56,8**	**182**	**54,47**	**204**	**91,13**	**156**
July	**66**	**178**	**46,71**	**201**	**74**	**197**	**Nan**	**Nan**
August	**59,32**	**154**	**67**	**145**	**59,32**	**171**	**Nan**	**Nan**
September	**56,80**	**151**	**50,73**	**139**	**56,80**	**193**	**Nan**	**Nan**
October	**55,54**	**186**	**40,32**	**178**	**57,68**	**188**	**Nan**	**Nan**
November	**57,20**	**170**	**53**	**157**	**53,53**	**156**	**Nan**	**Nan**
December	**59,93**	**165**	**62,9**	**164**	**56,45**	**166**	**Nan**	**Nan**
Correlation	**0,14**		**0,01**		**0,52**		**-0,51**	

Source: Authors (2025).

The data show that the relationship between humidity and the number of deaths is not consistent. Figure 3 shows that there is no direct correlation between the two variables.

Figure 3

Number of Deaths X Relative Humidity



Source: Authors (2025).

Table 8 shows the results of the statistical correlation between precipitation and the number of deaths per year.

Table 8

Statistical Correlation by Year

Year	Correlation between humidity and deaths	Interpretation
2021	0,14	absence of linear relationship
2022	0,01	absence of linear relationship
2023	0,52	moderate upward linear ratio (positive)
2024	-0,51	moderate (negative) linear downward relationship

Source: Authors (2025).

The correlation between these two variables fluctuated significantly from one year to another. In 2021, it presented a correlation of 0.14 which, according to the values presented by Rumsey (2023), suggests the absence of a linear relationship. This value suggests a slight upward trend in deaths with higher humidity, but the result is inconclusive. In 2022, with a correlation of 0.01, which demonstrates the absence of a linear relationship between humidity and the number of deaths.

For the year 2023, a moderate (positive) upward linear relationship of 0.52 was observed, a value that indicates that, in that year, months with higher humidity were associated with a higher number of deaths, suggesting that the worsening of respiratory diseases caused by humid, stuffy, and poorly ventilated environments, favoring the growth of fungi and mites.

In 2024, with a correlation value of -0.51, a moderate (negative) linear downward relationship was observed, indicating that higher humidity may be associated with a lower number of deaths, possibly by reducing respiratory irritation, dispersing pollutants, and attenuating symptoms of chronic respiratory diseases, such as asthma and Chronic Obstructive Pulmonary Disease - COPD.

The variations in the correlations between the years reinforce that mortality patterns are influenced by multiple factors, such as average temperature, public policies, preventive campaigns, and socio-environmental conditions. Although the data do not prove causality, the evidence reveals that humidity and precipitation conditions directly influence the tables of respiratory diseases, especially in vulnerable populations. The statistical analysis demonstrates relevant associations that can support public health strategies aimed at preventing respiratory diseases in critical climatic periods.

4.4 CORRELATION OF PRECIPITATION AND HUMIDITY WITH CASES OF DEATHS FROM RESPIRATORY DISEASES IN THE ELDERLY (60+)

Table 6 below shows the relationship between the number of deaths of people aged 60 years and over and precipitation (mm), in the period from 2021 to 2024.

Table 9

Number of Deaths X Precipitation

Year	Number of Deaths (60+)	Precipitation (mm)
2021	129	37,29
2022	323	153,36
2023	349	186,71
2024	206	316,83

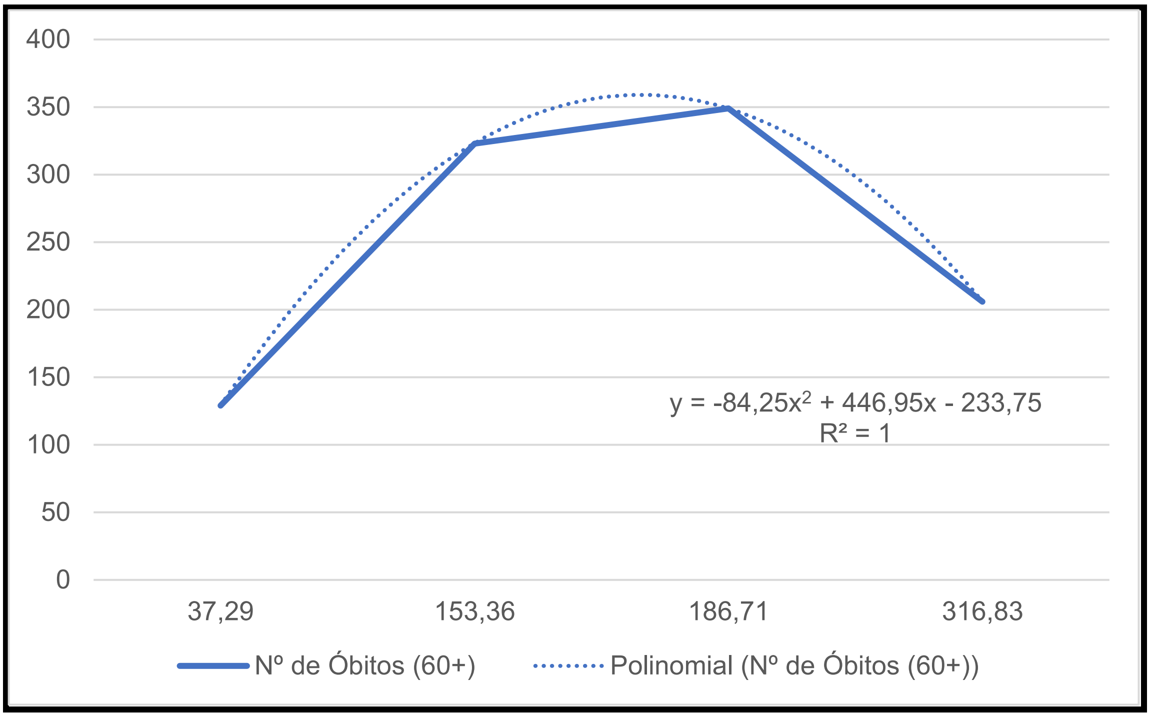
Source: Authors (2025).

According to the data, it is possible to observe that the number of deaths increases as precipitation rises from 2021 to 2023. However, in 2024, despite the higher rainfall of the period (316.83 mm), there was a reduction in deaths. The peak of mortality occurred in 2023, with 349 deaths, when rainfall was 186.71 mm.

This suggests that there is a critical range of precipitation (between 150 mm and 190 mm) in which the adverse effects on the health of the elderly population are more intense. Figure 4 expresses the data contained in Table 9.

Figure 4

Number of Deaths x Precipitation (2021 – 2024)



Source: Authors (2025).

There is a positive correlation between precipitation and deaths up to a critical point (186.71 mm). After this point (in 2024, with 316.83 mm), deaths decrease, suggesting a saturation or mitigation effect. The curve reaches a peak near 186 mm of precipitation, which marks the level of greatest vulnerability for the elderly population.

The relationship between precipitation and deaths is not linear, but parabolic, with an important inflection point between 180 and 190 mm. The graph above shows a non-linear relationship between annual precipitation levels and the number of deaths in the elderly (60+), in the period from 2021 to 2024. There is a sharp increase in deaths with the increase in precipitation between 37.29 mm (2021) and 186.71 mm (2023), where the maximum mortality point (349 deaths) is verified. Interestingly, in 2024, with even higher rainfall (316.83 mm), the number of deaths drops to 206. This inflection suggests that there is a precipitation threshold that maximizes negative health impacts on the elderly.

Table 10 then relates the number of deaths of elderly people (60+) with relative humidity for the years 2021 to 2024.

Table 10

Number of Deaths X Relative Humidity

Year	Number of Deaths (60+) and children	Relative Humidity (%)
2021	129	59,13
2022	323	57,79
2023	349	54,91
2024	206	58,49

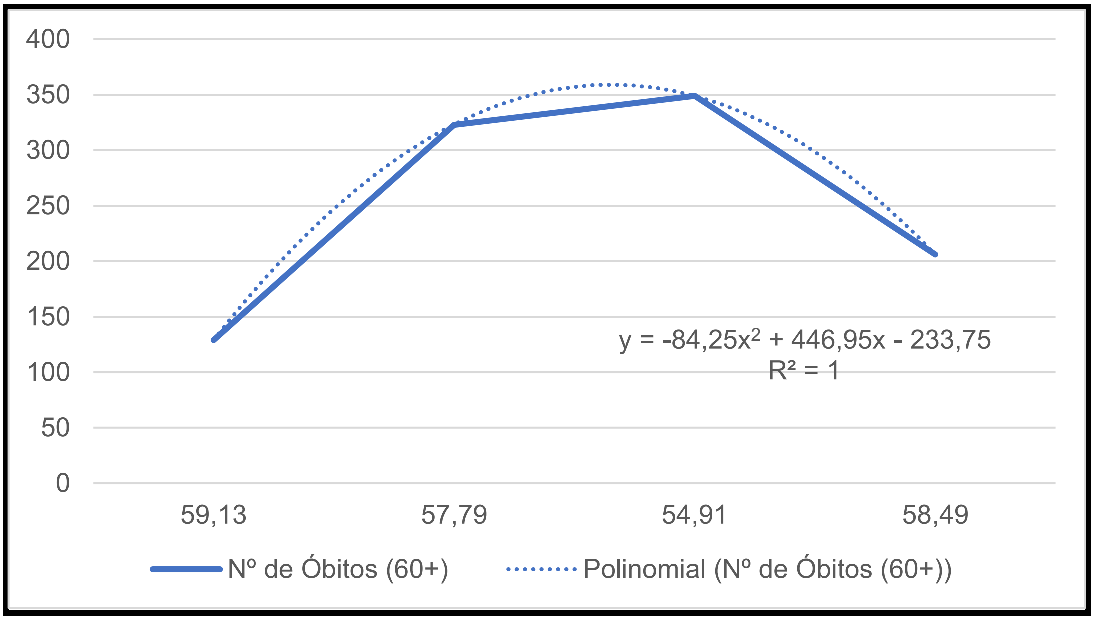
Source: Authors (2025).

The relative humidity values vary between 59.13% and 54.91%, representing the average annual relative humidity indexes. Between 2021 and 2023, there was a sharp increase in elderly deaths as relative humidity decreased. In 2024, with a small increase in humidity, a significant reduction in deaths was observed.

Figure 5, below, presents a representation of the data expressed in Table 10.

Figure 5

No. of Deaths X Relative Humidity (2021 – 2024)



Source: Authors (2025).

The polynomial curve of the graph indicates a nonlinear relationship between the variables. The number of deaths increases with the decrease in humidity to a certain extent (minimum of 54.91% in 2023), and then begins to fall with the increase in humidity in 2024. This suggests that lower humidity levels (between 54% and 56%) may be associated with more adverse health conditions for the elderly, possibly related to respiratory diseases, which are sensitive to climate change.

The polynomial model with $R^2 = 1$ indicates a perfect fit to the data provided, however, due to the limited number of points, it should be analyzed with caution. $-84x^2 + 446{,}95x - 233{,}75$

5 FINAL CONSIDERATIONS

The data analyzed reveal that, although there are moderate correlations in certain years, rainfall alone is not a determining variable in the oscillation of mortality rates due to respiratory diseases in São Luís. Despite the occurrence of heavy rainfall in some months, no statistically significant associations were observed between precipitation volumes and increased deaths, suggesting that its effects on public health are more contextual and indirect. Although extreme rainfall events can impact public health (through floods, difficulty in accessing services, or worsening diseases), such effects do not statistically translate into an increase in overall deaths over time, which we cannot infer about the increase in the number of hospitalizations.

On the other hand, the relative humidity of the air showed greater relevance in the variation of mortality. The drier months concentrated the highest number of deaths, especially among more vulnerable individuals, such as the elderly and children. This pattern may be related to poor air quality, thermal discomfort, and the intensification of infectious and chronic respiratory diseases in periods of dry weather.

Between 2021 and 2024, there was a significant variation in the number of deaths in the vulnerable group, in a possible association with relative humidity. The polynomial curve adjusted to the data suggests a nonlinear relationship between the variables, indicating that the reduction in humidity below 54.91% is correlated with the increase in mortality. This trend reinforces the need for climate monitoring as a component of public health prevention strategies, especially for vulnerable populations such as the elderly.

In view of the above, the importance of integrating climate data into the planning of public health actions is emphasized, especially in periods of seasonal transition, when the most fragile populations may face greater risk. Preventive strategies aimed at times of low humidity can contribute to the reduction of mortality from respiratory diseases, particularly in advanced age groups.

Finally, methodological improvement is recommended through the inclusion of complementary environmental variables, such as average temperature, levels of air pollutants, incidence of specific diseases (such as asthma, pneumonia, and respiratory viruses), as well as socioeconomic and urban infrastructure indicators. Considering that the analyzed period comprises only three years (July 2021 to June 2024), it is suggested to expand the time series to allow greater statistical robustness and capture seasonal oscillations or long-term trends. The investigation of secondary causes that potentially influence the evolution of respiratory diseases, such as vaccination campaigns, access to health, population density, housing quality, and changes in climate behavior, is also essential for a more integrated and effective approach in the planning of public actions.

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