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Health in the Legal Amazon: an analysis of morbidity and mortality indicators between 2010 e 2021

A saúde na Amazônia Legal: uma análise dos indicadores de morbidade e mortalidade entre 2010 e 2021

Salud en la Amazonía Legal: Un análisis de indicadores de morbilidad y mortalidad entre 2010 y 2021

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Resumo *Analisamos a saúde na Amazônia Legal por meio de indicadores de morbimortalidade e comparação intra e interestadual da região e Brasil. Foram utilizados dados secundários de sistemas oficiais de saúde para examinar a situação de saúde, tendências e clusters no período de 2010 a 2021. As doenças do aparelho circulatório foram a principal causa de morte, representando 23% dos óbitos. Causas externas e doenças respiratórias contribuíram com 16% e 9% dos óbitos; 52,6% dos óbitos infantis ocorreram no período neonatal precoce e a taxa de mortalidade infantil manteve-se acima da média nacional. A razão de mortalidade materna também foi elevada e acima da média nacional entre 2010 e 2021. A taxa de incidência de dengue permaneceu abaixo da média nacional com tendência de queda de -59,50%. No entanto, as taxas de doença de chagas, AIDS, hanseníase, leishmaniose tegumentar americana e tuberculose permaneceram acima da média do país. Concluiu-se que a população da Amazônia brasileira enfrenta desafios em relação à saúde, indicando uma situação preocupante. Os achados auxiliam na identificação de prioridades territoriais para a implementação de ações que visem reduzir a morbimortalidade na região.*
Palavras-chave *Morbimortalidade, Análise Espacial, Estudos de Séries Temporais*

Abstract *We carried out the health situation analysis in the Legal Amazon through morbidity and mortality indicators and the comparison between intra and inter-state federation of the region and Brazil. Analysis of the health situation, trends, and identification of clusters in the Brazilian Amazon, for the period from 2010 to 2021, using secondary data available in official health information systems. Circulatory diseases were the main cause of death, representing 23% of deaths. External causes and respiratory diseases contributed 16% and 9% of deaths, respectively; 52.6% of infant deaths occurred in the early neonatal period, and the infant mortality rate remained above the national average. The ratio of maternal mortality was also high and above the national average between 2010 and 2021. The dengue incidence rate remained below the national average with a drop trend of -59.50%. However, rates of Chagas disease, AIDS, Hansen's disease, American cutaneous leishmaniasis and tuberculosis remained above average rates in the country. It was concluded that the population of the Brazilian Amazon faces health challenges. The findings facilitate the identification of territorial priorities for the implementation of actions that impact morbidity and mortality reduction in the region.*
Key words *Morbidity and Mortality, Spatial Analysis, Time-series studies*

Resumen *Analizamos la salud en la Amazonía Legal utilizando indicadores de morbimortalidad y comparaciones intra e interestatales de la región y Brasil. Se utilizaron datos secundarios de los sistemas de salud oficiales para examinar la situación, las tendencias y los grupos de salud en el período de 2010 a 2021. Las enfermedades del sistema circulatorio fueron la principal causa de muerte, representando el 23% de las muertes. Las causas externas y las enfermedades respiratorias contribuyeron al 16% y al 9% de las muertes; el 52,6% de las muertes infantiles ocurrieron en el período neonatal temprano y la tasa de mortalidad infantil se mantuvo por encima del promedio nacional. La tasa de mortalidad materna también fue alta y superior al promedio nacional entre 2010 y 2021. La tasa de incidencia del dengue se mantuvo por debajo del promedio nacional con una tendencia a la baja del -59,50%. Sin embargo, las tasas de enfermedad de Chagas, SIDA, lepra, leishmaniasis cutánea americana y tuberculosis se mantuvieron por encima del promedio del país. Se concluyó que la población de la Amazonía brasileña enfrenta desafíos en relación a la salud, indicando una situación preocupante. Los hallazgos ayudan a identificar prioridades territoriales para implementar acciones destinadas a reducir la morbilidad y la mortalidad en la región.*
Palabras clave *Morbilidad y mortalidad, Análisis espacial, Estudios de series temporales*

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Introduction

The Legal Amazon, created by the Law No. 1,806, of January 6, 1953, with the aim of implementing policies of territorial and economic sovereignty to promote the development of the territory. The region encompasses 9 states and 772 municipalities with low demographic density and difficulty for the population to access health services. The area covers 58.9% of the national territory and has about 5.60 inhabitants per km², where approximately 28 million inhabitants live, of which 35% live in cities with more than 200 thousand inhabitants[1].

The socio-sanitary profile is complex, with overlapping health, environmental, social, and economic problems. The region has significant health problems compared to other parts of Brazil, particularly about tropical diseases such as Hansen's disease, leishmaniasis, malaria, Chagas disease, leptospirosis, dengue, and tuberculosis. In addition, there are concerns about vaccine-preventable diseases[2-4] contributing to a significant burden of these diseases in the world[4,5]. The territory has the lowest life expectancy in the country[6], particularly influenced by living conditions and conflicts related to the occupation of the area[7].

In 2010, the Legal Amazon reached an extreme poverty rate of 13%, higher than the Brazilian average of 6.62%, and an HDI of 0.683, lower than the national rate of 0.7277[8]. Its territory is home to the largest and most diverse tropical forest in the world, whose loss of biodiversity and environmental changes cause a severe impact on global warming and affects the regional climate of South America, as it plays a valuable role in climate regulation[9].

Health problems are strongly impacted by environmental factors, such as hydrographic cycles[10], air pollution mainly emitted by wildfires, and forest fires[11,12]. In addition, the lack of infrastructure in dwellings, including sewage and treated water networks for only 67% of the population[13]. Although there are data on health in the Amazon in the literature, most of them are linked to tropical medicine[14-16] or limited to specific disease categories[17-19].

Given the complex scenario, it becomes imperative to identify the extent of problems and risk disparities among population groups through continuous health situation analysis. This study aims to analyze the health situation in the Legal Amazon from 2010 to 2021, expressed by proportional mortality, specific mortality rate, infant and maternal mortality rates, incidence rates of the most important neglected diseases, and AIDS.

Methods

Design, area, and period of study

A descriptive ecological study was carried out, on the health situation in federal units and municipalities located in the Legal Amazon, from 2010 to 2021.

Indicator selection, data source and calculation

Concerning mortality, the proportional mortality indicators were calculated, according to causes of death, age range and infant mortality components; age-standardized cause-specific mortality rates (CSMR) of the leading causes of death; infant mortality rates (IMR) by category (early neonatal, late neonatal, and post-neonatal); and maternal mortality ratio (MMR). The proportional mortality indicator is necessary to describe the importance of a given cause or age range among deaths. Mortality rates exist to compare the risk of death from a specific cause between different locations. While the IMR and its category reveal risks and determinants for survival in the first year of life.

Regarding morbidity indicators, the incidence rates of six diseases selected due to the higher frequency and availability of data were calculated.

Death data were obtained from the Brazilian Mortality Information System (SIM); data on live births from the Live Birth Information System (SINASC); morbidity data from the Notifiable Diseases Information System (SINAN); and population data were obtained from annual population estimates according to the projections of the Brazilian Institute of Geography and Statistics (IBGE) made available by the Department of Informatics of the Unified Health System (DATASUS). Data for calculating proportional mortality and SMR were obtained using the DATASUS microdata download and pre-processing package (MicroDataSUS/DATASUS). The data for calculating the IMR, maternal mortality ratio, and the incidence rates of the selected diseases were obtained using the DATASUS TABNET data tabulator. For all mortality and morbidity indicators, deaths or cases among populations residing in the geographic units of analysis (states and municipalities) were always considered.

Annual proportional mortality, according to the cause of death and age range, was calculated by dividing the number of deaths in the group and place of interest by the total number of deaths and multiplying by 100. For the calculation of proportional mortality according to the cause of death, the causes grouped in the chapters of the 10th Revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) were considered, namely: I) some infectious and parasitic diseases; II) neoplasms (NEO); IV) endocrine, nutritional and metabolic diseases; IX) diseases of the circulatory system (DCS); X) diseases of the respiratory system (DSR); XVIII) not classified elsewhere; XX) external causes of morbidity and mortality (ECs); and others (which included the other chapters that represent about 12% of the total number of deaths). Proportional mortality according to age range was calculated for the age groups from under or equal to 09 years old, 10 to 19 years, 20 to 44 years, 45 to 64 years, 65 to 79 years, and 80 years or older.

The age-standardized CSMR were estimated for the following groups of causes: diseases of the circulatory system (codes I00-I99); diseases of the respiratory system (codes J00-J99); external causes of morbidity and mortality (codes V01-Y98). These causes were used because they have the highest proportion of deaths per Federation Unit. The CSMR was standardized by age, considering UF, Legal Amazon, and Brazil. The standardized CSMR was expressed as rates per 100,000 inhabitants, using the Brazilian population from the 2010 IBGE census as a standard.

For infant mortality, proportional mortality and IMR were calculated, according to both the categories of early neonatal (0 to 6 days), late neonatal (7 to 27 days) and post-neonatal (28 to 364 days). The calculations of IMR and categories were performed using the direct method[20]. This calculation was made by dividing the number of deaths by the number of live births (LB) multiplied per 1,000[20].

The MMR was calculated using the direct method, dividing the number of deaths among women by outcomes and conditions related to maternal death by the total LB multiplied per 100,000[20].

Incidence rates were calculated for acute Chagas disease (ACD), dengue, AIDS, leprosy, American Cutaneous Leishmaniasis (ACL) and tuberculosis. Rates were calculated by dividing the number of cases by the respective populations, multiplied per 100,000. Case definitions and endemicity parameters followed the guidelines of the Ministry of Health[21].

Data analysis

In the temporal trend analysis, the linear regression model was used, whose dependent variables were mortality and morbidity indicators (Y), and the independent variable (X) was the time calculated in years. The *Shapiro-Wilk* test was used to verify the normality of the data, and the Durbin-Watson test to analyze the independence of the residues. In the case of serial autocorrelation, the Prais-Winsten generalized linear regression model was applied.

An increasing and decreasing trend was considered for positive and negative estimators, respectively, and stable for non-significant estimators. In addition to interpreting trends, the relative percentage change (RPC) for Brazil, Legal Amazon and UFs was calculated between 2010 and 2021. The RPC is calculated by the difference between the last observation of the series (2021) and the first observation (2010), divided by the value of the first observation (2010), multiplied per 100. This measure made it possible to quantify the increase or decrease in indicators over the study period. Analyzes of temporal trends were performed using the statistical program R version (4.2.0). Statistical tests and adjustments of the linear regression models were carried out using the "*lmtest*" and "*prais*" libraries; the "*ggplot2*" library was used to create graphs and visualizations of the analysis results.

Spatial scan statistics performed in the SaTScan program (version 10.0.1) were used[22] to analyze the formation of spatial clusters of high or low risk of the analyzed outcomes, using municipalities as the unit of analysis in three periods: 2010-2012 and 2017-2019 and 2020-2021. With the first and last triennium, we sought to verify changes in spatial patterns at the extremes of the decade[17]. The analysis of the last two years was performed separately, considering the impact of COVID-19 on the events under study. The relative risks (RR) of occurrence of the event of interest inside each *cluster* in relation to the occurrence outside the cluster were estimated. Analyzes were carried out separately to identify high- and low-risk clusters across periods using the Poisson probability model. The following parameters were also considered across 999 replicates using the Monte Carlos test: absence of geographic overlap; maximum population size in each cluster equal to 50% of the population at risk, and circular cluster with a radius of 500 kilometers. Mortality and incidence clusters were elaborated considering the whole population of the study. All indicators were developed

by 100,000 inhabitants. The maps of mortality and morbidity indicators were prepared considering only the statistically significant high and low-risk clusters at the 5% level, in the ArcGIS software (version 10.8), with a digital grid in the shapefile format available by the IBGE.

The research does not require ethics committee approval, as it is a study with secondary data and in the public domain.

Results

Leading causes of death in the Legal Amazon

In the Legal Amazon, 1,547,716 deaths were recorded between 2010 and 2021, with an annual and daily average of 128,976 and 353 deaths, respectively. The leading cause of death in the region was DCS, responsible for 23% of deaths, followed by ECs (16%), NEO (12%), and DSR (9%). Among children under age 9 years, 8% of deaths occurred due to DSR; in the age groups of 10 to 19 and 20 to 44 years, ECs were the leading cause of death, responsible for 65% and 52% of deaths in each age group, respectively. For the other age groups (45 to 64, 65 to 79, and 80 or older), proportional mortality from DCS reached up to 33%. The highest proportion of deaths occurred in the age group from 65 to 79 years (26%), and the lowest number of deaths in the age group from 10 to 19 years (3%) (Figure 1[A]).

In the Federative Units, proportional mortality according to the cause of death was like the average for the Legal Amazon. In the analysis stratified by age range and Federative Units, Mato Grosso, Rondônia, Roraima and Tocantins differed from the region with the highest proportion of deaths by ECs among children under age 9 years, while in Amazonas, NEO stood out as the leading causes of deaths in the age range of 45 to 64 years (Figure 1[B]; Scielo data: https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3).

Mortality by the leading causes of death

There was an increase in mortality rates due to DCS and DSR between 2010 and 2021, which increased from 142.84 to 205.21 deaths per 100,000 population, and from 44.54 to 79.28 deaths per 100,000 population, respectively. The ECs mortality rate remained above 80 deaths per 100,000 population. It is important to highlight that the three outcomes showed RPC of growth higher than those presented by Brazil (https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3).

All UFs had increasing trends, with an average annual increase between 0.5 and 3.39% for the age standard SMR for DCS and DSR. As for ECs mortality rates, it was observed that the states of Amapá, Amazonas Roraima, and Tocantins had a growing trend, with an average annual increase ranging from 1.06 to 2.39% (Figure 2[A]).

Spatial analysis with the Scan statistics showed that, in all periods analyzed, primary clusters for DCS mortality rates were formed by municipalities located in the southeastern Legal Amazon. The high RR areas remained located in the south and southeast of the Legal Amazon. The RRs within the high RR areas were up to 3.6 times higher when compared to locations outside the clusters. For DSR mortality rates, it was observed that the risk areas remained around the Legal Amazon. The risk of death in areas of high RR clusters was about 3.10 times greater than in areas outside the clusters. For ECs mortality rates, there was a change in the spatial pattern with the formation of high RR clusters in Roraima, Roraima, northern Amazonas, and in the central area of Mato Grosso that occupies a large part of Pará and southern Tocantins. The risk of death from ECs in these clusters was up to 4.20 times higher than in the areas outside (Figure 2[B]). The presentation of RRs by municipality according to cluster analysis appears in: https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3.

Infant mortality

In the Legal Amazon, 84,672 deaths in children under one year of age were recorded between 2010 and 2021, with annual and daily averages of 7,056 and 19 deaths, respectively. Most deaths occurred in the early neonatal period (44,512 deaths, 52.6%), followed by those in the post-neonatal period (27,611 deaths 32.3%). The distribution of infant deaths according to categories by FU resembles the distribution verified for the entire Legal Amazon, with greater proportion of deaths in the early neonatal period (https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3).

The IMR for the analyzed region was 16.55 to 14.42 deaths per 1,000 LB between 2010 and 2021, a reduction of 12.86%. However, it remained above the national rate, which ranged

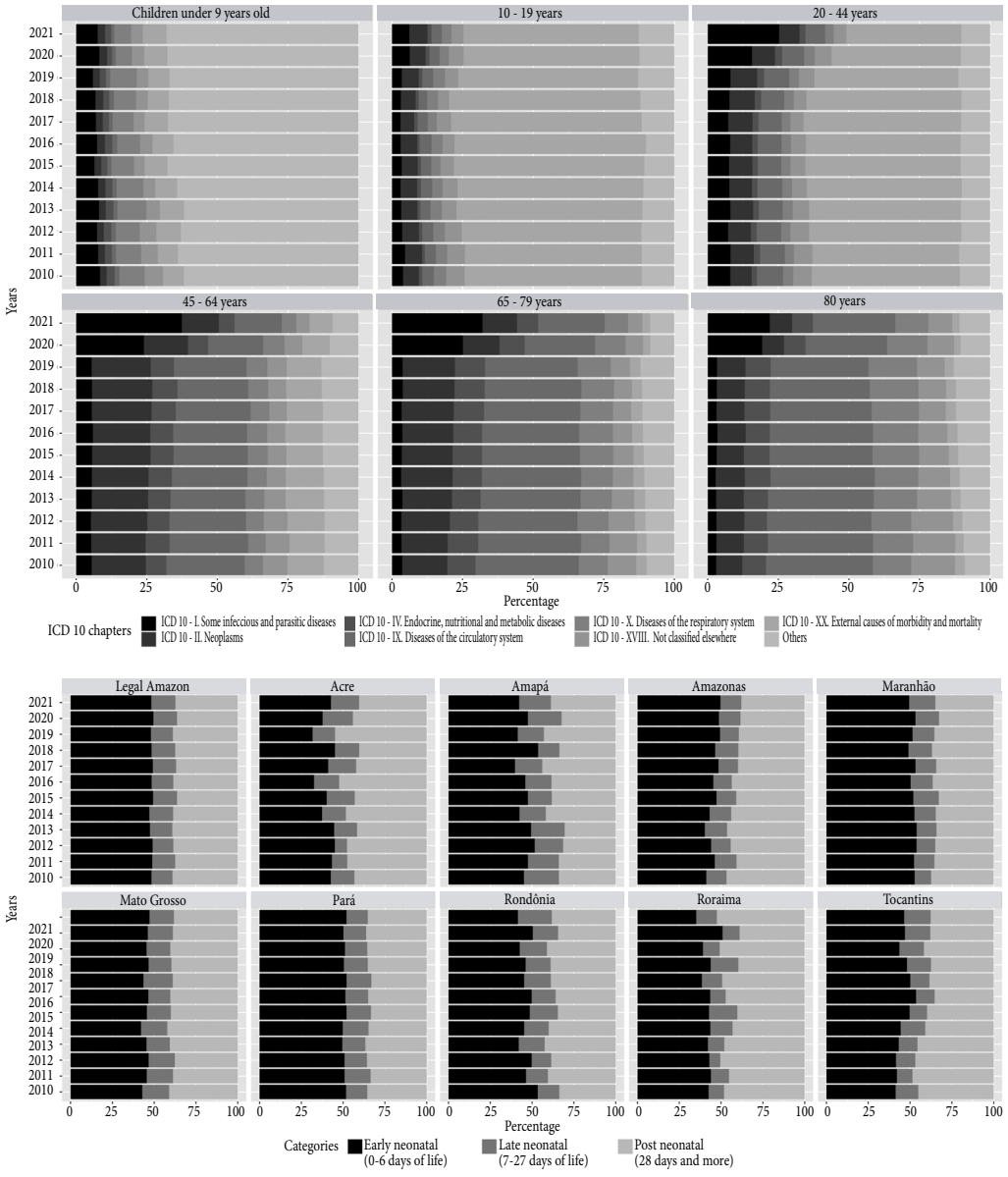

Figure 1. [A] Proportional mortality according to cause of death. [B] Proportional mortality according to cause of death and age range. Legal Amazon, 2010 to 2021.

Source: Authors.

from 13.93 to 11.9 deaths per 1,000 LB. The reduction in the infant mortality rate occurred in all categories (https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3). In the temporal trend analysis, the IMR and neonatal categories showed a decreasing trend for the entire region, but there were some differences in the FUs. Roraima showed an increasing trend in all neonatal categories, with an average annual increase in IMR of 1.33% (34 infant deaths per 1,000 LB per year) (Figure 3[A]).

Spatial patterns of the highest risk areas for infant mortality and their components were consistent in the three periods. High RR areas were identified in the states of Acre, Amazonas, Roraima and Pará. Alongside a low -risk infant mortality cluster (1), the high RR cluster (11) in

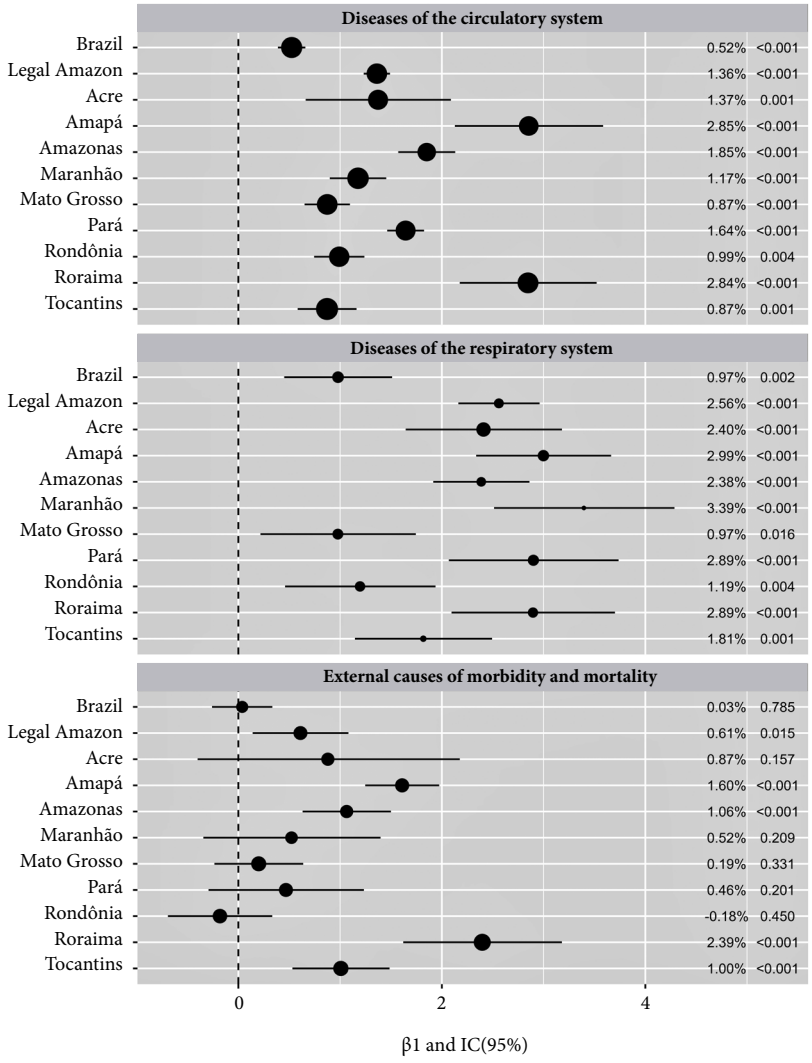

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Figure 2. [A] Linear coefficient, and their respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend of age-standardized of mortality rates, 2010 to 2021. [B] Distribution of spatial clusters of mortality rates according to ICD-10, chapters IX, X and XX. Legal Amazon, 2010-2012, 2017-2019 and 2020-2021.

southern Mato Grosso expanded its area in the second triennium. However, in the third interval, the areas of high RR in southeastern Mato Grosso reduced. It is noteworthy that the risk of death in the post-neonatal and late neonatal periods in the region is approximately 3 times greater than in the early neonatal period (Figure 3[B]). The comparative values of the relative risks about the clusters, as well as the population at risk of death, the IMR rates, and the neonatal categories, can be seen in https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3.

Maternal Mortality Ratio

A total of 4,457 maternal deaths were recorded, with an annual average of 371.4 during the study period. The MMR in the region remained above 71 maternal deaths per 100,000 LB between 2010 to 2019, it was to 142.15 maternal deaths for 100,000 LB in 2021, with an increase of 97,95% in the period. While Brazil went from 60.07 to 113.18 maternal deaths per 100,000 LB between 2010 and 2021. The largest RPC verified between 2010 and 2021 occurred in Acre, Amapá, Pará, and Roraima (https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/

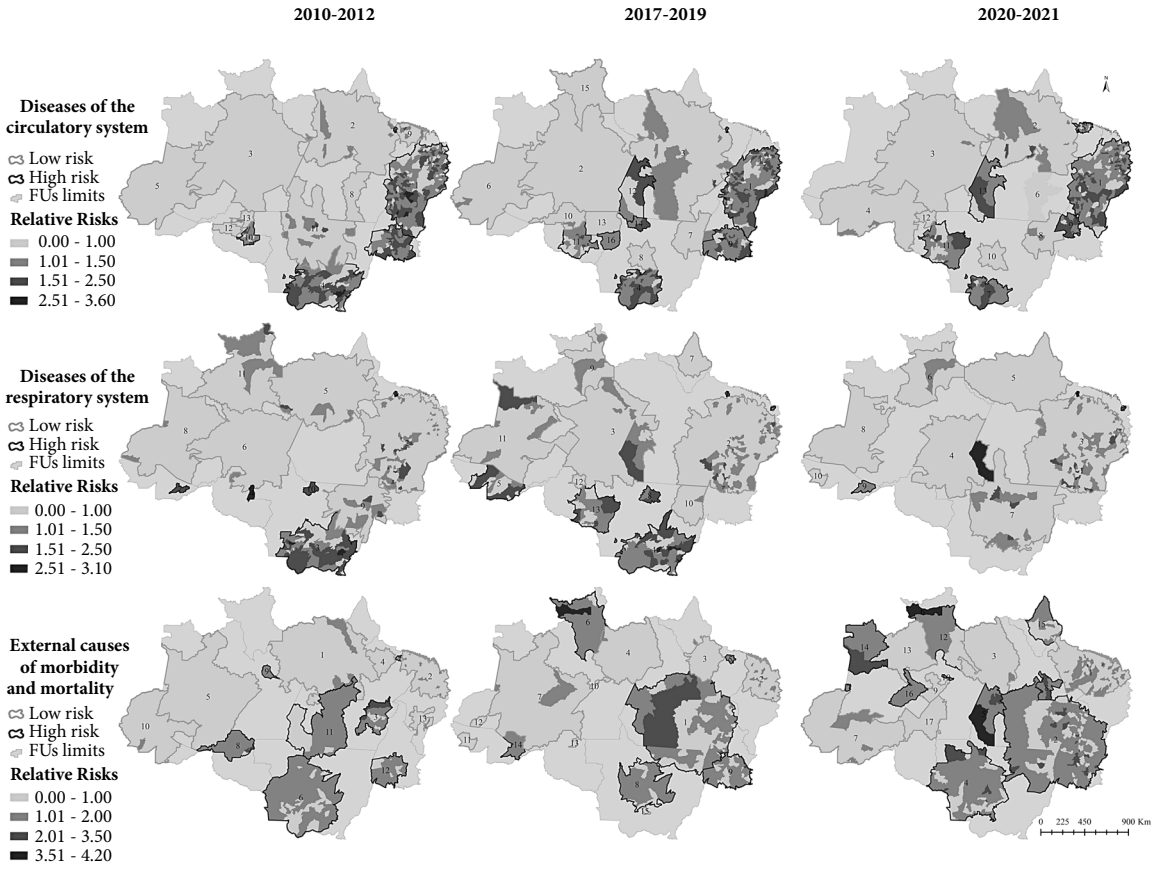


Figure 2. [A] Linear coefficient, and their respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend of age-standardized of mortality rates, 2010 to 2021. [B] Distribution of spatial clusters of mortality rates according to ICD-10, chapters IX, X and XX. Legal Amazon, 2010-2012, 2017-2019 and 2020-2021.

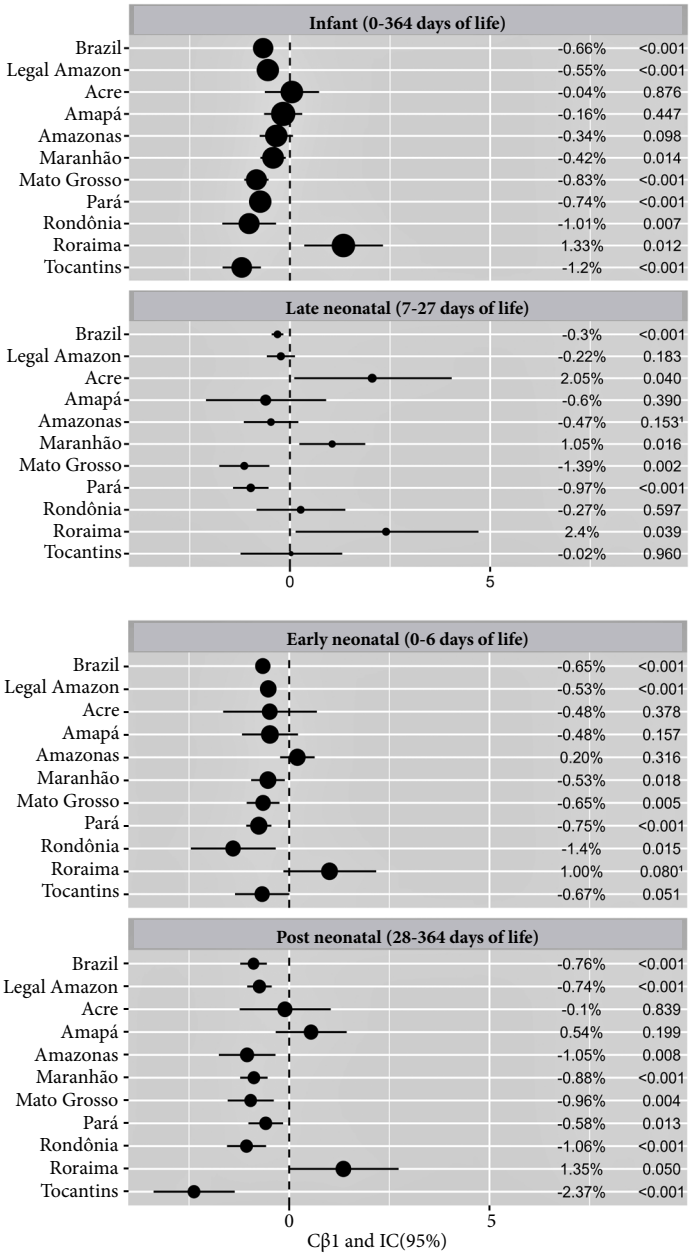
Source: Authors.

scielodata.V9H3V3). MMR showed a growing trend to the region, with an annual increase of 1.66% (74 deaths). Among the UFS, the states of Pará and Roraima showed increasing trends, with an annual increase of 2.27 % (30 deaths) and 7.81% (9 deaths), respectively (Figure 4[A]).

Spatial analysis identified a high RR cluster in the first interval, in Maranhão, and a low risk in the third, formed by municipalities that cover the states of Pará and Amapá, with RR of mortality within the cluster ranging from 1 to 11.50 (Figure 4[B]). In the second period, no clusters were identified. The RR values of the clusters, the population at risk and the MMR rates are shown in https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3.

Incidence rates of neglected diseases and AIDS

Among the diseases of acute evolution, 872,354 cases of dengue were reported in the Legal Amazon during the study period, with an annual and daily average of 72,696 and 199 occurrences, respectively. While Brazil showed an increase in the incidence rate of dengue of 51% in the period, in the Legal Amazon, there was a decrease from 557.35 to 225,74 cases per 100,000 inhabitants, a reduction of 59% in the period and a downward trend annual rate of 6.57% (49,149 cases). About ACD, 2,961 cases were notified in the region, an annual average of 247 cases, whose incidence rate increased from 0.45 to 1.08 per 100,000 inhabitants, higher than the rates in Brazil, with an average annual trend



[1]Applied the Prais-Winsten generalized linear regression model.

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Figure 3. [A] Linear coefficient, and respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend of infant mortality rates and their components, from 2010 to 2021. [B] Distribution of spatial clusters of infant mortality rates and categories neonatal. Legal Amazon, 2010-2012, 2017-2019 and 2020-2021.

of 2.78% (82 cases). For AIDS, 73,045 new cases were reported in the period, with an annual and daily average of 6,087 and 17 cases, respectively. There was an increase in incidence rates from 20.42 to 23.09 per 100,000 inhabitants in the period. AIDS incidence rates in the Amazon region were higher than those registered in Brazil from 2013 and presented a stable average annual trend. As for Hansen's disease (leprosy), 171,608 new cases were reported, an annual and

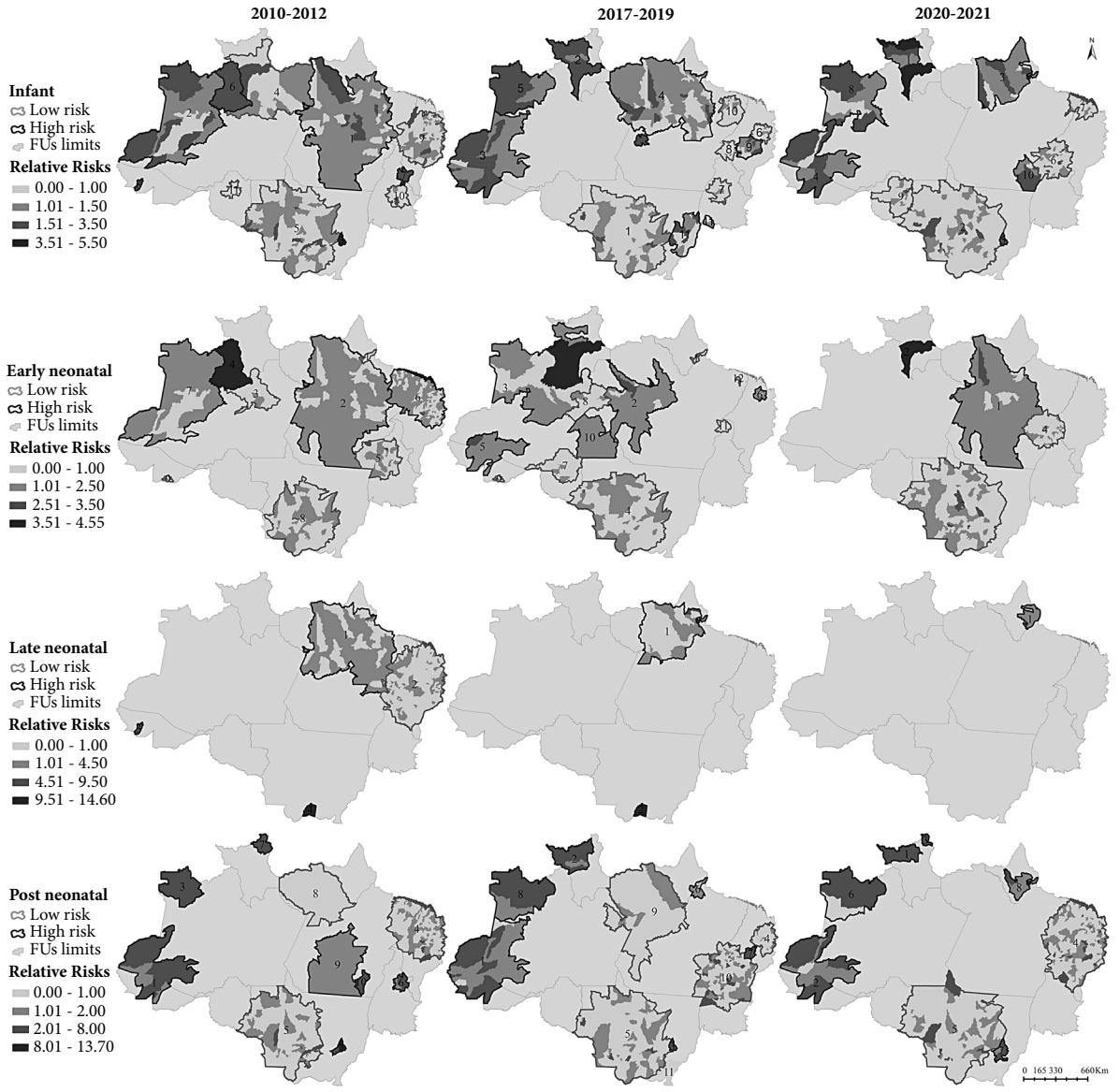

Figure 3. [A] Linear coefficient, and respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend of infant mortality rates and their components, from 2010 to 2021. [B] Distribution of spatial clusters of infant mortality rates and categories neonatal. Legal Amazon, 2010-2012, 2017-2019 and 2020-2021.

Source: Authors.

daily average of 14,300 and 39 cases. Despite the reduction in Hansen's disease detection rates for the Amazon with a decreasing trend, the rates were still higher than those for Brazil in the period. All UFS showed a decreasing trend, except Mato Grosso and Tocantins, which presented stable trend. A total of 146,382 cases of ACL were reported in the region, with an annual and daily average of 12,198 and 33 cases, respectively. ACL incidence rates decreased from 49.36 to 34.09 per 100,000 inhabitants, approximately 4.6 times higher than the rate in Brazil in 2021. The region showed an average annual downward trend of 1.94% (2,839 cases). For tuberculosis, 160,616 cases were notified, with an annual and daily average of 13,384 and 37 cases. As observed for Brazil, there was a gradual increase in incidence rates in the Legal Amazon, from 47.93 to 54.44 per 100,000 inhabitants between 2010 and 2021, with an increasing annual aver-

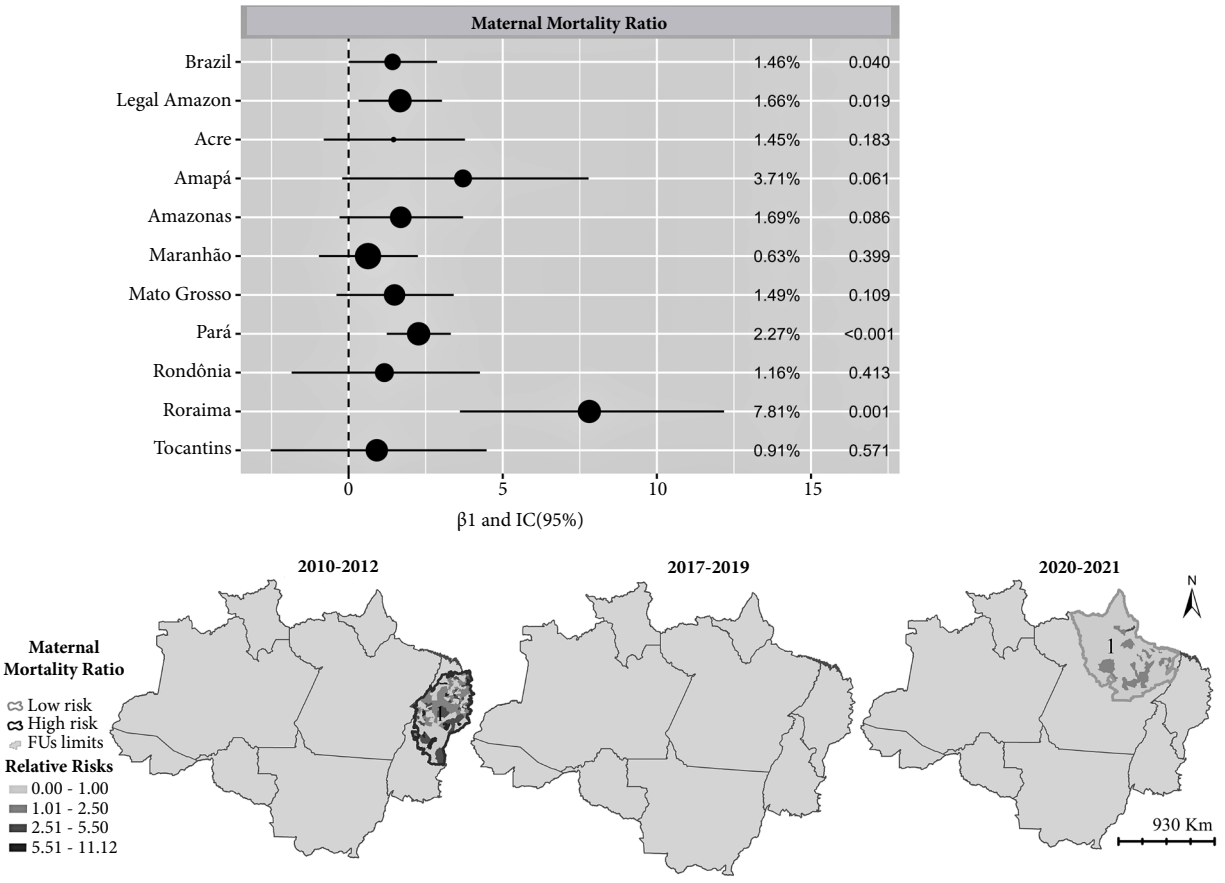

Figure 4. [A] Linear coefficient, and respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend Maternal Mortality Ratio, 2010 to 2021. [B] Distribution of spatial clusters of maternal mortality ratios in the Legal Amazon, 2010- 2012, 2017-2019 and 2020-2021.

Source: Authors.

age trend of 0.47% (754 cases). Only Mato Grosso presented a reduction in the incidence rate of the disease. The result of the trend analyzes of all conditions is shown in Figure 5[A], and the RPC of the incidence or detection rates for region and FUs are shown in https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3.

Figure 5[B] presents the result of the spatial analysis of the incidence rates of the diseases included in the study. Among the diseases of acute evolution, the areas of high RR for dengue were concentrated mainly in the North, South and Southeast regions of the Amazon. There was a change in the high RR areas, with territorial expansion in the 2017-2019 triennium in Acre, Amazonas, and Tocantins and the absence of the cluster in Pará. It is important to emphasize the northern region of Maranhão (cluster 4), which presented low risk in the first and third period, was the location with the highest risk in the second segment, up to 83 times greater than in areas outside the cluster. Regarding ACD, a primary cluster (1) of high RR was identified located in the north of Pará, in the three intervals analyzed. Despite the reduction of high RR areas between periods, the risk of illness of residents in the area of this cluster is 55 times greater than in regions outside the cluster. About chronic diseases, AIDS stands out for the number of low-risk clusters, in contrast to those with a high RR of smaller coverage. In the first triennium, the high RR clusters were more restricted to the capital areas (clusters 3,

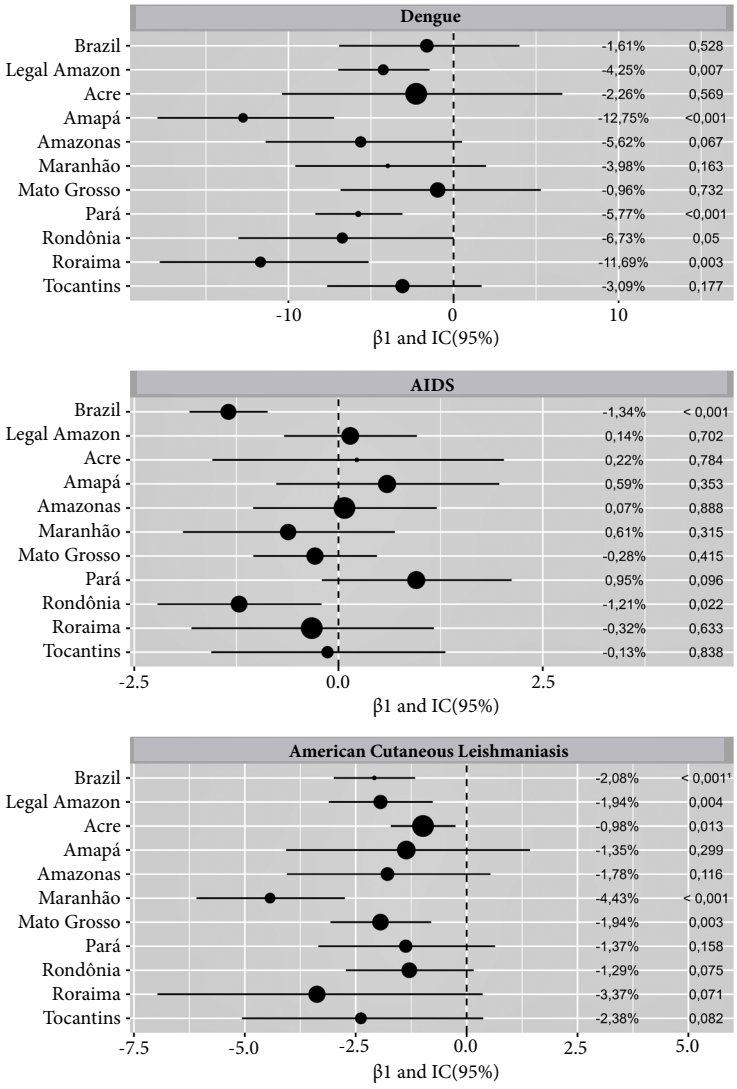

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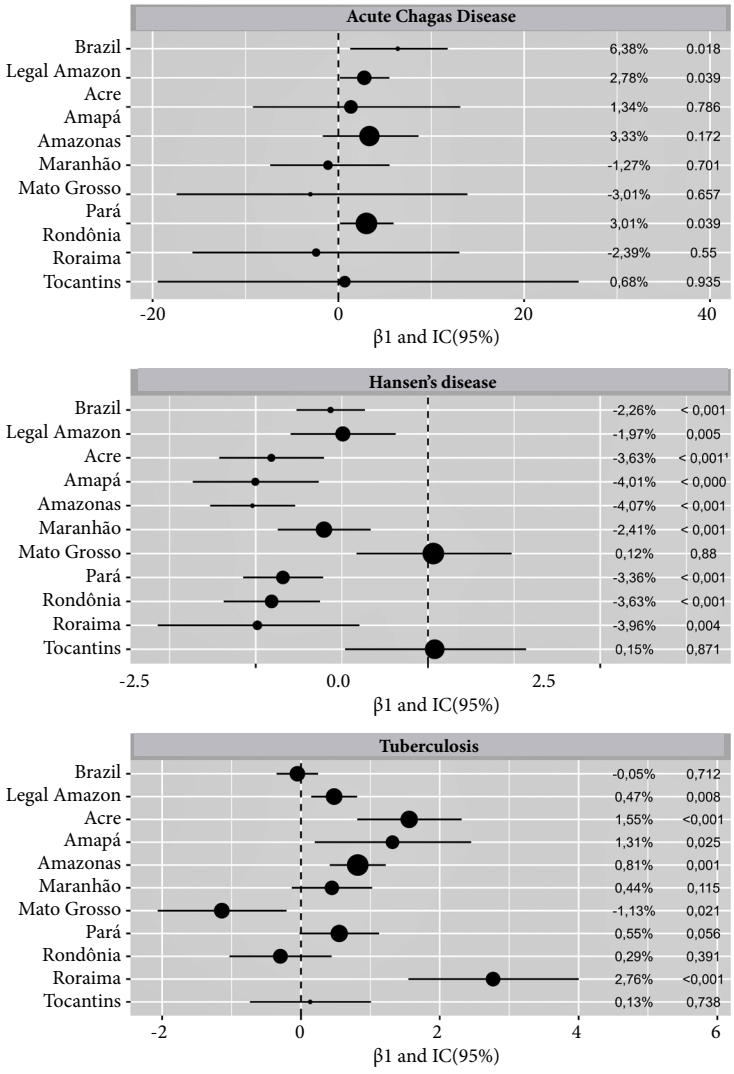
Figure 5. [A] Linear coefficient, and respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend of incidence rates, 2010 to 2021. [B] Distribution of spatial clusters of incidence rates of neglected diseases and AIDS. Legal Amazon, 2010-2012, 2017-2019 and 2020-2021.

4, 7 and 11, respectively). While in the second triennium, there is a junction between the clusters previously numbered as 11 and 1 formed in the north of Roraima (cluster 2) with RR of 2.10, in addition to the maintenance of the clusters located in the south of the region. In the third, clusters are observed in the capitals and occurs in large expansion of the state of Pará. In the case of Hansen's disease, despite the reduction in the extension of the cluster located in the central part of the Amazon in the second and third intervals (encompassing the northeast of Mato Grosso, the center-west of Tocantins and the south of Pará), there was an increase in the RR from 2.15 to 20. ACL increased in risk areas in all FUs, except in Maranhão and Tocantins. There was a decrease in the number of clusters between the triennium, but the number of high



*Mato Grosso and Rondônia presented records in less than 05 years for ACD in the analysis period.
[1]Applied the Prais-Winsten generalized linear regression model.

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Figure 5. [A] Linear coefficient, and respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend of incidence rates, 2010 to 2021. [B] Distribution of spatial clusters of incidence rates of neglected diseases and AIDS. Legal Amazon, 2010-2012, 2017-2019 and 2020-2021.

RR clusters remained higher. The high RR areas for tuberculosis were similar in the first two trienniums, with the highest rates concentrated in the north of the Amazon. In the third period there was no formation of high RR cluster in Mato Grosso. Information on the RR values of the clusters, the population at risk, and the morbidity rates referring to the clusters are detailed in https://data.scielo.org/dataset.xhtml?persistentId=doi:10.48331/scielodata.V9H3V3.

Discussion

In the Legal Amazon, between 2010 and 2021, DCS, DSR and ECs mortality rates were higher than the national average. The proportion of infant mortality was higher in the early neonatal period, and all categories had rates above national rates over the 12 years of study. MMR in the region exceeded the national rate and presented a growing trend. The incidence rate

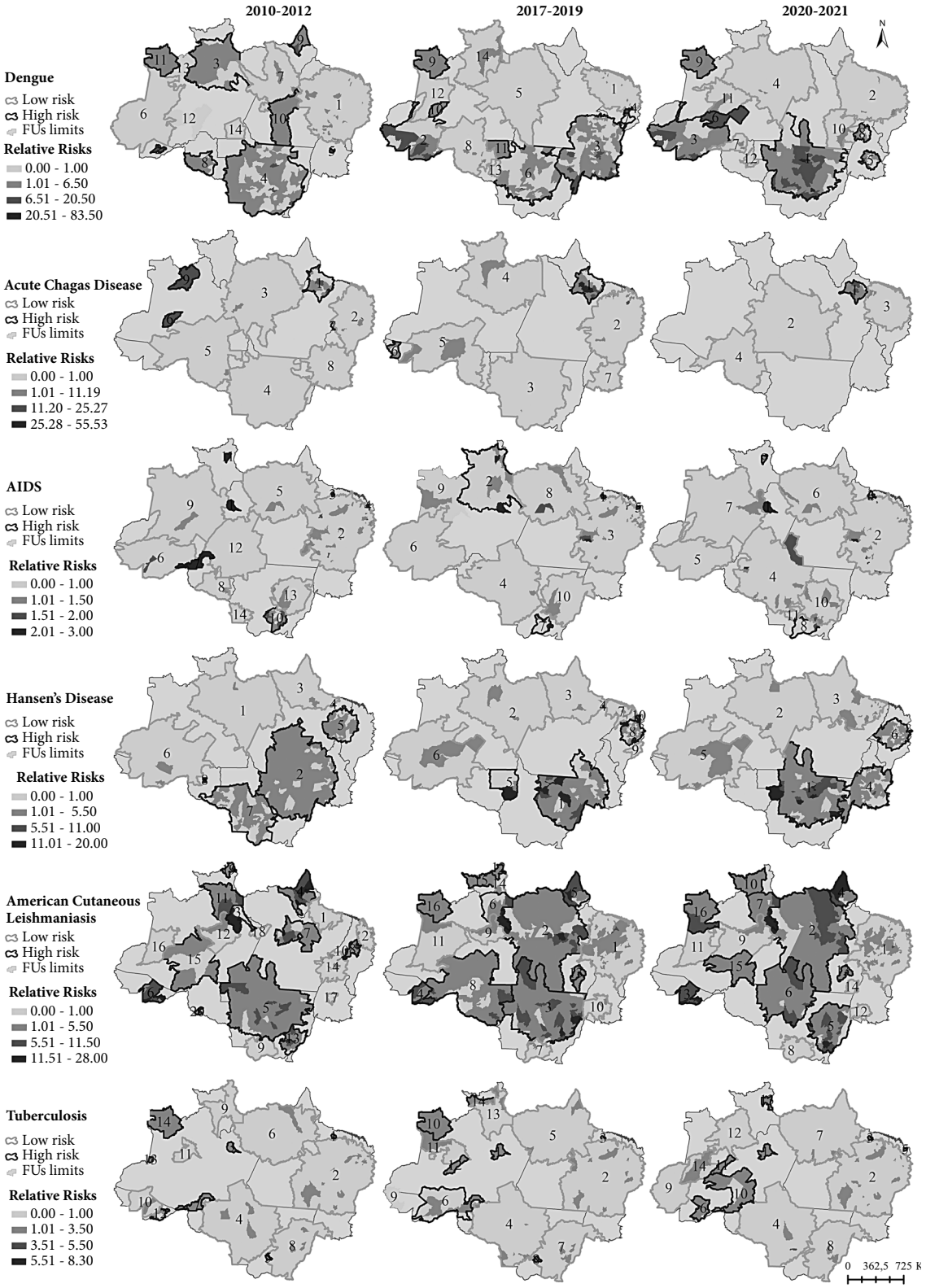

Figure 5. [A] Linear coefficient, and respective 95% confidence intervals (β1 - 95%CI), relative to the temporal trend of incidence rates, 2010 to 2021. [B] Distribution of spatial clusters of incidence rates of neglected diseases and AIDS. Legal Amazon, 2010-2012, 2017-2019 and 2020-2021.

Source: Authors.

of dengue decreased and remained below the country's average incidence rate. The incidence of Chagas disease, Hansen's disease, ACL, and tuberculosis remained above national average rates. Although the most risk areas may vary with indicators, the locations at the extremes of the Amazon, such as São Gabriel da Cachoeira, Vale do Acre, southern Mato-Grossense, in addition to the capitals Belém and São Luís configured high RR clusters with higher frequency and expansion trend between 2010 and 2021.

A study carried out by Brazilian regions for diseases of the circulatory and respiratory system observed a declining trend in the South and Southeast regions and an increase in the North and Northeast regions[23]. In the Legal Amazon, these differences in trends can be attributed to the persistence of unsatisfactory living conditions, reflected in the region's socioeconomic indicators and the limited supply and access to health services[17].

The infant mortality rate, both in the early neonatal and postneonatal categories, had a decreasing tendency, as well as the national rate. However, advances in economic and developmental indicators of the region do not seem to have benefited the local population equally. The northern Amazonas and the Araguaia region in Mato Grosso has high RR in infant's mortality rates, especially in the post-native category. These data show weaknesses in prenatal care, childbirth, and newborn in the Legal Amazon.

The MMR in the Amazon remained above the value established by the World Health Organization (WHO) for Brazil of 30 maternal deaths per 100,000 live births by 2030[24]. In the spatial analysis, a high RR for maternal death was observed in the first triennium (2010-2012) in the State of Maranhão. The State was classified with HDI of medium human development (0.639) in 2010[8]. The social vulnerability of this area may explain part of the high risk of maternal death since the MMR is a relevant indicator of population health, being related to the level of economic development in the region.

A study carried out for Brazil in 2018[25] identified the persistence of cases of ACD in the North region, with higher incidence rates than in Brazil (0.16 cases per 100,000 inhabitants) and formation of clusters with high RR in Acre and Pará, corroborating the findings of this study. The high risk of illness due to ACD in these regions may be associated with the precariousness of housing conditions and the migratory flow, with the occupation of floodplain forest areas and islands, and the risk of contamination by the pathogen when processing or consuming açaí incorrectly[2].

The increase in the incidence rate of AIDS in the Legal Amazon may be related to the largest male labor flow for activities such as mining, logging and heart of palm extraction, to build large infrastructure projects such as hydroelectric and highway, and the intensification of transportation of agricultural products along large road, river and border regions[17]. The high RR clusters for AIDS incidence were concentrated around cities with the high sociodemographic flow, a finding consistent with the study carried out in the State of Ceará between 2001 and 2011[26] where high AIDS rates were found in municipalities that had better living conditions and higher population density. These results suggest that AIDS may be associated with the rhythm of life and risk behaviors in these places.

There was a reduction in the overall detection rate of Hansen's disease in the Brazilian. However, the region has a very high situation classification (32.12 cases per 100,000 inhabitants) in 2021. These findings suggest the need to intensify active tracking of contacts of cases with Hansen's disease, awareness campaigns, and training of professionals in Primary Health Care to guarantee the interruption of transmission and reduction of Hansen's disease[27]. The high RR for Hansen's in the municipal aggregates where the region of the Xingu Indigenous Park is located may be associated with living conditions and the mode of territorial occupation enhanced by deforestation and small-scale agricultural and mining practices, causing an overload of existing infrastructure[28].

ACL is a public health problem in Brazil. Although the reduction in the incidence rate in the period studied, in 2021, the Legal Amazon had an incidence rate higher than Brazil's annual average. The geographic expansion of high RR clusters for the incidence of ACL was found in the second triennium and in the last two years in analysis in the regions occupied by indigenous lands. Indigenous territories are commonly located in endemic areas for the ACL and have a high rate of deforestation in their surroundings, which can interfere with the enzootic cycles of the parasite[28], resulting in increased transmission.

Contrary to the global trend, the Legal Amazon has a growing trend in the incidence rate of tuberculosis[29]. The results show a high RR of illness in municipal aggregates indigenous localities in the north of the region. These areas have high social vulnerability and infrastructure

deficit and sanitation. In addition to the difficulty of accessing health services, which prevents the diagnosis and adequate treatment of respiratory symptoms, contributes to the spread and maintenance of the disease[30].

In this study, we verified increased deaths from specific causes, including maternal, during the 2020-2021 period compared to the previous 2017-2019 triennium, according to studies covering the impacts of the COVID-19 pandemic[31,32]. Health protocols for the diagnosis and treatment of COVID-19 overloaded health systems and impaired the care and quality of services[29,33]. Except for dengue, the number of reported cases of neglected diseases in the Legal Amazon suffered a significant reduction, as an impact on the reduction of active search and case notification activities[34-36]. In the specific case of dengue, the increase in incidence happens from the reduction of environmental management activities by health systems[37].

The research reflects the unequal process of development in the Legal Amazon. The different socioeconomic and health indicators between the FUs and municipalities in the region[12,17] contribute to the differences in the pattern of distribution of morbidity and mortality rates of the analyzed outcomes. The variability between the risks identified in the analysis highlights the need for planning and reorganizing health services and their respective infrastructure to reflect the needs of the region's population.

As limitations of this study, we highlight that the analyzes performed with secondary data are subject to biases due to outdated data, incomplete and problems related to accuracy in the records. We emphasize that the results related to indicators calculated from the health information system should be interpreted with caution[17]. The study period of the last 12 years available in the databases has been selected due to the recent temporal cut and by contemplating more than a decade. It is an appropriate cut for health situation analysis. However, this period may have been insufficient to detect some relevant long-term trends[31].

The findings of this study can help in the planning of more effective strategies to improve the health care of residents in the Legal Amazon. Such actions are expected to impact morbidity and mortality in the region, promoting better health conditions for the population. The analysis of spatial clusters did not cover peculiar aspects beyond the territorial division of municipalities, which prevents the identification of problems in indigenous lands, riverside communities, and other specific contexts. These areas may present distinct health situations due to socioeconomic, cultural, and access to health services. It is recommended that future research study this gap through further analysis and collection of specific information from the subpopulations involved.

Conclusion

It was concluded that residents in the Legal Amazon face a difficult health situation and that there are important intra-variations and federative units. Morbimortality indicators have revealed higher rates and/or reasons than national averages for infant and maternal mortality, DCS, ECs, DSR, AIDS and Tropical Diseases and AIDS. We emphasize the need for prioritization of public policies to improve health conditions the regions of São Gabriel da Cachoeira, Vale do Acre, South Mato Grosso in addition to the capitals Belém and São Luís observed more frequently as a high-risk cluster.

Collaborations

NRO Lima: conception; data analysis and interpretation; writing of the manuscript; critical review; final approval of the version to be published. IN Oliveira: data analysis and interpretation; writing of the manuscript; critical review; final approval of the version to be published. RFV Sousa: data analysis and interpretation; writing of the manuscript; critical review; final approval of the version to be published. BFA Oliveira: data analysis and interpretation; writing of the manuscript; critical review; final approval of the version to be published. IH Silveira: data analysis and interpretation; writing of the manuscript; critical review; final approval of the version to be published. E Ignotti: drafting the work; Data analysis and interpretation; writing of the manuscript; critical review; final approval of the version to be published.

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