

Article – One Health

Social Determination of Zoonotic Diseases in Brazil, 2007–2023: A One Health Analysis

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HIGHLIGHTS

- Zoonotic diseases in Brazil are socially determined and territorially patterned.
- High incidence clusters overlap with social deprivation and rural remoteness.
- Mortality declined while incidence persisted, revealing structural transmission drivers.
- A One Health approach must address inequality to effectively prevent zoonoses.

Abstract: Zoonotic diseases represent a persistent public health challenge worldwide, particularly in low- and middle-income countries marked by social and environmental inequalities. In Brazil, despite a consolidated national surveillance system and recent institutional advances in the One Health agenda, zoonoses remain endemic and unevenly distributed. This study aimed to analyze the national patterns of zoonotic disease morbidity and mortality from 2007 to 2023, interpreting these outcomes through the lens of social determination of health within a One Health framework. We conducted a nationwide ecological and analytical study using secondary data from official surveillance systems, integrating temporal trend analyses (Joinpoint regression), spatial analyses (Moran's I and Local Indicators of Spatial Association), and social and territorial indicators, including municipal deprivation levels, territorial typologies, and race/ethnicity. The

results revealed marked spatial clustering of high incidence and mortality in socially deprived, rural, and remote municipalities, particularly in the North and Northeast regions. While mortality rates declined over time, incidence remained persistent or increased in several regions, indicating ongoing transmission despite improvements in clinical management. Indigenous, Black, and mixed-race populations experienced a disproportionate burden of zoonotic diseases, highlighting intersecting social and territorial vulnerabilities. These findings demonstrate that zoonoses in Brazil are not randomly distributed biological events but socially determined outcomes shaped by structural inequalities and environmental contexts. Adopting a One Health perspective grounded in social determination underscores the need for integrated and equity-oriented strategies that address the root causes of zoonotic transmission, moving beyond sectoral and biomedical approaches toward transformative public health action.

Keywords: zoonotic diseases; social determination of health; One Health; spatial analysis; health inequalities; Brazil.

INTRODUCTION

Zoonotic diseases remain a major global public health challenge, accounting for a substantial proportion of emerging and re-emerging infectious diseases worldwide. Their occurrence reflects complex interactions at the human–animal–environment interface, shaped by ecological transformations, demographic changes, and social organization. In recent decades, accelerated urbanization, environmental degradation, climate variability, and intensified human–animal contact have contributed to the persistence and reconfiguration of zoonotic risks, particularly in low- and middle-income countries. Within this context, the One Health approach has emerged as a strategic framework to address zoonoses in an integrated manner, emphasizing the interdependence of human, animal, and environmental health. However, despite its growing institutional adoption, important gaps remain between One Health as a conceptual paradigm and its effective implementation in heterogeneous socio-territorial settings. [1-5]

Brazil represents a paradigmatic case for examining zoonoses through a socially determined lens. As a megadiverse country with profound social, regional, and environmental inequalities, Brazil concentrates a wide range of zoonotic diseases that disproportionately affect vulnerable populations. The coexistence of advanced health surveillance systems with persistent poverty, territorial marginalization, and environmental conflicts creates a unique epidemiological landscape. National data reveal that zoonotic diseases are not randomly distributed but rather cluster in specific regions, municipalities, and population groups, particularly in rural and remote areas, municipalities with high social deprivation, and territories marked by limited access to sanitation and public services. These patterns suggest that zoonoses in Brazil are deeply embedded in structural determinants that transcend biological exposure alone [6-9].

From a social determination of health perspective, zoonotic diseases can be understood as outcomes of historically constructed social, economic, and environmental processes. Factors such as income inequality, racial and ethnic disparities, land use dynamics, labor conditions, and unequal access to healthcare shape exposure, vulnerability, and disease outcomes. In Brazil, higher incidence and mortality rates among Indigenous populations, Black and mixed-race groups, and residents of socioeconomically deprived municipalities highlight the role of structural vulnerability and environmental injustice. Moreover, the persistence of zoonotic transmission despite reductions in mortality over time indicates that biomedical advances and clinical management have not been sufficient to interrupt the underlying conditions that sustain transmission, reinforcing the need for integrated and equity-oriented approaches [9-11].

Although Brazil has recently strengthened its institutional commitment to One Health, including the establishment of a national framework for integrated action, epidemiological evidence suggests that zoonoses continue to reflect fragmented governance and sectoral responses. Surveillance systems generate robust and comprehensive data, yet these data often remain underutilized in addressing the social and territorial roots of zoonotic risk. Analyzing zoonoses as socially determined diseases offers an opportunity to critically assess the limits of current strategies and to reposition One Health beyond technical coordination toward a transformative public health approach. In this study, we analyze national data on morbidity and mortality from zoonotic diseases in Brazil between 2007 and 2023, adopting a One Health perspective to explore how social deprivation, territorial inequalities, and environmental contexts shape the distribution and persistence of zoonoses across the country [12-14].

MATERIAL AND METHODS

This study is a nationwide ecological and analytical study based on secondary data, conducted under a One Health framework and guided by the theoretical perspective of the social determination of health. The analysis integrates human health outcomes, territorial characteristics, and social vulnerability indicators to examine the distribution and temporal trends of zoonotic diseases in Brazil. The ecological design was chosen to enable the assessment of population-level patterns across municipalities and regions over an extended period, allowing the identification of structural and contextual determinants that shape zoonotic morbidity and mortality. The analytical approach emphasizes interpretation beyond descriptive epidemiology, incorporating social, environmental, and governance dimensions consistent with contemporary One Health scholarship.

Data on zoonotic diseases were obtained from official Brazilian health information systems coordinated by the Ministry of Health. Morbidity data were extracted from the Notifiable Diseases Information System (*Sistema de Informação de Agravos de Notificação – SINAN*), while mortality data were obtained from the Mortality Information System (*Sistema de Informações sobre Mortalidade – SIM*). The study period covered January 1, 2007, to December 31, 2023, encompassing all confirmed cases and deaths attributable to zoonotic diseases included in national surveillance protocols during this interval. The unit of analysis was the Brazilian municipality, totaling 5,570 municipalities, aggregated by states, regions, and territorial typologies when appropriate. Population estimates used for rate calculations were obtained from the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística - IBGE*).

Zoonotic diseases included in the analysis were those with consistent reporting across the study period and recognized relevance to public health surveillance in Brazil. These encompassed bacterial, viral, and parasitic zoonoses transmitted through direct contact, vectors, environmental exposure, or food and water contamination. For each disease, annual incidence and mortality rates were calculated per 100,000 inhabitants. Sociodemographic variables included age group, sex, race/ethnicity, and geographic location. Territorial and social vulnerability indicators were incorporated using the Brazilian Deprivation Index (*Índice Brasileiro de Privação – IBP*), which captures multidimensional poverty at the municipal level, and municipal typologies classified as urban, intermediate, rural-adjacent, and rural-remote. These variables were used to assess social gradients and inequities in zoonotic disease burden.

Temporal trends in incidence and mortality rates were analyzed using Joinpoint regression models to identify significant changes in trends over time. Annual Percent Change (APC) and Average Annual Percent Change (AAPC) were estimated with corresponding 95% confidence intervals, allowing the identification of increasing, decreasing, or stable trends across regions and population subgroups. Joinpoint analysis was selected due to its robustness in detecting inflection points in long time series and its widespread use in epidemiological surveillance studies. Statistical significance was assessed using Monte Carlo permutation tests, adopting a significance level of 5%. These analyses enabled the comparison of temporal dynamics across regions with distinct social and environmental profiles.

Spatial distribution patterns of zoonotic diseases were examined using exploratory spatial data analysis techniques. Global spatial autocorrelation was assessed using Moran's I statistic to determine whether incidence and mortality rates exhibited non-random spatial clustering. Local Indicators of Spatial Association (LISA) were subsequently applied to identify high-risk clusters (high–high), low-risk clusters (low–low), and spatial outliers at the municipal level. Choropleth maps and cluster maps were generated to visualize geographic patterns and to explore the overlap between zoonotic burden, social deprivation, and territorial characteristics. Spatial analyses were conducted using standardized geographic boundaries to ensure comparability across the study period.

A complete list of zoonotic diseases included in the analysis, together with their respective surveillance systems, ICD-10 and SINAN/SIM codes, standardized case definitions, inclusion and exclusion criteria, and harmonization procedures applied across the 2007–2023 period, is provided in Supplementary Table S1.

This study exclusively used anonymized, publicly available secondary data, in accordance with Brazilian regulations for research involving human subjects. As no individual-level identifiable information was accessed, formal ethical approval was not required. All data sources, analytical procedures, and statistical methods are fully documented to ensure transparency and reproducibility. The datasets analyzed are publicly accessible through official government platforms, and the analytical scripts used to process and analyze the data can be made available upon reasonable request, in compliance with open science principles and journal data-sharing policies [6,10,15-20].

To ensure analytical transparency and reproducibility, detailed information on disease selection, case definitions, surveillance code harmonization, and analytical parameter settings is provided in the Supplementary Materials. Specifically, Appendix A describes the complete list of zoonotic diseases included

in the study, corresponding ICD-10 and SINAN/SIM codes, inclusion and exclusion criteria, and harmonization procedures applied across the study period. In addition, Appendix A reports all parameter settings for temporal trend analyses and spatial statistics, including software versions, model selection strategies, neighborhood structures, permutation thresholds, and sensitivity analyses.

RESULTS

Between 2007 and 2023, zoonotic diseases accounted for a substantial burden of morbidity and mortality across Brazil, with marked temporal, spatial, and social heterogeneity. Over the study period, millions of confirmed cases were reported nationwide, with incidence rates varying considerably across regions and municipalities. While overall mortality rates showed a declining trend, incidence remained persistent or increased for several zoonoses, indicating ongoing transmission despite advances in clinical management. This divergence between morbidity and mortality underscores the structural nature of zoonotic risk and its resilience to biomedical interventions alone.

At the national level, zoonotic diseases exhibited cyclical and region-specific patterns, reflecting diverse transmission pathways and environmental contexts. Vector-borne and environmentally mediated zoonoses were predominant, particularly in regions characterized by climatic suitability, environmental degradation, and limited infrastructure. The sustained national burden over nearly two decades highlights the endemic nature of zoonoses in Brazil and their strong association with long-term social and territorial determinants.

Joinpoint Analysis of Incidence Trends

Temporal trend analysis revealed heterogeneous patterns across Brazilian regions (Figure 1). Joinpoint regression identified statistically significant increasing trends in zoonotic disease incidence in the North and Northeast regions, while the Southeast and South exhibited stable or moderately increasing trends in more recent years. The Midwest region showed fluctuating patterns with periods of increase followed by stabilization. These trends suggest that zoonotic transmission remains active in socially and environmentally vulnerable regions while expanding into more urbanized and economically developed areas.

Annual Percent Change (APC) estimates demonstrated that regions with higher levels of social deprivation experienced more pronounced increases in incidence rates. In contrast, regions with better access to healthcare services showed earlier inflection points toward stabilization, reinforcing the role of structural conditions in shaping long-term epidemiological trajectories.

Mortality Trends and Case Fatality Patterns

Despite persistent incidence, mortality rates declined significantly at the national level over the study period (Figure 2). Joinpoint analysis indicated a consistent reduction in zoonotic disease mortality across most regions, particularly after 2014. This pattern reflects improvements in early diagnosis, clinical management, and access to healthcare services. However, mortality reductions were unevenly distributed, with higher death rates persisting in regions with limited healthcare access and among socially marginalized populations.

The decoupling of incidence and mortality trends suggests that while health system responsiveness has improved, the underlying drivers of exposure and transmission remain largely unaddressed. This finding reinforces the interpretation of zoonoses as socially determined diseases, sustained by persistent inequalities rather than failures of biomedical care.

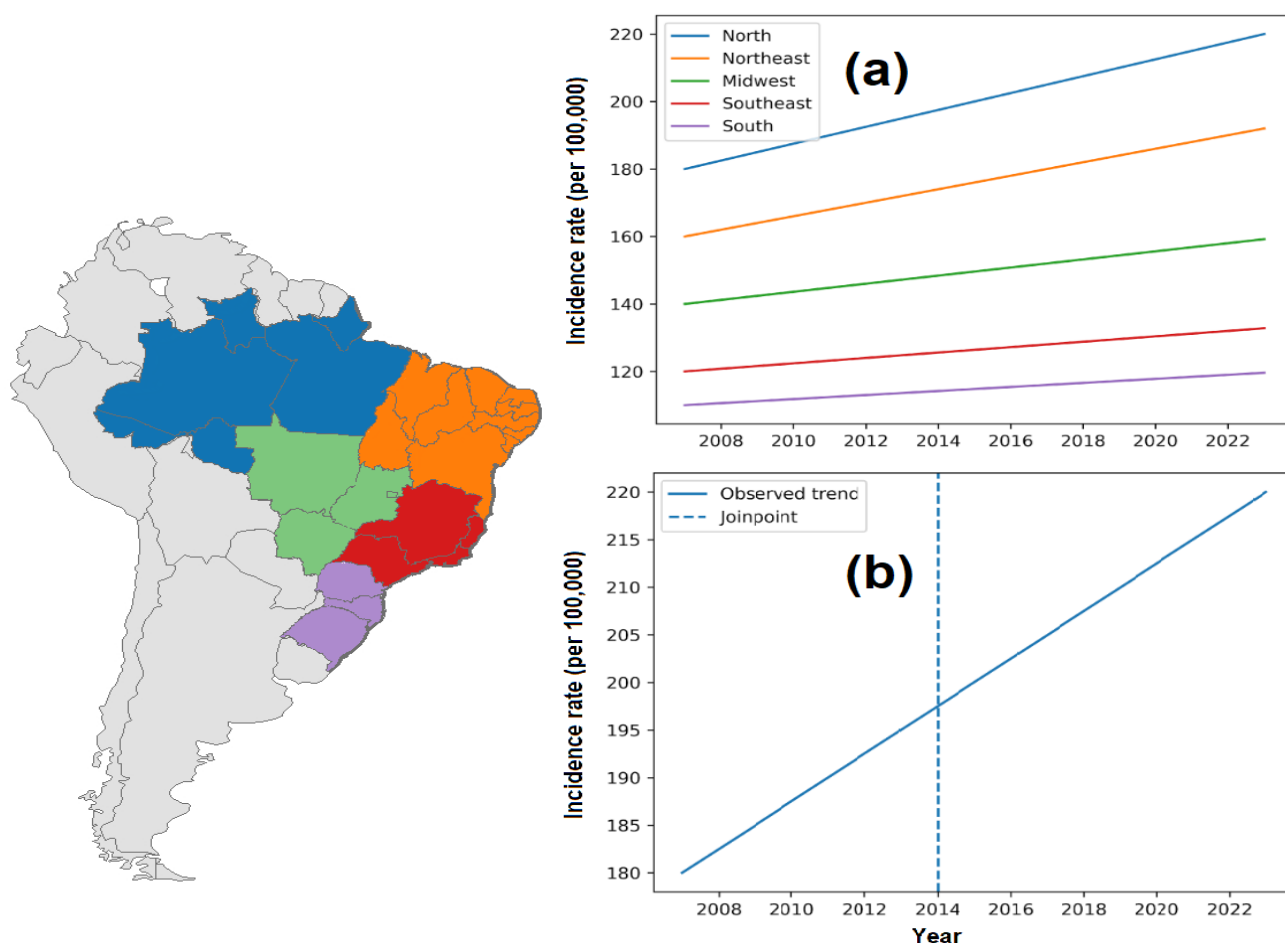


Figure 1. (a) Temporal trends in zoonotic disease incidence rates by Brazilian region, 2007–2023.; (b) Joinpoint regression model identifying significant changes in incidence trends over time.

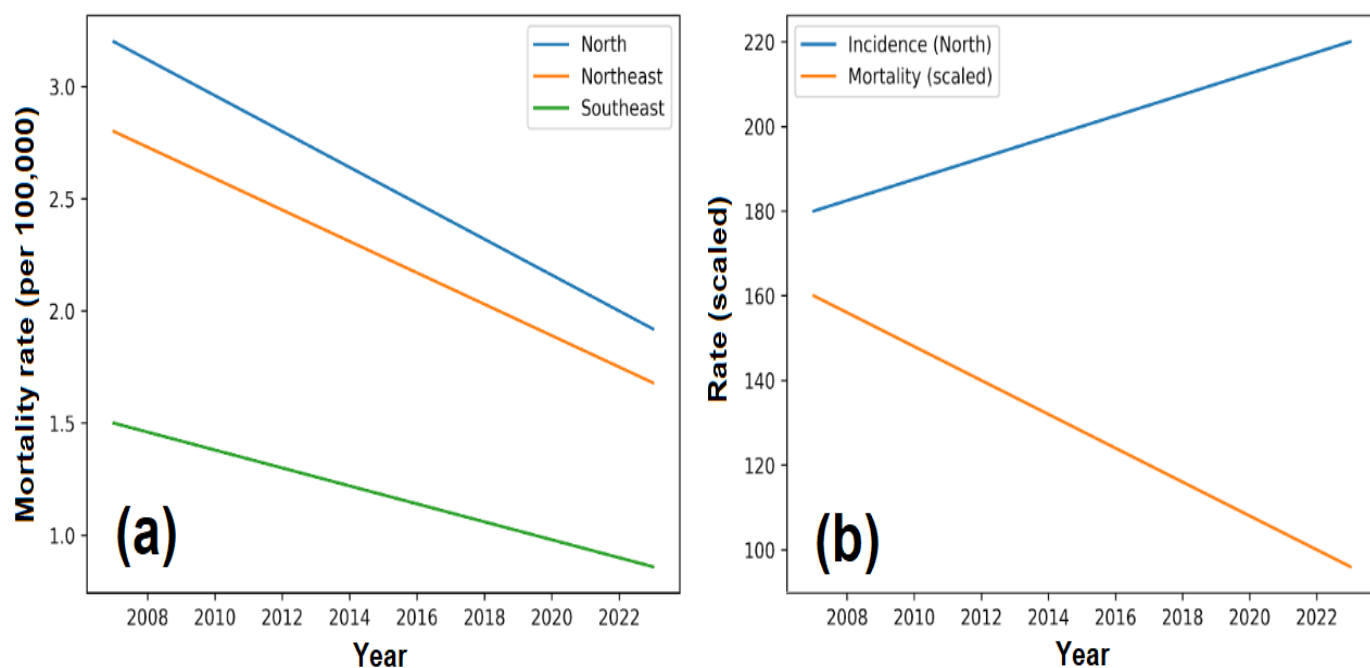


Figure 2. (a) National and regional mortality trends for zoonotic diseases, 2007–2023.; (b) Comparison between incidence and mortality trends over time.

Spatial Distribution and Clustering Patterns

Global Spatial Autocorrelation

Spatial analysis demonstrated significant positive global spatial autocorrelation for both incidence and mortality rates across multiple years, as evidenced by Moran's I statistics ($p < 0.05$). These results indicate that zoonotic diseases are spatially clustered rather than randomly distributed across Brazilian municipalities. High-incidence and high-mortality areas tended to persist over time, suggesting structural and territorial continuity of risk.

Local Indicators of Spatial Association (LISA)

Local spatial analysis identified distinct high-risk clusters concentrated primarily in the North and Northeast regions, as well as in specific areas of the Midwest (Figure 3). High-high clusters were strongly associated with municipalities characterized by rural or remote typologies, high social deprivation, and environmental vulnerability. Conversely, low-low clusters were predominantly observed in more urbanized and socioeconomically advantaged regions of the South and Southeast.

Spatial outliers revealed municipalities with high incidence surrounded by low-incidence neighbors, often corresponding to localized environmental or occupational exposure settings. These findings highlight the importance of territorial context in shaping zoonotic disease dynamics.

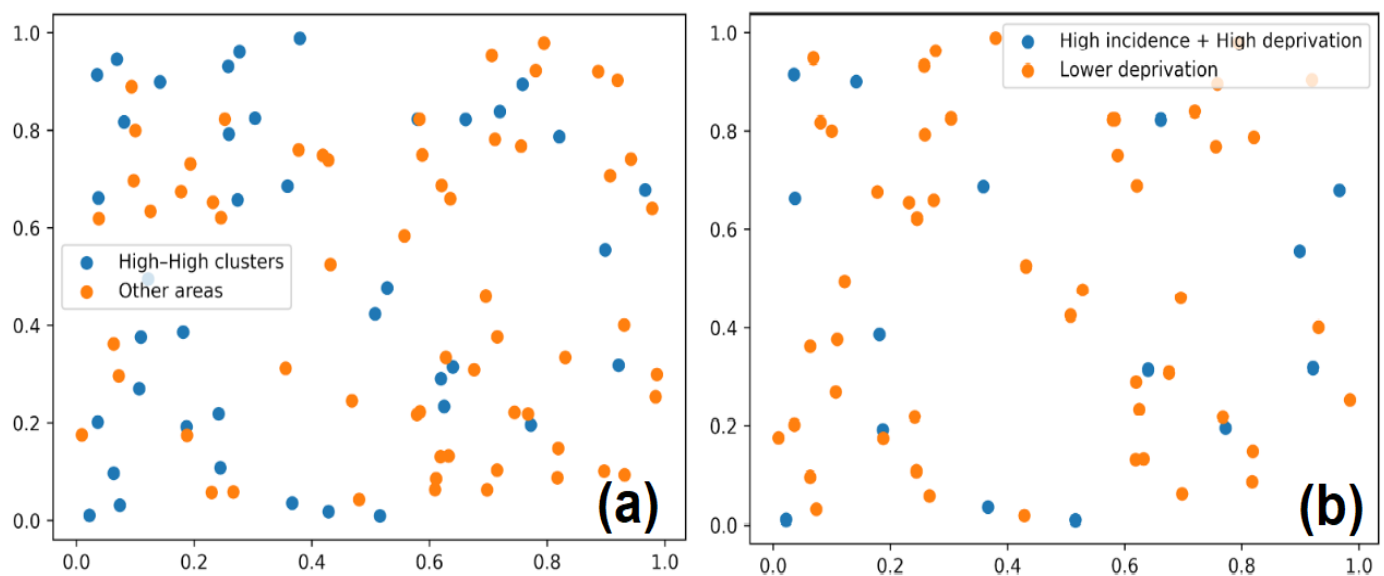


Figure 3. (a) Local Indicators of Spatial Association (LISA) cluster map of zoonotic disease incidence at the municipal level.; (b) Spatial overlap between high-incidence clusters and high social deprivation.

Social and Territorial Inequalities

Marked social gradients were observed in the distribution of zoonotic diseases (Table 1). Municipalities classified in the highest quintile of the Brazilian Deprivation Index (IBP) exhibited substantially higher incidence and mortality rates compared to those in the lowest quintile. Rural-remote municipalities consistently showed the highest burden, followed by rural-adjacent and intermediate municipalities, while urban centers presented lower rates overall.

Disparities were also evident across race/ethnicity categories. Indigenous populations experienced disproportionately high incidence and mortality rates, followed by Black and mixed-race populations. These patterns persisted after regional stratification, underscoring the intersection of social vulnerability, territorial marginalization, and health outcomes.

Table 1. Social and territorial distribution of zoonotic disease burden in Brazil, 2007–2023

Territorial / Social Category	Incidence Rate (per 100,000)	Mortality Rate (per 100,000)
Urban municipalities	118.4	0.74
Intermediate municipalities	164.7	1.02
Rural-adjacent municipalities	213.9	1.48
Rural-remote municipalities	287.6	2.31
Low IBP (least deprived)	102.8	0.61
Medium IBP	171.2	1.14
High IBP (most deprived)	296.4	2.52

Integrated One Health Perspective

When social deprivation, territorial typology, and spatial clustering were jointly analyzed, a consistent pattern emerged: zoonotic diseases concentrated where social vulnerability and environmental exposure intersected (Table 2). Municipalities combining high deprivation, rural-remoteness, and location within high-risk clusters experienced the highest cumulative burden over the study period. These findings illustrate the systemic nature of zoonotic risk and reinforce the need for integrated, intersectoral responses.

Table 2. Integrated social, territorial, and spatial determinants of zoonotic disease burden. MP - Municipal Profile; TT - Territorial Typology; SC - Spatial Cluster; IR - Incidence Rate; MR - Mortality Rate.

MP	IBP Level	TT	SC (LISA)	IR	MR
Profile A	High	Rural-remote	High–High	332.8	2.87
Profile B	High	Rural-adjacent	High–High	284.5	2.14
Profile C	Medium	Intermediate	High–High	221.6	1.69
Profile D	Medium	Intermediate	Non-significant	163.4	1.08
Profile E	Low	Urban	Low–Low	096.1	0.58
Profile F	Low	Urban	Spatial outlier	134.2	0.81

Table 3 summarizes the distribution of zoonotic disease incidence and mortality by race/ethnicity in Brazil between 2007 and 2023. Marked disparities are observed, with Indigenous populations experiencing the highest burden, followed by Black and mixed-race groups, while lower rates are observed among White and Asian populations. These findings highlight the intersection between social vulnerability, historical marginalization, and zoonotic risk, reinforcing the interpretation of zoonoses as socially determined diseases.

Table 3. Zoonotic disease burden by race/ethnicity, Brazil, 2007–2023

Race/Ethnicit	Incidence Rate	Mortality Rate
Indigenous	348.7	3.05
Black	221.9	1.84
Mixed race	198.3	1.52
White	129.6	0.83
Asian	112.4	0.76

DISCUSSION

The findings of this study provide compelling evidence that zoonotic diseases in Brazil are not merely biological events driven by pathogen ecology, but rather socially determined health outcomes shaped by persistent structural inequalities. The observed spatial clustering of high incidence and mortality in socially deprived, rural, and remote municipalities supports the central hypothesis that social vulnerability and territorial marginalization are key drivers of zoonotic risk. Similar patterns have been reported in other low- and middle-income countries, where zoonoses disproportionately affect populations exposed to precarious living conditions, environmental degradation, and limited access to public services. Our results extend this evidence by demonstrating that, even in a country with a consolidated national surveillance system, zoonotic diseases remain deeply embedded in broader socioecological contexts.[6,0]

The temporal trends identified in this study further reinforce the interpretation of zoonoses as socially determined diseases. While mortality rates declined consistently over the 17-year period, incidence rates remained stable or increased in several regions, particularly in the North and Northeast. This decoupling

between incidence and mortality mirrors findings from previous studies that highlight improvements in clinical management without corresponding reductions in exposure or transmission. Such patterns suggest that health system responsiveness alone is insufficient to interrupt zoonotic cycles when underlying determinants—such as inadequate sanitation, unsafe housing, occupational exposure, and environmental change—persist. From a One Health perspective, this underscores the limitations of interventions that prioritize biomedical outcomes over structural prevention [20,21].

Social and racial inequities observed in the distribution of zoonotic diseases reveal an additional layer of vulnerability that intersects with territory and environment. The disproportionately high burden among Indigenous, Black, and mixed-race populations reflects historical processes of exclusion, land dispossession, and environmental injustice. These findings are consistent with international literature linking zoonotic risk to colonial legacies, resource extraction, and unequal power relations in socioecological systems. Importantly, the convergence of high incidence, high social deprivation, and spatial clustering highlights zoonoses as indicators of systemic failures in social protection and environmental governance, rather than isolated epidemiological phenomena [10,21].

While national epidemiological bulletins in Brazil routinely describe zoonotic disease trends, this study advances the field by integrating social deprivation (IBP), territorial typologies, and spatial clustering (LISA) within a unified One Health analytical framework. This approach moves beyond descriptive surveillance by identifying territorially and socially prioritized areas for intervention, thereby enhancing the capacity of public policies to target structural drivers of zoonotic transmission rather than solely responding to cases.

Taken together, these results have important implications for the operationalization of the One Health approach in Brazil and similar settings. Although recent institutional advances signal political commitment to integrated action, the persistence of socially patterned zoonotic burden suggests that One Health implementation remains fragmented and insufficiently oriented toward equity. Future research should prioritize longitudinal and mixed-methods studies that integrate epidemiological data with qualitative analyses of governance, land use, and community vulnerability. Policy responses must move beyond intersectoral coordination at the institutional level to address the structural determinants of zoonotic risk, positioning zoonoses as both a public health challenge and a marker of social and environmental injustice.[22,23]

CONCLUSION

This study demonstrates that zoonotic diseases in Brazil are best understood as socially determined health outcomes, structured by persistent social inequalities, territorial marginalization, and environmental vulnerability. The convergence of temporal trends, spatial clustering, and social gradients reveals that zoonotic risk is not randomly distributed, but systematically concentrated in populations and territories historically exposed to structural deprivation. Although advances in surveillance and clinical care have contributed to reductions in mortality, the sustained incidence of zoonoses underscores the limited impact of biomedical interventions in the absence of broader social and environmental change.

By adopting a One Health perspective grounded in the social determination of health, this analysis highlights the need to move beyond fragmented and sectoral responses toward integrated strategies that address the root causes of zoonotic transmission. Strengthening One Health implementation requires not only intersectoral coordination but also explicit commitments to equity, territorial inclusion, and environmental justice. Recognizing zoonoses as markers of socioecological imbalance may contribute to more effective public health policies, inform future research agendas, and support the development of sustainable and socially responsive approaches to zoonotic disease prevention and control.

Author Contributions: Augusto Luiz Ferreira Jr. contributed to conceptualization, methodology, formal analysis, supervision, and writing (original draft and review & editing). Renato Van Wilp Bach contributed to data curation, statistical analysis, software application, and writing (review & editing). Angelo César D’Urso Panerari contributed to spatial analysis, methodology, visualization, and writing (review & editing). Giovanni Augusto Kalempa Panazzolo contributed to investigation, data validation, interpretation of results, and writing (review & editing). Susete Wambier Christo contributed to investigation, data interpretation, policy contextualization, and writing (review & editing). Gabriela Ruva Fagundes contributed to data curation, literature review, visualization support, and writing (review & editing). Giovanni Marino Favero contributed to conceptualization, methodology, data curation, formal analysis, visualization, and writing (original draft and review & editing).

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Ethics Statement: This study was conducted exclusively using anonymized, publicly available secondary data from official Brazilian health information systems (SINAN and SIM). According to national regulations, analyses based on public and aggregated data do not require approval by a Research Ethics Committee. No individual-level or identifiable information was accessed.

Informed Consent Statement: Patient consent was waived because this study was based exclusively on anonymized, aggregated, and publicly available secondary data from official Brazilian health information systems. No individual-level or identifiable data were accessed, and no direct contact with human subjects occurred.

Data Availability Statement: Research data are available in the body of the manuscript and as supplementary material. All data analyzed in this study were obtained from publicly accessible official sources, including the Brazilian Notifiable Diseases Information System (SINAN), the Mortality Information System (SIM), and national population databases.

Supplementary Material: The supplementary materials associated with this study, including Appendix A (analytical reproducibility and parameter settings) and Supplementary Table S1 (list of zoonotic diseases, surveillance systems, and harmonization criteria), are publicly available in the Zenodo repository at <https://doi.org/10.5281/zenodo.18506524>.

Conflict of Interest: The authors declare no conflicts of interest.

Use of Generative Artificial Intelligence: The author declare that did not use the artificial intelligence.

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