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# Spatiotemporal Patterns of AIDS Among Older Adults in Brazil: A Nationwide Ecological Study, 2001–2022

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## Abstract

# Background

Population aging and advances in antiretroviral therapy have contributed to an increasing number of older adults living with HIV. Despite this demographic shift, evidence on the epidemiological and spatial dynamics of AIDS among older adults in Brazil remains limited. This study aimed to analyze the sociodemographic profile, temporal trends, and spatial distribution of AIDS cases among older adults in Brazil between 2001 and 2022.

# Methods

A mixed ecological study was conducted using data from all AIDS cases reported among individuals aged 60 years or older in Brazil between 2001 and 2022, obtained from the Notifiable Diseases Information System (SINAN). Sociodemographic characteristics were described using absolute and relative frequencies. Temporal trends in incidence rates were assessed using Joinpoint regression, estimating Annual Percent Change (APC) and Average Annual Percent Change (AAPC). Spatial distribution was evaluated using Global Moran's Index and Local Indicators of Spatial Association (LISA).

# Results

A total of 40,015 AIDS cases were reported among older adults during the study period. Cases were more frequent among males (61.6%), individuals aged 60–69 years (79.1%), White individuals (30.5%), and those with low educational attainment. Nationally, AIDS incidence showed an increasing trend (AAPC = 1.42%; 95% CI 0.51–2.34; p = 0.002), with the highest increases observed in the North (AAPC = 9.59%; 95% CI 5.14–14.23; p < 0.001) and Northeast (AAPC = 6.33%; 95% CI 4.92–7.75; p < 0.001) regions. The Southeast was the only region with a decreasing trend (AAPC = − 1.07%; 95% CI − 1.77 to − 0.36; p = 0.003). Spatial analysis revealed significant spatial autocorrelation (Moran's I = 0.197; p = 0.001), with 474 municipalities (8.5%) classified as high-high clusters, accounting for 43.6% of all reported cases. High-priority clusters were predominantly concentrated in the South and Central-West regions, although progressive expansion to other areas of the country was observed over time.

# Conclusions

AIDS incidence among older adults increased in Brazil between 2001 and 2022, with marked regional inequalities and significant spatial clustering. The concentration of cases in specific territories and the persistence of increasing trends in several regions highlight the need for targeted prevention, early diagnosis, and healthcare strategies tailored to the aging population, particularly in socially vulnerable areas.

## Contributions to the Literature

- This study provides the first nationwide assessment integrating sociodemographic characteristics, temporal trends, and spatial distribution of AIDS cases among older adults in Brazil over a 22-year period.
- The findings reveal marked regional inequalities in AIDS incidence among older adults, with increasing trends concentrated in the North and Northeast regions and declining trends in the Southeast.
- Spatial analysis identified significant geographic clustering of cases, highlighting priority municipalities predominantly located in the South and Central-West regions.
- The study demonstrates the overlap between population aging and the HIV/AIDS epidemic, emphasizing the need for prevention, testing, and care strategies specifically tailored to older adults.
- By identifying temporal and spatial heterogeneity across the country, the findings provide evidence to support more equitable and targeted public health policies for aging populations affected by HIV/AIDS.

## Background

The Human Immunodeficiency Virus (HIV) is the retrovirus responsible for Acquired Immunodeficiency Syndrome (AIDS), a condition characterized by the progressive deterioration of the immune system, making the body more susceptible to opportunistic infections and neoplasms (1). Since its identification in the 1980s, HIV infection has evolved from a rapidly fatal condition into a manageable chronic disease, largely due to early diagnosis and advances in antiretroviral therapy (2).

According to data from the World Health Organization, an estimated 39 million people were living with HIV worldwide in 2023, including 38.6 million adults and 1.4 million children. In the same year, approximately 1.3 million new infections occurred, representing a 39% reduction since 2010 and a 60% reduction since 1995 (2). In Brazil, it is estimated that approximately 950,000 people are living with HIV, of whom 83% are receiving antiretroviral therapy (ART), with a viral suppression rate of 95% among those undergoing treatment (3).

In this context, strategies to address the epidemic have emphasized the expansion of policies targeting vulnerable populations (4), the integration of HIV care into health systems under the principles of universal health coverage and strengthened primary health care (1), as well as the promotion of combination prevention. This approach combines biomedical, behavioral, and structural interventions, including the use of pre-exposure prophylaxis (PrEP), treatment as prevention (TasP), and actions aimed at reducing stigma (1, 5).

Despite these advances, the epidemic remains a major public health challenge, particularly among groups with increased vulnerability, such as older adults (6). Population aging, associated with increased life expectancy, has contributed to the emergence of a new epidemiological profile characterized by the

growing number of people aged 60 years or older living with HIV (7). In Brazil, this process has occurred rapidly, with more than 30 million older adults, corresponding to approximately 14% of the population, and a continuing upward trend projected for the coming decades (8), thereby increasing the number of individuals potentially exposed to infection and living with the disease.

This phenomenon is driven both by the increased survival provided by antiretroviral therapy (ART), which allows individuals infected at younger ages to reach old age, and by the occurrence of new infections in this age group (2, 9), highlighting the overlap between population aging and the aging of people living with HIV.

In addition, behavioral and structural factors contribute to the continued transmission among older adults, including persistent sexual activity, low condom use, reduced risk perception, the invisibility of sexuality in older age, and the limited inclusion of this population in prevention strategies (10). This scenario poses a dual challenge for health systems, which must simultaneously respond to the demands of population aging and the clinical, epidemiological, and social specificities associated with HIV infection in this population.

Although HIV infection represents the initial event, epidemiological surveillance in Brazil has historically been based on the notification of AIDS cases, particularly in longer time series analyses. In this regard, the analysis of AIDS cases remains an important strategy for monitoring the dynamics of the epidemic in the country.

Given this context, this study aims to analyze the sociodemographic profile, as well as the temporal and spatial trends of AIDS cases among older adults in Brazil between 2001 and 2022.

# Methods

Study design, population, and period

This was a mixed ecological study involving all AIDS cases reported among the older adult population (≥ 60 years) in Brazil between 2001 and 2022. Cases reported to the Notifiable Diseases Information System (SINAN) were included, according to the case definitions in force during the analyzed period.

Location

The study encompassed Brazil, its five macroregions (North, Northeast, South, Southeast, and Central-West), and the 27 federative units, including the Federal District. The country has a territorial area of approximately 8.5 million km² and an estimated population of around 203 million inhabitants, with a population density of 23.86 inhabitants/km² (8). The demographic, socioeconomic, and structural heterogeneity across regions represents a relevant challenge for epidemiological analyses on a national scale.

Figure 1 presents the geographic distribution of Brazil, its macro-regions, and federative units, providing spatial context for the analyses conducted in this study.

**Figure 1– Geographic location of Brazil, its macro-regions, and federative units.**

**Legend**

Brazil's five macro-regions (North, Northeast, Central-West, Southeast, and South) and 27 federative units included in the study.

Data source and study variables

Data were obtained from the Notifiable Diseases Information System (SINAN), which is used to monitor compulsory notifiable diseases in Brazil. Information was accessed through the TabNet platform of the Department of Informatics of the Brazilian Unified Health System (DATASUS) (https://datasus.saude.gov.br/informacoes-de-saude-tabnet/). Population estimates used for the calculation of incidence rates were provided by the Brazilian Institute of Geography and Statistics (IBGE).

The following sociodemographic variables were analyzed: age group (60–69; 70–79; ≥80 years), year of diagnosis (2001–2022), sex, race/skin color, and education level, stratified by regions and federative units.

# Statistical analysis

# Step 1 – Descriptive analysis of the sociodemographic and clinical profile

Sociodemographic variables were analyzed using absolute values and relative frequencies (%), allowing characterization of the epidemiological profile of AIDS cases in the older adult population.

## Step 2 – Time series analysis

The incidence rate was calculated as the ratio between the number of new AIDS cases reported in a given year and the corresponding population in the same period, multiplied by 100,000 inhabitants. Additionally, rates estimated by the Joinpoint regression model, derived from the temporal series fitting, were considered to better represent trends throughout the study period.

Temporal trend analysis was performed using the Joinpoint Regression model, which allows the identification of significant changes in trends over time. The Annual Percent Change (APC) was estimated for each segment of the series, as well as the Average Annual Percent Change (AAPC) for the entire period.

The adopted parameters included a minimum of zero and a maximum of two joinpoints, model selection based on 4,499 permutations, a significance level of 5%, and 95% confidence intervals, with correction for residual autocorrelation.

Analyses were performed using the Joinpoint Regression Program, version 5.2.0 (National Cancer Institute, Bethesda, MD, USA), considering three levels of spatial aggregation: Brazil, macroregions, and federative units.

## Step 3 – Spatial analysis

Spatial analysis was conducted to evaluate the geographic distribution of AIDS incidence rates in the older adult population.

Initially, the global Moran's index was calculated to verify the presence of spatial autocorrelation. Once significant spatial dependence was identified, local analysis was performed using the Local Index of Spatial Association (LISA) (11).

A first-order contiguity criterion was adopted, considering neighboring municipalities as those sharing geographic boundaries. The spatial weights matrix was constructed based on this criterion and row-standardized, so that the sum of the weights for each spatial unit equaled 1.

Municipalities were classified into the quadrants of the Moran scatterplot as follows: Q1 (high-high), indicating areas with high rates surrounded by municipalities with high rates; Q2 (low-low); Q3 (high-low); and Q4 (low-high). Municipalities classified as Q1 were considered the highest priority for intervention.

Spatial analyses were performed using QGIS software (version 3.40.0) and GeoDa (version 1.22.0.10).

Ethical aspects

Only secondary data from publicly accessible information systems were used in this study, with no possibility of individual identification. Therefore, approval by a Research Ethics Committee was not required.

## Results

Between 2001 and 2022, 40,015 older adults were diagnosed with AIDS in Brazil, with a higher prevalence among males (61.56%; n = 24,635), individuals aged 60–69 years (79.12%; n = 31,658), White individuals (30.48%; n = 12,196), and those with low or no educational attainment, including illiterate individuals and those with incomplete elementary education (28.68%; n = 11,481) (Table 1).

Table 1
Sociodemographic profile of older adults diagnosed with AIDS. Brazil, 2001–2022.

| Variable | n | % |
|---|---|---|
| **Age** | | |
| 60–69 | 31,658 | 79.12% |
| 70–79 | 7,028 | 17.56% |
| ≥ 80 | 1,329 | 3.32% |
| **Sex** | | |
| Male | 24,635 | 61.56% |
| Female | 15,378 | 38.43% |
| **Race/skin color** | | |
| White | 12,196 | 30.48% |
| Black | 2,410 | 6.02% |
| Brown | 7,911 | 19.77% |
| Asian | 165 | 0.41% |
| Indigenous | 71 | 0.18% |
| Ignored/Missing | 17,262 | 43.14% |
| **Education level** | | |
| Illiterate | 1,898 | 4.74% |
| 1st–4th grade incomplete | 3,902 | 9.75% |
| 4th grade complete | 1,798 | 4.49% |
| 5th–8th grade incomplete | 3,883 | 9.70% |
| Complete elementary education | 1,819 | 4.55% |
| Incomplete high school | 1,081 | 2.70% |
| Complete high school | 1,878 | 4.69% |
| Incomplete higher education | 213 | 0.53% |
| Complete higher education | 1,390 | 3.47% |
| Not applicable | 6 | 0.01% |
| Ignored/Missing | 22,147 | 55.35% |

**Source**

Datasus (2025) / Authors' own elaboration.

When analyzing the trend of AIDS cases among older adults in Brazil during the study period, an average annual increase of 1.42% (95% CI 0.51 to 2.34; p = 0.002) was observed. Four of the five regions of the country also showed increases in incidence rates, all above the national average, particularly the North and Northeast regions, with annual increases of 9.59% (95% CI 5.14 to 14.23; p < 0.001) and 6.33% (95% CI 4.92 to 7.75; p < 0.001), respectively. The Southeast region was the only one showing a decreasing trend, with an annual average of -1.07% (95% CI -1.77 to -0.36; p = 0.003). This increasing trend in the country persisted between 2001 and 2013 (APC 4.09% [95% CI 2.94 to 5.26]; p < 0.001), followed by a decreasing segment from 2013 to 2022 (APC – 2.02% [95% CI -3.68 to -0.34]; p = 0.021) (Fig. 2).

**Figure 2–** Joinpoint Regression Model for AIDS Incidence Rates among Older Adults by Regions and in Brazil, 2001–2022.

**Legend**: AAPC: *Average Annual Percent Change.* APC: *Annual Percent Change*. **Source**: DATASUS (2025) / Authors' own elaboration.

There was an increase in AIDS incidence among older adults in Brazil during the study period, with an incidence rate of 5.71 cases per 100,000 inhabitants in 2001 and 8.34 cases per 100,000 inhabitants in 2022. Analysis by federative units showed that 21 of the 27 units presented increasing trends during the period, with the Northeast region being the only one in which all states demonstrated this pattern. In the North region, Tocantins and Amapá stood out as the states with the highest trends, with AAPCs of 74.94% (49.69 to 104.45; p < 0.001) and 73.70% (40.60 to 114.60; p < 0.001), respectively. Four states showed stationary trends (Acre, Federal District, Minas Gerais, and Santa Catarina), and only two states showed decreasing trends during this period, both in the Southeast region: Rio de Janeiro (AAPC – 1.24% [95% CI -1.89 to -0.59; p < 0.001]) and São Paulo (AAPC – 1.67% [95% CI -2.28 to -1.05; p < 0.001]) (Table 2).

Table 2
Average Annual Percent Change (AAPC) in the proportion of new AIDS cases among the older adult population according to incidence rate, by regions and federative units, 2001–2022.

| **Spatial unit** | **Rate[1]** | | | | | **AAPC (CI 95%) p value** | |
|---|---|---|---|---|---|---|---|
| | 2001 | | 2022 | | Mean rate | | Trend |
| | Crude rate | Adjusted rate | Crude rate | Adjusted rate | | | |
| **North** | **1.52** | **1.80** | **13.95** | **12.37** | **9.51** | **9.59% (5.14 to 14.23; p < 0.001)** | ⬆ |
| Rondônia | 3.83 | 4.81 | 9.02 | 10.91 | 10.23 | 3.97% (0.70 to 7.34; p = 0.016) | ⬆ |
| Acre | 0.00 | 0.15 | 5.15 | 2.34 | 4.22 | 14.02% (-15.17 to 53.27; p = 0.365) | ⬌ |
| Amazonas | 0.64 | 0.76 | 17.43 | 18.03 | 10.12 | 16.29% (10.25 to 22.65; p < 0.001) | ⬆ |
| Roraima | 6.39 | 0.74 | 9.60 | 43.31 | 13.75 | 21.41% (1.26 to 45.56; p = 0.037) | ⬆ |
| Pará | 1.77 | 2.10 | 15.67 | 14.19 | 10.15 | 9.52% (5.01 to 14.23; p < 0.001) | ⬆ |
| Amapá | 0.00 | 0.00 | 17.59 | 12.52 | 11.90 | 73.70% (40.60 to 114.60; p < 0.001) | ⬆ |
| Tocantins | 0.00 | 0.00 | 7.97 | 8.01 | 5.35 | 74.94% (49.69 to 104.45; p < 0.001) | ⬆ |
| **Northeast** | **1.57** | **1.93** | **7.59** | **7.01** | **5.21** | **6.33% (4.92 to 7.75; p < 0.001)** | ⬆ |
| Maranhão | 1.35 | 1.13 | 12.07 | 10.42 | 7.51 | 11.17% (7.16 to 15.32; p < 0.001) | ⬆ |
| Piauí | 1.16 | 1.24 | 6.54 | 5.20 | 4.07 | 7.05% (3.53 to 10.68; p < 0.001) | ⬆ |
| Ceará | 1.52 | 1.68 | 7.35 | 5.40 | 4.41 | 5.72% (2.71 to 8.82; p < 0.001) | ⬆ |

| Spatial unit | Rate[1] | | | | | AAPC (CI 95%) p value | |
|---|---|---|---|---|---|---|---|
| Rio Grande do Norte | 1.11 | 1.15 | 9.67 | 10.15 | 6.10 | 10.92% (7.54 to 14.41; p < 0.001) | ⬆ |
| Paraíba | 1.35 | 1.75 | 3.75 | 3.61 | 3.59 | 3.51% (0.90 to 6.19; p = 0.008) | ⬆ |
| Pernambuco | 2.81 | 3.09 | 7.49 | 7.42 | 6.29 | 4.26% (2.68 to 5.86; p < 0.001) | ⬆ |
| Alagoas | 1.88 | 1.87 | 11.76 | 9.44 | 5.07 | 8.00% (5.38 to 10.69; p < 0.001) | ⬆ |
| Sergipe | 2.82 | 1.49 | 8.58 | 12.33 | 5.47 | 10.59% (7.34 to 13.95; p < 0.001) | ⬆ |
| Bahia | 0.96 | 1.76 | 6.02 | 5.87 | 4.66 | 5.89% (3.58 to 8.26; p < 0.001) | ⬆ |
| **Central-West** | **3.84** | **4.60** | **9.15** | **9.09** | **8.37** | **3.29% (1.28 to 5.33; p = 0.001)** | ⬆ |
| Mato Grosso do Sul | 6.37 | 6.94 | 14.69 | 11.83 | 11.38 | 2.57% (0.22 to 4.97; p = 0.031) | ⬆ |
| Mato Grosso | 3.09 | 5.09 | 12.64 | 11.47 | 11.57 | 3.95% (0.25 to 7.78; p = 0.035) | ⬆ |
| Goiás | 2.53 | 2.47 | 6.55 | 7.06 | 6.19 | 5.13% (2.81 to 7.50; p < 0.001) | ⬆ |
| Distrito Federal | 5.40 | 7.66 | 6.04 | 6.49 | 7.21 | -0.78% (-1.80 to 0.24; p = 0.126) | ⬌ |
| **Southeast** | **8.51** | **7.90** | **6.55** | **6.30** | **7.81** | **-1.07% (-1.77 to -0.36; p = 0.003)** | ⬇ |
| Minas Gerais | 3.46 | 4.19 | 5.19 | 5.03 | 5.87 | 0.88% (-0.82 to 2.61; p = 0.312) | ⬌ |
| Espírito Santo | 7.41 | 6.08 | 10.81 | 9.76 | 9.91 | 2.27% (0.35 to 4.23; p = 0.019) | ⬆ |

| Spatial unit | Rate[1] | | | | | AAPC (CI 95%) p value | |
|---|---|---|---|---|---|---|---|
| Rio de Janeiro | 9.22 | 10.27 | 8.05 | 7.90 | 10.30 | -1.24% (-1.89 to -0.59; p < 0.001) | ⬇ |
| São Paulo | 10.77 | 8.85 | 6.24 | 6.21 | 7.50 | -1.67% (-2.28 to -1.05; p < 0.001) | ⬇ |
| **South** | **6.74** | **7.53** | **12.20** | **11.32** | **11.81** | **1.96% (1.11 to 2.81; p < 0.001)** | ⬆ |
| Paraná | 3.95 | 3.98 | 8.79 | 8.28 | 7.76 | 3.54% (2.15 to 4.96; p < 0.001) | ⬆ |
| Santa Catarina | 8.38 | 10.42 | 13.94 | 12.41 | 13.71 | 0.83% (-1.01 to 2.72; p = 0.378) | ⬌ |
| Rio Grande do Sul | 8.23 | 8.57 | 14.16 | 13.18 | 14.23 | 2.07% (0.99 to 3.15; p < 0.001) | ⬆ |
| **Brazil** | **5.71** | **5.80** | **8.34** | **7.82** | **7.90** | **1.42% (0.51 to 2.34; p = 0.002)** | ⬆ |

**Legend**: Statistical significance (p < 0.05); [1–] Rate per 100,000 inhabitants; AAPC: *Average Annual Percent Change*. **Source**: DATASUS (2025) / Authors' own elaboration.

The South region presented the highest mean incidence rate (11.81 per 100,000 inhabitants) during the study period, exceeding the national rate (7.90 per 100,000 inhabitants), particularly in the states of Santa Catarina and Rio Grande do Sul, which showed incidence rates in 2001 (8.38 and 8.23 per 100,000 inhabitants, respectively) and 2022 (13.94 and 14.16 per 100,000 inhabitants, respectively) higher than those observed nationally. Also in the South region, Paraná presented a higher incidence rate than the national rate in 2022. In the other regions, four additional states showed incidence rates above the national rate in 2001 (Roraima, Mato Grosso do Sul, Espírito Santo, and São Paulo), and 12 states did so in 2022 (Rondônia, Amazonas, Roraima, Pará, Amapá, Maranhão, Rio Grande do Norte, Alagoas, Sergipe, Mato Grosso do Sul, Mato Grosso, and Espírito Santo) (Table 2).

Regarding spatial analysis, a heterogeneous distribution of AIDS incidence rates among older adults was observed during the study period, with spatial concentration predominantly in the Central-West and South regions, although expansion to other regions was also noted. A total of 44.82% (n = 2,494) of municipalities reported no cases during the analyzed period. Conversely, 0.55% (n = 31) of municipalities presented incidence rates above 30 cases per 100,000 inhabitants and were responsible for 5.53% (n = 2,213) of AIDS cases among older adults during this period (Fig. 3a). A total of 8.51% (n = 474) of

municipalities were classified as Q1 (high-high), covering areas in 17 Brazilian states. Together, these municipalities accounted for 43.60% (n = 17,437) of AIDS cases among older adults during the study period. Additionally, 39.02% (n = 185) of these municipalities were located in the South region (Fig. 3b).

**Figure 3–** Spatial analysis of incidence rates and Moran's index in Brazil, 2001–2022.

**Source**

DATASUS (2025) / Authors' own elaboration.

Between 2001 and 2022, the number of municipalities classified as Q1 increased from 67 to 78, representing a 16.41% increase. In 2001, these municipalities were concentrated in the Southeast region, which accounted for 68.66% (n = 46) of municipalities in this quadrant, and in the South region, with 31.34% (n = 21). In 2022, all regions presented municipalities classified as Q1, although the South region stood out, with an increase in municipalities classified as Q1 to 46.15% (n = 36), whereas the Southeast region showed a reduction to 6.41% (n = 5). Regarding the incidence rates of Q1 municipalities by year, rates increased from 14.09 cases per 100,000 inhabitants in 2001 to 19.09 cases per 100,000 inhabitants in 2022, with emphasis on 2003, which showed the lowest rate during the analyzed period (11.72 cases per 100,000 inhabitants), and 2013, which presented the highest rate (28.19 cases per 100,000 inhabitants) (Fig. 4).

**Figure 4–** Spatial analysis of Moran's index by year in Brazil, 2001–2022.

**Source**

DATASUS (2025) / Authors' own elaboration.

# Discussion

This study analyzed the epidemiological profile, temporal trend, and spatial distribution of AIDS cases among older adults in Brazil, revealing significant sociodemographic, temporal, and territorial heterogeneity. A higher burden was observed among individuals aged 60–69 years, males, White individuals, and those with low educational attainment. In addition, incidence decreased with advancing age, indicating a greater impact among younger older adults.

Regarding spatial distribution, an unequal pattern of incidence was identified across the national territory, with a concentration of higher-priority municipalities in the South and Central-West regions and progressive expansion into other areas of the country throughout the historical series. This pattern should be interpreted with caution, since the absence of reported cases in part of the municipalities may reflect either low incidence or underreporting, especially in small municipalities with limited health surveillance capacity.

These findings are consistent with international studies that also demonstrate a reduction in incidence rates with increasing age (12, 13). This pattern has been associated with the maintenance of sexual activity after the age of 60 years, lower condom use, low risk perception, sexual dysfunctions and the use of erectile dysfunction medications, as well as age-discrepant partnerships, stigma in healthcare settings, and lower adherence to combination prevention strategies. A Chinese study demonstrated that married or cohabiting men aged 60–69 years were more likely to maintain sexual activity (OR 3.37; 95% CI 2.19–5.18) compared with other age groups (14).

Regarding sex, a higher burden was observed among men. Although the World Health Organization estimates a higher absolute number of women living with HIV globally, the recent increase in new cases has been concentrated among the male population (15). A Chinese study reported that, despite the predominance of cases among women, the highest mean annual rates among older adults occurred among men in the age groups 60–69, 70–79, and ≥ 80 years (11.89, 11.57, and 7.96, respectively), exceeding those observed among women (4.23, 1.68, and 0.37, respectively) (16). The maintenance of sexual desire until approximately 70 years of age, combined with risky sexual behaviors adopted in response to difficulties in achieving sexual satisfaction (14), contributes to the increasing incidence among older men.

The higher proportion of cases among White individuals is supported by a national study that identified this ethnic group as accounting for 57.7% of diagnoses among older adults (17). The predominance of individuals with lower educational attainment and lower socioeconomic status among reported cases may reflect weaknesses in the understanding of the disease and its preventive measures. An Iranian study found greater HIV-related knowledge among individuals from middle and upper-middle socioeconomic classes (OR 4.41; 95% CI 3.01–6.15 and OR 5.46; 95% CI 2.91–10.15, respectively), highlighting that lack of knowledge acts as a barrier to testing and prevention (18). Similarly, several studies(17, 19, 20) have identified low educational attainment as a factor associated with risky behaviors and lower adoption of preventive measures.

Throughout the study period, Brazil showed an overall increasing trend in AIDS cases among older adults, with a joinpoint identified in 2013. During this period, the new “Clinical Protocol and Therapeutic Guidelines for the Management of HIV Infection in Adults” was published, establishing treatment as prevention (TasP) and recommending immediate initiation of antiretroviral therapy for all diagnosed individuals, regardless of CD4 + lymphocyte count (21). The World Health Organization later expanded this recommendation to all individuals with confirmed HIV infection (22, 23).

This strategy has been widely recognized for its ability to reduce HIV incidence, particularly when integrated with other preventive approaches (24, 25). Additional evidence reinforces its benefits: a Canadian study identified TasP as the only intervention capable of simultaneously reducing incidence and mortality while prolonging viral suppression (26). The HPTN 052 clinical trial, involving 1,763 serodiscordant couples across nine countries, demonstrated greater preventive efficacy when ART is

initiated early (27), promoting faster CD4 T-cell recovery and reducing the risk of opportunistic infections (28).

In Brazil, four of the five major regions showed increasing trends, although with an inflection point and subsequent stabilization around 2010. This pattern may reflect expanded access to diagnosis and treatment, favoring early detection and transmission control (29). Between 2005 and 2011, the number of tests performed increased from 3.3 to 6.3 million (30), while the number of individuals receiving ART increased by 97% between 2009 and 2015, rising from 231,000 to 455,000 users (31).

Nevertheless, despite the universal and free provision of antiretroviral therapy, AIDS cases among older adults have remained stable, suggesting the persistence of barriers specific to this age group. The literature highlights low risk perception, prejudice related to sexuality in old age, shortcomings in prevention strategies, frequently delayed diagnosis, and limited knowledge regarding preventive measures, as well as difficulties in accessing healthcare services adapted to the specificities of aging (32, 33).

Among the regions, the South presented the highest mean incidence rate, an increasing trend, and more than 30% of municipalities classified within the Q1 cluster. A 2025 study reconstructed the phylogenetic pathway of the HIV-1C lineage, which is more prevalent in the South region, suggesting predominantly local dissemination, with 60 clusters identified in Rio Grande do Sul and 85% restricted to the state itself. It was also observed that Santa Catarina and Paraná acted as potential sources for São Paulo and subsequently for other regions (34). Such viral behavior may explain the increasing trend observed, and although the cited study included all age groups, older adults in this region are exposed to the same transmission dynamics.

In the opposite direction, the Southeast region showed a decreasing trend. Time-series studies demonstrated reductions in AIDS incidence rates (AAPC = -3.5) (34) and mortality in this region (AAPC = -5.6 [– 6.8 to – 4.4]) (35). One hypothesis for this contrast is the historical regional inequality in access to healthcare services and technologies. Although ART is universally available, differences persist in the practical availability of medications and continuity of clinical follow-up (36). Another relevant factor is that the Southeast was the initial epicenter of the epidemic in Brazil, with subsequent dissemination to other regions (37).

The regional inequalities observed are also reflected in the installed capacity for HIV care. A Brazilian cohort study (2015–2018) identified a greater concentration of healthcare services for people living with HIV in the South and Southeast regions (733 units), compared with the other regions (208 units). Consistent with this distribution, patients receiving care in the South and Southeast regions showed better virological outcomes, achieving viral suppression more rapidly than those in the North, Northeast, and Central-West regions (38).

Considering that older adults are inserted within these same socioeconomic and structural contexts, they remain equally exposed to regional inequalities. In this sense, these findings reinforce the role of

social and structural determinants in shaping the distribution of AIDS among older adults in Brazil, highlighting the influence of the social determination of the health-disease process (39), including the capacity for detection, reporting, and response by healthcare services.

Despite the analytical robustness and nationwide scope, the findings of this study should be interpreted in light of limitations inherent to the use of secondary data from SINAN. Problems such as underreporting, incompleteness, and inconsistencies in records may compromise the accuracy of estimates and do not occur homogeneously throughout the territory. In contexts marked by greater social vulnerability, lower institutional capacity, and more limited access to healthcare services, as observed in parts of the North and Northeast regions, these weaknesses tend to be more pronounced, potentially resulting in underestimation of the true magnitude of the epidemic in these locations. Furthermore, changes in mandatory reporting requirements over the analyzed period may have affected temporal comparability, particularly during the early years of the historical series.

Other factors, such as the possible duplication of records across information systems and the migration of patients for diagnosis or treatment in different municipalities or states, may have introduced distortions in case classification, including records categorized as imported cases. From a spatial perspective, the use of units with small population denominators may generate instability in rates, particularly in small municipalities, thereby influencing the identification of clusters and autocorrelation patterns. Finally, because this is an ecological study, the results reflect aggregated patterns and do not allow causal inferences at the individual level, being subject to ecological bias.

Paradoxically, these limitations also reflect structural inequalities within the Brazilian healthcare system, insofar as the quality of health information is directly related to surveillance capacity, healthcare service organization, and population access to diagnosis and care. Thus, the observed weaknesses not only condition the interpretation of the results but also constitute, in themselves, an important marker of the regional inequities underlying the AIDS epidemic in the country.

# Conclusion

This study demonstrated an increasing trend in AIDS incidence among older adults in Brazil between 2001 and 2022, particularly in the North and Northeast regions, while the Southeast region showed a decreasing trend. The affected population profile was predominantly composed of White men aged 60–69 years with low educational attainment. Spatial analysis revealed important regional inequalities and identified priority areas, reinforcing the need for more targeted, equitable, and aging-sensitive prevention and care strategies.

Further investigations are needed to complement the findings of this study, particularly regarding the impact of socioeconomic inequalities on access to treatment across states and regions. Research exploring the invisibility of sexuality in older age and the absence of prevention programs specifically directed toward older adults may contribute to improving prevention actions, enhancing healthcare

delivery, and strengthening public policies capable of responding more effectively to aging with HIV in Brazil.

# Declarations

### Ethics approval and consent to participate

This study used only secondary data obtained from publicly available information systems and official institutional documents, without access to identifiable individual data. Therefore, according to Brazilian regulations, ethics committee approval and informed consent were not required.

### Consent for publication

Not applicable.

### Availability of data and materials

The data analyzed in this study are publicly available from the Brazilian Ministry of Health through the AIDS and HIV database of the Notifiable Diseases Information System (SINAN), accessible via the DATASUS TabNet platform at http://www2.aids.gov.br/cgi/deftohtm.exe?tabnet/br.def. Population estimates used to calculate incidence rates were obtained from the Brazilian Institute of Geography and Statistics (IBGE). The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

### Competing interests

The authors declare no competing interests.

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### Authors' contributions

**Davi Rios do Nascimento (DRN):** Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Writing – original draft, and Writing – review & editing.

**Ana Clara Marques Pacheco (ACMP):** Data curation, Formal analysis, and Writing – review & editing.

**Paula Esbaltar de Oliveira (PEO):** Data curation, Investigation, and Writing – review & editing.

**Sarah Fonseca Serpa (SFS):** Data curation, Investigation, and Writing – review & editing.

**Thaís Silva Matos (TSM):** Methodology, Validation, Formal analysis, Writing – review & editing, and Supervision.

**Rodrigo Feliciano do Carmo (RFC):** Methodology, Validation, Formal analysis, Writing – review & editing, and Supervision.

**Carlos Dornels Freire de Souza (CDFS):** Conceptualization, Methodology, Validation, Supervision, Project administration, and Writing – review & editing.

All authors read and approved the final manuscript.

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**AI declaration**

During the preparation of this manuscript, generative artificial intelligence tools were used exclusively for language refinement and editorial assistance. All scientific content, interpretations, and conclusions were critically reviewed and validated by the authors, who assume full responsibility for the final version of the manuscript.

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# Figures




**Figure 1**

**Geographic location of Brazil, its macro-regions, and federative units.**

**Legend:** Brazil's five macro-regions (North, Northeast, Central-West, Southeast, and South) and 27 federative units included in the study.

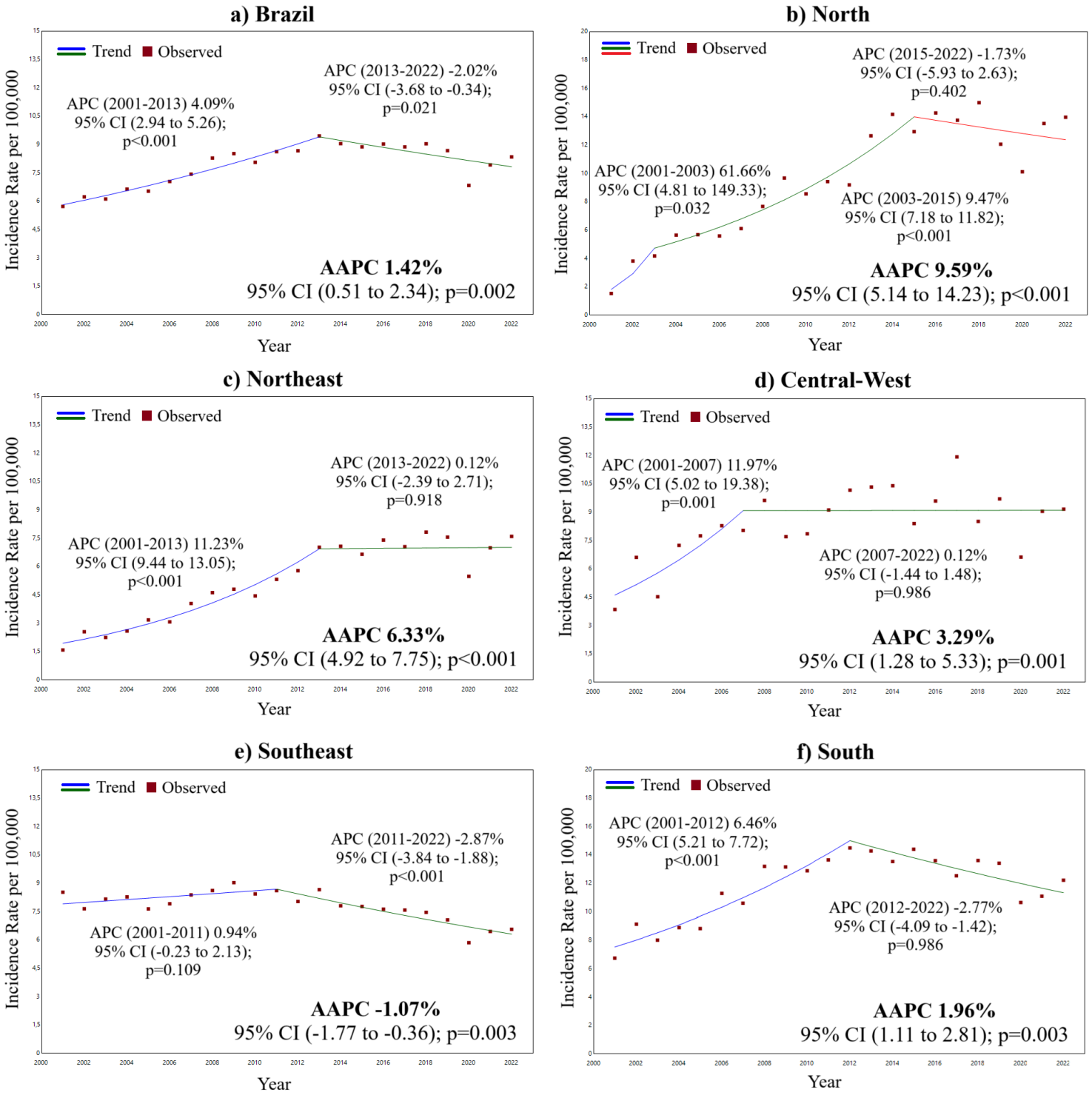



**Figure 2**

Joinpoint Regression Model for AIDS Incidence Rates among Older Adults by Regions and in Brazil, 2001–2022.

**Legend**: AAPC: *Average Annual Percent Change.* APC: *Annual Percent Change*. **Source:** DATASUS (2025) / Authors' own elaboration.

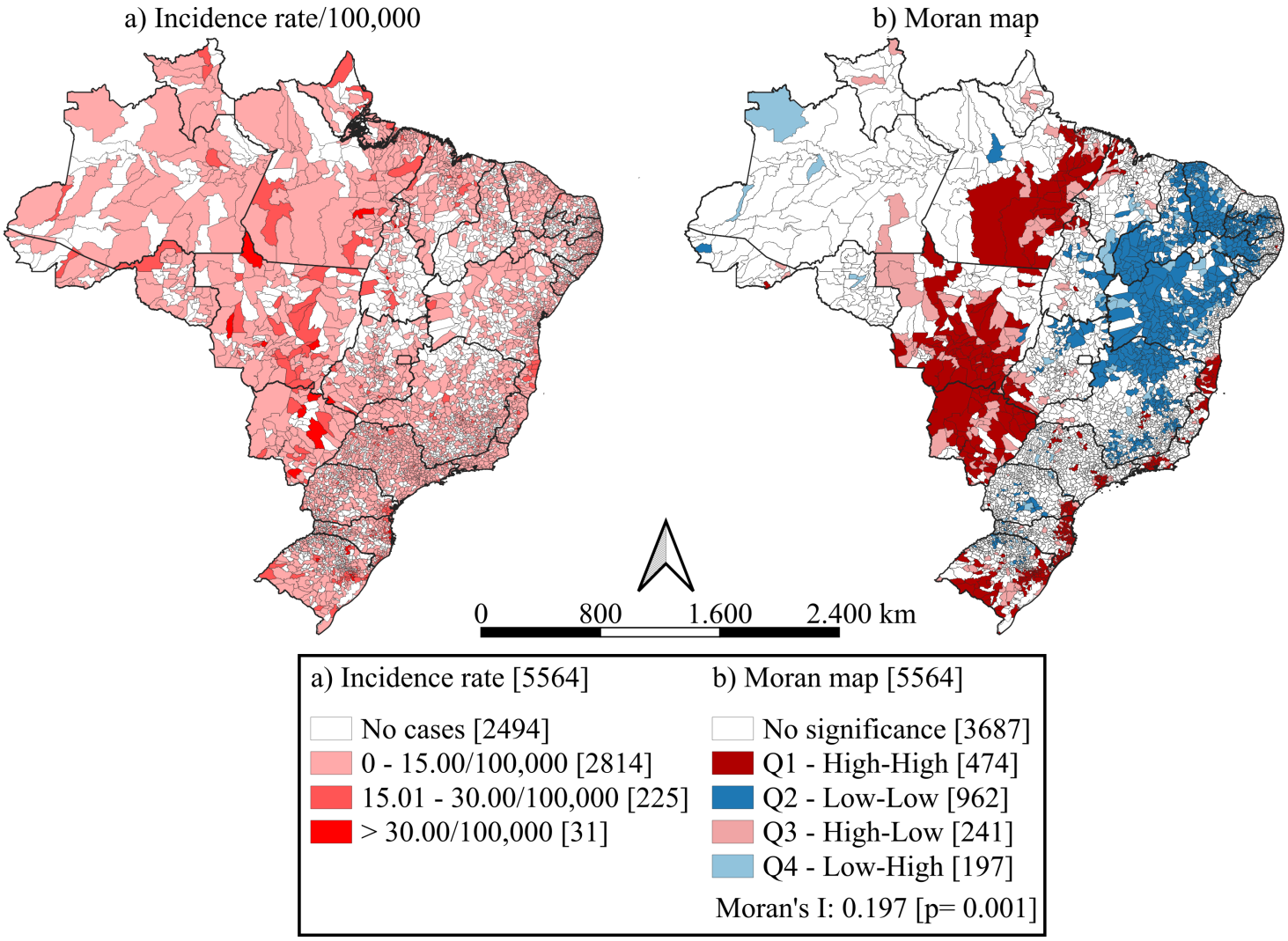
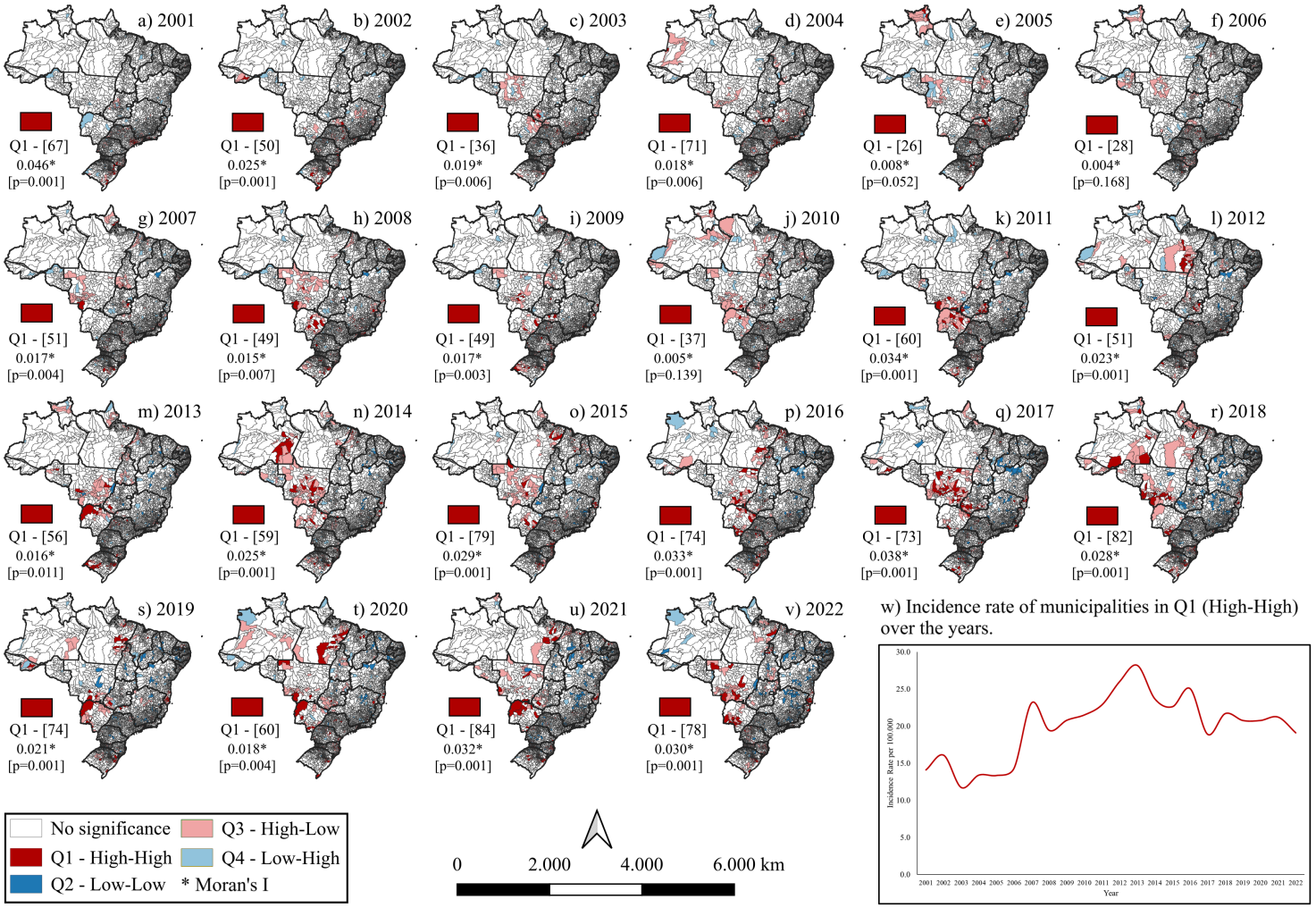



**Figure 3**

Spatial analysis of incidence rates and Moran's index in Brazil, 2001–2022.

**Source**: DATASUS (2025) / Authors' own elaboration.




## Figure 4

Spatial analysis of Moran's index by year in Brazil, 2001–2022.

**Source:** DATASUS (2025) / Authors' own elaboration.