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Review Article

GEOPROCESSING AND SPATIAL ANALYSIS RELATED TO TUBERCULOSIS/HUMAN IMMUNODEFICIENCY VIRUS CO-INFECTION: AN INTEGRATIVE REVIEW

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RESUMO

Objective: to investigate the scientific evidence regarding geoprocessing techniques and spatial analysis related to tuberculosis/Human Immunodeficiency Virus co-infection. **Method:** an integrative literature review of published articles, without time and language cuts, with different study designs, available electronically from the Latin American and Caribbean Literature on Health Sciences, Nursing Database, Web of Science, Excerpta Medica DataBASE, and the National Library of Medicine National Institutes of Health databases. It was used as a research question: what is the scientific evidence regarding geoprocessing techniques and spatial analysis related to tuberculosis/Human Immunodeficiency Virus co-infection? The State of the Art through Systematic Review software was used for database management, and data were presented descriptively. **Results:** the search resulted in 1,837 articles. Of these, ten articles made up the sample. The main techniques used were Moran, spatial scanning and spatial modeling. As for the main characteristics related to tuberculosis/Human Immunodeficiency Virus co-infection, low wealth, precarious access to health, black/brown and indigenous race, low education, women, advanced age with risk of mortality. **Conclusion:** it is understood that geoprocessing and spatial analysis techniques are extremely important for the identification of areas of spatial risk, in addition to helping in the development of health actions in specific territories, a factor that contributes positively to management and public health.

Descritores: Spatial Analysis; HIV Infections; Nursing; HIV; Tuberculosis.

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INTRODUCTION

Tuberculosis (TB) is an infectious and transmissible disease caused by the bacterium Mycobacterium tuberculosis, also known as Koch's bacillus, which mainly affects the lungs (pulmonary), although it can affect other organs and/or systems such as kidneys, eyes, bones, among others (extrapulmonary)[1]. It is estimated that, in 2021, TB affected about 10.6 million people in the world and, of these, only 6.4 million (60.4%) were notified, showing an underreporting of people with TB in the world, a reduction resulting from the COVID-19 pandemic2. In Brazil, in 2022, 78,057 new cases were reported, which is equivalent to an incidence coefficient of 36.3 cases per 100,000 inhabitants[2].

In this sense, TB is a priority public health issue, and some population groups are more vulnerable to developing the disease, such as People Living with the Human Immunodeficiency Virus (PLHIV), Homeless Population (PSR) and Population Deprived of Liberty (PDL)[3-4]. Some potential factors that influence the outcome of treatment are also highlighted, such as gender, age, education, form of TB, associated diseases such as diabetes mellitus, mental illness, users of psychoactive substances and with limited access to health services[1,5].

TB, when associated with co-infection with the Human Immunodeficiency Virus (HIV), can enhance the clinical and epidemiological picture of this condition[6]. TB/HIV co-infection in 2020 and 2021 had a decrease in new cases with a design of 82.2% and 76.9%, respectively,3 and, in 2022, Brazil had 6,557 cases of TB/HIV co-infection[2].

Patients diagnosed with HIV need to routinely perform the rapid TB test and the culture test for mycobacteria aiming at an early diagnosis and immediate initiation of treatment[6], since immunosuppressed patients, i.e., PLHIV, have a 10% risk of developing the active form of TB in their lifetime as well as the mortality rate in this group is 19% when compared to the general population[7].

In this sense, it is necessary that public health services, especially primary care, carry out actions aimed at the early diagnosis of TB and HIV, for introducing the therapeutic scheme with antiretroviral therapy to be implemented, since HIV is a dominant factor for TB activation and unfavorable outcomes[6].

Faced with this finding, spatial analysis can be an ally in the management of health care, considering that this is a method used to interpret data and understand the epidemiological situation of a given disease within a territory, in addition to formulating hypotheses to test patterns observed in certain specific regions, being widely used in management and support to face problems presented in public health[8]. It is believed that spatial analysis and geoprocessing techniques can help organize health services and improve collaborative activities to improve TB/HIV co-infection prevention, diagnosis and treatment.

Therefore, this review aims to describe the scientific evidence regarding geoprocessing techniques and spatial analysis related to TB/HIV co-infection.

METHOD

This is an integrative literature review, carried out according to the six stages, namely: 1st stage: research question elaboration; 2nd stage: selection of primary studies; 3rd stage: identification of study characteristics and data extraction; 4th stage: assessment of primary studies; 5th stage: analysis and interpretation of results; and 6th stage: review presentation.[9].

First, the acronym PCC (Population, Context and Concept) was structured for structuring the research question as well as for descriptor selection. For that, it used the meanings: P – scientific productions; C – TB/HIV coinfection; C – geoprocessing and spatial analysis techniques, structuring the following research question: what is the scientific evidence regarding geoprocessing and spatial analysis techniques related to TB/HIV co-infection?

Original research articles, available in full, with free access, without restriction on language and/or time of publication, which exclusively addressed TB and HIV co-infection, were included. Studies that did not present analysis techniques used in the method and that investigated other types of health problems, as well as reviews, scientific abstracts, opinions, letters to the editor, reports, case studies, books, abstracts of annals of events, dissertations and theses, were excluded.

For structuring the descriptors in the databases, the Medical Subject Headings (MeSH) were used for international databases, and Health Sciences Descriptors (DeCS - Descritores em Ciências da Saúde), for the national ones, using the following databases: Latin American and Caribbean Literature in Health Sciences (LILACS) and Nursing Database (BDENF) (national databases); and Web of Science (WoS), Excerpta Medica

DataBASE (EMBASE) and Medical Literature Analysis and Retrieval System Online (MEDLINE) (international databases).

After defining the descriptors and databases, different tests and combinations of descriptors were performed in order to expand searches and obtain a greater number of articles for inclusion in this review. Furthermore, to obtain an awareness of the search strategy, the Boolean operators AND were used for the simultaneous occurrence of subjects and OR for synonyms, as shown in Chart 1. The search in the databases took place in December 2021.

Article eligibility, i.e., the reading of studies, was subdivided into two stages: 1st stage – study screening; 2nd stage - data extraction. Screening was double-blinded by independent reviewers. When there was disagreement among the evaluators, the study was referred to a third evaluator, thus reducing research bias.

In the extraction stage, complete reading was carried out in a critical/reflexive way to obtain the information. In this sense, to assist in reading and extracting data, the researchers structured an instrument in Excel consisting of the following information: study characteristics (authors, year, country, study design, level of evidence, scientific journal, sample, time period and study period). The articles included in this study were categorized and named according to the identification code of each article (ID) using a numeral system (01, 02, 03, etc.).

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations10. For the interpretation of results and the review presentation, it was decided to discuss the findings from a critical assessment of the themes on the research question of the study.

RESULTS

Initially, 1,837 studies were identified and 21 were excluded due to duplicity. Subsequently, the articles were screened, of which 1,736 studies did not meet the inclusion criteria. Afterwards, the full reading of the 80 articles that were included for the next step (data extraction) was carried out and, of these, 10 composed this integrative review, as shown in Figure 1.

Chart 2 presents the characterization of scientific production included in this review. Of the 10 articles analyzed, 50% were developed in Brazil, followed by 20% in South

Chart 1 – Search strategies and the total number of studies found according to databases. Parana Brazil, 2023

DATABASES	SEARCH STRATEGY	TOTAL
MEDLINE	(Human Immunodeficiency Virus[Title]) OR (Immunodeficiency Virus, Human[Title])) OR (Virus, Human Immunodeficiency[Title])) OR (HIV Infection[Title])) OR (Infections, HIV[Title])) OR (HIV Coinfection[Title])) OR (Coinfection, HIV[Title])) OR (Coinfections, HIV[Title])) OR (Tuberculoses[Title])) OR (Kochs Disease[Title])) OR (Koch's Disease[Title])) OR (Mycobacterium tuberculosis Infection[Title])) OR (Infection, Mycobacterium tuberculosis[Title])) AND (Autocorrelation, Spatial[Title])) OR (Spatial Autocorrelations[Title])) OR (Spatial Dependency[Title])) OR (Dependencies, Spatial[Title])) OR (Spatial Dependencies[Title])) OR (Kernel Density Estimation[Title])) OR (Density Estimations, Kernel[Title])) OR (Estimation, Kernel Density[Title])) OR (Analyses, Spatial[Title])) OR (Analysis, Spatial[Title])) OR (Spatial Analyses[Title])) OR (Spacial Analysis[Title])) OR (Population Spatial Distribution[Title])) OR (Distribution, Population Spatial[Title])) OR (Interrupted Time Series[Title])) OR (Time Series, Interrupted[Title])) OR (Epidemiological Studies[Title])) OR (Epidemiological Study[Title])) OR (Studies, Epidemiological[Title])	1.486
EMBASE	('hiv'/exp OR 'hiv' OR 'human immunodeficiency virus'/exp OR 'human immunodeficiency virus 'OR' immunodeficiency virus, human' OR 'hiv infection'/exp OR 'hiv infection' OR 'coinfection, hiv') AND ('tuberculosis'/exp OR 'tuberculosis' OR 'tuberculosis' OR 'kochs disease' OR 'mycobacterium tuberculosis infection'/exp OR 'mycobacterium tuberculosis infection' OR 'infection, mycobacterium tuberculosis') AND ('spatial analysis' OR 'spatial analysis' OR 'analyses, spatial' OR 'analysis, spatial' OR 'population spatial distribution' OR 'distribution, population spatial' OR 'interrupted time series' OR 'epidemiological studies')	189
LILACS	(ti:(hiv)) AND (ti:(tuberculose)) AND (ti:('análise espacial')) OR (ti:('distribuição espacial')) OR (ti:('estudos epidemiológicos')) AND (db:("LILACS"))	128
WoS	#1 hiv (Título) OR hiv (Título) OR human immunodeficiency virus (Título) OR immunodeficiency virus, human (Título) OR hiv infection (Título) OR hiv infection (Título) OR coinfection, hiv (Título) #2 tuberculosis (Título) OR tuberculosis (Título) OR kochs disease (Título) OR mycobacterium tuberculosis infection (Título) OR mycobacterium tuberculosis infection (Título) OR infection, mycobacterium tuberculosis (Título) #3 spatial analysis (Título) OR analyses, spatial (Título) OR analysis, spatial (Título) OR population spatial distribution (Título) OR distribution, population spatial (Título) OR interrupted time series (Título) OR epidemiological studies (Título)	7
BDENF	ti:(hiv)) AND (ti:(tuberculose)) AND (ti:('análise espacial')) OR (ti:('distribuição espacial')) OR (ti:('estudos epidemiológicos')) AND (db:("BDENF"))	27

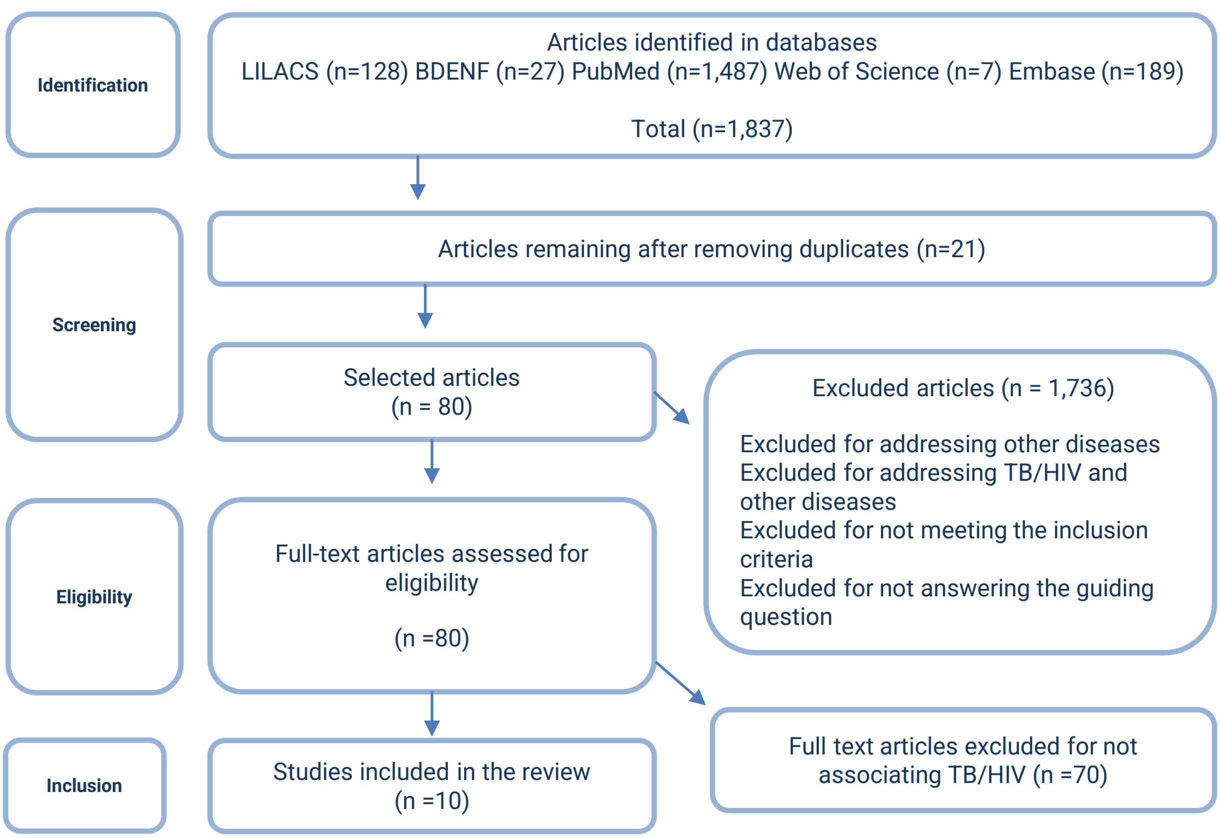
Source: own author.

Africa. As for the year of publication, 40% were published in 2019 and 20% in 2020.

Regarding study design 80% were ecological and, according to Qualis/CAPES 2017-2020, most of the articles were published in journals with a Qualis A1, A3 and B1, of which 50% were in international journals (ID: 01, 03, 04, 05 and 08). Regarding the population/sample of the studies, it was identified that the mean of the studied population was 1,883,429 people (minimum of 996 and maximum of 12,491,280 people). With regard to study time, the mean was 8.66 years (minimum 1 and maximum 25 years).

Still in Chart 2, when observing the main analysis techniques used in studies of TB/HIV co-infection, it is possible to verify that

Figure 1 - Distribution flowchart of the number of articles found, excluded and selected by databases, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Paraná, Brazil, 2023



Source: research flowchart based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Method.

that the Moran technique was present in 50%, followed by spatial scanning and spatial modeling, both with 20%. All studies worked with secondary data base. National studies used the Notifiable Diseases Information System (SINAN - *Notifiable Diseases Information System*), and international studies used the information systems of the respective countries.

When analyzing Chart 3, regarding the main results characteristics, it is observed that the risk factors that influence TB/HIV co-infection were socioeconomic factors and precarious access to the health system (ID: 01, 02 and 05), low level of education (ID: 01, 05 10), race/color black, brown or indigenous (ID: 06 and 07), not having a fixed residence (ID: 02), population and territorial turnover (ID: 04) and injecting drug use (ID: 07).

It was also possible to verify that TB/HIV co-infection was present in both sexes. However, distinct characteristics were observed, since being male, having up to three years of study and not having health care were risk factors (ID: 02 and 09). Thus, when analyzing mortality in adults due to TB/HIV co-infection, it was found that being male, advanced age, black race/color and residing in southern Brazil had a greater chance of progressing to death (ID: 06). When analyzing infant mortality, being female is twice as likely to die from co-infection, but with growth and development, the probability of mortality decreased (ID: 08).

Among females, being illiterate and having a sexually active life after the age of 15 was a risk factor (ID: 03, 04, 10). When analyzing child mortality, it is noted that families headed by women had a 60% higher risk of infant mortality due to TB/HIV co-infection compared to families headed by men (ID: 08).

As for the spatial analysis techniques, it is noted that the Moran technique was the most prevalent in the studies (ID: 01, 02, 05, 07 and 10), and it was also used in association with other analysis techniques (ID: 05 and 07). Thus, when viewing the associated techniques, it is noted that Moran's Index and Spearman correlation analysis showed that co-infection is highly correlated with time, and TB rates were influenced by HIV rates in the neighborhood and vice versa (ID: 05). It also observed using Moran, Kriging geoprocessing technique and spatial trend in which areas with high incidences of TB/HIV co-infection were

Chart 2 – Characterization of studies included in the integrative review according to identification code, country and year of publication, study design, Qualis/CAPES, journal in which the article was published, sample or total of cases studied, time the study was carried out, applied analysis techniques and databases used. Paraná, Brazil, 2023

ID	Country	Year	Study design	Qualis/ CAPES	Journal	Sample/total	Time	Applied analysis techniques	Database used
01	Ethiopia	2019	Ecological	A1	Plos One	2,023,239	2015-2017	Moran's Index	National Health Management Information System
02	Brazil	2020	Ecological	A1	*Revista Saúde Pública*	6,092	2007-2015	Moran's Index	Notifiable Diseases Information System
03	South Africa	2020	Ecological	A1	The Journal of Infectious Diseases	8,966	2004-2010	Spatial scanning	World Health Organization Definitions
04	South Africa	2019	Ecological	A1	Scientific Report	41,812	2009-2015	Spatial scanning and Kernel density	Africa Centre Demographic Information System
05	Uganda	2019	Cohort	A3	BMC Infectious Disease	10,000	2015-2017	Moran's Index	World Health Organization Definitions
06	Brazil	2016	Descriptive	A1	*Cadernos de Saúde Pública*	12,491,280	2000-2011	Spatial trend, joinpoint regression model, Monte Carlo and spatial distribution	Mortality Information System
07	Brazil	2014	Ecological	A3	*Revista Brasileira de Epidemiologia*	81,590	1982-2007	Kriging geoprocessing technique, Moran's Index and trend	Notifiable Diseases Information System
08	England	2013	Ecological	A1	Global Health Action	6,692	2004	Likelihood, geospatial logistic regression, Bayesian inference and spatial modeling	Agincourt Health and Socio-Demographic Surveillance System
09	Brazil	2019	Ecological	B1	*Revista de Epidemiologia e Controle de Infecção*	3,322,820	2001-2016	Spatial modeling	Notifiable Diseases Information System
10	Brazil	2010	Ecological	B1	*Revista da Sociedade Brasileira de Medicina Tropical*	415,508	1998-2006	Moran's Index	Notifiable Diseases Information System

Source: own author.

visualized, especially in coastal territories in southern, southeastern and northern Brazil (ID: 07).

DISCUSSÃO

This study aimed to describe the scientific evidence regarding geoprocessing techniques and spatial analysis related to TB/HIV co-infection. In this sense, it was shown that the Moran technique, spatial modeling and spatial scanning were the most used among international[11-15] and national[6-19] geoprocessing and spatial analysis studies on TB/HIV co-infection. In this context, it is important to know and describe the types of analyzes currently used, to reproduce them in studies at national, state or municipal level, contributing to health management[8].

Using data analysis and geoprocessing techniques in health services is an important tool for the implementation of health actions and in the prevention and promotion of the population's health. This data collection technology assists in the production of geographic information and provides elements that demonstrate risk territories for the development of certain health problems, assisting managers and health professionals in the construction of thematic maps that contribute to planning actions, monitoring and assessing health services[20].

The incorporation of geoprocessing within health services is a factor that helps in the development of health indicators, since, when making maps through geoprocessing and spatial analysis, it is possible to identify territories with greater vulnerability to the development of TB/HIV co-infection and, thus, define priority areas for the development of health actions and intervene effectively and resolutely to the identified problem, contributing to TB as well as TB/HIV co-infection elimination.

It should also be noted that the incorporation of studies involving the theme contributes to the development of public policies as well as to assess the effectiveness of health services, because it is possible to understand the disease behavior within the territory, i.e., if the TB/HIV co-infection is decreasing, increasing and/or stationary. This factor is in line with the End TB strategy, which mentions the importance of intensifying

Chart 3 – Characterization of the studies included in the review according to identification code, study title, main characteristics of the study and main results of the spatial analyzes performed. Paraná, Brazil, 2023

ID	Title	Main characteristics	Main results of spatial analysis
01	Spatial patterns of tuberculosis and HIV coinfection in Ethiopia	HIV prevalence among TB patients was 7.34%. The ecological level factors associated with the prevalence of TB among people living with HIV were poor access to health services (OR: 0.76; 95% CrI: 0.59, 0.95), low wealth index (OR: 1.31; 95% CrI: 1.01, 1.67) and low literacy rate (OR: 1.37; 95% CrI: 1.03, 1.78).	Hot spots were observed in districts located in Amhara, Afar, and Gambela regions, and cold spots were observed in Oromiya and Southern Nations, Nationalities, and People regions. TB prevalence among people living with HIV ranged from 0.7% in the Oromia region to 14.5% in the Afar region. TB prevalence hotspots among people living with HIV were observed in districts located in Gambela, Afar, Somali and Oromiya regions, while cold spots were observed in districts located in Amhara and Tigray regions.
02	TB-HIV co-infection: spatial and temporal distribution in the largest Brazilian metropolis	The proportion of TB/HIV co-infection ranged from 10.5% to 13.7%, with a decrease of 3.0% per year (95%CI -3.4% - -2.6%) and was higher in individuals with no fixed residence and poor access to health care. Incidence rates decreased by 3.6% per year (95%CI -4.4% – -2.7%), going from 7.0 to 5.3 per 100,000 inhabitants/year.	Co-infection showed positive and significant spatial autocorrelation, with a heterogeneous spatial pattern and high-risk cluster in the central region of the municipality. Cure was achieved in 55.5% of cases with fixed residence and in 32.7% of cases without fixed residence.
03	Spatiotemporal clustering of multidrug-resistant and extensively drug-resistant TB is associated with HIV status and drug-susceptibility patterns in KwaZulu-Natal, South Africa	Approximately 51% of the cohort were female and young (mean age, 33; IQR, 26-41). Most people with known HIV status (4126/6704) were infected with HIV (72.1%). Among HIV co-infected patients, 2,294 (55.6%) were on ART.	In the sensitivity analysis, the maximum scan window was defined spatially up to 500 km and temporally up to 100% of the study period. By continuous analysis over 7 years, we identified 11 spatiotemporal loci of increased TB incidence (clusters), 10 of which were statistically significant
04	Space-time clustering of recently-diagnosed tuberculosis and impact of ART scale-up: Evidence from an HIV hyper-endemic rural South African population	Newly diagnosed TB was identified in a region characterized by high HIV prevalence and population movement. The cohort sample consisted of 41,812 individuals aged 15 years and older and consisted of women (n = 25,218) and men (n = 16,594) who answered the TB question from 2009 to 2015.	Bivariate analysis of individual risk predictors suggested that communities with higher HIV prevalence were associated with a higher likelihood of newly diagnosed TB. Individuals residing in communities with higher ART coverage were associated with lower prevalence of newly diagnosed HIV. There were nine high-risk spatiotemporal clusters of newly diagnosed TB ($p < 0.05$). The four largest clusters were in overlapping areas in the southeast of the study area, an urban community close to the national highway, three of which persisted throughout the study period.
05	Spatial analysis of HIV-TB co-clustering in Uganda	The highest prevalence of HIV associated with the most recently diagnosed TB was the population with low income (aOR = 1.03, 95% CI: 1.01–1.04). Thus, families with higher income use it as a protection factor (aOR = 0.67, 95% CI: 0.54–0.84).	TB and HIV diseases are correlated (55–76%) showing different spatial clustering patterns in Uganda. TB/HIV prevalence shows consistent outbreaks around the Lake Victoria districts as well as in northern Uganda. Spearman's correlation showed that the two diseases were related with time. The correlation was highest in 2015 (76%), low in 2016 (55%) and moderately high (60%) in 2017. Both Moran diseases are positive, and observed TB rates were influenced by neighborhood HIV rates and vice versa.
06	Mortality related to tuberculosis-HIV/AIDS co-infection in Brazil, 2000-2011: epidemiological patterns and time trends	The highest mortality rates were found in males, economically productive age groups, black race/color and residents of the South.	There was a decrease in the trend of mortality by age at the national level (AAPC: -1.7%; 95%CI: -2.4; -1.0). Mortality increased significantly in the North (AAPC: 5.7%; 95%CI: 2.2; 9.4), Northeast (AAPC: 5.4%; 95%CI: 3.3; 7.6) and Midwest (AAPC: 3.5%; 95%CI: 0.2; 6.9) regions. A decreasing trend is observed in the Southeast region throughout the period (AAPC: -4.1%; 95%CI: -2.4; -1.0), with a decrease in the period 2000-2005 and stabilization in the period 2005-2011. The South region showed a stable trend in the period (AAPC: -0.5%; 95%CI: -2.9; -1.9), with an increase from 2000 to 2004, and a downward trend from 2004 to 2011. The sex-specific mortality rate showed a significant downward trend for males and a stable trend for females. For mortality by age, we observed a significant decrease in the age groups of 20 to 29 years and 30 to 39 years. The most advanced age groups showed trends towards a significant increase in mortality rates: 50-59 years, 60-69 years and ≥ 70 years.

Continuation...

Continuation Chart 3

07	Spatial distribution of the human development index, HIV infection and AIDS-Tuberculosis comorbidity: Brazil, 1982-2007	There is a higher incidence in people aged between 20 and 49 years, in addition to transmission through using injecting drugs in the South and Southeast.	Spatial correlation showed significance for the distribution of HIV/AIDS incidence (I = 0.22, Z-score = 60.76), TB/AIDS incidence (I = 0.19, Z-score = 54.03) and Human Development Index (HDI) (I = 0.78, Z-score = 791.44). Areas with high incidence were especially the coastal cities of the South, Southeast and North. The temporal evolution of TB/AIDS incidence revealed a sharp increase in TB detection among notified cases of HIV/AIDS, until 1992, mainly in the Southeast macro-region, which stabilized between 1992 and 1997, and declined after 1998. The decline may be due to the infrastructure and organization of diagnostic services.
08	The contribution of spatial analysis to understanding HIV/TB mortality in children: a structural equation modelling approach	Child-specific differentials showed that boys were almost twice as likely to die compared to girls. As children grew up, there was a protective effect against death. For each year children aged, the probability of death decreased by about 50% [logit=−0.630 (0.137); ORA=0.53; 95% BCI 0.40–0.70]. Male-headed households had a 60% lower risk of infant mortality from HIV/TB compared to female-headed households [logit=−0.895 (0.30); AOR=0.41; 95% BCI 0.23–0.74].	TB/HIV co-infection increased from 1.4% in 2001 to 14.6% in 2016, with a variation and positive trend of 1180% (p<0.05). The mean annual ratio (MAR) of TB/HIV co-infection from 2001-2016 was 5.6% (95% CI 3.5 to 7.9). The time series of the TB/HIV incidence rate revealed the occurrence of fluctuations in the co-infection coefficients for residents of the state of Alagoas and its administrative region. There was growth in this indicator in the two major health macro-regions of the state and in six of the ten health regions. TB/HIV co-infection incidence in the state ranged from 0.6/100,000 in 2001 to 4.1/100,000 in 2016, with a mean co-infection rate of 2.0/100,000 (95%CI 1.4 to 2.5). The highest rates of new cases were satisfactory for the male population. However, the MK statistics showed a significant and increasing trend in both genders. The mean annual rate for men and women was 3.0/100,000 and 1.4/100,000.
09	*Análise temporal dos casos de coinfecção Tuberculose-HIV na população de um estado do Nordeste do Brasil*	TB/HIV co-infection increased by 27.51% in the analyzed period. TB/HIV co-infection incidence increased by almost 8% in women, 5.4% more than that found for men. There was significance in the ranges 0-9 years and 40-59 years for TB incidence. There was a 31% reduction in the 0-9 age group, contrasting with the nearly 11% increase in those aged 40-59 years. As for the outcome, the cure rate for TB/HIV co-infection was 50.74%. When calculating the odds ratio, TB/HIV co-infection reduced the chance of cure by 58%. Abandonment was 13.60% in co-infection compared to 9.52% in patients with TB.	The rates of change show a reduction of 20.19% in the Southeast, 20.14% in the Northeast, 12.37% in the North, and 7.80% in the Midwest. The South region presented a stable evolution, with a significant growth in the North and Northeast regions, and the incidence was above 150% in the 11 years studied. The South region did not show significant differences in the data, while the Midwest region recorded an increase of almost 47%. The Southeast region, unlike the others, reduced TB/HIV co-infection rates by 25%.
10	*Análise espacial da coinfecção TB/HIV: relação com níveis socioeconômicos em municípios do sudeste do Brasil*	Being heads of families with up to three years of study, illiterate women, people with an income of 2 to 3 minimum wages, illiterate heads of families, illiterate people and heads with 11 to 14 years of education) revealed an association with TB/HIV incidence.	Moran's Index was 0.0635 (p = 0.00), indicating spatial dependence. The variable that best explains the spatial dependence of incidence was the percentage of heads of household with up to three years of education. The LISA cluster map for the incidence coefficients of TB/HIV co-infection showed clusters of high incidence in the North region and low incidence in the South and West of the city.

Source: own author.

research and innovation to achieve a TB-free world with zero deaths, zero new cases and zero suffering due to TB[3].

Thus, a study that sought to describe the spatial and temporal distribution of TB/HIV co-infection showed progress in co-infection control in the analyzed period; however, areas and populations that are unequally affected by the disease were identified[16]. It is possible to note the importance of investing in studies because when viewing areas and populations most affected by TB/HIV co-infection, health intervention becomes more precise and consequently better treatment outcomes and TB elimination.

The spatial analysis technique, on the other hand, allows measuring geographic and territorial aspects taking into account the spatial location of the phenomenon under study, i.e., the disease. Using spatial analysis in Brazil began to be used in the field of public health in 1980, resulting from the expansion of urban territories and population densities. These factors led to a rapid spread of communicable diseases, especially those whose epidemiological chain involves the participation of reservoirs and urban vectors[21].

In this context, in TB/HIV co-infection, the spatial analysis technique suits the needs since, through the development of Geographic Information Systems (GIS) based on digital cartography, it is possible to identify territories or areas of risk and/or protection for the disease. GIS' main objective is to represent, in a computational environment, the geographic phenomena that are intended to be studied as well as the spatial distribution of diseases that can be mapped and analyzed, thus contributing to determine the spatial location of diseases and the graphic analysis of epidemiological indicators[22].

Spatial analysis techniques measure properties and relationships, taking into account the spatial location of the phenomenon under study in a high way, consisting of a set of chained procedures whose purpose is to choose an inferential model that explicitly considers the spatial relationship present in the phenomenon[6].

In this way, spatial analysis is widely used in the health area, revealing situations and helping to solve problems as well as helping to identify the spatial distribution of the disease, cases, epidemics, pandemics in specific regions, the source of the problem, among other things[23].

Moreover, through spatial analysis technologies, nurses will be able to collect information and implement health intervention projects and build maps and discuss them with the various actors involved in their territory, such as users, health professionals, managers, students, among others[24]. Thus, the triad time/place/people makes it possible to correlate social, economic and environmental variables with the human population's health situation[25].

Among the analysis techniques, it is evident that the main ones used were Moran, spatial modeling and spatial scanning. The spatial analysis technique based on Moran's Index is a non-spatial statistical measurement coefficient of spatial correlation, adapted to the spatial context. Moran's Index has two different forms of analysis: Global Index and Local Index. Therefore, the Global Moran's Index (I) assessed the spatial interdependence between all polygons in the study area and expresses it through a single value for the entire region. The Local Moran's Index (Ii) identifies the existing relationship between a given polygon and its neighborhood, from a predefined distance through the existing covariance between them, allowing data homogeneity/diversity examination[26].

A study carried out in Ethiopia showed that critical points of TB prevalence among PLHIV were observed in districts located in the regions of Gambela, Afar, Somali and Oromiya, and cold points were observed in districts located in the regions of Amhara and Tigray[11]. In this context, it is possible to observe the importance of incorporating Moran's Index in the studies, because, when applying the technique, the priority points for the intensification of health actions are verified.

Spatial modeling is used in conjunction with a GIS to properly analyze and visually present the data for better understanding by human readers. Its visual nature helps researchers to understand the data in a dynamic way and to formulate numerical and textual conclusions, i.e., spatial modeling will formulate hypotheses and/or estimate relations of diseases with geographic space[21,27].

In this context, spatial modeling is capable of simulating objects or spatial phenomena that occur in the real world, thus facilitating the articulation of problem solutions as well as the planning of interventions related to the problems associated with the population's health[25].

Spatial modeling was used to investigate the determinants of HIV/TB mortality and its spatial distribution among children aged 1 to 5 years in South Africa, showing that low socioeconomic status and maternal deaths had an impact on infant mortality. These factors should be used in the formulation of interventions to reduce infant mortality as well as spatial forecast maps that can guide the formulation of public policies to direct health actions[15].

Spatial scanning is a technique that confirms statistics of clusters, which correspond to a set of areas that present a significantly high risk in relation to a given event,[26] i.e., through the application of this technique, it is possible to identify spatial clusters with greater risk for developing the disease.

Furthermore, scanning is used for the statistical confirmation of spatial clusters, i.e., spatial clusters, which correspond to a set of areas that are more vulnerable to the development of a given event. It should be noted that using this technique helps to identify priority areas for disease control[28].

Researchers in South Africa conducted a spatial scanning study that found spatial clusters of newly diagnosed TB in a region characterized by high HIV prevalence and population movement[13].

Another research that used the technique identified that spatial clusters with a higher TB density incidence can provide managers with the opportunity to develop public health programs and health and intervention actions in these places with a higher TB incidence as well as TB control and elimination actions[29].

As for the limitations of this study, we highlighted using only controlled descriptors, since, although an attempt was made to develop a comprehensive search strategy, some relevant studies may have been lost. Another limitation is that the gray literature was not explored, in addition to the exclusion of articles not freely available.

In this regard, studies that use spatial analysis techniques directly contribute to the population's health and help health professionals, managers for the incorporation of public policies in territories with greater social vulnerability and thus directly imply disease behavior within the territory.24 It is also possible to highlight the need for targeted policies to improve access to health care and greater investment in infrastructure, sanitation and health education aimed at environmental issues and reducing inequality, since the highest number of co-infections occur in less favored areas.

CONCLUSION

This literature review described the scientific evidence regarding geoprocessing and spatial analysis techniques related to TB/HIV co-infection, showing that Moran's Index, spatial scanning and spatial modeling are the techniques with the highest mentions in studies at the national and international level.

Therefore, it is understood that geoprocessing and spatial analysis techniques are extremely important for the diagnosis and identification of risk areas, helping to provide better care and intervention in health problems and of great relevance for public health services. Thus, using spatial analysis techniques contributes to technological advances, research development and greater knowledge of the studied area.

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