Factors Influencing Pulmonary Tuberculosis Incidence in Banggai Laut

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Abstract

Background: Tuberculosis (TB) remains a global health priority, especially in developing countries. The increasing incidence, compounded by drug-resistant strains, poses significant public health challenges. In Indonesia, the TB burden is evident in Central Sulawesi, particularly in Banggai Laut Regency, where low detection rates and geographic barriers complicate control efforts. This study aims to analyze the spatial distribution of pulmonary TB in Banggai Laut Regency from 2021 to 2023, contributing to evidence-based public health strategies in maritime regions. Methods: A quantitative ecological study was conducted, analyzing 399 pulmonary TB cases registered from 2021 to 2023. The study incorporated demographic and geographic variables, including gender, population density, elevation, healthcare access, and housing conditions. Data were collected from TB registers and regional reports, and spatial analysis was performed using GIS tools to map TB distribution. Statistical analysis, including univariate, bivariate, and correlation analysis, was conducted using STATA and QGIS software. Results: The study found that TB incidence was higher in males and varied by age group, with the highest incidence recorded in 2022. Significant negative correlations were identified between TB incidence and healthcare workers, and positive correlations with the distance to healthcare facilities. Spatial analysis revealed that TB cases were concentrated in subdistricts with lower population density, fewer healthcare workers, and greater distance from healthcare services. Geographic factors, such as elevation and male-to-female sex ratio, also influenced TB distribution. Conclusion: The findings underscore the critical role of healthcare accessibility, workforce availability, and geographic factors in TB control. Interventions to improve healthcare services, increase healthcare worker density, and enhance housing conditions are essential to reduce TB incidence in remote regions. Spatial and environmental factors should guide future TB control strategies in maritime areas.

Keywords: Tuberculosis, spatial analysis, healthcare accessibility, Banggai Laut Regency, GIS

Significance | This study identifies factors influencing TB distribution in Banggai Laut, offering insights for targeted interventions to improve public health outcomes.

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Introduction

Tuberculosis (TB) is an infectious disease categorized as a re-emerging infectious disease, referring to conditions that had significantly declined in prevalence but have resurged to become public health concerns. The World Health Organization (WHO) has identified TB as a global health priority (Madjid et al., 2019; Muliati et al., 2018). The increasing prevalence of TB, particularly in developing nations, compounded by the emergence of drug-resistant bacterial strains, presents a critical challenge for global health systems.

According to the WHO's Global TB Report 2023, TB remains a major public health issue, causing approximately 1.3 million deaths worldwide in 2022. That year, 7.5 million individuals were newly diagnosed with TB. The burden of TB is highly uneven across

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countries, with 87% of global cases concentrated in the 30 countries with the highest burden. Eight countries accounted for two-thirds of total global cases, including the Philippines (638 cases per 100,000 population), Indonesia (386 cases per 100,000 population), the Democratic Republic of the Congo (317 cases per 100,000 population), Pakistan (258 cases per 100,000 population), Bangladesh (221 cases per 100,000 population), Nigeria (219 cases per 100,000 population), and China (52 cases per 100,000 population) (WHO, 2022). TB disproportionately affects specific demographic groups; in 2022, 55% of TB patients were male, 33% were female, and 12% were children aged 0–14 years (Ministry of Health of the Republic of Indonesia [Kemenkes RI], 2024).

While global efforts led to a decline in TB incidence and mortality between 2000 and 2020, progress stalled and reversed during the COVID-19 pandemic. For instance, TB incidence rose from 819,000 cases in 2020 to 969,000 cases in 2021, representing an 18% increase. Similarly, TB-related mortality increased by 55% during the same period, highlighting the impact of pandemic-related disruptions on TB prevention and control programs (Kemenkes RI, 2022).

The situation in Central Sulawesi, Indonesia, reflects these global trends. The detection and treatment of TB cases in the province remained suboptimal, with only 47% of cases detected in 2022, falling short of the 85% target. The incidence of TB in Banggai Laut Regency fluctuated between 2021 and 2023, increasing from 16 cases per 10,000 population in 2021 to 19 cases per 10,000 population in 2022, before declining slightly to 17 cases per 10,000 population in 2023. Low case detection rates, particularly in remote and hard-to-reach areas, were linked to inadequate active case-finding efforts, such as contact tracing and targeted screenings (Health Department of Central Sulawesi Province, 2022).

Banggai Laut Regency, a maritime region in Central Sulawesi, poses unique challenges for TB control due to its geographical characteristics. The regency consists of seven sub-districts, with 94.37% of its area comprising sea and only 5.63% land. Three sub-districts are accessible only by sea, and many villages are located in remote areas (RPJMD of Banggai Laut, 2021). These geographic and infrastructural limitations hinder access to healthcare services, making it difficult to achieve the TB program's targets.

In recent years, Geographic Information Systems (GIS) have emerged as essential tools in public health for analyzing and mapping disease distribution. GIS enables the visualization of the relationship between diseases and environmental factors, such as population density, healthcare accessibility, and socio-economic conditions. This approach allows for more precise identification of high-risk areas and facilitates the development of targeted interventions (Jannah et al., 2023). Spatial analysis of TB distribution can provide critical insights for policymakers, guiding the allocation of resources and the design of effective control measures.

Given these challenges, this study focuses on the spatial analysis of pulmonary TB case distribution in Banggai Laut Regency from 2021 to 2023. The findings aim to contribute to a better understanding of TB epidemiology in maritime regions and support evidence-based public health strategies.

2. Materials and Methods

This study employed a quantitative research approach with an ecological study design. The spatial model used in this research incorporates point and area-based techniques to analyze data from a spatial perspective, facilitating the identification of patterns and relationships between variables and the geographic distribution of pulmonary tuberculosis (TB) cases.

2.1 Population and Sample

The population for this study consisted of the entire unit of analysis within Banggai Laut Regency, encompassing seven sub-districts. The sample included all registered cases of pulmonary TB in Banggai Laut Regency, Central Sulawesi Province, from 2021 to 2023, totaling 399 cases. A purposive sampling technique was applied to select cases based on predefined criteria. The dependent variable was the incidence of pulmonary tuberculosis, while the independent variables included gender, population density, elevation, healthy housing, the number of healthcare workers, healthcare facilities, and the distance to healthcare facilities.

The inclusion criteria for this study required participants to be diagnosed with pulmonary tuberculosis (TB) and registered in the TB register maintained by the Public Health Center and Health Office between 2021 and 2023. Additionally, the patient's residential address needed to be clearly recorded to ensure accurate geographic analysis.

The exclusion criteria, on the other hand, excluded individuals who did not reside permanently in Banggai Laut Regency. Patients diagnosed with drug-resistant TB were also excluded from the study to maintain a specific focus on pulmonary TB cases.

2.2 Data Collection

Data collection was conducted using secondary data obtained from the TB registers of the Public Health Center and Health Office in Banggai Laut Regency. Additional data regarding population density, elevation, healthcare facilities, and the number of healthcare workers were sourced from regional government reports and geospatial data repositories. The geographic coordinates of healthcare facilities and patient residences were recorded using Geographic Information Systems (GIS) tools to facilitate spatial analysis.

2.3 Statistical Analysis

The collected data were analyzed using STATA software version 14 for statistical computations and QGIS for spatial analysis. Two

primary types of analysis were employed to derive meaningful insights from the data. First, univariate analysis was performed to examine the frequency distribution and descriptive statistics of the respondents' general characteristics, including demographic and geographic variables.

Second, bivariate analysis was conducted to evaluate the relationship between the independent variables and the dependent variable, namely TB incidence, with a significance level (α) set at 0.05. The choice of statistical tests depended on the distribution of the data. Pearson's correlation test was applied to assess relationships when the data followed a normal distribution, while Spearman's correlation test was used when the data did not meet the assumption of normality.

Finally, spatial analysis was carried out using QGIS to create maps visualizing the distribution of TB cases and their association with independent variables, such as population density and healthcare accessibility. Advanced techniques, including hotspot analysis and spatial clustering, were employed to identify regions with higher TB incidence rates and explore their potential correlations with environmental and demographic factors.

2.4 Ethics

This study was conducted after obtaining approval from the Research Ethics Committee of the Faculty of Public Health, Hasanuddin University, Makassar, with the issuance of ethical clearance number 1860/UN4.14.1/TP.01.02/2024, dated August 6, 2024.

3. Results

3.1 Sample Characteristics

Pulmonary tuberculosis (TB) cases in Banggai Laut Regency from 2021 to 2023 exhibited notable demographic and geographic trends. Men were more affected than women, with the highest proportion of male cases recorded in 2022 at 57.24%. The age group most affected by TB varied by year: in 2021 and 2023, the 56–66 age group had the highest proportion of cases (20.63% and 20.66%, respectively), while in 2022, the 34–44 age group accounted for the highest proportion (22.37%). Geographically, Banggai Subdistrict consistently recorded the highest number of cases across the study period, peaking in 2021 with 35.71% of the cases and subsequently declining to 32.23% by 2023. The year 2022 marked the highest overall number of cases, with 151 cases, representing 37.84% of the total reported during the study period.

3.2 Correlation Analysis Results

Correlation analysis revealed statistically significant associations between pulmonary TB incidence and two variables: the number of healthcare workers and the distance to healthcare facilities (Table 2). For healthcare workers, a significant negative correlation was observed across all three years (2021: r = -0.832, p = 0.020; 2022: r = -0.794, p = 0.033; 2023: r = -0.832, p = 0.020). This suggests that subdistricts with fewer healthcare workers tended to report higher TB incidence. Similarly, the distance to healthcare facilities showed a significant positive correlation with TB incidence in all years (2021: r = 0.829, p = 0.021; 2022: r = 0.818, p = 0.025; 2023: r = 0.829, p = 0.021), indicating that subdistricts located farther from healthcare facilities experienced higher TB rates.

Other variables, including gender (2021: r = 0.700, p = 0.079; 2022: r = 0.636, p = 0.124; 2023: r = 0.700, p = 0.079), population density (2021: r = 0.523, p = 0.229; 2022: r = 0.691, p = 0.086; 2023: r = 0.523, p = 0.229), elevation (2021: r = -0.717, p = 0.069; 2022: r = -0.667, p = 0.102; 2023: r = -0.798, p = 0.031), healthy housing (2021: r = -0.417, p = 0.352; 2022: r = -0.511, p = 0.241; 2023: r = -0.729, p = 0.063), and healthcare facilities (2021: r = -0.637, p = 0.124; 2022: r = -0.573, p = 0.179; 2023: r = -0.637, p = 0.124), demonstrated some degree of correlation with TB incidence but did not achieve statistical significance ($p > 0.05$).

3.3 Spatial Analysis of Pulmonary Tuberculosis Distribution

Spatial analysis revealed key geographic patterns in the distribution of pulmonary TB cases across Banggai Laut Regency. TB cases were more prevalent in subdistricts with a higher male-to-female sex ratio (SR > 100), such as Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan. Cases were also more frequent in areas with low population density (≤150 people/km²), such as South Banggai, North Banggai, Central Banggai, Labobo, Bangkurung, and Bokan Kepulauan, compared to Banggai Subdistrict, which had a higher population density (201–400 people/km²).

Elevation played a role in TB distribution, with most cases occurring in subdistricts at very low elevations (0–10 meters above sea level), including Banggai, North Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan. Central Banggai, which lies at a slightly higher elevation (11–50 meters), reported fewer cases. Subdistricts with a high proportion of healthy housing coverage (≥70%)—such as Banggai, South Banggai, North Banggai, and Central Banggai—also reported more cases compared to areas with lower healthy housing coverage (<70%), such as Labobo, Bangkurung, and Bokan Kepulauan.

The availability of healthcare workers and proximity to healthcare facilities further influenced TB distribution. Subdistricts with fewer healthcare workers (≤3 workers), including Banggai, North Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan, reported higher TB incidences compared to Central Banggai, which had more healthcare workers (>3 workers). Similarly, subdistricts without access to Molecular Rapid Test (MRT) facilities—such as Banggai, North Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan—reported more cases compared to Central Banggai, where MRT facilities were available. Lastly, TB cases were more prevalent in subdistricts located farther from healthcare facilities (>30 minutes away), such as North

Table 1. Distribution of Pulmonary Tuberculosis Cases Based on Gender, Age Group, and Sub-districts in Banggai Laut Regency, Central Sulawesi Province, 2021-2023

Characteristics	2021		2022		2023	
	n	%	n	%	n	%
Gender						
Male	64	50.79	87	57.24	67	55.37
Female	62	49.21	65	42.76	54	44.63
Age Group (Years)						
< 12 Years	6	4,76	7	4,61	4	3,31
12-22 Years	14	11,11	21	13,82	23	19,01
23-33 Years	20	15,87	23	15,13	17	14,05
34-44 Years	24	19,05	34	22,37	22	18,18
45-55 Years	24	19,05	28	18,42	23	19,01
56-66 Years	26	20,63	27	17,76	25	20,66
67-77 Years	11	8,73	11	7,24	7	5,79
78-88 Years	0	0,00	1	0,66	0	0,00
> 88 Years	1	0,79	0	0,00	0	0,00
Subdistrict						
Banggai	45	35,71	54	35,53	39	32,23
Banggai Tengah	9	7,14	13	8,55	11	9,09
Banggai Utara	10	7,94	12	7,89	10	8,26
Banggai Selatan	10	7,94	11	7,24	6	4,96
Labobo	10	7,94	12	7,89	11	9,09
Bangkurung	19	15,08	21	13,82	18	14,88
Bokan Kepulauan	23	18,25	29	19,08	26	21,49
Total	126	100	152	100	121	100

Table 1. Results of Correlation Analysis of Gender, Population Density, Area Altitude, Healthy Homes, Health Workers, Health Service Facilities, Distance to Health Facilities with Pulmonary Tuberculosis Incidence in Banggai Laut Regency, Central Sulawesi Province, 2021-2023

Years	Variables	r	p	Description
2021	Gender	0,700	0,079	Positive correlation and not significant.
	Population Density	0,523*	0,229*	Positive correlation and not significant.
	Altitude of Region	-0,717*	0,069*	Negative correlation and not significant.
	Healthy Homes	-0,417	0,352	Negative correlation and not significant.
	Health Workers	-0,832	0,020	Negative correlation and significant.
	Health Service Facilities	-0,637	0,124	Negative correlation and not significant.
	Distance to Health Facilities	0,829	0,021	Positive correlation and significant.
2022	Gender	0,636	0,124	Positive correlation and insignificant
	Population Density	0,691*	0,086*	Positive correlation and insignificant
	Altitude of Region	-0,667*	0,102*	Negative correlation and insignificant
	Healthy Homes	-0,511	0,241	Negative correlation and insignificant
	Health Workers	-0,794	0,033	Negative correlation and significant
	Health Service Facilities	-0,573	0,179	Negative correlation and insignificant
	Distance to Health Facilities	0,818	0,025	Positive correlation and significant
2023	Gender	0,475	0,283	Positive correlation and insignificant
	Population Density	0,487*	0,268*	Positive correlation and insignificant
	Altitude of Region	-0,523*	0,228*	Negative correlation and insignificant
	Healthy Homes	-0,729	0,063	Negative correlation and insignificant
	Health Workers	-0,761	0,046	Negative correlation and significant
	Health Service Facilities	-0,344	0,449	Negative correlation and insignificant
	Distance to Health Facilities	0,845	0,017	Positive correlation and significant

Notes: *Spearman Correlation Test, Pearson Correlation Test

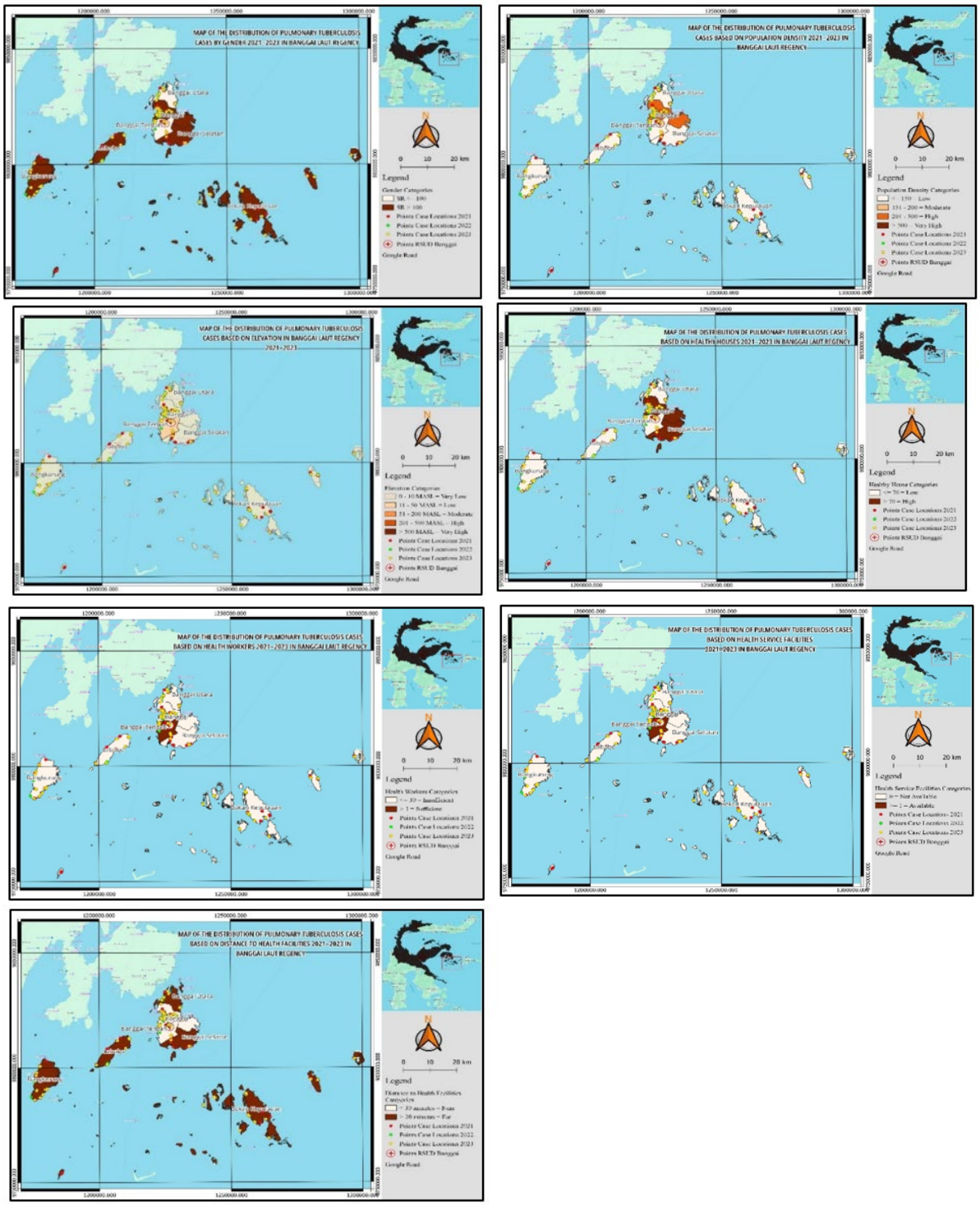

Figure 1. Spatial Distribution Map of Gender, Population Density, Area Altitude, Healthy Homes, Health Workers, Health Service Facilities, Distance to Health Facilities with Pulmonary Tuberculosis Incidents in Banggai Laut Regency Central Sulawesi Province 2021-2023

Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan, while Banggai and Central Banggai, which are closer to healthcare facilities (≤30 minutes away), recorded fewer cases.

4. Discussion

The incidence of pulmonary tuberculosis (TB) has consistently been higher in males compared to females. This disparity is often attributed to behavioral and social factors, including higher rates of smoking and alcohol consumption among males, both of which are known to increase the risk of TB (Seifert et al., 2021). A study in Myanmar reported that 70% of individuals diagnosed with TB were male, with a positivity rate of 47%, compared to 39% in females (Seifert et al., 2021).

Population density significantly impacts the transmission of infectious diseases, particularly airborne ones like TB. Higher population densities facilitate the spread of Mycobacterium tuberculosis through increased interpersonal interactions, enhancing the likelihood of inhaling airborne pathogens (Heriyani et al., 2013). Similarly, altitude affects climatic factors such as humidity, temperature, and oxygen density, all of which play crucial roles in the survival and viability of Mycobacterium tuberculosis. For example, higher humidity at lower temperatures creates favorable conditions for microbial growth, extending the bacteria's viability.

Unhealthy housing conditions are another significant factor contributing to TB transmission. Poor housing serves as a reservoir for environmental pathogens, significantly increasing the risk of disease transmission. Homes that fail to meet healthy housing standards are seven times more likely to harbor TB compared to those that meet these standards (Achmadi, 2008). Housing factors such as poor ventilation have been shown to exacerbate the risk of TB (Sinaga et al., 2016).

The availability and accessibility of healthcare resources are vital in controlling TB. The presence of trained healthcare workers enhances TB management through early detection and timely treatment, which are critical for preventing disease transmission. According to the Ministry of Health of Indonesia (2023), regions with better coverage of trained healthcare workers showed higher rates of TB case detection, enabling faster interventions. However, the lack of counseling and home visits by healthcare workers often leads to irregular treatment and dropout rates (Cana et al., 2024).

Similarly, the distribution and accessibility of healthcare facilities significantly influence TB incidence. Adequate facilities, including health centers and hospitals equipped for TB diagnosis and treatment, facilitate early detection and management of cases (Komala Dewi & Fazri, 2023). However, uneven distribution of these facilities or geographical barriers can hinder their effectiveness in reducing TB incidence (Wahyono, 2020).

Distance to healthcare facilities presents another challenge, particularly in rural areas where patients often face transportation difficulties and additional costs. Studies indicate that patients living farther from healthcare facilities are less likely to adhere to treatment schedules, leading to delayed diagnosis and increased transmission risk (Wahyono, 2020).

Correlation analyses in this study revealed statistically significant relationships between the availability of healthcare workers (2021: $p = 0.020$, $r = -0.832$; 2022: $p = 0.033$, $r = -0.794$; 2023: $p = 0.046$, $r = -0.761$) and the distance to healthcare facilities (2021: $p = 0.021$, $r = 0.829$; 2022: $p = 0.025$, $r = 0.818$; 2023: $p = 0.017$, $r = 0.845$) with pulmonary TB cases. In contrast, other variables, including gender, population density, altitude, housing conditions, and healthcare facility coverage, did not demonstrate significant correlations. These results may have been influenced by the small sample size and unmeasured factors such as age, nutritional status, social behaviors, and socioeconomic conditions.

Research supports the role of various environmental and individual factors in TB transmission. For instance, humidity and temperature were found to be more influential than population density in TB incidence (Dewi & Juniyarti, 2021). Housing conditions, particularly ventilation, also play a significant role, with poor ventilation contributing to higher TB rates (Tatangindatu & Umboh, 2021). Individual factors, including nutritional status and contact history with TB patients, further exacerbate the risk. For example, individuals with poor nutrition or a history of close contact with TB patients are at higher risk, even when residing in healthy housing (Nurwitasari & Wahyuni, 2015).

Spatial analyses from 2021 to 2023 in Banggai Laut Regency highlighted that pulmonary TB cases were concentrated in areas with a higher male population, low population density, low altitude, insufficient healthy housing coverage, fewer healthcare workers, limited healthcare facilities, and greater distances to these facilities. These findings align with prior studies emphasizing the role of environmental and healthcare factors in TB distribution (Heriyani et al., 2013; Achmadi, 2008).

The complex interplay of environmental, healthcare, and individual factors necessitates a multifaceted approach to TB control. Interventions should prioritize improving housing conditions, enhancing healthcare worker training, increasing the accessibility of healthcare facilities, and addressing individual risk factors such as nutrition and smoking cessation. Moreover, spatial and environmental considerations should inform TB prevention strategies to target high-risk areas effectively.

5. Conclusion

In conclusion, this study highlights the complex factors influencing the distribution of pulmonary tuberculosis (TB) in Banggai Laut

Regency, emphasizing the role of healthcare access, environmental conditions, and demographic variables. Significant correlations were found between TB incidence and the availability of healthcare workers and the distance to healthcare facilities, underscoring the importance of improving healthcare infrastructure. Additionally, the geographic and environmental factors, including population density, altitude, and housing conditions, were identified as key contributors to TB transmission. These findings suggest that targeted interventions focusing on healthcare accessibility and environmental improvements are crucial for effective TB control in this region.

Author contributions

M.I.R. collected secondary data on the distribution of pulmonary tuberculosis cases in Banggai Laut Regency from 2021 to 2023, conducted spatial data analysis, and performed correlation analysis between variables. N.N.N. and I.L.M. provided guidance and input at every stage of the research, from problem formulation and methodology to data analysis. A.A.A. and A.I.M. evaluated the research results in terms of methodology, analysis, and conclusions, and offered constructive criticism and suggestions to enhance the quality of the research. All authors have read and approved the final version of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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