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RESEARCH ARTICLE

Spatial Analysis and Correlation of Pulmonary Tuberculosis Case Distribution in Banggai Laut Regency, Central Sulawesi, 2021–2023

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ABSTRACT

Tuberculosis is an infectious disease classified as a re-emerging disease and remains a public health issue. The World Health Organization (WHO) has declared it a global concern. The use of Geographic Information Systems (GIS) in the health sector serves as a tool to process and analyze disease distribution patterns. This study aims to spatially analyze and examine the correlation of pulmonary tuberculosis case distribution in Banggai Laut Regency from 2021 to 2023. The research employed a quantitative approach using an ecological study design. The study population consisted of 7 sub-districts as the units of analysis, with a total sample of 399 pulmonary tuberculosis cases from 2021–2023. The sampling technique used was purposive sampling. Data were analyzed using STATA version 14 and Quantum GIS. The statistical tests applied were Spearman and Pearson correlation analyses. There is a significant correlation between the number of healthcare workers (2021: p=0.023, r=0.832; 2022: p=0.033, r=0.794; 2023: p=0.047, r=0.761) and the distance to healthcare facilities (2021: p=0.021, r=0.829; 2022: p=0.024, r=0.817; 2023: p=0.016, r=0.845) with pulmonary tuberculosis cases in Banggai Laut Regency. Spatially, pulmonary TB cases predominantly occur in areas with a high male population, low population density, very low elevation, low coverage of healthy housing, insufficient healthcare workers, lack of healthcare facilities, and significant distance to healthcare services. Conclusion: Healthcare workers and the distance to healthcare facilities are significant variables associated with pulmonary tuberculosis cases in Banggai Laut Regency from 2021 to 2023.

INTRODUCTION

Tuberculosis is an infectious disease classified as a re-emerging infectious disease, which refers to diseases that have previously experienced a significant decline but have resurfaced and become a public health issue. The World Health Organization (WHO) has declared it a global concern (1)(2). A major issue today is not only the increasing prevalence of the disease, particularly in developing countries, but also the emergence of resistance to tuberculosis bacterial strains, which is a primary concern in many developing nations (3).

According to the World Health Organization (Global TB Report, 2023), tuberculosis remains a global health problem. In 2022, tuberculosis caused approximately 1.30 million deaths worldwide. The burden of TB varies significantly across countries (4). Globally, 7.5 million people were newly diagnosed with tuberculosis in 2022. The 30 countries with the highest TB burden accounted for 87% of global TB cases in 2022, with two-thirds of the total global cases occurring in eight countries:

the Philippines (638/100,000 population), Indonesia (386/100,000 population), the Democratic Republic of the Congo (317/100,000 population), Pakistan (258/100,000 population), Bangladesh (221/100,000 population), Nigeria (219/100,000 population), and China (52/100,000 population) (WHO, 2022). In 2022, 55% of TB patients were male, 33% were female, and 12% were children (aged 0-14 years) (6).

Based on the TB incidence data from 2000–2020, there was a decline in TB incidence and mortality, albeit not significantly sharp. However, an increase was observed between 2020 and 2021. The TB incidence in 2021 increased by 18% (absolute numbers: 819,000 cases in 2020 to 969,000 in 2021; rate per 100,000 population: 301 in 2020 to 354 in 2021). Similarly, TB-related mortality increased by 55% in absolute numbers (93,000 deaths in 2020 to 144,000 in 2021) and by 52% in the mortality rate per 100,000 population (34 in 2020 to 52 in 2021)(7).

The detection and treatment of tuberculosis (TB) cases in Central Sulawesi in 2022 was only 47%, far below the target of 85%. Between 2021 and 2023, the TB incidence rate in Banggai Laut Regency fluctuated. From 2021 to 2022, the TB incidence rate increased from 16/10,000 population to 19/10,000 population. However, in 2023, the incidence rate decreased to 17/10,000 population, and the distribution of TB cases was uneven across several regions. The case detection rate in 2022 was still low at 53%, compared to the TB program target of 85%. This was due to suboptimal active case finding (contact investigations, screening in high-risk areas) (8).

Banggai Laut Regency is a maritime region consisting of 7 sub-districts, with a sea area of approximately 12,156.78 km^2, or around 94.37% of the total area, and a land area of 725.67 km^2, or around 5.63% of the total area of Banggai Laut Regency. There are 3 sub-districts that can only be accessed by sea transport, and many remote villages are located within the area (9).

The use of Geographic Information Systems (GIS) in environmental health is a necessary tool to process, analyze, and map disease distribution patterns based on the environment. The ability to process specific disease information and analyze the relationship between diseases and factors such as population settlements, healthcare services, and the environment makes GIS highly suitable for epidemiological data analysis. This can help policymakers visualize existing health issues (Jannah et al., 2023).

Thus, spatial analysis of pulmonary tuberculosis not only helps in understanding the disease distribution and identifying areas with high TB incidence but also serves as a strong foundation for planning and implementing more effective health interventions. Based on the issues mentioned above, the author has undertaken research on Spatial Analysis of Pulmonary Tuberculosis Case Distribution from 2021 to 2023 in Banggai Laut Regency, Central Sulawesi Province.

MATERIALS AND METHODS

The type of research used in this study is quantitative research with an ecological study design. The spatial model is a modeling approach that involves point and area techniques to explore data from a spatial perspective.

Population and Sample

The population in this study consists of the unit of analysis, which includes 7 sub-districts in Banggai Laut Regency. The sample in this study includes all pulmonary tuberculosis (TB) cases that

occurred in Banggai Laut Regency, Central Sulawesi Province, from 2021 to 2023, totaling 399 cases. The sampling technique used is purposive sampling. The dependent variable in this study is the incidence of pulmonary tuberculosis, while the independent variables are gender, population density, elevation, healthy housing, healthcare workers, healthcare facilities, and the distance to healthcare facilities.

Inclusion Criteria

Diagnosed with pulmonary tuberculosis (TB) and registered in the TB register at the Public Health Center and Health Office from 2021 to 2023 (cases).

The patient's address is clearly recorded.

Exclusion Criteria

Individuals who do not reside permanently in Banggai Laut Regency.

Patients diagnosed with drug-resistant TB.

Data Analysis

The data were processed using STATA software version 14 and QGIS. This study employed two types of analysis: univariate and bivariate. Univariate analysis was conducted to determine the frequency distribution of respondents' general characteristics. Bivariate analysis was performed to evaluate the relationship between independent variables and the dependent variable with a significance level (alpha) of 0.05. Pearson's

correlation test was used to identify

relationships when the data followed a normal distribution. Meanwhile, Spearman's correlation test was employed to identify relationships when the data did not follow a normal distribution.

RESULTS

Sample characteristics

Based on Table 1, Pulmonary TB cases in Banggai Laut Regency from 2021 to 2023 were more prevalent among men, with the highest proportion in 2022 at 57.24%. The age group with the highest cases varied each year, which were 56-66 years in 2021 (20.63%) and 2023 (20.66%), and 34-44 years in 2022 (22.37%). Geographically, the highest number of pulmonary TB cases was found in Banggai Subdistrict, with the highest proportion in 2021 (35.71%), which decreased to 32.23% in 2023. The peak of cases occurred in 2022 with 151 cases (37.84%).

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

Correlation Analysis Results

Based on Table 2 above, it shows a correlation between healthcare workers (2021: r = -0.832, p = 0.020; 2022: r = -0.794, p = 0.033; 2023: r = -0.832, p = 0.020) and distance to healthcare facilities (2021: r = 0.829, p = 0.021; 2022: r = 0.818, p = 0.025; 2023: r = 0.829, p = 0.021) with pulmonary TB incidence, both of which are statistically significant ($p < 0.05$). Meanwhile, 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) show correlations with pulmonary TB incidence but are not statistically significant ($p > 0.05$).

Table 2. 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

Spatial Analysis of Pulmonary Tuberculosis Distribution

Based on Figure 1, Pulmonary tuberculosis (TB) cases in Banggai Laut Regency from 2021 to 2023 were more prevalent in subdistricts with a higher male-to-female sex ratio (SR > 100), namely Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan. These cases were also more frequently found in subdistricts with low population density (≤150 people/km^2), such as South Banggai, North Banggai, Central Banggai, Labobo, Bangkurung, and Bokan Kepulauan, compared to Banggai Subdistrict, which has a higher population density (201–400 people/km^2). Most cases occurred in areas with very low elevation (0–10 meters above sea level), including Banggai, North Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan. Central Banggai, which has a low elevation (11–50 meters above sea level), recorded fewer cases. TB cases were also more common in subdistricts with a high proportion of healthy housing coverage (≥70%), such as Banggai, South Banggai, North Banggai, and Central Banggai. Conversely, Labobo, Bangkurung, and Bokan Kepulauan, which have lower healthy housing coverage (<70%), reported fewer cases.

Subdistricts with fewer healthcare workers (≤3 workers), such as Banggai, North Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan, reported more cases compared to Central Banggai, which had sufficient healthcare workers (>3 workers). Additionally, subdistricts without a Molecular Rapid Test (MRT) facility, such as Banggai, North Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan, reported more cases compared to Central Banggai, which has an MRT facility. Furthermore, TB cases were more commonly found in subdistricts located far from healthcare facilities (>30 minutes away), such as North Banggai, South Banggai, Labobo, Bangkurung, and Bokan Kepulauan. In contrast, Banggai and Central Banggai, which are closer to healthcare facilities (≤30 minutes away), recorded fewer cases.

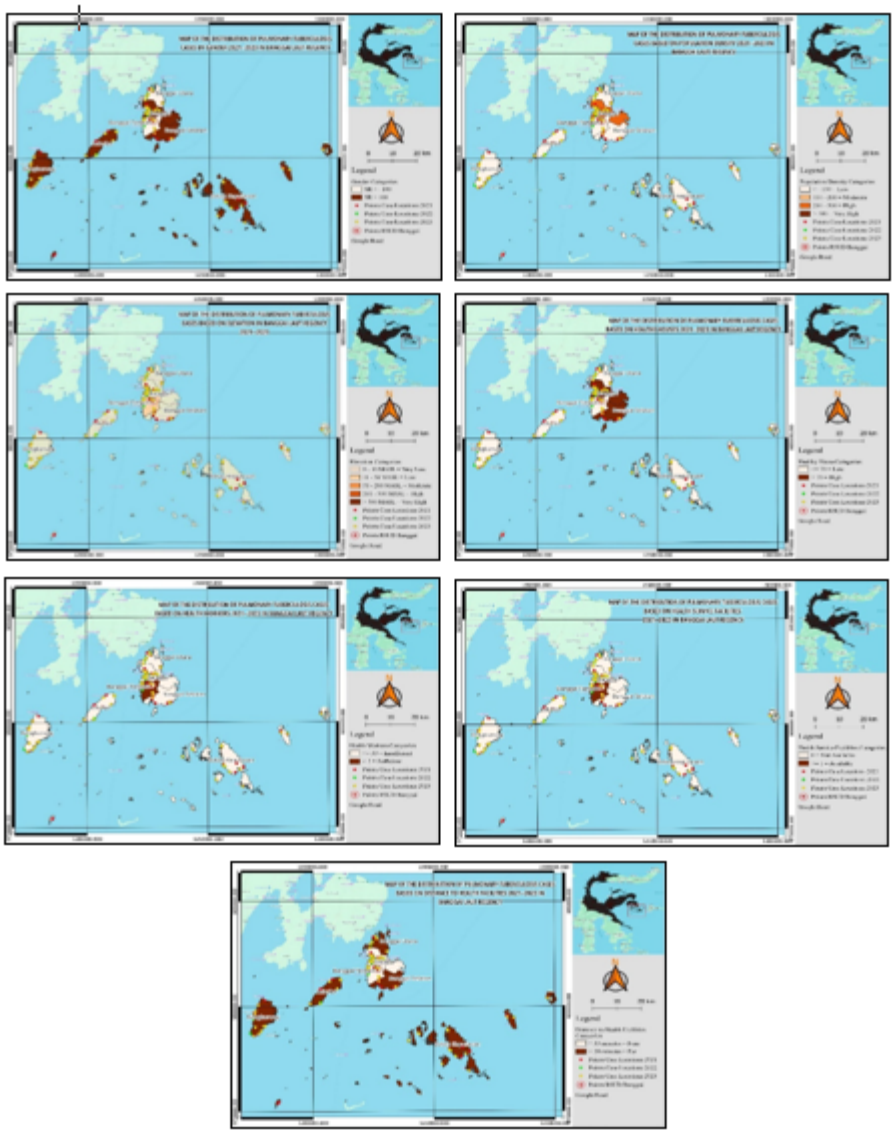

Figure 1. Spatial Distribution Map of Gender, Population Density, Area Altitude, Healthy Homes, Health Workers, Health Service Facilities, Distance to Health Facilities with Pulmonary Tuberculosis Incidents in Banggai Laut Regency

Central Sulawesi Province 2021-2023

DISCUSSION

Pulmonary TB tends to be higher in males compared to females (9). Males are more exposed to risk factors such as smoking and high alcohol consumption, both of which are known to increase the risk of pulmonary tuberculosis. Additionally, a study conducted by Seifert et al. (2021) in Myanmar revealed that 70% of individuals diagnosed with TB were male. Positive test results were higher among males (47%) compared to females (39%).

Population density can accelerate the transmission and spread of diseases from one person to another (11). For airborne diseases such as pulmonary TB, higher population density increases the likelihood of individuals inhaling airborne pathogens, facilitating disease spread (12).

Altitude affects humidity, temperature, and oxygen density, all of which influence the viability of Mycobacterium tuberculosis (13). Humidity plays a significant role in the transmission and spread of pulmonary TB. Air humidity affects the concentration of TB bacteria in the air; higher humidity at lower temperatures creates favorable conditions for microbial growth, including TB bacteria, prolonging their viability.

Unhealthy housing conditions can act as a reservoir for environmental pathogens. Better coverage of healthy housing in an area reduces the risk of disease. Houses not meeting healthy housing standards are seven times more likely to harbor TB compared to houses that do meet these standards (14).

The availability of trained healthcare workers significantly influences the management and prevention of pulmonary TB cases. Trained healthcare workers are better equipped to perform early detection, particularly in high-risk areas. Early detection is critical to initiate treatment promptly and reduce TB transmission in the community. According to a report by the Indonesian Ministry of Health (2023), regions with more trained healthcare workers exhibited increased TB case detection rates, enabling faster and more effective interventions. Studies also indicate that irregular treatment and treatment dropout (DO) are often due to a lack of counseling and home visits by healthcare workers (15).

The availability of healthcare facilities for TB examination greatly impacts the distribution of pulmonary TB cases in a region. Areas with adequate healthcare facilities, such as health centers, clinics, and hospitals with TB services, can detect the disease more quickly (16). Research by Komala Dewi & Fazri (2023) found a significant relationship between access to healthcare services and pulmonary TB incidence. However, if these facilities are not evenly distributed or accessible to all, their impact on reducing TB incidence may not be significant.

Distance to healthcare facilities has a significant influence on pulmonary TB incidence, particularly in terms of access to treatment and patient compliance. Patients living far from healthcare facilities face challenges in obtaining timely treatment, increasing the risk of treatment discontinuation or delayed diagnosis. Greater distance from health facilities can lead to barriers such as higher transportation costs and longer travel times (18).

Based on Pearson and Spearman correlation tests, there was a significant correlation between healthcare workers (2021: p=0.020, r=-0.832; 2022: p=0.033, r=-0.794; 2023: p=0.046, r=-0.761) and 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. Other variables, such as gender (2021: p=0.079, r=0.70; 2022: p=0.124, r=0.636; 2023: p=0.283, r=0.475), population density (2021: p=0.229, r=0.523; 2022: p=0.086, r=0.691; 2023: p=0.268, r=0.487), altitude (2021: p=0.069, r=-0.717; 2022: p=0.102, r=-0.667; 2023: p=0.228, r=-0.523), healthy housing (2021: p=0.352, r=-0.417; 2022: p=0.241, r=-0.511; 2023: p=0.063, r=-0.729), and healthcare facilities (2021: p=0.124, r=-0.637; 2022: p=0.179, r=-0.573; 2023: p=0.449, r=-0.761), showed correlations that were not statistically significant. Small sample size and unit analysis may have affected the study outcomes. Additionally, unmeasured factors could weaken the relationship, including age, nutritional status, social behaviors such as smoking, humidity, temperature, housing conditions, close contact history, socioeconomic conditions, and lifestyle factors.

A study by Dewi & Juniyarti (2021) found that factors such as humidity, temperature, and close contact history had a stronger influence on TB incidence compared to population density. Another study by Sinaga et al. (2016) revealed that physical housing conditions, such as ventilation, had a greater impact on TB incidence than population density. Research by Tatangindatu & Umboh (2021) showed that poor ventilation and high housing density increased the risk of pulmonary TB. Socioeconomic factors and individual health behaviors also play a role. For instance, nutritional status and contact history with TB patients are significant risk factors. A study by Nurwitasari &

Wahyuni (2015) found that individuals with poor nutrition or high contact history were more affected, even if their homes met healthy housing standards.

Spatial analysis results indicate that the distribution of pulmonary TB cases in Banggai Laut Regency from 2021 to 2023 is concentrated in areas with a higher male population, low population density, very low altitude, low healthy housing coverage, fewer healthcare workers, lack of healthcare facilities, and greater distance to healthcare services.

CONCLUSION

Healthcare workers and the distance to healthcare facilities are significant variables associated with pulmonary tuberculosis cases in Banggai Laut Regency from 2021 to 2023. Based on spatial analysis, pulmonary TB cases are predominantly found in areas with a higher male gender ratio, low population density, very low altitude (0-10 meters above sea level), low coverage of healthy housing, insufficient number of health workers, lack of available healthcare facilities, and long distances to healthcare facilities.

AUTHORS CONTRIBUTIONS

Muhammad Irwan Rizali: 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.

Nur Nasry Noor and Ida Leida Maria: Provided guidance and input at every stage of the research, from problem formulation and methodology to data analysis.

Andi Arsunan Arsin and Apik Indarty Moedjiono: Evaluated the research results in terms of methodology, analysis, and conclusions, and offered constructive criticism and suggestions to enhance the quality of the research.

ETHICAL CLEARENCE

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.

CONFLICT OF INTEREST

The authors declare no conflict of interest in the writing of this article. This research was conducted independently, funded entirely by the authors without any grants, sponsorships, or scholarships from any parties.

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