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RESEARCH PAPER
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Analysis of the Distribution Pattern of Tuberculosis (TB) Incidence in the Muara Beliti Health Center Working Area, Musi Rawas District, 2025

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ABSTRACT

Tuberculosis (TB) does not only affect physical health but also psychological and economic aspects of individuals and their families. In 2020, global TB-related deaths reached 1.3 million, and Indonesia ranks third globally, with the number of cases increasing every year. In South Sumatra, especially in the working area of the Muara Beliti Health Center, TB cases increased from 27 in 2022 to 42 in 2024. This study aimed to analyze the spatial pattern of TB risk in Muara Beliti Regency in 2025 using the Analytic Hierarchy Process (AHP) and Inverse Distance Weighting (IDW) methods. The integration of behavioral and environmental factors with spatial analysis allows for more focused intervention planning. By utilizing Geographic Information Systems (GIS), this analysis identified high-risk areas and provides insights for efficient prevention strategies. A descriptive quantitative method was used, involving the collection of data on patient characteristics and geographic coordinates, along with visualization of TB risk patterns using IDW. The results showed that areas with low contour values (0.5–0.5912) represented high-risk zones, especially around Air Lesing, Ketuan Jaya, the southern part of Durian Remuk, and Muara Beliti Baru. In contrast, areas with higher contour values (0.786–1) are at lower risk. This risk map supports mitigation efforts by highlighting residential areas with poor ventilation and sanitation. The combination of AHP and IDW is effective in identifying spatial TB risk patterns and designing more targeted interventions.

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1. INTRODUCTION

Tuberculosis (TB) is a chronic infectious disease caused by the bacterium Mycobacterium tuberculosis. This bacterium, which is rod-shaped, can survive in acidic environments, hence the name is Acid-Fast Bacillus (AFB). While Mycobacterium tuberculosis primarily targets lung tissue and causing pulmonary TB, it can also infect other organs outside the lungs, resulting in extrapulmonary TB, including pleura, lymph nodes, bones, and other organs [1]. From an epidemiological perspective, TB occurs due to the interaction between several factors: agents (bacteria) [2], host (individual), and environment [3]. TB is a complex disease that is influenced by the characteristics of the causative microorganism, the host's immune response, and the environmental conditions that individuals face throughout their lives [4]. TB is transmitted from an infected individual to another person through respiratory droplets containing Mycobacterium tuberculosis [3]. TB continues to be a significant public health threat due to its ease of transmission [5][6]. The impact of TB goes beyond physical health, affecting the psychological and economic well-being of affected individuals and their families. TB patients often experience a decline in work productivity and face economic hardship [7], especially if the patient is the head of household [8]. As a result, effective TB management is essential not only for public health but also for the sustainability of the national economy [9]. In 2020, global TB-related deaths reached 1.3 million, almost double the number of deaths due to HIV/AIDS. This marks the first annual increase in TB-related deaths since 2005. TB was the second leading cause of death

worldwide in 2022, with an estimated 10.6 million people suffering from TB globally, up from 10.3 million cases in 2021 [10]. Indonesia is one of the 30 countries with the highest burden of TB, ranking third globally in terms of TB incidence [11]. In Indonesia, the number of TB cases increased from 724,309 in 2022 to 821,200 in 2023. This increase was also seen in South Sumatra, where TB cases rose from 18,122 in 2022 to 20,070 in 2023 [12]. Particularly, within the working area of the Muara Beliti Health Center, the cases increased from 27 in 2022 to 42 in 2024 [13], This data shows a continuous increase in TB cases annually. Today, research on TB is developing rapidly with a variety of approaches, including the use of Geographic Information Systems (GIS) technology [14]. GIS is a computerized system that integrates spatial (geographical) and non-spatial (attribute) data to generate information that supports decision-making. By leveraging geographic information, GIS enables visualization and analysis that helps users understand patterns, relationships, and trends in location-related data [15]

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. GIS has been used in studies investigating the transmission of diseases, such as Hepatitis [16], cholera [17] [18], and Covid-19 [19]. GIS can also be used to predict the suitability of healthcare facility locations in 2030 [20]. This method maps the location and causative factors of the disease, monitors disease trends to support surveillance, and implements interventions to prevent the spread of the disease. As a result, GIS plays a crucial role in designing more effective prevention and control strategies [21] [22]. A study in Moscow that analyzed TB incidence from 2000 to 2015 revealed that there are clusters responsible for TB incidence with rates 3-4 times higher than other regions [23]. Studies conducted in various locations have shown a varied pattern of TB clusters, influenced by local characteristics. For example, research in Yogyakarta found significant TB clusters in areas with high population density, while research in Magelang Regency [24] suggests that the spread of TB is influenced by population density and close contact between individuals in low- to moderate-elevation areas. International studies, such as those in Africa, show that TB is influenced by environmental factors such as temperature, population density and air pollution [25]. Furthermore, a study in Hubei, China, found significant clusters of TB in high-density population areas [26]. These findings underscore the effectiveness of GIS for spatial analysis, as it helps identify patterns of disease spread and causative factors included in the time sequence of events [25]. Advantages of previous research lies in the effective use of GIS in identifying patterns and clusters of disease distribution, providing deep spatial insights. However, not all studies have comprehensively integrated behavioral and environmental factors with spatial analysis. In addition, research in areas with characteristics similar to Musi Rawas, which have different geographical and social conditions, has been limited, potentially affecting the validity of the results when compared to other regions. The World Health Organization (WHO) has developed a global strategy to end TB, with a significant target of reducing TB-related deaths and incidences by 2035 [9] . In Indonesia, the National TB Strategy for 2020-2024 aims to eliminate TB by 2030 [12]. This effort involves strengthening the commitment of central, provincial, and district governments to improve access to TB services, promote prevention, and improve treatment [27].

The importance of implementing strategies to end TB requires deeper research into the underlying causes of TB and a spatial analysis of its spread. Understanding the correlation between TB behavior, environment, and transmission will allow for more targeted intervention planning [28]. By using technologies such as GIS, spatial analysis can provide more accurate insights into high-risk areas, enabling effective and efficient mitigation measures [29]. Spatial analysis and understanding of the factors that contribute to the incidence of TB are important tools to understand the distribution of TB, especially in Muara Beliti District, Musi Rawas. Given the dynamic nature of TB[30], the risk map generated from the 2025 data provides a static snapshot for a specific point in time. Because the spread of TB can change over time, affecting the distribution of risk, further mapping that considers temporal variability in the future is strongly recommended. Although many studies have been conducted in various regions, spatial analysis and identification of TB-related causative factors have not been explored in Musi Rawas Regency. Therefore, this study is entitled "Analysis of Spatial Distribution, Behavior, and Environmental Factors in the Relationship between Tuberculosis (TB) Incidence in Muara Beliti District, Musi Rawas, 2025", aiming to fill this gap. The main objective of this study is to analyze the spatial distribution pattern of TB risk in the working area of the Muara Beliti Health Center, Musi Rawas District, using a more integrated and comprehensive approach. This study used a combination of the Analytic Hierarchy Process (AHP) [29], Reverse Distance Weighting (IDW) [31] [32], and Geographic Information Systems (GIS), which are considered more advanced than previous research due to the integration of behavioral and environmental factors in spatial analysis. Previous research has often focused only on spatial factors without considering behavioral aspects (such as medication adherence and access to health care [33] [34] or environmental factors [35] [36], which significantly affects the risk of TB transmission. By integrating these factors, the study provided a more comprehensive and specific understanding of the elements that affect TB risk.

This research is highly justified because of the need to gain a deeper understanding of the factors that influence the spread of tuberculosis, especially in areas with unique social, economic, and geographical characteristics such as Musi Rawas Regency. Although there has been research on the spatial analysis of TB, approaches that comprehensively integrate behavioral and environmental factors are still limited. Therefore, the main objective of this study is to analyze the spatial distribution pattern of TB risk in the working area of the Muara Beliti Health Center, taking into account spatial, behavioral, and environmental factors that can affect disease transmission. Using combined methods such as Analytic Hierarchy Process (AHP), Inverse Distance Weighting (IDW), and Geographic Information Systems (GIS), this study aimed to produce more accurate and relevant risk maps to design more targeted interventions. The main contribution of this study is to provide data-driven models that can be used by policymakers to design more effective TB prevention and control strategies, as well as to offer insights that can be applied to other areas with similar characteristics. The research also supports Indonesia's national efforts to eliminate TB by 2030 [12] by providing a more localized and data-driven risk map.

2. MATERIALS AND METHODS

A. Research Design

This study applied a descriptive quantitative design. The main objective of this study is to describe the characteristics of TB patients and analyze the spatial distribution of TB risk. To achieve this goal, the study integrated several analysis methods. First, patient characteristics data (including health access, medication adherence, air ventilation, housing density, social support, knowledge, education, age, and access to clean water) were collected through observations and questionnaires administered at the respondents' homes, with the research team also recording the geographical

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coordinates of the patient's residence using GPS.

Second, the Analytical Hierarchy Process (AHP) [37] [38] was applied to determine the priority weights of each variable that contributes to TB risk. The weight determination process using AHP involves stakeholders consisting of the Head of the Muara Beliti Health Center, the Health Center Doctor, and the TB Program Coordinator. Weights were determined based on paired comparisons of existing risk variables, and consistency ratio (CR) calculations were used to check consistency and weight validation. Once the AHP weights were determined, the data collected from respondents through a questionnaire was multiplied by the AHP weight to generate a Z score, which was then used in the IDW analysis. This approach allows for the creation of a more accurate and focused TB risk distribution map. Lastly, reverse distance weighting (IDW) [39] [32] was also employed. The interpolation method was used to visualize and analyze the spatial distribution pattern of TB risk in the study area. This approach facilitates the identification of areas with different levels of risk, providing a comprehensive picture of the spatial distribution of TB risk.

B. Data Collection

The sample of this study consists of all active tuberculosis patients registered in the working area of the Muara Beliti Health Center, Musi Rawas District. The sample size used in this study includes 42 active TB patients registered at the Muara Beliti Health Center in 2025. Although this number includes all TB cases in the area, a small sample size may affect the representativeness of the findings for a larger population, both spatially and temporally. Additionally, potential bias in sample selection can affect the accuracy of the results. Data were collected directly through interviews using questionnaires given to respondents, accompanied by their family members, and observations were carried out to assess ventilation and housing density in respondents' houses. Geographic coordinates were measured using GPS right inside the respondent's home. The purpose of this data collection process is to obtain comprehensive information on variables relevant to TB risk. The data collected, which includes respondent characteristics and risk factors, will serve as input for the AHP process to determine the priority and relative weight of each variable [40]. The second stage is the spatial risk distribution analysis using the Inverse Distance Weighted (IDW) method. The weighting of the variables obtained from the AHP will be integrated into the spatial mapping as a Z-score for the IDW analysis, which will visualize the areas with different levels of TB risk in the study area.

3. RESULT

A. Accuracy

In the analysis of AHP, several stages were carried out. First, a hierarchy of variables was constructed to represent the potential factors influencing TB incidence (health care access, medication adherence, air ventilation, housing density, social support, knowledge, education, age, and access to clean water) in relation to TB incidence. Second, a comparison matrix was formulated, followed by the normalization of the matrix in the third stage, the calculation of priority weights in the fourth stage, and finally the calculation of the consistency ratio (CR) to check the consistency of the weights. Table 1 shows the weights of each variable calculated from the AHP process. The weights listed in the table have no units and only represent priority scores calculated using the Analytics Hierarchy Process (AHP). This priority score was used to determine the relative importance of each variable that affects the risk of tuberculosis (TB) in this study. The consistency ratio (CR) calculation shows that the set weights are consistent and reliable. The calculated CR value is 0.0162, which is below the threshold of 0.1, indicating that the paired comparisons in the AHP matrix were very consistent and valid for further analysis.

Table 1. Results of the Weight variable

Indicators	Priority Weight
Access to Health Care	0.315
Medication Compliance	0.152
Air Vents	0.152
Housing Density	0.152
Social Support	0.095
Knowledge	0.069
Education	0.058
Age	0.027
Access to Clean Water	0.018
Entire	1

In addition to collecting the characteristics of respondents, the geographical coordinates of TB patients were measured to observe the distribution of TB cases in the working area of the Muara Beliti Health Center. The distribution of TB case locations based on Figure 1.

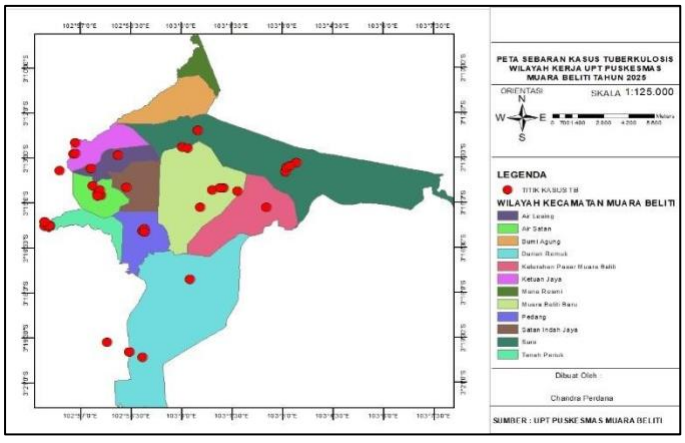

Figure 1. Map of the Spread of TB Cases in the Muara Beliti Health Center Working Area, 2025

Based on Figure 1, the distribution map of TB cases in the Muara Beliti Health Center work area in 2025, it is proven that TB cases (indicated by red dots) are spread throughout the work area. The highest concentrations of cases appear in the western and eastern regions of the map, especially in the

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villages of Air Satan, Muara Beliti Baru, and Suro, which indicate the presence of TB clusters in these areas. In contrast, the northern regions of the map, such as the villages of Bumi Agung and Manah Oficial, showing a lower number of cases. Based on Figure 2, the results of the Inverse Distance Weighting (IDW) interpolation analysis for the Muara Beliti Health Center work area in 2025 reveal variations in the level of TB susceptibility in various regions. The resulting risk map shows high-risk and low-risk zones based on contour values. It is recommended to use heat maps to clarify the boundaries of risk zones and improve the interpretability of the maps. Darker contour colors (especially reddish-brown) represent lower contour values, ranging from 0.5 to 0.5912, indicating areas at high risk of TB occurring. High-risk areas were observed around Air Lesing, Ketuan Jaya, the southern part of Durian Recru, and a small part of the village of Muara Beliti Baru. In contrast, areas with light green to dark green contour colors reflect higher contour values (ranging from 0.786 to 1), indicating a lower level of risk. Areas such as Suro, the eastern part of Muara Beliti Baru, and the southern part of Tanah Periuk fall into this category. The interpretation of these contour patterns is critical to prioritizing public health interventions, with areas showing the lowest contour values being the primary focus for TB prevention and control efforts

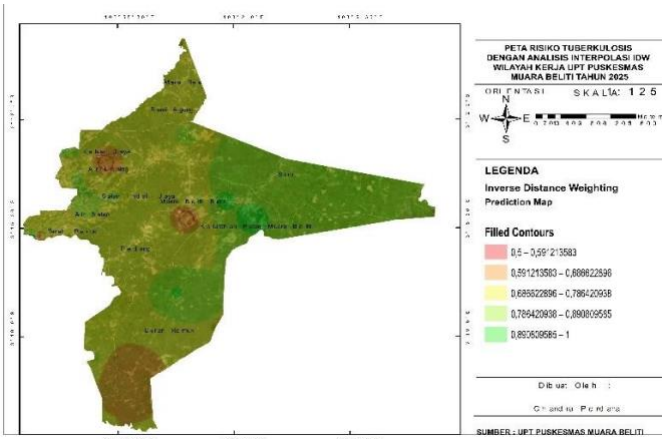

Figure 2. IDW Analysis Results

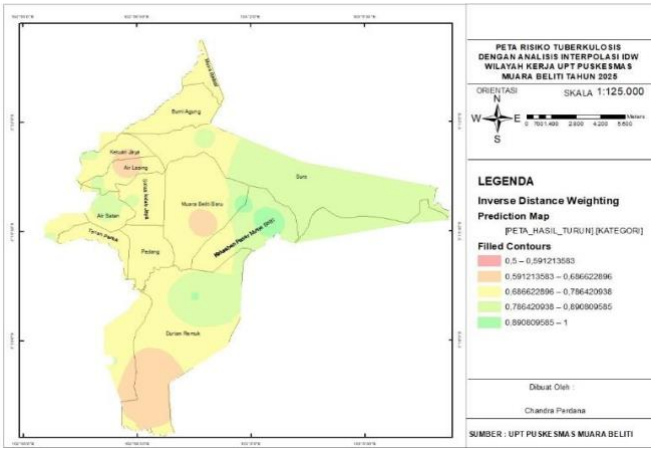

Figure 3. IDW Analysis Results with Satellite Image Layer

Based on Figure 3, the tuberculosis risk map with IDW interpolation analysis, complemented by a layer of satellite imagery, provides a more contextual representation of high-risk TB locations within the working area of the Muara Beliti Health Center in 2025. The red to orange contour color on the map represents lower contour values (ranging from 0.5 to 0.686), indicating areas with a high risk of tuberculosis. According to the visualization of satellite images, these areas are clearly located in residential zones, such as around the villages of Air Lesing, Ketuan Jaya, Muara Beliti Baru, and the southern part of Durian Remuk.

These conditions suggest that the predicted spread of TB is concentrated in areas with higher population densities and potentially inadequate sanitation and ventilation. In contrast, areas dominated by green, with higher contour values (close to 1), reflect a lower level of risk. These areas are generally located in areas with wider land coverage, such as agricultural or forest areas, where human interaction is lower.

4. DISCUSSION

The results of spatial analysis using the Inverse Distance Weighting (IDW) interpolation method for the working area of the Muara Beliti Health Center in 2025 revealed a clear spatial pattern of tuberculosis (TB) susceptibility. Based on data from all respondents, the majority live in areas with inadequate ventilation, which contributes to a higher risk of TB where in the indoor environment, infectious aerosols can accumulate progressively. Poor ventilation is directly correlated with high-risk areas, which require more attention in health interventions [41]. The lower contour values (ranging from 0.5 to 0.5912), depicted in reddish-brown color, indicate areas with a high risk of TB, especially around Air Lesing, Ketuan Jaya, the southern part of Durian Remuk, and parts of the village of Muara Beliti Baru. These findings are consistent with previous research demonstrating IDW's effectiveness in identifying spatial risk zones for infectious diseases [42] [43]. From the results of satellite images that show that the risk of TB exists in high population areas is in line with the research Liyew et al., environmental factors such as temperature, population density, and air pollution were found to be positively associated with the prevalence of DR-TB[25] .

Methodologically, this study combined the Analytical Hierarchy Process (AHP) for weighting of risk variables with IDW spatial interpolation techniques, allowing the integration of subjective weights with quantitative spatial analysis. This approach contrasts with the spatial scan statistics (SaTScan) method used by Rengganis (2020), Resha (2019), and Simbolon (2019) [44] to detect TB clusters without qualitative weighting. The strength of the AHP-IDW combination lies in its ability to accommodate stakeholder perceptions in prioritizing risk factors, although presenting challenges in clarifying the role of compliance variables, which have dual functions [37]. Although IDW is more often used to estimate the physical aspects of the environment [45] [4], IDW parameters were not explicitly selected in this study, thus the findings suggest that IDW is effective in mapping TB risk. Future studies may consider variations in the selection of IDW parameters to evaluate the sensitivity of the results.

The risk map produced by this analysis is invaluable for prioritizing TB control interventions in the working area of the

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Muara Beliti Health Center. Although this study did not conduct formal validation of the risks maps, such as comparing them to known TB clusters or cross-validation methods, further validation using more comprehensive TB cluster data is recommended in future studies to ensure the reliability of the resulting risk maps. Identifying high-risk areas allows for more effective resource allocation for active case detection, health education on ventilation and hygiene, and improvement of environmental conditions. Variable-weight information from the AHP supports the design of interventions that target critical risk factors such as health care access and poor ventilation in densely populated areas. These findings are in line with research by J. Zhang (2022) [22] which suggests that healthcare accessibility is a key factor in TB control in urban areas, albeit with a different emphasis on drug adherence as the main outcome.

Furthermore, significant differences among respondents were noted. This study focused on areas with dense populations and certain socio-economic characteristics, unlike research conducted in suburban areas with more diverse migration patterns and education levels [46]. These variations affect the weighting of risk factors and the spatial distribution patterns of TB, such as the low weights assigned to access to clean water and age in the study, which can be attributed to relatively homogeneous local conditions. Nevertheless, the limitations of the geographical scope of the study suggest the need for further research with a wider scope. This study has limitations in terms of sample size, lack of risk map validation, selection of IDW parameters, and environmental factors that have not been fully explored. These limitations should be recognized and grounded for future research with larger sample sizes and deeper validation, as well as the integration of socio-economic and environmental variables to deepen spatial TB risk analysis in other areas. This will allow for more targeted and effective interventions.

5. CONCLUSION

This study aims to analyze the spatial pattern of TB risk in Muara Beliti Regency in 2025 using the Analytic Hierarchy Process (AHP) and Inverse Distance Weighting (IDW) methods. The red to orange contour color on the map represents lower contour values (ranging from 0.5 to 0.686), indicating high-risk areas around the villages of Air Lesing, Ketuan Jaya, Muara Beliti Baru, and the southern part of Durian Remuk. The study successfully identified the spatial pattern of TB risk in the working area of the Muara Beliti Health Center using the combined interpolation method of AHP and IDW, providing an accurate picture of the high-risk areas. The resulting risk maps can be used by local health authorities to allocate resources more efficiently, focusing on high-risk areas that require greater attention. These recommendations can be translated into targeted health programs, such as TB awareness campaigns in high-risk areas and increased access to health facilities in those regions, as well as the allocation of technological innovations in TB treatment systems [47]. These findings highlight the importance of data-driven spatial approaches and weighting of risk variables in supporting decision-making for more targeted health interventions [48]. The methodological differences and characteristics of the samples, compared to previous studies, emphasize the need to adapt intervention strategies to the local context. Therefore, interventions that focus on high-risk areas, taking into account socio-economic and environmental factors, are expected to improve the effectiveness of TB control. Further studies in the future are essential to be conducted with a wider geographical scope and the integration of additional variables is highly recommended to strengthen validity and applicability in subsequent research.

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