Spatio-temporal analysis of pulmonary tuberculosis in Astambul District, South Kalimantan, Indonesia 2020-2021

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ABSTRACT

Respiratory tuberculosis (TB) remains a significant global health concern and ranks among the top 10 leading causes of death worldwide, following human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS). Globally, it is estimated that 1.2 billion people are at risk of being infected with tuberculosis, and Indonesia is the country that contributes the third-highest number of TB cases worldwide, behind China and India. Tuberculosis is still a significant issue in South Kalimantan, notably in Banjar Regency. This study is a descriptive study that intends to identify respiratory TB clusters spatially and temporally in Astambul District during 2020–2021 with the SatScan application, which is visualized as a map of respiratory TB clusters using the Quantum GIS 3.28 application. Data on respiratory TB cases collected from the Banjar District Health Office were examined using retrospective space-time scan statistics, employing a Poisson probability model for analysis. This study found 4 respiratory TB clusters, and 2 of them had significant results, namely in 2020 (RR=6.90, p-value=0.000030) and 2021 (RR=5.27, p-value=0.00003). Factors that affect these clusters are population density, the physical condition of houses, humidity levels, and the availability of health facilities.

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1. INTRODUCTION

Tuberculosis is a contagious illness triggered by Mycobacterium tuberculosis, transmitted through airborne particles when individuals infected with TB cough, sneeze, or spit. Besides affecting the lungs (respiratory TB), these bacteria can also target other organs (extra-respiratory TB) like the brain lining, skin, lymph nodes, bones, joints, intestines, and urogenital system [1]. Tuberculosis continues to pose a significant challenge to global health and ranks among the top 10 causes of death globally, following only HIV/AIDS as a single infectious agent. In 2019, it is estimated that the disease affected around 10 million individuals and resulted in approximately 1.4 million deaths [2]. Tuberculosis primarily affects the adult population, with approximately 90% of cases occurring in this age group. The ratio of male to female cases is 2 to 1 [3]. The high risk of tuberculosis in men can be caused by heavy workloads and unfavorable lifestyle choices such as smoking and alcohol consumption [4]. World health organization (WHO) identifies countries with significant tuberculosis burdens based on various indicators such as TB, TB/HIV, and MDR-TB. Indonesia is among the 13 nations listed as high burden countries (HBC) due to its high prevalence across these three indicators [5].

Indonesia is also one of eight countries that are estimated to contribute two-thirds of the total global tuberculosis cases, namely as many as 10% of cases, and ranks two in the world after India [5]. The tuberculosis situation in Indonesia has shown no signs of improvement, with cases persistently high, and a significant portion of affected individuals remain unaddressed and undetected [6]. The disease can affect all ages, but the productive age group is the most vulnerable [7]. According to 2018 data from the basic health research (RISKESDAS), the prevalence of respiratory TB in Indonesia stands at 0.42%. The tuberculosis situation in Indonesia based on the Indonesian tuberculosis dashboard as of March 23, 2021, shows that the estimated number of tuberculosis cases is 1,060,000 cases, of which as many as 634,273 have been notified from 2000 to 2022, with the number of cases of death from this disease amounting to 134,000 deaths [5]. South Kalimantan also has a serious tuberculosis problem. The prevalence of respiratory TB in South Kalimantan was 0.41% in 2018, which made it one of the 10 provinces with the highest prevalence of respiratory TB in Indonesia. According to the South Kalimantan Provincial Health Office data, there were more than 8,000 tuberculosis patients in 2018, with an estimated total of 18,251 cases. In the same year, Banjar Regency ranked second-highest in South Kalimantan for tuberculosis cases, accounting for 14.4%, trailing only Banjarmasin City. Additionally, it had the highest mortality rate during tuberculosis treatment, with 19% of deaths occurring in 2021. One of the key indicators in tuberculosis control is the case notification rate (CNR), which represents the total number of TB patients identified and recorded per 100,000 residents in a specific area. As per the 2020 Health Profile of Banjar Regency, the CNR for all TB cases tended to increase from 2016 to 2019 but began to decrease in 2020. In a row, the CNR of TB cases in Banjar Regency in 2016 was 191.8/100,000 population; in 2017, it was 186.15/100,000 population; in 2018, it was 225.33/100,000 population; in 2019, it was 291.77/100,000 population; and in 2020, it was 99.44/100,000 population. This indicates that the case notification rate (CNR) in Banjar Regency remains lower than the targeted range set in the district's strategic plan, which aims for a figure between 160 and 180 per 100,000 residents [8].

In epidemiology, a health problem can be viewed from several perspectives, including person, time, and place [9]. In the case of pulmonary TB, local clusters are formed due to high-intensity transmission of Mycobacterium tuberculosis (Mtb) at the household or small community level as a result of prolonged and frequent physical contact. Many things may influence the spatial clustering of pulmonary TB that make it different from other infectious diseases, such as long latency and long transmission periods. So, clustering of cases does not necessarily indicate intense transmission but reflects a collection of population groups at higher risk of disease. It is important to identify the spatial heterogeneity of pulmonary TB cases and understand the factors that contribute to spatial clustering. This understanding is critical as spatio-temporal clustering of TB may be due to disease reactivation or ongoing transmission, making this approach attractive for research. In addition, it is important to note that factors beyond transmission, such as data type, resolution, and spatial analysis methods, can influence the observed spatial patterns of TB. Spatial-temporal analysis is a valuable method to study this phenomenon as it allows for a more comprehensive examination of disease distribution based on spatial and temporal aspects [10]. However, spatio-temporal approaches in the analysis of diseases, such as respiratory TB, have mostly only been conducted in urban areas over a short period of time. As a result, disease distribution patterns in most rural areas are still not fully known.

Various earlier investigations that examined the effectiveness of space-time clusters in detecting TB outbreaks have yielded differing results, influenced by factors such as spatial resolution and the characteristics of the study population. As a result, the purpose of this study is to conduct a spatio-temporal analysis of pulmonary tuberculosis cases in rural areas, specifically in the Astambul District, Banjar Regency. In practice, this study makes extensive use of geographic information system (GIS) functions due to its ability to combine various types of spatial information to examine the influence and interaction between individuals and populations as long as the data has spatial elements, such as geographic location coordinates. This technology also allows the analysis of spatial relationships between different dimensions [11]. The study outcomes were presented through a respiratory TB cluster map generated using Quantum GIS, aiming to offer an overview and streamline the monitoring of respiratory TB. This was achieved through spatio-temporal analysis, integrating spatial and non-spatial data alongside time-related calculations. Geospatial analytical methods have increasingly served as effective means to pinpoint and illustrate regions at elevated risk of infectious diseases. While a descriptive map can outline TB incidence levels, a hotspot or cluster map is essential for making informed decisions [12]. Therefore, employing data visualization methods such as mapping can serve as a persuasive tool for policy makers in prioritizing health issues, selecting tailored health programs for specific regions, and providing material for evaluating ongoing or completed health initiatives [13].

2. METHOD

This research is a retrospective spatio-temporal study of pulmonary TB cases in Astambul District, Banjar Regency, South Kalimantan Province, Indonesia, which were reported to the Banjar District Health Office for 2 periods from 2020–2021.

2.1. Study area

Based on data from the Central Bureau of Statistics for Banjar Regency, Astambul is one of the sub-districts in Banjar Regency, South Kalimantan Province, which has a total population of 35,342 people spread over 22 villages with an average population density of 163.27 km^2. Astambul District has a total area of 216.5 km^2, and it is bordered to the north by Mataraman District, to the south by Karang Intan District, to the east, and to the west by East Martapura District. Administratively, Astambul Sub-District is depicted as Figure 1.

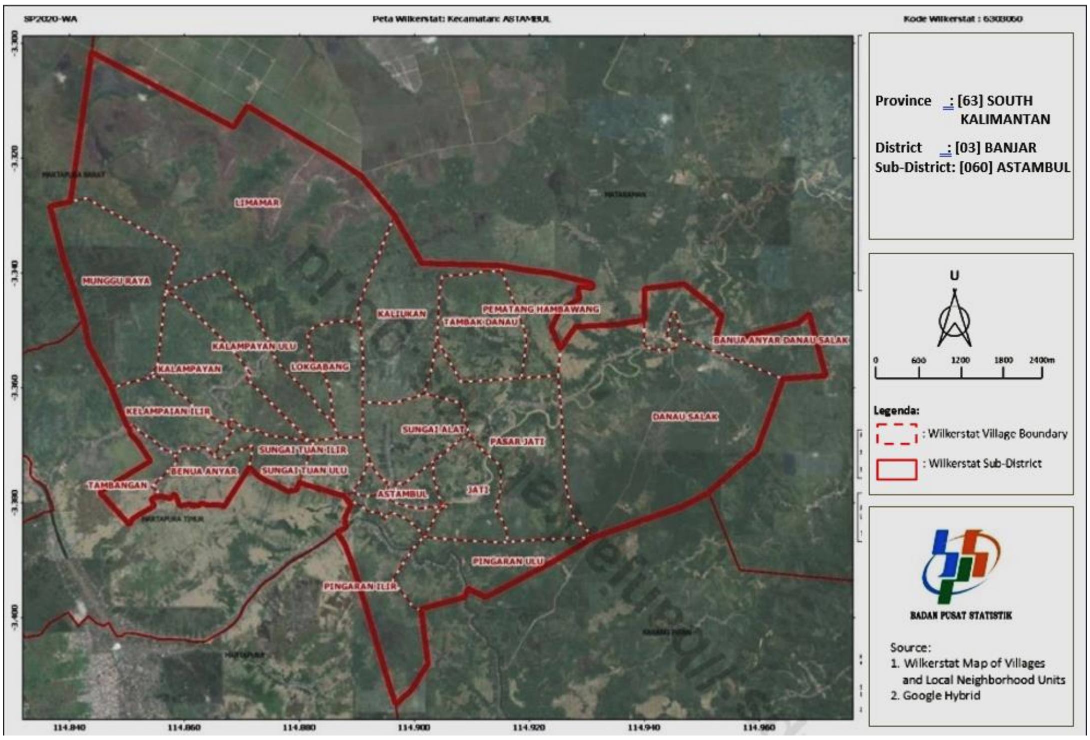

Figure 1. Map of Astambul District

2.2. Data source

The data used in this study were sourced from pulmonary TB case reports from January 1, 2020 to December 31, 2021 obtained from the Banjar District Health Office. For study purposes, we only considered pulmonary TB cases, excluding extrapulmonary TB cases, as only respiratory TB cases were implicated in person-to-person transmission. It was found that there were 69 pulmonary TB cases in Astambul sub-district during 2020 to 2021. Meanwhile, population data was obtained online from the Central Bureau of Statistics of Banjar District website which can be accessed at https://banjarkab.bps.go.id/, The coordinates of the case location data were obtained using Google Earth Pro to represent the case location.

2.3. Spatial analysis

In this study, clusters were examined using Statistic Scan (SaTScan) v10.1, a software developed by Martin Kulldorf at the national cancer institute (NCI) and Farzad Mostashari at the New York City Deparment of Health and Mental Hygiene [14]. This tool is This software contains a variety of spatial and space-time scanning statistics that are very useful for detecting and analyzing geographic disease clusters, including applications for detecting community disease outbreaks [15]. SaTScan conducts cluster analysis by determining cluster size and location through the calculation of relative risk (RR) and assigning a P-value using monte carlo simulation [16]. The spatial units analyzed in this study include 22 villages in Astambul

District. For this spatial analysis, the dataset includes information on the number of cases, population figures, and geographical coordinates as input. To detect clusters ranging from small to large groups, the maximum spatial cluster size was restricted to 50% of the population at risk, aiming to mitigate potential biases. The most likely cluster is determined based on the largest likelihood ratio (LLR) value, that is, the cluster least likely to be caused by chance. While other clusters with lower LLRs are considered as Secondary clusters [17]. The analysis findings are presented in tabular format, and subsequently, a map illustrating respiratory TB clusters will be generated using the Quantum GIS 3.28 application. This visualization aims to depict locations where notably high disease rates occur.

2.4. Space-time analysis

In this study, a retrospective space-time scan statistic using a poisson probability model was employed for data analysis to pinpoint respiratory TB clusters in Astambul District during the period from 2020 to 2021. The Poisson probability model was utilized under the assumption that the number of cases in each location follows a Poisson distribution, with the population being known [18]. For this study, the time window is limited to 12 months and the spatial window to 25 km. Clusters will be considered statistically significant if the p-value <0.05.

3. RESULTS AND DISCUSSION

3.1. Result

– Descriptive analysis of respiratory TB cases in Astambul District.

From 2020 to 2021, 70 cases of respiratory tuberculosis were reported in the Astambul District. The distribution of respiratory TB cases in Astambul District can be seen in the map as shown in Figure 2:

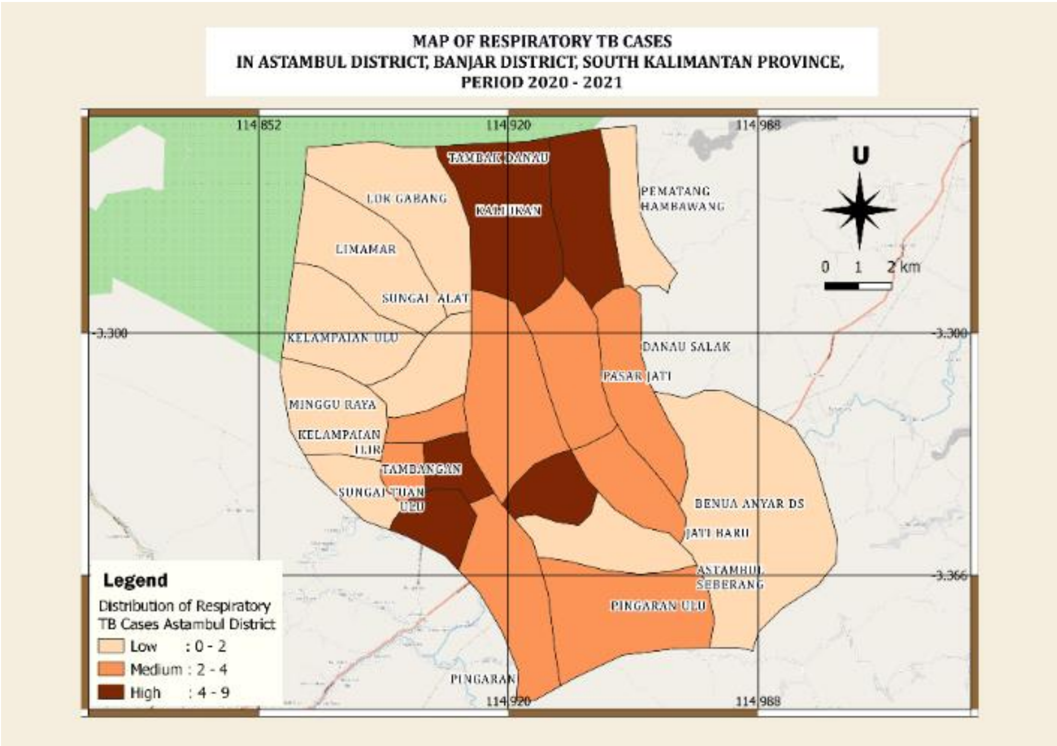

Figure 2. Map of respiratory TB case distribution in astambul district

From the map of the distribution of respiratory TB cases above, it is clear that the darker the color of an area indicates that the area has a high number of TB cases. As a result, villages such as Benua Anyar, Astambul, Sungai Tuan Ulu, Kaliukan, and Tambak Danau will have relatively high Respiratory TB cases in 2020-2021.

– Spatial and temporal analysis of respiratory TB in Astambul District

The spatial and temporal analysis conducted detected four clustersof respiratory TB cases in Astambul District: one cluster in 2020 and three clusters in 2021, spanning across 22 villages. The findings indicate the presence of one significant cluster each year, whereas the other two clusters in 2021 were not statistically significant, as their p-values exceeded 0.05. The highest relative risk (RR) is found in the most likely cluster in 2020 during January-December (RR=6.90, p-value=0.000030) with the cluster center located in Sungai Tuan Ulu Village, and the lowest relative risk (RR) is in a secondary cluster in 2021 during January-May (RR=1.73, p-value=0.998) with the cluster center located in Astambul City. Likewise with the radius, the cluster that has the smallest radius is found in 2021, namely at 0 km, while the largest radius is found in 2020, at 11.96 km to be precise. This shows that Respiratory TB cases spread over a wide area.

Of the 4 clusters (1 cluster in 2020 and 3 clusters in 2021) formed, the pulmonary TB cluster in 2020 has the largest radius of all reach 11.96 km that spreads almost throughout Astambul Sub-district, except the southeast and south. This shows that Respiratory TB cases spread over a wide area. The center of the pulmonary TB cluster this year is in the northwest part of Astambul sub-district as shown in Figure 3. Meanwhile, in 2021, the Pulmonary TB cluster that was formed was smaller than the previous year with a transmission radius of 4.85 km. The center of the Pulmonary TB cluster this year is known to be in the northwest of Astambul District as seen in Figure 4. The most likely clusters that will form in both 2020 and 2021 mostly be in areas that have relatively moderate or high levels of population density. Table 1 as shown in provides an overview of the spatio-temporal clustering of respiratory TB cases in Astambul sub-district during 2020-2021.

Table 1. Spatio-temporal clusters of respiratory TB cases in Astambul district in 2020-2021

Year	Cluster Type	Coordinates (latitude, longitude)	Period	Radius (Km)	Cases (n)	Expected Cases (n)	RR	LLR	P-*value*
2020	Most Likely	-3.278801 S, 114.882455 E	2/1/2020 – 3/12/2020	11.96	33	1.78	6.90	12.1817	0.00003
2021	Most Likely	-3.336619 S, 114.904265 E	11/2/2021 – 30/12/2021	4.85	23	2.20	5.27	10.2958	0.00003
	1st Secondary	-3.386809 S, 114.894643 E	7/1/2021 – 27/12/2021	0.78	3	1.01	3.16	1.33546	0.701
	2nd Secondary	-3.380899 S, 114.899667 E	7/1/2021 – 25/5/2021	0	2	1.19	1.73	0.24070	0.998

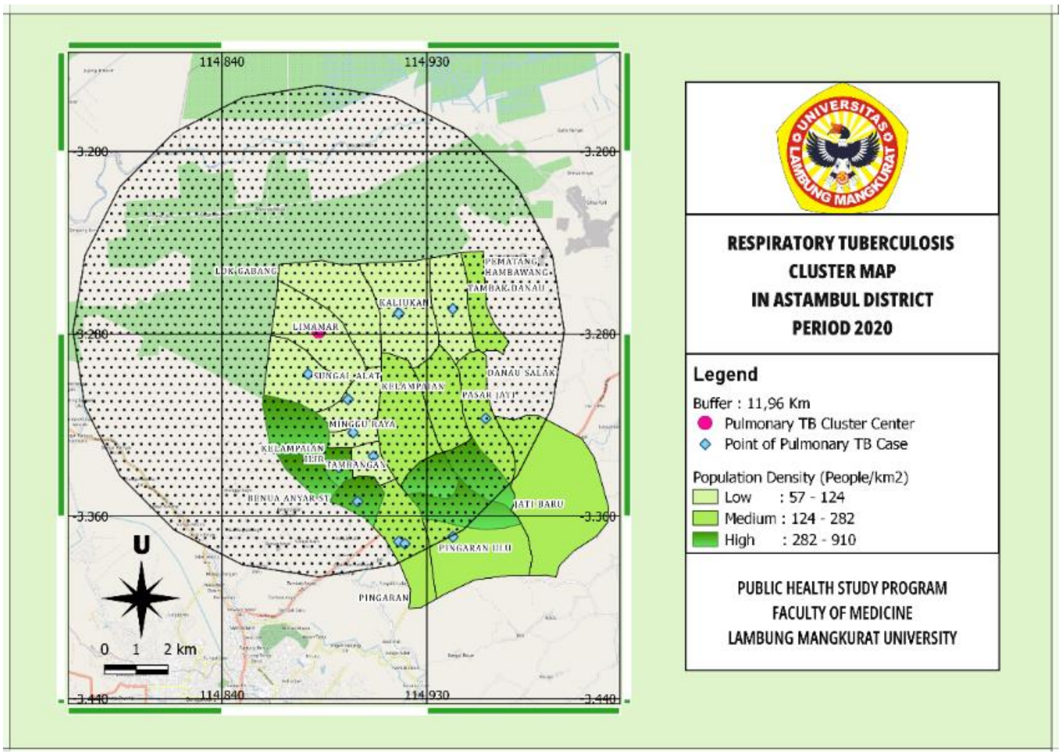

Figure 3. Map of respiratory tuberculosis case clusters in astambul district in period 2020

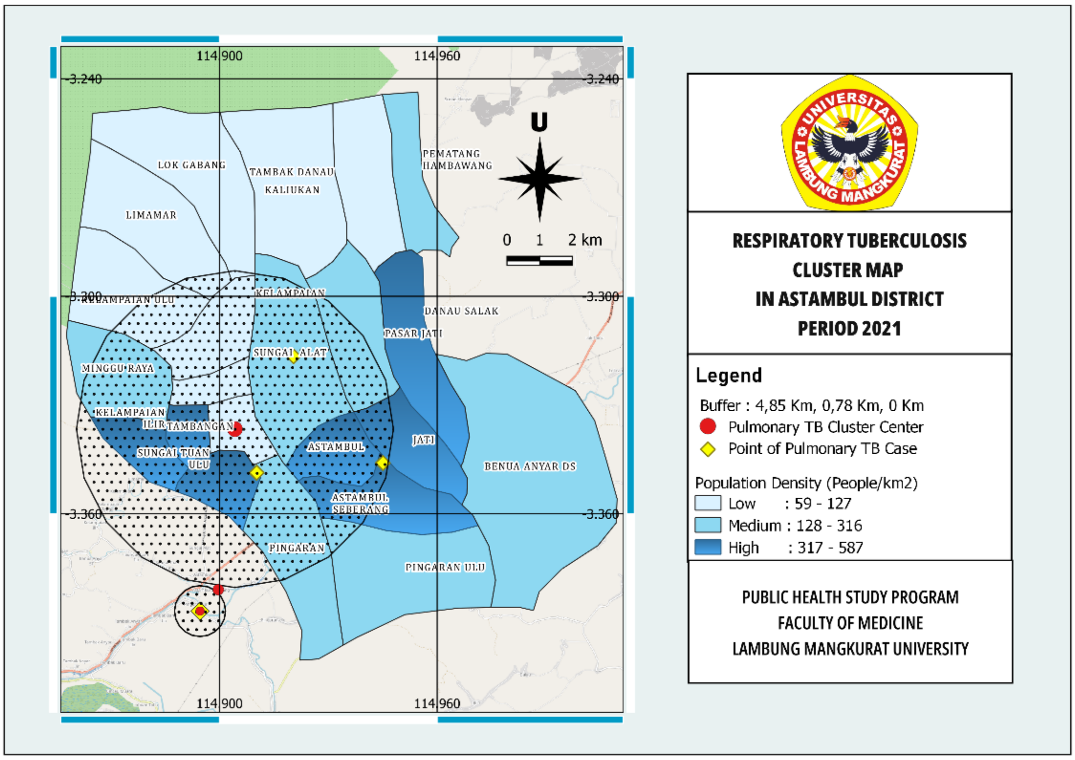

Figure 4. Map of respiratory tuberculosis case clusters in Astambul District in period 2021

3.2. Discussion

In this study, the model used to analyze respiratory TB clusters in Astambul District is a spatio-temporal approach. This analysis succeeded in identifying 1 cluster in 2020 and 3 clusters in 2021. The respiratory TB clusters shown by SaTScan will then produce an overview in the form of the main cluster (most likely cluster) and potential clusters (secondary cluster) [19]. Out of a total of 4 clusters formed during the 2020–2021 period, it shows that two of them have significant results because the p-value <0.05, namely in each of the main clusters formed in the two research time periods. In the January-December 2020 period, the main cluster was formed in the northwest, with the center point concentrated in Limamar Village. The results of the SaTScan analysis for clusters in this period are relative risk (RR)=6.90 and p-value=0.00003. Based on the visualization of the map as shown in Figure 2, it can be seen that respiratory TB disease in 2020 spread very widely, even reaching a radius of 11.96 km. Meanwhile, in the January-December period of 2021, the cluster center moved westward, and the center point was identified in Sungai Tuan Ulu Village, but within a smaller radius of 4.85 km. This is because the total number of cases in the 2021 period has decreased compared to the previous year. The results of the SaTScan analysis for clusters in this period show relative risk (RR)=5.27 and p-value=0.00003.

Several studies have been conducted in other countries using this method to look for spatio-temporal clusters of TB, such as the study by Wang *et al*, who explore the spatial-temporal clusters and associated risk factors of pulmonary TB in south-western China [20]. Likewise Fahdhienie and Sitepu used spatio-temporal analysis to investigate the presence of TB clusters in North Aceh District, Indonesia, and investigate the temporal distribution pattern of TB clusters over the three last years (2019-2021) [21]. Ullah *et al* applied this method to identified spatio-temporal clustering with highrisk clusters across the country during 2015–2019, particularly in the northern and western parts of the Khyber Pakhtunkhwa province, Pakistan [17]. The results of research using the spatiotemporal analysis method are also recognized as effective in detecting clusters of cases and areas of infectious diseases, such as Pulmonary TB. Spatiotemporal analysis can also identify high-risk periods as well as a complementary tool for epidemiological surveillance of infectious diseases. In the last few years, various studies have shown how spatiotemporal analysis of TB cases has become an important source of public health knowledge, supporting local strategic interventions, and decision-making related to health policies at certain levels of government [22].

If viewed from the perspective of the risk factors, respiratory TB cases in Astambul District are caused by various complex factors, including economic and environmental aspects. Occupancy density and housing conditions rank second at 70% after economic status which influences the transmission of pulmonary TB disease, which is equal to 90% [23]. Data from the Central Bureau of Statistics of Banjar District indicates a persistent increase in the poverty rate within the region, with the percentage of poor people in Banjar Regency since 2019 increasing from 2.72% to 3.04 % in 2021 [24]. This condition is enough to illustrate that the economic level of the people in Banjar Regency is not entirely good. Individuals from lower socioeconomic backgrounds may experience compromised immune systems, rendering them less capable of suppressing tuberculosis replication or preventing the disease. Additionally, economic constraints often hinder their ability to plan for seeking diagnosis or treatment, as they may face challenges due to limited financial resources [25].

The increase in tuberculosis cases can also be caused by access to health services being quite difficult or far away. It is known that the existence of health facilities in Astambul District is still uneven, where only 1 health center and 3 auxiliary health centers are found to serve the community spread over 22 villages. In addition, it is also known that there is still 1 village, namely Pematang Hambawang Village, which does not have any health facilities, be they village health posts, polindes, health centers, or auxiliary health centers. Basically, people should have access to good health services, meaning that they are not hampered by anything such as the type of transportation, distance, travel time, or other physical barriers that can prevent someone from obtaining health services [26]. Poor accessibility to health centers (long distances, poor condition of roads and footpaths, lack of availability of public transport), economic constraints (direct and indirect costs associated with travel). These barriers are further exacerbated by low awareness of TB, delays in seeking treatment, alternative means of seeking treatment (e.g. traditional healers and over-the-counter drugs), the complexity of treatment and the stigma associated with TB [27]. However, in this study, it is impossible for us to know the extent of the effect on the distribution because this variable was not included in the study.

The poor physical environment of the house can also trigger the transmission of respiratory TB. A healthy home, according to Winslow and american public health association (APHA), must meet several requirements, such as ventilation, space, lighting, floor type, and occupant density. Density of residence greatly affects the transmission of respiratory tract TB disease because respiratory TB disease can be transmitted through the air, so these germs are easily transmitted if the house is in a dense area. There are several rules enforced so that the house is not overcrowded, one of which is that the bedroom may not be occupied by more than two people, except husband and wife and children under the age of two. If there are family members who suffer from tuberculosis, you should not sleep with other family members. Mycobacterium tuberculosis can survive for years in a cool and moist environment without sunlight but dies when exposed to sunlight [23]. The average sun exposure in Astambul District for the January-December 2021 period is 34.7% [28]. However, this number is considered not optimal enough to kill the cause of respiratory TB, so artificial lighting is needed such as kerosene lamps, electricity, fire, and so on.

It should also be noted that the air temperature and humidity of the room are greatly influenced by the lighting. Natural light in the form of sunlight containing ultraviolet rays has the property to kill bacteria. The ideal size of light intensity in a room is >60 lux [29]. Therefore, if a room lacks proper lighting due to insufficient ventilation, closed windows, or blocked sunlight resulting from neighboring houses' dense settlement, it can lead to increased humidity and darkness within the room. This condition triggers the TB bacteria to survive even for months [30]. In addition, Room ventilation that does not meet health requirements (10% of the floor area) will have an impact on increasing indoor air temperature and humidity, reduced oxygen concentration, increased levels of carbon dioxide gas which is toxic to residents. The absence of good air circulation in a room will be a suitable place for tuberculosis bacteria to multiply rapidly so that residents of the house can easily contract pulmonary TB disease [31].

One of the things that can influence the growth of disease-causing microbes is the environment. Ecosystem modifications brought on by climate change may alter how people and the environment interact, which could have an effect on health. Relationships that affect human health between the environment and people. Wintertime brings with it fewer levels of solar exposure and an increase in indoor activity, making for thick, muggy, and hazardous environmental conditions. The density, humidity, and reduced air circulation lead to a heightened survival rate for tuberculosis bacteria [32]. In this case, Astambul District is known to have a humidity level above normal, which is 78.6% [28], while the normal humidity level is in the range of 40–60% [33]. House with inadequate room temperature and high humidity increase the body's susceptibility to diseases, especially tuberculosis [34]. This is because 80% of the cell volume of Mycobacterium tuberculosis consists of water, so a humid environment with a temperature of 35 °C-37 °C is very supportive of the life and development of tuberculosis disease [35].

4. CONCLUSION

During 2020-2021, this study discovered four respiratory tuberculosis clusters in the Astambul District. The clusters found in 2020 in the January-December period showed significant results (RR=6.90, p-value=0.000030), with the cluster center located in Limamar Village within a radius of 11.96 km from the center point. Meanwhile, in 2021, there will only be 1 significant cluster (RR=5.27, p-value=0.00003) out of the 3 identified clusters. The cluster was formed in the January-December period and is centered in Sungai Tuan Ulu Village within a 4.85-kilometer radius of the center point. Transmission of Respiratory tuberculosis clusters within two years was mostly found in areas with moderate to high population density. The factors that are most likely to influence the clusters and distribution of Respiratory TB in Astambul District are population density, the physical condition of houses, humidity levels, and availability of health facilities. The implications of this spatio-temporal research can assist in the development of accurate modeling to predict the distribution and spread of TB in Astambul sub-district which can be used to identify areas at high risk of the disease. The results of spatio-temporal research can be used as a basis for decision-making by decision makers, such as government and health research agencies, to identify effective TB prevention and management strategies.

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