Original Article

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Spatial Distribution of Tuberculosis in the Western Region of Java Island, Indonesia

Tri Bayu Purnama, M.Med.[1], Taro Kamigaki, M.D., Ph.D.[2], Minsarnawati[3], Hitoshi Oshitani, M.D., MPH, Ph.D.[2]

[1]Faculty of Public Health, Universitas Islam Negeri Sumatera Utara Medan, Utara, Medan 20235, Indonesia.
[2]Department of Virology, School of Medicine, Tohoku University, Sendai, Miyagi 980-8574, Japan.
[3]Faculty of Health Science, Universitas Islam Negeri Syarif Hidayatullah, Jakarta 15412, Indonesia.

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Abstract:

Objective: This study aimed to map the spatiotemporal hotspots of tuberculosis (TB) prevalence distribution in the Western Region of Java Island.

Material and Methods: To investigate the spatiotemporal pattern of TB prevalence, we standardized TB prevalence by year, with the percentile of TB prevalence being clustered with natural Jenks breaks optimization. To estimate the continuous geographical distribution of TB prevalence within each district, we performed inverse distance weighting (IDW) methods for spatial interpolation. We calculated the expected number of TB cases per 1 km^2 grid cell in the aim of detecting TB prevalence hotspots.

Results: The overall mean prevalence of newly reported TB cases was 73.2 cases per 100,000. The TB prevalence in West Java province, Banten province, and Jakarta province were 71.7, 69.7 and 85.8 per 100,000, respectively. High prevalence grid cells along the coast in the north, and low cells in West Java province; except nearby Bandung city where most areas are mountainous, were detected. Hotspots area was mostly found in either West Java province or Banten province; only 1 hotspot was detected in Jakarta province.

Conclusion: Several hotspots were observed, not only in town administration areas but also in lower population density areas in West Java province. Raster grid cells with high prevalence were identified along the coastal area in the northern study area.

Keywords: grid cell estimation, interpolation, spatial, tuberculosis

Contact: Tri Bayu Purnama, M.Med.
Faculty of Public Health, Universitas Islam Negeri Sumatera Utara Medan, Utara, Medan 20235, Indonesia.
Jl IAIN No 1 Medan, The Province of North Sumatera, 20235, Indonesia.
E-mail: tribayupurnama@uinsu.ac.id

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Introduction

Tuberculosis (TB) is a bacterial airborne infectious disease, caused by *Mycobacterium tuberculosis*.[1] In 2020, approximately 9.9 million new TB cases and 1.4 million TB associated deaths were reported worldwide in 2015.[2] Thus, a conservative control and collective effort is required to reduce the prevalence and mortality of TB. The sustainable development goals (SDGs) have already set up a new target to end TB epidemics by 2030, in which endemic countries need to exert extra effort to halt or lower the impact of TB. Indonesia is ranked as third in countries with high TB prevalence, with an 8.4% laboratory confirmed TB cases in 2020.[2] The Indonesia government mandates Public Health Center (PHC) and government hospitals to notify and report confirmed cases, relapsed cases, and risk of TB cases to the health authority within one month in order to monitor TB in the area.[3]

National TB surveillance is one of the components of the strategic information for controlling TB in the country. TB surveillance in PHC provides information concerning TB prevalence and risk factors, which is elaborated with monitoring and evaluating systems of TB programs in order to identify the outcome of the intervention. Most TB data is collected via passive surveillance; however, there are also active or sentinel surveillance for TB cases operated in the country, depending on local epidemic levels, performance of TB care, and health resources available at the PHC and public hospital level.[3]

In Indonesia, the national directly observed treatment, short-course (DOTS) program, established in 1995, has been set as the main strategy for case detection and treatment in all healthcare facilities.[3] The health care facilities provide laboratory examination as well as health promotion programs for early diagnosis, prevention and rehabilitation. Programs made specifically for TB-HIV (human immunodeficiency virus) cases or pediatric tuberculosis is also provided in healthcare facilities. TB programs have been initiated in PHC, then expanded to general practitioners and private hospitals. To increase public and patient access to TB care services, the public-private mix (PPM) tuberculosis program was introduced to the community.[3]

Spatial-temporal TB cases have been reported in many countries.[4,5] A study in Zimbabwe found that TB occurrence detected spatial heterogeneity that was dominantly within high poverty levels. An individual spatial level study in Indonesia from 2020, reported that distribution patterns of extra high pulmonary TB had been detected in high population density areas.[6] The Western Region of Java Island is located on Java Island, Indonesia (Figure 1), and has an estimated population of 62 million or one-quarter of the total population spread over 3 provinces.[7]

TB prevalence in these provinces was still above the national average of TB prevalence in 2007-2013. Each PHC in these provinces has already established the DOTS program; however, the proportion of TB confirmed cases were still under the minimum target (70%). This study used secondary aggregated data of TB cases, obtained from the passive national surveillance system The Ministry of Health, Indonesia elaborated with other data sources is required to detected spatial patterns due to limited data source availability. Hence, this study aimed to map the spatiotemporal hotspots of TB prevalence distribution in the Western Region of Java Island.

Material and Methods

Study site

This study was located in the Western Region of Java Island, Indonesia (Figure 1), which has an estimated population of 62 million or one-quarter of the total population spread over 3 provinces. In this study, TB data were obtained from three sites: Banten province, West Java province, and Jakarta province (Figure 1). Banten province is located in the western part of Java Island, with a geographical area of

around 9,700 km^2. Banten province consists of 4 districts; Tangerang district, Pandeglang district, Lebak district and Serang district, and 4 cities; Tangerang city, Serang city, Cilegon city and South Tangerang city, with 217 PHCs across the province. The majority of the population use public transportation to visit hospitals, which takes around 16 to 60 minutes, and motorbikes to visit the PHC in Banten province; with the same estimated travel time.[8]

Jakarta province is the capital city of Indonesia, with a population of approximately 10 million and an area of 662.33 km^2. This province is a lowland area, with an average altitude of around ±7 meters above sea level. This province has 5 cities (Central Jakarta, West Jakarta, East Jakarta, North Jakarta and South Jakarta) and 1 island district (Kepulauan Seribu District), with 336 PHCs within the entire province. We excluded island districts in Jakarta province (Kepulauan Seribu/Seribu Island) in the analysis, due to it being an outland of the main island. West Java province has the largest population, with about 43 million; consisting of 18 districts and 9 cities.

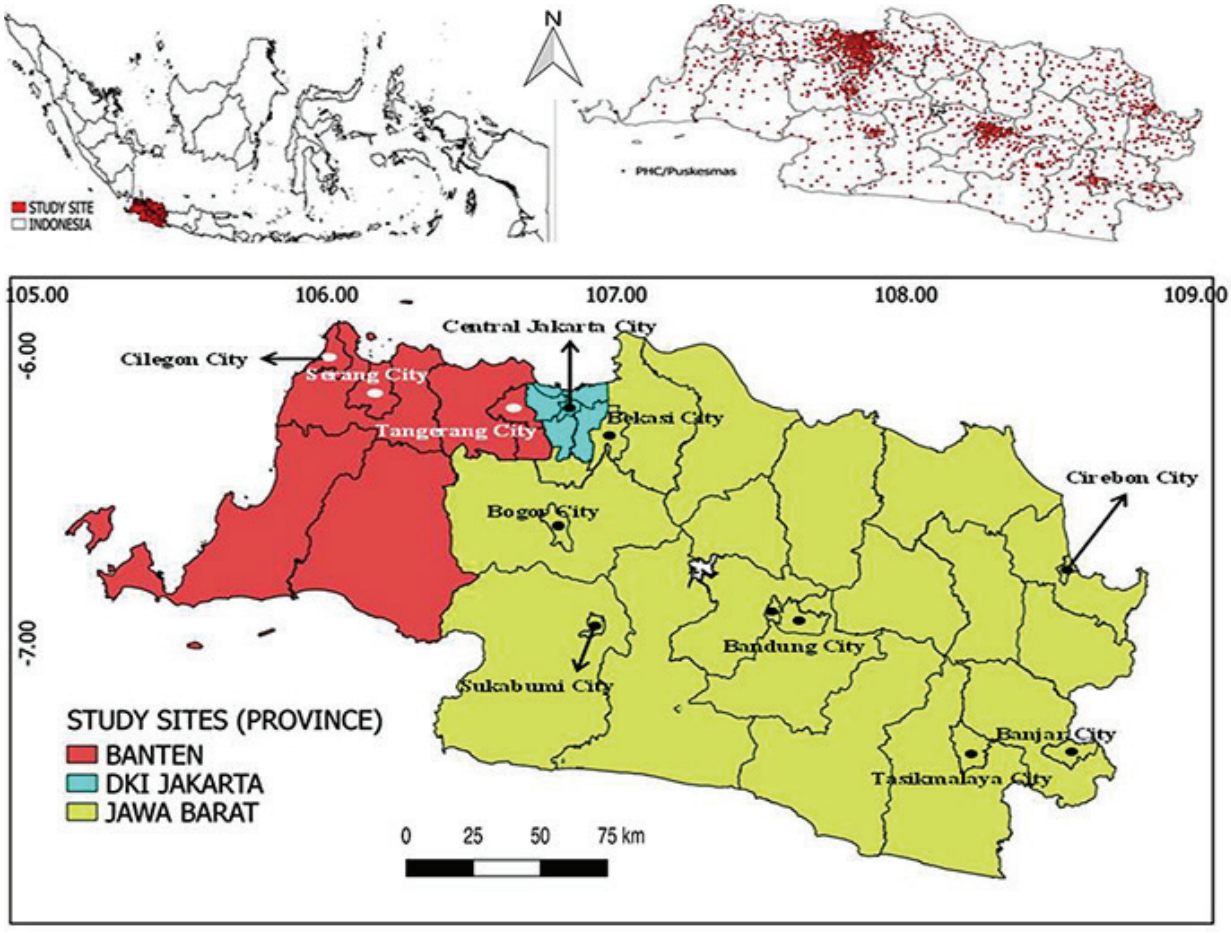


Figure 1 Map of study sites (Jakarta province, Banten province and West Java province), in the Western Region of Java Island, Indonesia and Point map of Public Health Centers. No different meaning in a different color of city name.

Tuberculosis cases reported through national surveillance

In this study, we used data from the annual TB surveillance report; from 2010 to 2014. Those who consulted a PHC or government hospital with a cough for at least 2 weeks were defined as a suspected TB case. The case definitions for both suspected and confirmed TB cases are consistent with those in the World Health Organization (WHO) guidelines.[3] Although, several methods for laboratory testing have been established to detect smear positive of Acid Fast Bacilli in the sputum samples with high sensitivity results, PHCs can only perform microscopic examination. Additionally, they cannot perform chest X-ray and real-time PCR due to limited available facilities in whole registered PHCs in the study setting. When *M tuberculosis* is isolated from a sputum sample and Acid Fast Bacilli (AFB) is observed in at least one of two sputum samples, the case is diagnosed as a bacteriologically confirmed TB in the surveillance. We used the number of confirmed TB cases in this study. Variables such as gender (male/female), age group (children/adult), year of registration, province (West Java/Jakarta/Banten), and region type (town administration/rural district) were also included. Town administration is defined as an area that is accessible to: (1) less than 2.5 km to school and hospital (2) less than 5 km to market- at the lowest administrative level, and (3) electricity is available among over 90% of households; according to the Indonesia Central Bureau of Statistics. Areas not meeting the above criteria are classified as rural administration.[9]

Spatial interpolation of tuberculosis case distribution

In this study, we calculated TB prevalence with the total number of the population per district, and then synchronized this data to the study's location via digital mapping. We used a digital map from he Central Bureau of Statistics, Indonesia; from 2015.[10] To compute annual prevalence rates by age group and gender for each district, the number of TB cases per district was integrated with the projected total population. To investigate the spatiotemporal pattern of TB prevalence, we standardized TB prevalence by year, and the percentile of TB prevalence by age and gender was clustered with natural Jenks breaks optimization. The Natural Jenks break is useful in highlighting areas of extreme TB prevalence differences, because data variation is considered to minimize differences between data values in the same class as well as to maximize the differences between classes.[11] This study used heat-map visualization in order to investigate the temporal distribution of TB prevalence.

To estimate the continuous geographical distribution of TB prevalence in each district, we performed inverse distance weighting (IDW) methods for spatial interpolation. Each known/measured point has a local influence that diminishes when the distance is assumed by IDW methods.[11] We used the centroid of each district as a point layer, and assumed that each point layer (interpolation surface) should be influenced the most by the nearby point and the least by a more distant point.

Furthermore, we calculated the expected number of TB cases per 1 km^2 grid cell in the aim of detecting TB prevalence hotspots. We assumed that TB prevalence is proportional to population size in each grid population cell, because there was a strong correlation between these variables (Pearson correlation coefficients=0.9, p-value <0.001).

Statistical analysis

TB data was classified according to age, gender, year of registration, type of region and estimated prevalence rate; Wherein, the total population per group was obtained from the Central Bureau of Statistics, Indonesia. To draw geographical distribution of TB prevalence, a digital map of the study site mapped TB prevalence per each region. Map visualization, and spatial analysis were performed by Arc GIS 10.4 (ESRI, Redlands, CA, USA) packages. Heat-

map analysis was conducted using RStudio version 1.1.463 (R Development Core Team, Vienna, Austria). Statistical analyses were performed with IBM SPSS Statistics 20 (IBM Corp., Armonk, NY, USA). Ethics approval was obtained from the ethical review committee of the Graduate School of Medicine, Tohoku University, Japan: registration number 2017-1-221.

Results

A total of 232,289 TB cases were reported in the Western Region of Java Island during the study period. Percentages of smear-positive TB cases registered in PHCs, and outside PHC; such as governmental hospitals and within other private sectors, were at 92.4% and 7.6%, respectively (Table 1). Overall, the mean prevalence of newly reported TB cases was 73.2 cases per 100,000. TB prevalence in West Java province, Banten province, and Jakarta province were 71.7, 69.7 and 85.8 per 100,000, respectively. Throughout the study period, TB prevalence in Banten and West Java province were the same; except for Jakarta province, which had a rise in TB prevalence from 2010 to 2011, and from 2012 to 2014. In Jakarta province, 2 districts had a lower TB prevalence category throughout the period, while Jakarta Pusat, Jakarta Selatan, and Jakarta Timur shifted to a high TB prevalence category class from 2013 (Figure 3). Other than cities in Banten and West Java provinces, there were some rural districts that were included in the high TB prevalence category class; such as, Serang and Sukabumi.

The number of TB cases in males was significantly higher, and the majority of cases were aged equal to or more than 15 years old (99.3%). There was no significant difference in the number of cases by provinces and region types. Districts belonging to the high TB prevalence category were quite overlapped between genders; except for districts in eastern Java (Figure 4A-B). These included Serang and neighboring districts in West Java province where the majority of people engage in agriculture. There was no district where both age groups belonged to the high category; except for Sukabumi city and Jakarta city (Figure 4C-D).

Table 1 Demographic characteristics of reported TB cases (N=232,289) in the Western region of Java Island, Indonesia

Characteristic	No of case (%)	p-value
Gender		
Male	135,900 (58.5)	0.003
Female	96,389 (41.5)	
Age (years)		
<15	16,61 (0.7)	0.008
≥15	230,628 (99.3)	
Province		
Banten	39,915 (17.2)	0.760
Jakarta	37,520 (16.1)	
West Java	154,854 (66.7)	
Region type		
Rural district	82,653 (35.6)	0.860
Town administration	149,636 (64.5)	

High population density areas were identified in Bandung, Serang city and Central Jakarta cities (Figure 2B). Aside from Jakarta province, the other two provinces have highland or mountainous areas; particularly in the southwest (Figure 2C). When estimating TB prevalence by 1 km^2 grid cells, we found high prevalence grid cells along the coast in the north, and low cells in West Java province; except nearby Bandung city where most areas are mountainous (Figure 5A). Hotspot areas were mostly found in either West Java province or Banten province, and only 1 hotspot was detected in Jakarta province (Figure 5b). Most of the hotspots detected were classified in town administrations; such as, Bogor city, Sukabumi city, and Cimahi city in West Java province, Cilegon city and Serang city in Banten province; while there was a broad hotspot area in the eastern part of study sites.

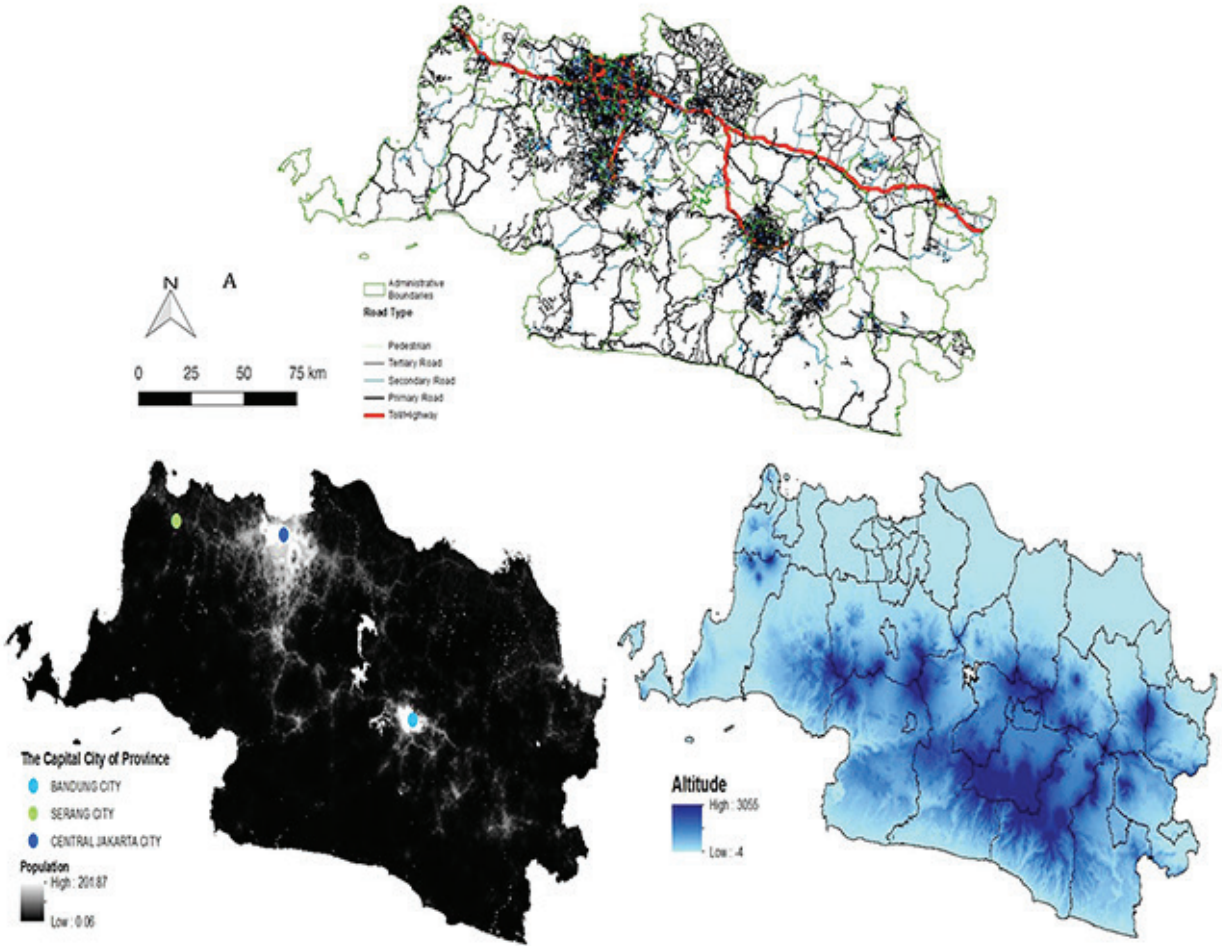


Figure 2 A–C Map of road networks (A), Population density (B) and Terrain map in the Western Region of Java Island, Indonesia.

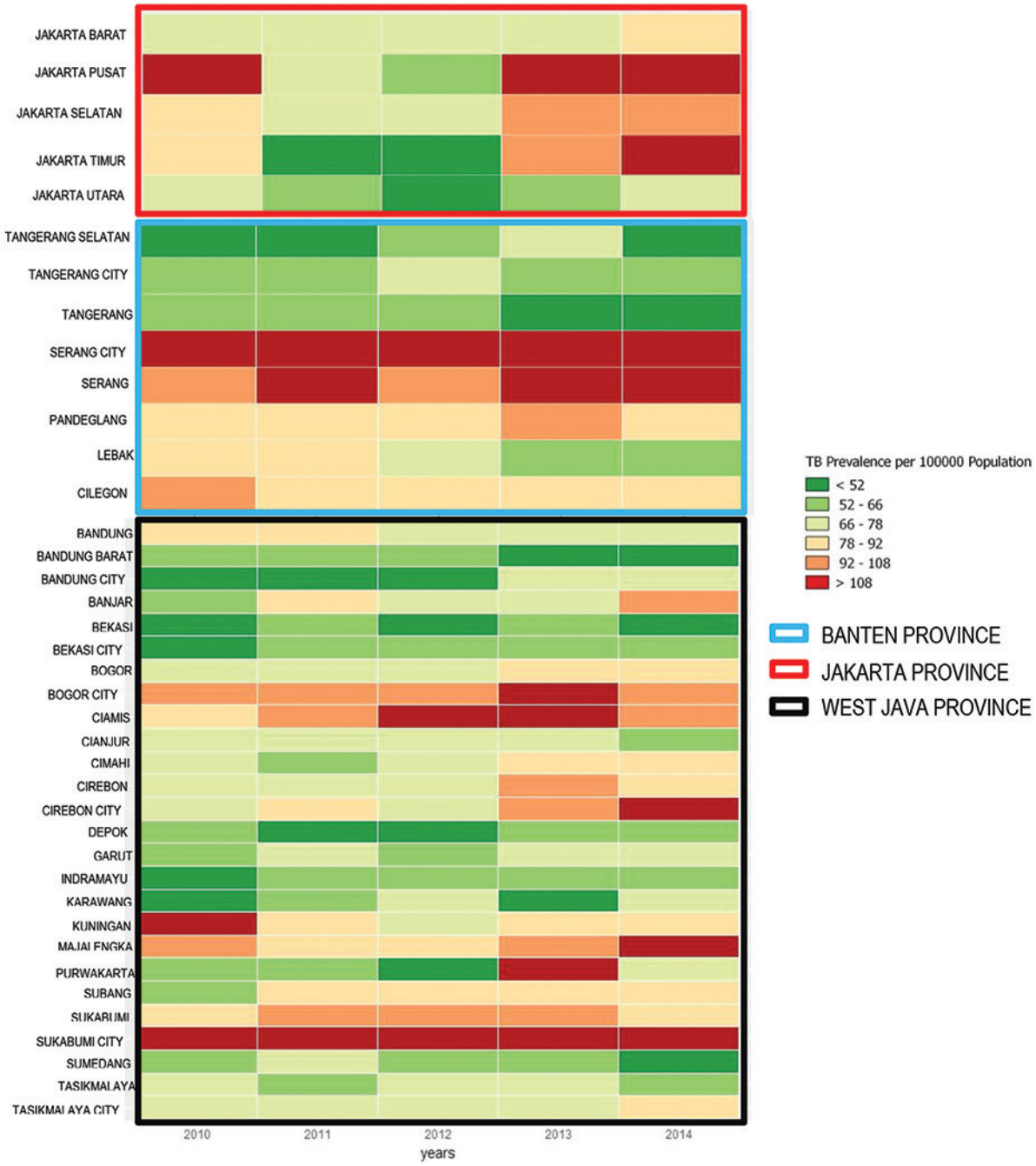
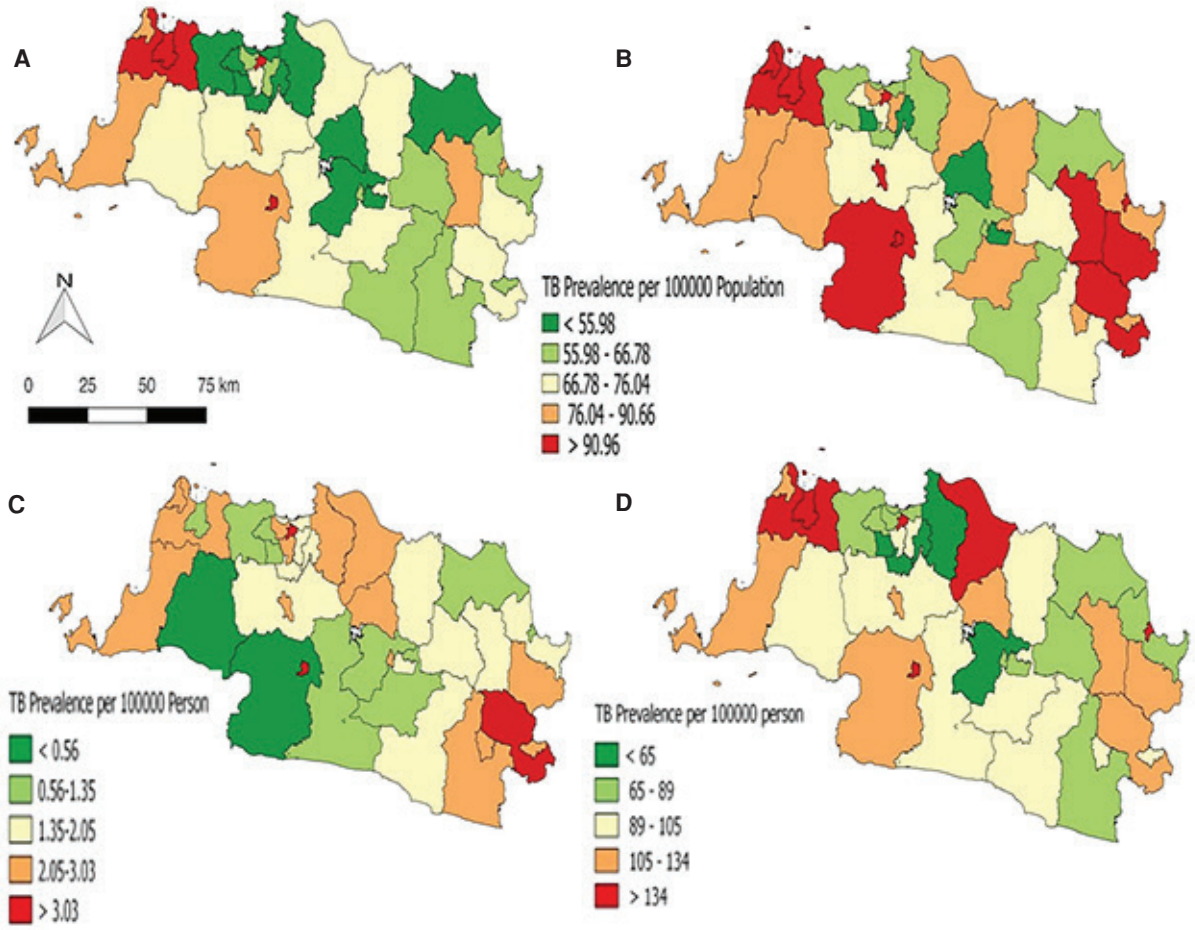
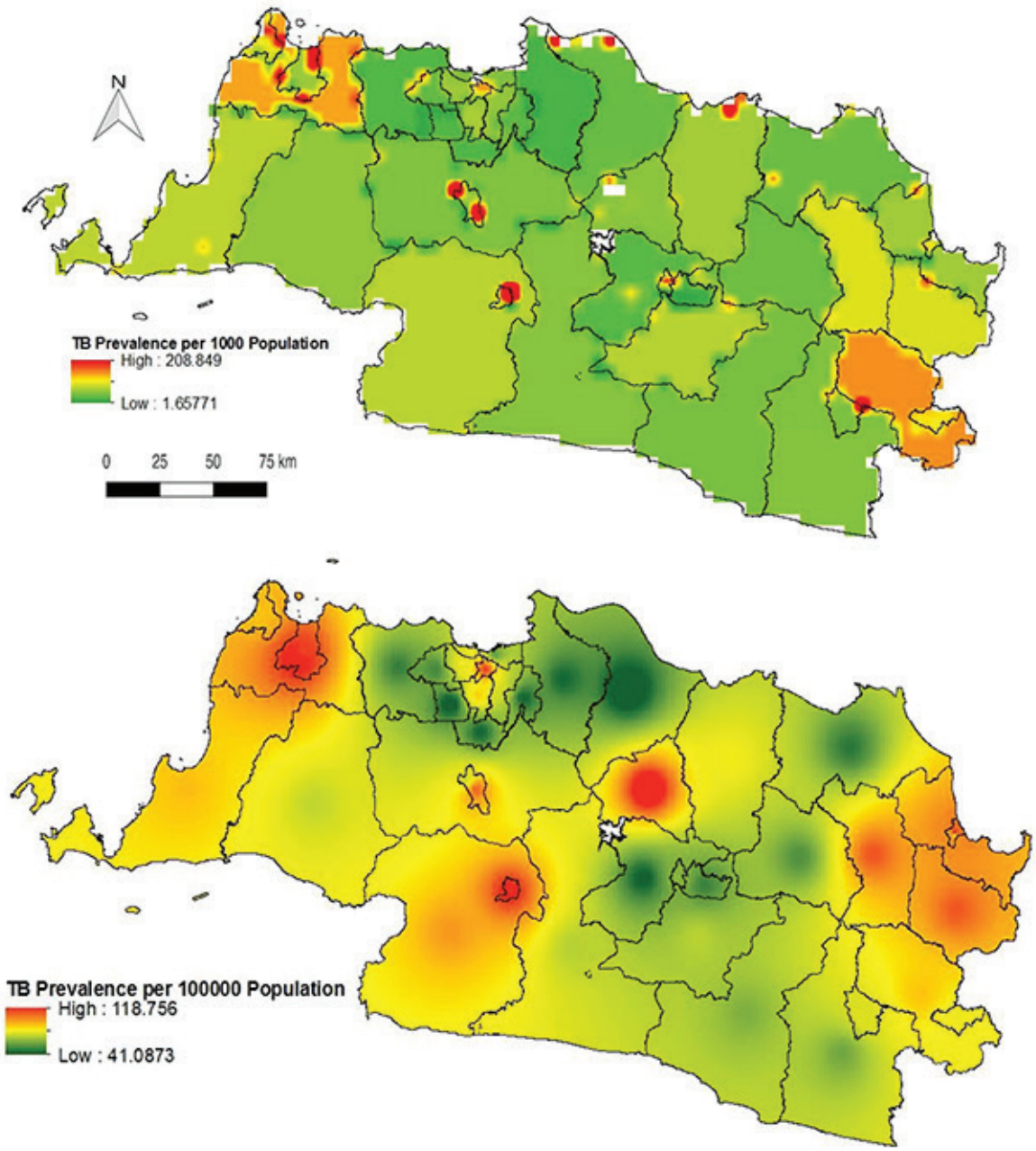


Figure 3 Annual TB prevalence per 100,000 population by district level in Jakarta province (red line box), Banten province (blue line box) and West Java province (black line box).



TB=tuberculosis

Figure 4 A–B Map of cumulative TB prevalence by gender (right: female, left: male), and district from 2010 to 2014 in the Western Region of Java Island, Indonesia. Map of cumulative TB prevalence by age (C–D) (right: <15 years old group, left: ≥15 years old group) and district from 2010 to 2014, by district in the Western Region of Java Island, Indonesia.



TB=tuberculosis

Figure 5 (A) Maps of TB prevalence per 1,000 population per km^2. (B) Hotspot map with spatial interpolation of cumulative TB prevalence in the Western Region of Java Island, Indonesia.

Discussion

In this study, TB cases in PHC were frequently observed among the adult, male population. The same trend was observed in other studies from Indonesia and China.[12–14] A systematic review in Asia found that more than 50% of the male population is more likely to seek health care earlier, and is also negatively correlated with the delay in diagnosis and treatment.[15,16] The ability to follow medical prescriptions also relies on the economic capacity of the; wherein, families who have financial constraints are more likely to result in self-medication[17], which contributes to diagnosis delay in health care facilities. Higher TB prevalence observed among the male population in the eastern, rural area is reflected by different health seeking behavior when compared with the female population. Gender differences, particularly in health literacy barriers, social stigma and financial issues, are also associated with the delay in hospitalization, which consequently affects TB diagnosis and treatment.[16] In town administrations, high adult TB prevalence is associated with activities outside of households. Among males of productive age, those who engaged in public transportation or work outside of the household were more likely to have culture-positive TB than housewives, and these hotspots were close to railway stations, commercial facilities, and homeless areas.[18] In addition, male adults have more smoking habits compared to females; according to the Global Adults Tobacco Survey in 2011, and the Indonesia Health Survey in 2013.[19] Smoking habits also led to a delay in diagnosis and poor adherence to TB treatments.[20]

There was a small number of child cases in this study. It is difficult to estimate the impact of tuberculosis; especially, case incidence as well as case fatality among children, due to possible failure of sputum collection occurring in children less than 5 years old.[21] Infection likelihood is significantly increased among children via close contact with either mother or father; as reported in town/urban settings within Indonesia.[22] A systematic review study in South East Asia documented child TB infection was caused by close contact to index cases (adults or those who were aged over 15 years).[23] TB can be transmitted among children via household contact.[24] Female index cases as well as sleeping proximity[25] were also associated with child TB incidence. Social binding and interaction in maternal lines; such as, mothers and grandmothers with young children rather than father or other male relatives are considered as a social determinant in TB prevalence.[25] We assume that the lesser number of female cases lead to smaller numbers of child cases.

TB prevalence was different by district level. We found high TB prevalence in cities in each province as well as districts in the eastern part of West Java province. We also found high TB prevalence grids in the west area of the study site (Banten province) as well as in the northern coastal area. This coastal area had low population density grids where low TB prevalence was observed at the district level, consequently a similar finding was reported in the south coast region of Brazil.[26] Hotspots were partially associated with increasing HIV prevalence and co-infectious TB. High HIV prevalence was reported along the northeast coastal areas; such as Bekasi, Karawang, and Subang. Increasing TB prevalence in higher HIV-AIDS areas was also reported elsewhere.[27,28] Those with HIV infection have a 30 times higher likelihood to acquire infection.[29] Spatial dependence of HIV-AIDS prevalence patterns affected the emerging TB prevalence in that area. Higher HIV prevalence was significantly affected by spatial dependence in the neighboring area, which implies that there are TB endemics around the hotspots. However, more investigation is needed to confirm spatial dependence correlation between TB prevalence and HIV cases.

This study has met several limitations, because of a lack of adequate data. This study used TB cases from the national surveillance system; during 2010 to 2014, which might have different spatial-temporal patterns with current

conditions; this may affect program implementations in the future. Both maps could affect the results partly due to misleading interpretation, because we used an average number of TB case per grid cells. However, this is the first study in Indonesia that mapped high TB intensity areas based on proportional of population distribution, and identified the existence of TB hotspot mapping, by using inverse distance weighting methods. However, further research is required in the future to strengthening the methods.

Conclusion

From the 232,289 total TB cases in the three provinces, 92.4% were registered in PHC. This study observed higher TB prevalence in male adults in both town administrations and rural districts throughout the study period. The highest TB prevalence was constantly found in Serang district, Serang city, Central Jakarta city, and Sukabumi city of the western area. Several hotspots were observed not only in town administration areas but also in lower population density areas in West Java province. Raster grid cells with high prevalence were identified along the coastal area in the northern study area.

Conflict of interest

None

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