Modeling the Prevalence of Tuberculosis in Java, Indonesia: An Ecological Study Using Geographically Weighted Regression

I Gusti Ngurah Edi Putra[1]*, Martya Rahmaniati[2], Tiopan Sipahutar[2], and Tris Eryando[2]

[1] Institute of Population Health, University of Liverpool, Liverpool, United Kingdom
[2] Department of Biostatistics and Population, Faculty of Public Health, University of Indonesia, Depok, Indonesia
* I Gusti Ngurah Edi Putra, corresponding author. Email: ediputra.ign@gmail.com
Submitted: 29 December 2021, Accepted: 16 May 2022, Published: 13 June 2022
Volume 30, 2022. pp. 741–763. http://doi.org/10.25133/JPSSv302022.041

Abstract

There is a paucity of studies investigating the spatial pattern and factors associated with the prevalence of tuberculosis (TB) in Java. This study aimed to identify spatial autocorrelation, clusters, and factors associated with TB prevalence in Java using district- or city-level data. This was an ecological study using data from 118 districts or cities across six provinces in Java. Spatial analyses (i.e., Global Moran's I, Local Indicator Spatial Autocorrelation [LISA], and Geographically Weighted Regression [GWR]) were used. This study found positive spatial autocorrelation of TB prevalence in Java (Global Moran's I = .45, p = .001). Statistically significant high-high clusters (p < .05) were identified in some districts within the capital city of Jakarta, Banten, and West Java provinces. The GWR model with the Bi-square Kernel weighting function was selected as the best model to predict the prevalence of TB (R^2 = 37.50%, AIC = -59.94%). Findings from the GWR model indicate that the average number of years in education, the percentages of households with floor space per capita < 8 m^2 and reporting easy access to health care facilities were associated with the prevalence of TB in some districts within West and Central Java provinces. Therefore, considering district differences in factors associated with TB prevalence, locally-focused interventions are worth considering.

Keywords

Geographical access; household density; Java; spatial analysis; tuberculosis

Introduction

Tuberculosis (TB) is an infectious disease mostly affecting the lungs, caused by *Mycobacterium tuberculosis*. Tuberculosis remains a public health challenge documented in most low- and middle-income countries. Globally, TB infected 10 million people and contributed to 1.5 million deaths, estimated in 2020. Tuberculosis is recognized as the second leading infectious killer and the thirteenth leading cause of death worldwide (World Health Organization, 2021a).

Indonesia currently ranks as the third-highest TB burden country after India and China (World Health Organization, 2021a). It was estimated that there were 845,000 TB cases in 2020, and 98,300 people died of TB in 2018 in Indonesia (World Health Organization, 2021b). Findings from two most recent rounds of a nationally-representative survey, *Riset Kesehatan Dasar* – Basic Health Research, by the Ministry of Health, showed that the prevalence of TB in Indonesia remained the same at 0.4% in a 5-year period (2013–2018) (Ministry of Health [Indonesia], 2018). This might indicate that more efforts are needed to progress the reduction in TB prevalence and prevent its associated adverse impacts. A previous study suggested the extremely high economic burden due to TB in Indonesia (Collins et al., 2017). The economic burden approximately accounted for US$ 6.9 billion, of which, the loss of productivity due to premature death contributed the most, around 86.6% or US$ 6.0 billion. Due to these deleterious impacts of TB in Indonesia, understanding factors associated with individuals' or communities' vulnerability to TB infections is important to inform policies and design public health interventions in a targeted manner.

There have been some studies investigating individual- or community-level factors of TB incidence within the context of Indonesia. Past work using individual-level data, derived from a nationally representative survey (e.g., Basic Health Research) indicated that age, sex, region, urban-rural status, educational level, history of household contact with TB patients, household conditions, and smoking behavior are associated with the likelihood of being diagnosed with TB (Anwary et al., 2016; Nurjana, 2015; Pangaribuan et al., 2020; Rukmini & Chatarina, 2011). Meanwhile, some ecological studies using district- or provincial-level data also appeared to understand factors associated with TB prevalence. These previous studies demonstrated that population density or size (Ardiyanti et al., 2021; Noorcintanami et al., 2021; Rizky et al., 2020), the percentage of people with low socioeconomic status (with low education and/or in poverty) (Ipa & Laksono, 2021), the number or percentages of houses that met particular health requirements (Dewi et al., 2020; Ipa & Laksono, 2021; Rizky et al., 2020), and the proportion of smokers (Ipa & Laksono, 2021) are correlates of TB prevalence and/or cases.

According to the findings from the most recent Basic Health Research in 2018, the prevalence of TB in Indonesia was distributed unevenly across different provinces and different islands or regions (Ministry of Health [Indonesia], 2019). Four out of the six provinces in Java were in the top 10 provinces with the highest prevalence of TB in Indonesia, namely Banten, West Java, the capital city of Jakarta, and Central Java, ranked first, third, sixth, and tenth, respectively. Given the high prevalence of TB in Java, there is a lack of studies that investigated the spatial distribution of TB prevalence across all provinces and its associated factors, indicating current research gaps. A previous study by Noorcintanami et al. (2021) modeling the prevalence of TB in Java in 2017 did not include data from a province with the highest TB prevalence, Banten province. In addition, this study did not investigate the spatial

distribution and clusters of TB prevalence in Java, signaling more studies are warranted to add or update previous findings.

Accordingly, this study aimed to (1) understand the spatial distribution, (2) identify clusters, and (3) evaluate factors associated with TB prevalence in Java using spatial analysis on district-level data. Compared to classical linear regression, the use of spatial analysis in developing regression models can consider spatial autocorrelation and spatial heterogeneity in the data (Raza et al., 2019). This is important in examining factors associated with TB prevalence across administrative areas since differences in TB prevalence might be attributed to the differences in area characteristics (e.g., the proportion of poor people, access to health facilities, etc.). In addition, areas that are geographically close in the distance might have a similar level of TB prevalence and characteristics of factors associated with TB. Due to potential differences in factors associated with the prevalence of TB by districts, this present study employed geographically weighted regression (GWR) to develop local regression models of factors associated with TB prevalence in each district in Java, Indonesia. Therefore, findings from this study potentially inform specific and targeted interventions focusing on correlates of TB prevalence in each district.

Methods

Study design and data

Using spatial analysis, this study was ecological in design, which aimed to understand the spatial distribution, clusters, and factors associated with the TB prevalence in Java, Indonesia. This study involved district- or city-level data retrieved from some relevant reports of all six administrative provinces (i.e., Banten, West Java, the capital city of Jakarta, Central Java, Special Region of Yogyakarta, and East Java) in Java Island. The prevalence of TB as the dependent variable and some independent variables at the district or city level were extracted from provincial reports of the Basic Health Research in 2018. Meanwhile, other socioeconomic data were informed by Statistics Indonesia. Out of 119 districts and cities in Java, only data from 118 districts or cities were involved in the analysis since one district, namely *Kepulauan Seribu* [Thousand Islands], a district within the administrative area of the capital city of Jakarta, borders the sea and does not have any neighboring districts.

In brief, the Basic Health Research is a quinquennial national survey representative of the Indonesian population. The most recent survey in 2018 aimed to provide national and provincial estimates of public health status and risk factors to monitor health development initiatives and health-related behaviors and outcomes. The National Institute of Health Research and Development (NIHRD), Ministry of Health of Indonesia, was responsible for this national survey. More detailed information about the survey's methodology, content, and findings are available elsewhere (Ministry of Health [Indonesia], 2018, 2019). Meanwhile, Statistics Indonesia regularly provides updated estimates or indicators of the population's socio-economic development from sub-district to national level. The provincial or national reports on which this study was based are publicly accessible and can be found on the website of the respective institutions.

Variables

The dependent variable was the prevalence of TB reported in the 2018 Basic Health Research. This is presented as the proportion between the number of people who have ever been diagnosed with TB by a physician in the last 12 months and the number of people who participated in the survey. The independent variables in this study were grouped into three categories, namely area socioeconomic characteristics (i.e., poverty severity index; and the number of years in education), household living conditions (i.e., the percentages of households with proper ventilation; proper lighting; and with floor space per capita < 8 m^2), and health-related factors (i.e., the percentages of smokers; and people reporting easy access to health facilities). Data for the majority of independent variables were extracted from the reports in the same year as the TB prevalence was reported (i.e., 2018), except the percentages of households with floor space per capita were derived from a report in 2019 due to the unavailability of these data in or before 2018. Table 1 provides information on the variables analyzed in this study.

Table 1: Descriptions of the District- or City-Level Variables or Indicators Used in this Study

Variables	Descriptions	Sources
Dependent variable		
Prevalence of TB (%)	The number of household members diagnosed with pulmonary TB by a physician in the last 12 months divided by the number of all household members.	Basic Health Research, Ministry of Health [Indonesia]
Socio-demographic characteristics		
Poverty severity index	The distribution of spending or expenditure among poor people with the higher index value indicating the widening gap in spending among poor people.	Statistics Indonesia
Average number of years in education	The number of years in education by people aged ≥ 25 years divided by the number of people aged ≥ 25 years.	Statistics Indonesia
Household living conditions		
Households with proper ventilation (%)	The number of households with ventilation area > 10% of floor area in the living room divided by the number of households who had living rooms.	Basic Health Research, Ministry of Health [Indonesia]
Households with proper lighting (%)	The number of households with proper lighting (i.e., the lighting enables household members to read and see small objects) in the living room was divided by the number of households that had living rooms.	Basic Health Research, Ministry of Health [Indonesia]
Households with floor space per capita < 8 m^2 (%)	The number of households with floor space per capita < 8 m^2 (i.e., the number of household members/floor area in meters squared) divided by the number of households.	Statistics Indonesia
Health-related factors		
People smoking (%)	The number of household members aged ≥ 10 years who smoked every day divided by the number of household members aged ≥ 10 years.	Basic Health Research, Ministry of Health [Indonesia]

Variables	Descriptions	Sources
Households reporting easy access to health care facilities (%)	The number of households perceived easy access to health care facilities based on the modes and cost of transportation and travel time to facilities, divided by the number of households that knew the location of health care facilities.	Basic Health Research, Ministry of Health [Indonesia]

Data analysis

Descriptive statistics were used to present the characteristics of the data. We also identified correlations between independent and dependent variables using Spearman's Rank correlation since the dependent variable (i.e., TB prevalence) did not meet the normality assumption. This study used spatial statistics to identify spatial autocorrelation and evaluate factors associated with TB prevalence in Java. Global Moran's I was used to test the presence of spatial autocorrelation of TB prevalence between districts or cities. The presence of positive spatial autocorrelation (i.e., areas with similar values tend to be clustered or neighboring areas tend to share similar values) is indicated by the higher value of Global Moran's I compared to the expected value of observed Moran's I or E(I) (Abdulhafedh, 2017; Ghodousi et al., 2020), and by a significant p value (Fontoura et al., 2018). Local Moran's I, or Local Indicator Spatial Autocorrelation (LISA), was then applied to identify high-high clusters of TB prevalence in Java. High-high clusters indicate areas with a high value or number of events, surrounded by areas with similar characteristics (Raza et al., 2020).

This study used the GWR to model the prevalence of TB in each district in Java, considering spatial autocorrelation and spatial heterogeneity of residuals. Prior to the use of GWR, factors associated with the prevalence of TB were fitted using a linear regression model, followed by the assessment of model diagnostics. The GWR model using different weighting functions (i.e., Gaussian Kernel, Bi-square Kernel) was then employed to develop local regression models. The best model of factors associated with TB prevalence was evaluated based on the lowest Akaike Information Criterion (AIC) and the highest adjusted R-squared (R^2) values.

The GWR model is a development or an expansion of "classical" or "global" regression analysis to consider the potential spatial effect of the location where observation is collected. Compared to the classical regression model, which only provides the "global" estimate of parameters over the study area, the GWR model allows parameter estimates to vary across locations (Raza et al., 2019; Shoff et al., 2012). Therefore, results from GWR provide local parameter estimates for each location. The GWR model is an appropriate method to analyze spatial data since the assumptions of independent and homogenous residuals are more likely to be violated; using a classical regression model might yield biased estimates and lead to flawed conclusions (Hidayat et al., 2018). In the GWR model, the response or dependent variable (y_i) in each location is predicted by independent variables (x_i), and the regression coefficients or slopes (β_k) vary by location (u_i, v_i) where the observation is collected. The GWR model is as follows:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) x_{ik} + e_i; \quad i = 1,2, \dots, n$$

The GWR model uses Weighted Least Squares (WLS) method to estimate the parameters by assigning different geographical weights according to the location where the observation

belongs. Adaptive Kernel with two different predominantly used weighting functions, namely Gaussian Kernel and Bi-square Kernel, were applied to determine weights for each location (Amaliana et al., 2018). Therefore, this study compared GWR models using different weighting functions. In this present study, different open-source software was used, such as QGIS (to map TB prevalence), GeoDA (to identify spatial autocorrelation and clusters of TB prevalence), and R Studio (to conduct descriptive statistics and develop regression models).

Ethics consideration

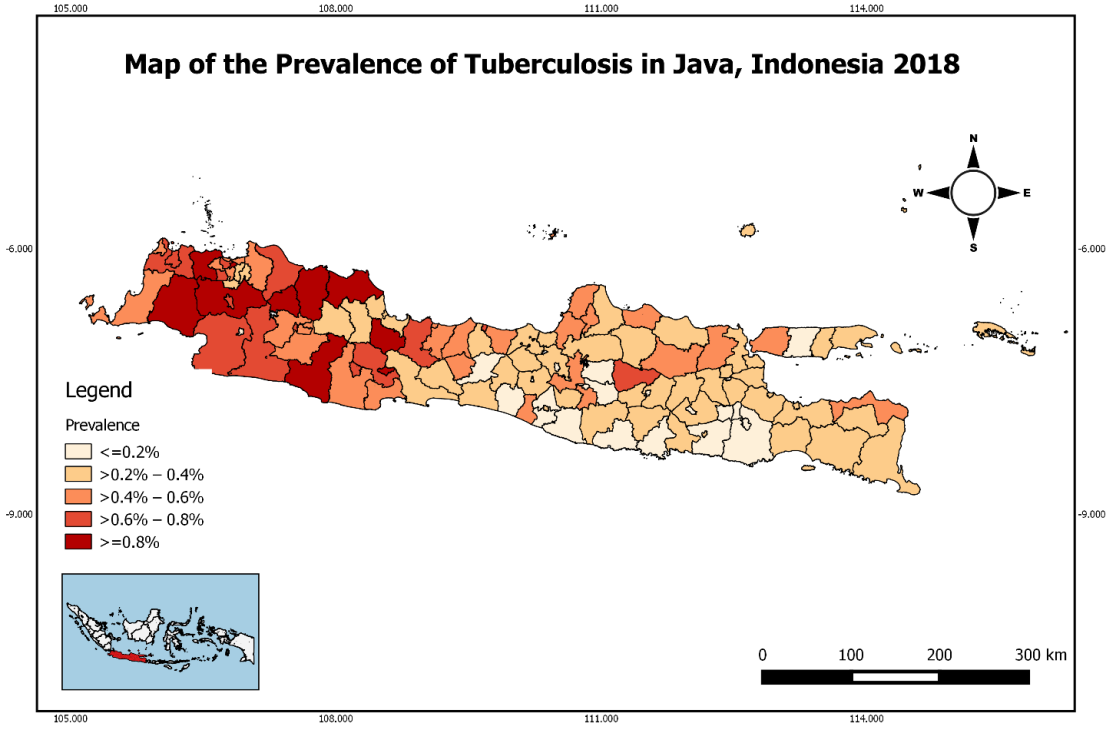
This study used district- or city-level data available in public domains; therefore, ethical approval is not required for this study.

Results

Tuberculosis prevalence and characteristics of districts or cities in Java

Overall, the unweighted average prevalence of tuberculosis across all districts in Java in 2018 was 0.42%, ranging from the lowest in Sleman district and Sukabumi city at 0.02% each to the highest in Lebak district at 1.19% (Table 2). Figure 1 presents the distribution of TB prevalence in Java. Ten districts or cities within three provinces in Java (Banten, West Java, capital city of Jakarta) had prevalence of TB ≥ 0.80%, namely Purwakarta, Indramayu, Bogor, Garut, Kuningan, Subang, Lebak, Tangerang districts, and Banjar and Central Jakarta cities. Meanwhile, a low prevalence of TB (< 0.04%) was predominantly observed in districts within Central Java, the Special Region of Yogyakarta, and the East Java provinces.

Figure 1: Tuberculosis Prevalence in Java, Indonesia 2018



Note: Findings of the 2018 Basic Health Research; TB prevalence mapped using QGIS

Table 2 shows the mean, SD, minimum, and maximum values of independent variables. Some independent variables were also found to be statistically significantly correlated with the prevalence of TB ($p < .05$), with the magnitude of correlation ranging from low to moderate. All variables of the household living conditions, such as the percentages of households with proper ventilation ($r = -.36$); proper lighting ($r = -.34$); and floor space per capita < 8 m^2 ($r = .36$), and health-related factors that included the percentages of smokers (r = .26); and households reporting easy access to health facilities ($r = -.49$) were statistically significant correlates of TB prevalence in Java. However, none of the socio-demographic characteristics was found to be associated with TB prevalence. In addition, there were no pairs of the independent variables strongly correlated ($r < .70$).

Table 2. Prevalence of Tuberculosis and Characteristics of Districts in Java, Indonesia

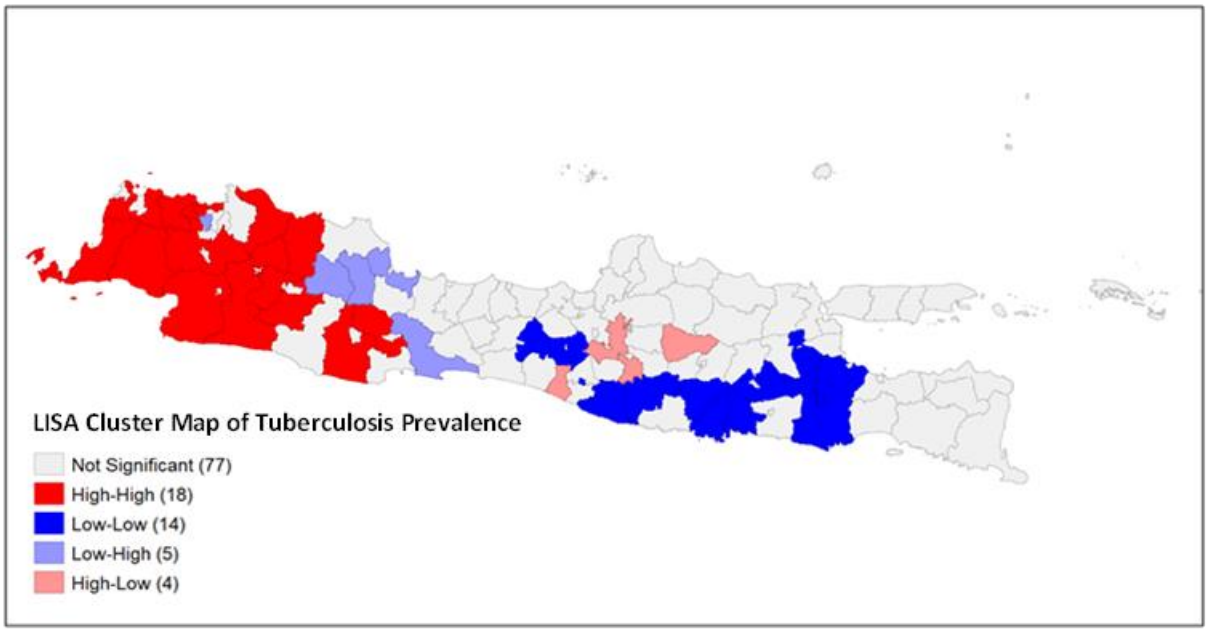
Variable	Mean (SD)	Min, Max	*r*	*p* value
Dependent variable				
Prevalence of TB (%)	0.42 (0.24)	0.02, 1.19		
Socio-demographic characteristics				
Poverty severity index	0.36 (0.23)	0.04, 1.16	-.13	.175
Average number of years in education	8.10 (1.65)	4.36, 11.78	-.04	.659
Household living conditions				
Households with proper ventilation (%)	57.44 (11.54)	32.91, 90.82	**-.36**	**< .001**
Households with proper lighting (%)	82.39 (6.37)	56.84, 95.75	**-.34**	**< .001**
Households with floor space per capita < 8 m^2 (%)	6.91 (7.73)	0.20, 41.32	**.36**	**< .001**
Health-related factors				
People smoking (%)	24.32 (3.91)	17.47, 33.46	**.26**	**.004**
Households reporting easy access to health care facilities (%)	42.46 (13.31)	13.13, 70.63	**-.49**	**< .001**

Note: SD = standard deviation; Min = minimum value; Max = maximum value; r = correlation coefficient; % = percentage; m = meter

Spatial autocorrelation and clusters of Tuberculosis prevalence

This study found that the Global Moran's I (.45) of TB prevalence was higher than E(I) (-.01) with $p = .001$, suggesting that the presence of positive spatial autocorrelation is evident. This indicates that districts with a high prevalence of TB in Java were spatially clustered. Moreover, the LISA cluster map found 41 districts with statistically significant local spatial autocorrelation ($p < .05$), consisting of 18, 14, 5, and 4 districts classified into high-high, low-low, low-high, and high-low clusters, respectively (Figure 2). High-high clusters (i.e., a group of districts with a high prevalence of TB surrounded by other districts with a similarly high prevalence of TB) were observed in the western part of Java, covering Banten, the capital city of Jakarta, and West Java provinces. Meanwhile, low-low clusters, as the opposite of high-high clusters, were found within Central Java, the Special Region of Yogyakarta, and East Java province. A list of districts grouped into clusters (high-high and low-low clusters) and outliers (low-high and high-low clusters) is presented in Appendix 1.

Figure 2: LISA Cluster Map of Tuberculosis Prevalence in Java, Indonesia



Note: Findings of the 2018 Basic Health Research; LISA cluster map generated using GeoDa

Regression models of factors associated with Tuberculosis prevalence

Before using GWR, the model was fitted using global or linear regression to evaluate factors associated with the prevalence of TB in Java, Indonesia (Table 3). Out of seven independent variables in the model, only the percentage of households reporting easy access to health facilities was found to be associated with the prevalence of TB (β = -0.0076, p = .001). Based on the model diagnostics, the residuals were normally distributed, and no multicollinearity was detected among independent variables. However, two assumptions of linear regression, namely homoscedasticity and no autocorrelation, were violated. The heteroscedasticity in the model strengthens the assumption of spatial variation in the data, suggesting potential differences in the variables that can explain TB prevalence in each district. In addition, the presence of spatial autocorrelation of the residuals (i.e., statically significant of Moran's I with p = .016) in the model shows the spatial effect in the model. This also indicates that the coefficients obtained from the linear regression model would be biased since the location with a higher prevalence of events can significantly impact the model estimate (Raza et al., 2019). Therefore, linear regression was not suitable to model the prevalence of TB in Java. In addition, even though the autocorrelation assumption of linear regression was not met in this present study, GWR was used to model the prevalence of TB in order to consider spatial autocorrelation and heterogeneity.

Table 3: Linear Regression Model

Variable	Linear regression	
	β	***p* value**
Socio-demographic characteristics		
Poverty severity index	-0.1547	.180
Average number of years in education	-0.0012	.576
Household living conditions		
Households with proper ventilation (%)	-0.0013	.576
Households with proper lighting (%)	-0.0012	.768
Households with floor space per capita < 8 m^2 (%)	0.0050	.206
Health-related factors		
People smoking (%)	0.0048	.474
Households reporting easy access to health care facilities (%)	**-0.0076**	**.001**
Model diagnostics for linear regression		
Normality of residuals (Anderson-Darling normality test)	p = .101	
Homoscedasticity (Breusch-Pagan test)	p = .014	
Autocorrelation (Durbin Watson test)	p < .001	
Multicollinearity (variance of inflation factors - VIF)	None of the variables with VIF>10	
Model diagnostic for spatial dependence		
Spatial autocorrelation of residuals (Moran's I)	.136, p = .016	
Model fit		
Adjusted R^2	27.14%	
Akaike Information Criterion (AIC)	-25.88	

Note: β = adjusted regression coefficient; % = percentage; m = meter; R^2 = R-squared

Table 4 shows parameter estimates of two GWR models developed using different weighting functions, namely Gaussian and Bi-square Kernel. Generally, GWR models provided better models of TB prevalence than the linear regression model, indicated by the higher adjusted R^2, but lower AIC values. GWR model with Bi-square Kernel weighting function was selected as the final model due to its lowest AIC value compared to the GWR model with Gaussian Kernel weighting function. Minimum and maximum values of regression coefficients of the selected model are displayed in Table 4. Estimated regression coefficients of 118 districts in Java are presented in Appendix 2. Results from GWR models presented in Appendix 2 are summarized in Table 5. Findings suggest that none of the independent variables was found to be statistically significantly associated with the prevalence of TB in any district within the capital city of Jakarta, the Special Region of Yogyakarta, East Java, and Banten provinces. Only the average number of years in education, percentages of households with floor space per capita < 8 m^2, and/or reporting easy access to health facilities were associated with the prevalence of TB in some districts within West and Central Java provinces (Table 5). Two variables: the average number of years in education and the percentage of households with floor space per capita < 8 m^2, were found as paramount factors contributing to TB prevalence in Central Java province, while the percentage of households reporting easy access to health facilities was a prominent factor in West Java province.

Table 4: Geographically Weighted Regression Models

Variable	Gaussian Kernel weighting function		Bi-square Kernel weighting function	
	β (Min)	β (Max)	β (Min)	β (Max)
Socio-demographic characteristics				
Poverty severity index	-0.2618	-0.0184	-0.2740	-0.0332
Average number of years in education	-0.0588	-0.0147	-0.0762	-0.0305
Household living conditions				
Households with proper ventilation (%)	-0.0038	0.0015	-0.0036	0.0014
Households with proper lighting (%)	-0.0036	0.0029	-0.0031	0.0033
Households with floor space per capita < 8 m^2 (%)	0.0044	0.0132	0.0050	0.0164
Health-related factors				
People smoking (%)	-0.0149	0.0073	-0.0115	0.0065
Households reporting easy access to health care facilities (%)	-0.0072	-0.0022	-0.0067	-0.0018
Model fit				
Adjusted R^2	35.87%		37.50%	
Akaike Information Criterion (AIC)	-58.05		-59.94%	

Note: β = adjusted regression coefficient; Min = minimum value; Max = maximum value; % = percentage; m = meter; R^2 = R-squared

Table 5: The Classification of Districts or Cities with Statistically Significant Independent Variables

District or city	Statistically significant variable ($p < .05$)	N
<u>*East Java province*</u> Banyumas, Tegal districts; Tegal city	Average number of years in education	3
<u>*East Java province*</u> Wonosobo, Temanggung districts	Households with floor space per capita < 8 m^2 (%)	2
<u>*West Java province*</u> Bandung, Garut, Tasikmalaya, Ciamis, Majalengka, Sumedang, Indramayu, Subang, West Bandung, Pangandaran districts; Bandung, Cimahi, Tasikmalaya, Banjar cities;	Households reporting easy access to health care facilities (%)	14
<u>*East Java province*</u> Purbalingga, Banjarnegara, Kendal, Batang, Pekalongan, Pemalang districts; Pekalongan city	Average number of years in education **and** households with floor space per capita < 8 m^2 (%)	7
<u>*West Java province*</u> Kuningan, Cirebon districts; Cirebon city <u>*East Java province*</u> Cilacap, Brebes districts	Average number of years in education **and** households reporting easy access to health care facilities (%)	5

Discussion

This study aimed to investigate the spatial distribution of tuberculosis prevalence in Java, identify its clusters, and examine the factors associated. Overall, we found that the prevalence of TB tended to be clustered in the western part of Java. High-high clusters were statistically significant among districts within the capital city of Jakarta, Banten, and West Java provinces. Findings from the GWR model with Bi-square Kernel weighting function suggested seven variables, namely poverty severity index; the average number of years in education; the percentages of households with proper ventilation; lighting; and floor space per capita < 8 m^2; the percentages of people smoking; and households reporting easy access to health care facilities explained the variation of TB prevalence in Java by 37.5%. However, only three variables (i.e., the average number of years in education; the percentages of households with floor space per capita < 8 m^2; and reporting easy access to health care facilities) were statistically significantly associated with the prevalence of TB in some districts within West and Central Java provinces.

The average number of years in education was negatively associated with the prevalence of TB in this present study. Previous cross-sectional studies using nationally representative data showed that a higher educational level was associated with lower odds of being diagnosed with TB (Nurjana, 2015; Pangaribuan et al., 2020). These also align with findings from an ecological study suggesting that a higher prevalence of people completing primary education was associated with a lower prevalence of TB (Ipa & Laksono, 2021). More years of schooling or a high educational level might contribute to better knowledge and preventive behaviors toward TB. This is supported by findings from past work highlighting the importance of better education on better TB-related knowledge, attitude, preventive, and/or treatment behaviors (Huddart et al., 2018; Luba et al., 2019; Nezenega et al., 2020).

Areas (i.e., districts or cities) with higher years of schooling can indicate better socioeconomic development where most city or district dwellers might participate in better-paid employment. They can afford healthy housing, which can increase their health status and decrease vulnerability to TB infection. This is also in line with another finding from this present study that higher household density or crowding (i.e., the percentage of households with floor space per capita < 8 m^2) was positively associated with the prevalence of TB. A previous study from different study settings also found the associations between household crowding and TB incidence using area-level data (Baker et al., 2008; Myers et al., 2006). Living in a house with inadequate floor space for all household members can intensify exposure to TB through household contacts of TB patients, as reported by an earlier study (Adane et al., 2020). While studies found other healthy housing criteria, such as proper ventilation and lighting, are environmental determinants of TB infection (Anwary et al., 2016; Ipa & Laksono, 2021; Nurjana, 2015), these factors were not identified as predictors of TB prevalence, particularly within the context of Java. However, further investigation is needed in this regard.

Access to health facilities appeared as a contributing factor to TB prevalence. Living close to health facilities might increase the use of health services and exposure to health-related information delivered by health providers, increasing TB-related knowledge and behavior. In addition, TB patients are more likely to have favorable treatment outcomes if they have better access to health facilities (Ruru et al., 2018; Subbaraman et al., 2020). Better TB treatment outcomes among TB patients can reduce the prevalence of TB by minimizing TB transmission

in the community (World Health Organization, 2002). Meanwhile, accessible health services might also contribute to the increased uptake of basic immunization, including the BCG vaccine among children (Hardhantyo & Chuang, 2021; Holipah et al., 2018) that can protect them from being infected with TB as they become older, as well as improve community's protection towards TB transmission. A previous study found that the percentage of toddlers receiving the BCG vaccine was associated with a lower prevalence of TB (Noorcintanami et al., 2021).

Findings from this study provide a basis for developing targeted interventions by considering differences in factors contributing to TB prevalence by districts. For example, increasing educational attainment and improving housing quality might be important factors in reducing TB prevalence in some districts within Central Java. Meanwhile, interventions on reducing geographical barriers to access to health facilities might address the high TB prevalence in some districts within West Java. Public health policies and/or interventions at the community or population level, such as increasing access to education, aiding healthy housing among those who are in need, and ensuring health facilities are accessible, particularly in remote or hard-to-reach areas, might work in reducing the prevalence of TB in Java.

Strengths and limitations

This study used GWR to model TB prevalence in Java that was able to estimate local parameters of factors associated with TB prevalence in each district, providing stronger support for locally-focused interventions. This analysis also considered the spatial autocorrelation and heterogeneity of the data. The number of observations—118 districts—can provide more variation in the data and more power to detect the significance of factors associated with TB prevalence compared to previous ecological studies with a small number of observations.

Findings from this study should be carefully interpreted due to its limitations. Other variables that might influence TB prevalence in Java were not assessed in this study. Seven variables can explain only 37.5% of the variance of TB prevalence in the multivariate model. For instance, a previous study found that the percentage of toddlers receiving the BCG vaccine was an associated factor (Noorcintanami et al., 2021). However, not all provincial reports of the 2018 Basic Health Survey present the findings by districts or cities. In addition, no variables in the multivariate model were statistically significantly associated with the prevalence of TB in districts or cities within Banten, the capital city of Jakarta, the Special Region of Yogyakarta, and the East Java provinces. This indicates that more studies are needed to identify variables that might help explain the prevalence of TB in these provinces.
All spatial analyses are vulnerable to modifiable area unit problem (MAUP) since individual-level data are aggregated to higher spatial unit levels (i.e., district- or city-level data) (Wong, 2004). The associations might be found to be inconsistent by using data from different spatial units (e.g., district- vs. province-level data) (Andresen, 2021). This also potentially leads to the "ecological fallacy" when the relationships derived using area-level data might not necessarily reflect the individual relationship within these area units (Openshaw, 1984). Therefore, future studies should take these limitations into account.

Conclusion

Districts or cities with a high prevalence of TB tended to be clustered in the western part of Java, covering three provinces, namely Banten, West Java provinces, and the capital city of Jakarta. High-high clusters were also identified within these provinces. Some variables, such as the average number of years in education, the percentages of households with floor space per capita < 8 m^2, and reporting easy access to health care facilities, were found to be factors associated with the prevalence of TB within West and Central Java provinces. Findings from this study serve as a basis for developing interventions in a targeted manner by considering different factors associated with the prevalence of TB in each area. Future studies will benefit from examining other contributing factors to TB prevalence that were not investigated in this study. This can add to our findings and help us understand other factors that might work in different districts or provinces.

Acknowledgments

We thank the Ministry of Health and Statistics Indonesia for making the reports, which this study was based on, publicly accessible.

References

Abdulhafedh, A. (2017). A novel hybrid method for measuring the spatial autocorrelation of vehicular crashes: Combining Moran's Index and Getis-Ord Gi* Statistic. *Open Journal of Civil Engineering*, *7*(2), 208–221. https://doi.org/10.4236/ojce.2017.72013

Adane, A., Damena, M., Weldegebreal, F., & Mohammed, H. (2020). Prevalence and associated factors of tuberculosis among adult household contacts of smear positive pulmonary tuberculosis patients treated in public health facilities of Haramaya district, Oromia Region, Eastern Ethiopia. *Tuberculosis Research and Treatment*, *2020*, Article 6738532. https://doi.org/10.1155/2020/6738532

Amaliana, L., Fernandes, A. A. R., & Solimun. (2018). Comparison of two weighting functions in geographically weighted zero-inflated Poisson regression on Filariasis Data. *Journal of Physics: Conference Series*, *1097*, Article 012070. https://doi.org/10.1088/1742-6596/1097/1/012070

Andresen, M. A. (2021). Modifiable areal unit problem. In J. C. Barnes & D. R. Forde (Eds.), *The Encyclopedia of Research Methods in Criminology and Criminal Justice* (pp. 854–855). John Wiley & Sons, Inc. https://doi.org/10.1002/9781119111931.ch164

Anwary, A. Z., Lazuardi, L., Hasanbasri, M., & Mansur, F. (2016). Hubungan kondisi lingkungan fisik rumah dengan kejadian tuberkulosis paru di Jawa Barat (Analisis Data Riskesdas 2013) [Correlation of house physical environmental conditions with occurrence of pulmonary tuberculosis in West Java (Riskesdas 2013 Data Analysis)]. *Jurnal Kesehatan Indonesia*, *6,* 34–39. https://journal.stikeshb.ac.id/index.php/jurkessia/article/view/72

Ardiyanti, M., Sulistyawati, & Puratmaja, Y. (2021). Spatial analysis of tuberculosis, population and housing density in Yogyakarta city 2017–2018. *Epidemiology and Society Health Review*, *3*(1), 28–35. https://doi.org/10.26555/eshr.v3i1.3629

Baker, M., Das, D., Venugopal, K., & Howden-Chapman, P. (2008). Tuberculosis associated with household crowding in a developed country. *Journal of Epidemiology and Community Health*, *62*(8), 715–721. https://doi.org/10.1136/jech.2007.063610

Collins, D., Hafidz, F., & Mustikawati, D. (2017). The economic burden of tuberculosis in Indonesia. *International Journal of Tuberculosis and Lung Disease*, *21*(9), 1041–1048. https://doi.org/10.5588/ijtld.16.0898

Dewi, N. K. A., Sukarsa, I. K. G., & Srinadi, I. G. A. M. (2020). Faktor-faktor yang memengaruhi penyebaran penyakit tuberkulosis (TBC) di provinsi Jawa Barat [Factors influencing the spread of tuberculosis (TBC) in West Java province]. *E-Jurnal Matematika*, *9*(3), 165–170. https://doi.org/10.24843/MTK.2020.v09.i03.p294

Fontoura, V. M., Graepp-Fontoura, I., Santos, F. S., Santos Neto, M., de Almeida Tavares, H. S., Bezerra, M. O. L., de Oliveira Feitosa, M., Neves, A. F., de Morais, J. C. M., & Nascimento, L. F. C. (2018). Socio-environmental factors and diarrheal diseases in under five-year old children in the state of Tocantins, Brazil. *PloS ONE*, *13*(5), Article e0196702. https://doi.org/10.1371/journal.pone.0196702

Ghodousi, M., Sadeghi-Niaraki, A., Rabiee, F., & Choi, S. M. (2020). Spatial-temporal analysis of point distribution pattern of schools using spatial autocorrelation indices in Bojnourd city. *Sustainability, 12*(18), Article 7755. https://www.mdpi.com/2071-1050/12/18/7755

Hardhantyo, M., & Chuang, Y. C. (2021). Urban-rural differences in factors associated with incomplete basic immunization among children in Indonesia: A nationwide multilevel study. *Pediatrics and Neonatology*, *62*(1), 80–89. https://doi.org/10.1016/j.pedneo.2020.09.004

Hidayat, N. R., Otok, B. W., Mahsyari, Z., Sa'diyah, S. H., & Fadhila2, D. A. (2018). Geographically weighted regression for prediction of underdeveloped regions in East Java province based on poverty indicators. In *Proceedings of the 2nd International Conference Postgraduate School (ICPS 2018)*, 898–907. https://doi.org/10.5220/0007553708980907

Holipah, Maharani, A., & Kuroda, Y. (2018). Determinants of immunization status among 12- to 23-month-old children in Indonesia (2008–2013): A multilevel analysis. *BMC Public Health*, *18*(1), Article 288. https://doi.org/10.1186/s12889-018-5193-3

Huddart, S., Bossuroy, T., Pons, V., Baral, S., Pai, M., & Delavallade, C. (2018). Knowledge about tuberculosis and infection prevention behavior: A nine city longitudinal study from India. *PloS ONE*, *13*(10), Article e0206245. https://doi.org/10.1371/journal.pone.0206245

Ipa, M., & Laksono, A. D. (2021). Ecological analysis of the prevalence of pulmonary tuberculosis in Indonesia. *Indian Journal of Forensic Medicine & Toxicology*, *15*(3), 3586–3595. https://doi.org/10.37506/ijfmt.v15i3.15857

Luba, T. R., Tang, S., Liu, Q., Gebremedhin, S. A., Kisasi, M. D., & Feng, Z. (2019). Knowledge, attitude and associated factors towards tuberculosis in Lesotho: A population based study. *BMC Infectious Diseases*, *19*(1), Article 96. https://doi.org/10.1186/s12879-019-3688-x

Ministry of Health [Indonesia]. (2018). *Hasil Utama Riset Kesehatan Dasar 2018 [Main findings of the 2018 Basic Health Research]*. https://www.litbang.kemkes.go.id/hasil-utama-riskesdas-2018/

Ministry of Health [Indonesia]. *Profil Kesehatan Indonesia 2018 [The 2018 Indonesia Health Profile]*. https://pusdatin.kemkes.go.id/resources/download/pusdatin/profil-kesehatan-indonesia/PROFIL_KESEHATAN_2018_1.pdf

Myers, W. P., Westenhouse, J. L., Flood, J., & Riley, L. W. (2006). An ecological study of tuberculosis transmission in California. *American Journal of Public Health, 96*(4), 685–690. https://doi.org/10.2105/ajph.2004.048132

Nezenega, Z. S., Perimal-Lewis, L., & Maeder, A. J. (2020). Factors influencing patient adherence to tuberculosis treatment in Ethiopia: A literature review. *International Journal of Environmental Research and Public Health*, *17*(15), Article 5626. https://doi.org/10.3390/ijerph17155626

Noorcintanami, S., Widyaningsih, Y., & Abdullah, S. (2021). Geographically weighted models for modelling the prevalence of tuberculosis in Java. *Journal of Physics: Conference Series*, *1722*, Article 012089. https://doi.org/10.1088/1742-6596/1722/1/012089

Nurjana, M. A. (2015). Faktor risiko terjadinya tuberkulosis paru usia produktif (15–49 tahun) di Indonesia [Risk factors of pulmonary tuberculosis on productive age 15-49 years old in Indonesia]. *Media Litbangkes*, *25*(3), 165–170. https://doi.org/10.22435/mpk.v25i3.4387.163-170

Openshaw, S. (1984). Ecological fallacies and the analysis of areal census data. *Environment and Planning A: Economy and Space*, *16*(1), 17–31. https://doi.org/10.1068/a160017

Pangaribuan, L., Kristina, K., Perwitasari, D., Tejayanti, T., & Lolong, D. B. (2020). Faktor-faktor yang mempengaruhi kejadian tuberkulosis pada umur 15 tahun ke atas di Indonesia (Analisis Data

Survei Prevalensi Tuberkulosis (SPTB) di Indonesia 2013–2014) [Factors influencing pulmonary tuberculosis occurrence of 15 years old or above in Indonesia (Tuberculosis Prevalence Survey Data Analysis in Indonesia 2013-2014). *Buletin Penelitian Sistem Kesehatan*, *23*(1), 10–17. https://doi.org/10.22435/hsr.v23i1.2594

Raza, O., Mansournia, M. A., Rahimi Foroushani, A., & Holakouie-Naieni, K. (2019). Geographically weighted regression analysis: A statistical method to account for spatial heterogeneity. *Archives of Iranian Medicine*, *22*(3), 155–160. http://www.aimjournal.ir/Article/aim-3740

Raza, O., Mansournia, M. A., Rahimi Foroushani, A., & Holakouie-Naieni, K. (2020). Exploring spatial dependencies in the prevalence of childhood diarrhea in Mozambique using global and local measures of spatial autocorrelation. *Medical Journal of the Islamic Republic of Iran*, *34*, Article 59. https://doi.org/10.34171/mjiri.34.59

Rizky, H. P., Pramesti, W., & Anuraga, G. (2020). Penggunaan analisis kluster K-Means dalam pemodelan regresi spasial pada kasus tuberkulosis di Jawa Timur tahun 2017 [The use of K-Means cluster analysis in spatial regression modeling in cases of tuberculosis in East Java in 2017]. *Indonesian Journal of Statistics and Its Applications*, *4*(1), 164–178. https://doi.org/10.29244/ijsa.v4i1.563

Rukmini, R., & Chatarina, U. (2011). Faktor-faktor yang berpengaruh terhadap kejadian TB paru dewasa di Indonesia (Analisis Data Riset Kesehatan Dasar Tahun 2010) [Factors that influence the incidence of adult pulmonary TB in Indonesia (Basic Health Research Data Analysis 2010)]. *Buletin Penelitian Sistem Kesehatan*, *14*(4), 320–331. https://media.neliti.com/media/publications/20972-ID-faktor-faktor-yang-berpengaruh-terhadap-kejadian-tb-paru-dewasa-di-indonesia-ana.pdf

Ruru, Y., Matasik, M., Oktavian, A., Senyorita, R., Mirino, Y., Tarigan, L. H., van der Werf, M. J., Tiemersma, E., & Alisjahbana, B. (2018). Factors associated with non-adherence during tuberculosis treatment among patients treated with DOTS strategy in Jayapura, Papua province, Indonesia. *Global Health Action*, *11*(1), Article 1510592. https://doi.org/10.1080/16549716.2018.1510592

Shoff, C., Yang, T. C., & Matthews, S. A. (2012). What has geography got to do with it? Using GWR to explore place-specific associations with prenatal care utilization. *GeoJournal*, *77*(3), 331–341. https://doi.org/10.1007/s10708-010-9405-3

Subbaraman, R., Jhaveri, T., & Nathavitharana, R. R. (2020). Closing gaps in the tuberculosis care cascade: An action-oriented research agenda. *Journal of Clinical Tuberculosis and Other Mycobacterial Diseases*, *19*, Article 100144. https://doi.org/10.1016/j.jctube.2020.100144

Wong, D. W. S. (2004). The Modifiable Areal Unit Problem (MAUP). In D. G. Janelle, B. Warf, & K. Hansen (Eds.), *WorldMinds: Geographical Perspectives on 100 Problems: Commemorating the 100th Anniversary of the Association of American Geographers 1904–2004* (pp. 571–575). Springer. https://doi.org/10.1007/978-1-4020-2352-1_93

World Health Organization. (2002). An Expanded DOTS Framework for Effective Tuberculosis Control (WHO/CDS/TB/2002.297). *International Journal of Tuberculosis and Lung Disease*, *6*(5) 378–388. https://www.ingentaconnect.com/content/iuatld/ijtld/2002/00000006/00000005/art00005;jsessionid=312v6g8l2eb56.x-ic-live-03#

World Health Organization. (2021a, October 14). *Tuberculosis: Key facts*. https://www.who.int/news-room/fact-sheets/detail/tuberculosis

World Health Organization. (2021b). *World TB Day 2021 Making TB everyone's business – Indonesia's path towards eliminating TB*. https://www.who.int/indonesia/news/campaign/tb-day-2021

Appendices

Appendix 1: Clusters or Outliers of Tuberculosis Prevalence in Java, Indonesia

Clusters or outliers	Districts or cities
High-high clusters (n = 18) Areas with high prevalence of TB are surrounded by areas with a high prevalence of TB.	*Banten province* (Pandeglang, Lebak, Tanggerang districts, and Serang, Tanggerang, and South Tanggerang cities); *Capital city of Jakarta* (West Jakarta and North Jakarta cities); *West Java province* (Bogor, Sukabumi, Cianjur, Bandung, Tasikmalaya, Ciamis, Subang, Purwakarta, Karawang, and West Bandung districts).
Low-low clusters (n = 14) Areas with a low prevalence of TB are surrounded by areas with a low prevalence of TB.	*Central Java province* (Wonosobo, Magelang, Wonogiri districts); *Special Region of Yogyakarta province* (Gunung Kidul district and Yogyakarta city); *East Java province* (Ponorogo, Trenggalek, Tulungagung, Kediri, Malang, Pasuruan, Mojokerto districts, and Malang and Batu cities).
Low-high clusters (n = 5) Areas with a low prevalence of TB are surrounded by areas with a high prevalence of TB.	*Capital city of Jakarta* (South Jakarta city); *West Java province* (Cirebon, Majalengka, and Sumedang districts); *Central Java province* (Cilacap district).
High-low clusters (n = 4) Areas with a high prevalence of TB are surrounded by areas with a low prevalence of TB.	*Central Java province* (Boyolali and Sukoharjo districts); *Special Region of Yogyakarta province* (Kulon Progo district); *East Java province* (Ngawi district).

Appendix 2: Geographically Weighted Regression Models for Each District in Java, Indonesia

No	Districts or cities	average years in education		poverty severity index		(%) proper ventilation		(%) proper lighting		(%) floor area per capita < 8 m²		(%) smoker		(%) easy access to health facilities	
		β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value
Capital city of Jakarta															
1	South Jakarta (city)	-0.0505	.076	-0.2671	.098	0.0014	.651	-0.0031	.507	0.0051	.236	0.0062	.472	-0.0059	.069
2	East Jakarta (city)	-0.0506	.075	-0.2663	.098	0.0014	.651	-0.0031	.507	0.0051	.234	0.0062	.474	-0.0059	.067
3	Central Jakarta (city)	-0.0506	.076	-0.2664	.099	0.0014	.648	-0.0031	.505	0.0051	.236	0.0062	.472	-0.0059	.070
4	West Jakarta (city)	-0.0506	.077	-0.2669	.100	0.0014	.647	-0.0031	.504	0.0051	.239	0.0063	.471	-0.0059	.072
5	North Jakarta (city)	-0.0506	.075	-0.2658	.100	0.0014	.646	-0.0031	.503	0.0051	.236	0.0062	.473	-0.0059	.070
West Java province															
6	Bogor (district)	-0.0503	.076	-0.2689	.093	0.0013	.660	-0.0030	.516	0.0051	.233	0.0062	.472	-0.0060	.064
7	Sukabumi (district)	-0.0501	.077	-0.2722	.087	0.0012	.675	-0.0028	.536	0.0051	.230	0.0061	.476	-0.0061	.058
8	Cianjur (district)	-0.0501	.072	-0.2688	.085	0.0012	.691	-0.0027	.547	0.0053	.215	0.0058	.489	-0.0063	.050
9	Bandung (district)	-0.0501	.066	-0.2628	.086	0.0010	.716	-0.0026	.561	0.0055	.194	0.0054	.512	**-0.0064**	**.042**
10	Garut (district)	-0.0503	.064	-0.2612	.085	0.0009	.753	-0.0024	.598	0.0056	.182	0.0050	.538	**-0.0065**	**.037**
11	Tasikmalaya (district)	-0.0507	.059	-0.2530	.091	0.0006	.835	-0.0019	.665	0.0060	.155	0.0042	.604	**-0.0067**	**.032**
12	Ciamis (district)	-0.0517	.053	-0.2421	.103	0.0004	.893	-0.0017	.698	0.0065	.129	0.0034	.670	**-0.0066**	**.032**
13	Kuningan (district)	**-0.0527**	**.049**	-0.2367	.110	0.0004	.888	-0.0018	.683	0.0068	.117	0.0031	.695	**-0.0065**	**.035**
14	Cirebon (district)	**-0.0532**	**.047**	-0.2377	.111	0.0006	.834	-0.0021	.641	0.0066	.122	0.0034	.673	**-0.0064**	**.038**
15	Majalengka (district)	-0.0515	.054	-0.2481	.098	0.0008	.771	-0.0024	.594	0.0061	.152	0.0043	.588	**-0.0064**	**.037**
16	Sumedang (district)	-0.0508	.059	-0.2551	.092	0.0010	.730	-0.0026	.565	0.0057	.175	0.0050	.541	**-0.0064**	**.040**

No	Districts or cities	average years in education		poverty severity index		(%) proper ventilation		(%) proper lighting		(%) floor area per capita < 8 m²		(%) smoker		(%) easy access to health facilities	
		β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value
17	Indramayu (district)	-0.0518	.055	-0.2498	.100	0.0010	.713	-0.0027	.550	0.0058	.166	0.0048	.557	**-0.0063**	**.043**
18	Subang (district)	-0.0509	.063	-0.2585	.094	0.0012	.682	-0.0029	.528	0.0055	.196	0.0055	.509	**-0.0062**	**.049**
19	Purwakarta (district)	-0.0505	.068	-0.2631	.092	0.0012	.676	-0.0029	.526	0.0053	.210	0.0058	.492	-0.0062	.052
20	Karawang (district)	-0.0507	.069	-0.2622	.097	0.0013	.656	-0.0030	.510	0.0053	.218	0.0059	.486	-0.0060	.059
21	Bekasi (district)	-0.0507	.072	-0.2643	.098	0.0013	.651	-0.0031	.507	0.0052	.228	0.0061	.478	-0.0060	.064
22	West Bandung (district)	-0.0501	.069	-0.2643	.088	0.0011	.692	-0.0028	.540	0.0054	.206	0.0057	.494	**-0.0063**	**.047**
23	Pangandaran (district)	-0.0522	.055	-0.2374	.110	0.0000	.990	-0.0010	.817	0.0069	.120	0.0025	.753	**-0.0067**	**.032**
24	Bogor (city)	-0.0503	.076	-0.2688	.093	0.0013	.661	-0.0030	.517	0.0051	.232	0.0062	.473	-0.0060	.063
25	Sukabumi (city)	-0.0500	.075	-0.2695	.088	0.0012	.676	-0.0029	.531	0.0052	.224	0.0061	.477	-0.0061	.055
26	Bandung (city)	-0.0502	.066	-0.2614	.088	0.0011	.707	-0.0027	.549	0.0055	.195	0.0055	.508	**-0.0063**	**.043**
27	Cirebon (city)	**-0.0532**	**.047**	-0.2376	.111	0.0006	.834	-0.0021	.641	0.0066	.121	0.0034	.673	**-0.0064**	**.038**
28	Bekasi (city)	-0.0506	.074	-0.2659	.097	0.0013	.652	-0.0031	.508	0.0051	.231	0.0061	.475	-0.0060	.066
29	Depok (city)	-0.0504	.076	-0.2677	.096	0.0013	.655	-0.0030	.511	0.0051	.234	0.0062	.472	-0.0060	.066
30	Cimahi (city)	-0.0502	.067	-0.2626	.088	0.0011	.698	-0.0028	.544	0.0054	.200	0.0056	.502	**-0.0063**	**.045**
31	Tasikmalaya (city)	-0.0510	.057	-0.2501	.094	0.0006	.837	-0.0020	.659	0.0061	.149	0.0041	.612	**-0.0066**	**.032**
32	Banjar (city)	-0.0526	.052	-0.2357	.112	0.0001	.972	-0.0013	.768	0.0070	.114	0.0026	.741	**-0.0066**	**.033**
Central Java province															
33	Cilacap (district)	**-0.0567**	**.049**	-0.2156	.146	-0.0008	.774	0.0001	.977	0.0087	.081	0.0000	.997	**-0.0064**	**.045**
34	Banyumas (district)	**-0.0601**	**.047**	-0.1965	.176	-0.0015	.597	0.0011	.814	0.0106	.058	-0.0021	.804	-0.0061	.060

No	Districts or cities	average years in education		poverty severity index		(%) proper ventilation		(%) proper lighting		(%) floor area per capita < 8 m²		(%) smoker		(%) easy access to health facilities	
		β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value
35	Purbalingga (district)	**-0.0677**	**.040**	-0.1871	.194	-0.0021	.481	0.0020	.666	**0.0132**	**.047**	-0.0047	.610	-0.0057	.095
36	Banjarnegara (district)	**-0.0704**	**.043**	-0.1708	.227	-0.0026	.383	0.0029	.546	**0.0156**	**.042**	-0.0073	.451	-0.0055	.114
37	Kebumen (district)	-0.0660	.055	-0.1689	.232	-0.0027	.357	0.0033	.502	0.0149	.050	-0.0069	.472	-0.0058	.095
38	Purworejo (district)	-0.0618	.063	-0.1403	.300	-0.0027	.349	0.0030	.539	0.0148	.050	-0.0082	.377	-0.0057	.084
39	Wonosobo (district)	-0.0663	.050	-0.1495	.274	-0.0026	.369	0.0028	.565	**0.0154**	**.043**	-0.0082	.385	-0.0055	.098
40	Magelang (district)	-0.0588	.066	-0.1204	.361	-0.0025	.372	0.0025	.623	0.0137	.061	-0.0088	.321	-0.0052	.099
41	Boyolali (district)	-0.0522	.089	-0.0864	.504	-0.0023	.431	0.0016	.765	0.0103	.174	-0.0107	.216	-0.0043	.171
42	Klaten (district)	-0.0507	.099	-0.0868	.504	-0.0024	.421	0.0019	.730	0.0104	.172	-0.0105	.225	-0.0046	.148
43	Sukoharjo (district)	-0.0466	.119	-0.0706	.580	-0.0022	.454	0.0014	.808	0.0085	.261	-0.0111	.195	-0.0041	.197
44	Wonogiri (district)	-0.0422	.148	-0.0604	.630	-0.0023	.445	0.0013	.811	0.0075	.315	-0.0110	.190	-0.0039	.217
45	Karanganyar (district)	-0.0434	.137	-0.0605	.628	-0.0022	.445	0.0012	.833	0.0073	.322	-0.0112	.182	-0.0037	.243
46	Sragen (district)	-0.0458	.121	-0.0633	.614	-0.0022	.459	0.0010	.857	0.0075	.311	-0.0115	.176	-0.0036	.255
47	Grobogan (district)	-0.0472	.110	-0.0692	.581	-0.0023	.436	0.0011	.841	0.0082	.265	-0.0107	.202	-0.0036	.242
48	Blora (district)	-0.0401	.159	-0.0506	.676	-0.0025	.380	0.0012	.826	0.0062	.397	-0.0112	.173	-0.0029	.347
49	Rembang (district)	-0.0402	.158	-0.0492	.684	-0.0026	.370	0.0011	.835	0.0060	.413	-0.0113	.169	-0.0027	.386
50	Pati (district)	-0.0475	.108	-0.0636	.611	-0.0022	.446	0.0007	.895	0.0074	.314	-0.0112	.181	-0.0031	.315
51	Kudus (district)	-0.0513	.089	-0.0737	.562	-0.0022	.459	0.0008	.883	0.0086	.245	-0.0110	.194	-0.0034	.271
52	Jepara (district)	-0.0546	.075	-0.0814	.526	-0.0022	.461	0.0007	.888	0.0096	.193	-0.0106	.212	-0.0035	.265
53	Demak (district)	-0.0564	.070	-0.0920	.477	-0.0023	.440	0.0013	.808	0.0109	.142	-0.0104	.225	-0.0040	.200
54	Semarang (district)	-0.0568	.070	-0.1032	.429	-0.0024	.402	0.0019	.708	0.0122	.101	-0.0099	.257	-0.0046	.142

No	Districts or cities	average years in education		poverty severity index		(%) proper ventilation		(%) proper lighting		(%) floor area per capita < 8 m²		(%) smoker		(%) easy access to health facilities	
		β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value
55	Temanggung (district)	-0.0650	.050	-0.1337	.318	-0.0025	.379	0.0025	.615	**0.0150**	**.048**	-0.0091	.320	-0.0052	.112
56	Kendal (district)	**-0.0665**	**.045**	-0.1345	.314	-0.0024	.402	0.0021	.663	**0.0151**	**.043**	-0.0090	.325	-0.0050	.123
57	Batang (district)	**-0.0728**	**.036**	-0.1589	.252	-0.0024	.408	0.0024	.613	**0.0164**	**.035**	-0.0084	.386	-0.0051	.129
58	Pekalongan (district)	**-0.0745**	**.033**	-0.1769	.216	-0.0023	.438	0.0024	.618	**0.0157**	**.037**	-0.0070	.471	-0.0052	.133
59	Pemalang (district)	**-0.0683**	**.034**	-0.1893	.190	-0.0017	.569	0.0012	.788	**0.0126**	**.040**	-0.0040	.659	-0.0055	.095
60	Tegal (district)	**-0.0629**	**.036**	-0.2017	.171	-0.0011	.720	0.0003	.943	0.0103	.052	-0.0017	.845	-0.0059	.069
61	Brebes (district)	**-0.0573**	**.041**	-0.2159	.144	-0.0004	.891	-0.0007	.881	0.0084	.073	0.0006	.943	**-0.0063**	**.046**
62	Magelang (city)	-0.0599	.063	-0.1231	.352	-0.0025	.371	0.0025	.616	0.0140	.059	-0.0089	.319	-0.0052	.100
63	Surakarta (city)	-0.0468	.116	-0.0729	.566	-0.0023	.435	0.0014	.793	0.0087	.239	-0.0106	.211	-0.0041	.191
64	Salatiga (city)	-0.0557	.075	-0.1005	.440	-0.0024	.402	0.0019	.708	0.0119	.109	-0.0099	.255	-0.0046	.141
65	Semarang (city)	-0.0602	.058	-0.1135	.385	-0.0023	.409	0.0018	.723	0.0132	.068	-0.0091	.297	-0.0047	.138
66	Pekalongan (city)	**-0.0762**	**.029**	-0.1740	.222	-0.0022	.457	0.0022	.652	**0.0161**	**.033**	-0.0073	.452	-0.0051	.144
67	Tegal (city)	**-0.0624**	**.034**	-0.2047	.167	-0.0007	.807	-0.0002	.968	0.0098	.053	-0.0010	.904	-0.0059	.065
Special Region of Yogyakarta															
68	Kulon Progo (district)	-0.0569	.076	-0.1224	.357	-0.0026	.353	0.0028	.569	0.0137	.062	-0.0085	.341	-0.0056	.082
69	Bantul (district)	-0.0533	.090	-0.1066	.418	-0.0026	.364	0.0027	.603	0.0125	.093	-0.0093	.291	-0.0053	.095
70	Gunung Kidul (district)	-0.0483	.115	-0.0847	.515	-0.0024	.416	0.0021	.704	0.0102	.180	-0.0103	.234	-0.0048	.131
71	Sleman (district)	-0.0548	.082	-0.1067	.417	-0.0026	.373	0.0025	.628	0.0126	.095	-0.0096	.276	-0.0051	.107
72	Yogyakarta (city)	-0.0539	.087	-0.1063	.419	-0.0026	.369	0.0026	.618	0.0125	.095	-0.0094	.283	-0.0052	.101

No	Districts or cities	average years in education		poverty severity index		(%) proper ventilation		(%) proper lighting		(%) floor area per capita < 8 m²		(%) smoker		(%) easy access to health facilities	
		β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value
East Java province															
73	Pacitan (district)	-0.0386	.178	-0.0542	.660	-0.0024	.409	0.0015	.782	0.0069	.348	-0.0107	.197	-0.0037	.236
74	Ponorogo (district)	-0.0362	.199	-0.0482	.689	-0.0027	.356	0.0017	.758	0.0062	.394	-0.0106	.192	-0.0032	.303
75	Trenggalek (district)	-0.0348	.217	-0.0465	.699	-0.0027	.339	0.0019	.735	0.0062	.401	-0.0105	.199	-0.0032	.312
76	Tulungagung (district)	-0.0338	.232	-0.0439	.714	-0.0029	.311	0.0020	.717	0.0059	.420	-0.0104	.201	-0.0029	.356
77	Blitar (district)	-0.0327	.250	-0.0414	.731	-0.0031	.284	0.0022	.697	0.0058	.436	-0.0104	.208	-0.0027	.404
78	Kediri (district)	-0.0336	.236	-0.0421	.726	-0.0030	.293	0.0020	.713	0.0058	.436	-0.0105	.198	-0.0027	.399
79	Malang (district)	-0.0320	.265	-0.0392	.747	-0.0033	.264	0.0023	.681	0.0057	.447	-0.0103	.216	-0.0024	.451
80	Lumajang (district)	-0.0313	.280	-0.0372	.762	-0.0034	.248	0.0025	.669	0.0056	.456	-0.0103	.227	-0.0022	.498
81	Jember (district)	-0.0308	.294	-0.0357	.775	-0.0035	.238	0.0026	.660	0.0056	.461	-0.0102	.239	-0.0021	.533
82	Banyuwangi (district)	-0.0305	.304	-0.0345	.784	-0.0036	.231	0.0027	.654	0.0056	.463	-0.0101	.250	-0.0019	.561
83	Bondowoso (district)	-0.0308	.297	-0.0345	.784	-0.0036	.232	0.0026	.660	0.0056	.467	-0.0102	.240	-0.0019	.560
84	Situbondo (district)	-0.0308	.298	-0.0340	.787	-0.0036	.230	0.0026	.660	0.0056	.470	-0.0103	.241	-0.0019	.571
85	Probolinggo (district)	-0.0313	.282	-0.0362	.770	-0.0035	.243	0.0025	.670	0.0056	.463	-0.0103	.227	-0.0021	.522
86	Pasuruan (district)	-0.0320	.266	-0.0378	.757	-0.0034	.255	0.0023	.683	0.0056	.459	-0.0105	.214	-0.0023	.487
87	Sidoarjo (district)	-0.0325	.257	-0.0380	.756	-0.0033	.258	0.0022	.693	0.0055	.462	-0.0106	.206	-0.0022	.489
88	Mojokerto (district)	-0.0328	.250	-0.0392	.746	-0.0032	.268	0.0022	.700	0.0056	.455	-0.0106	.202	-0.0024	.462
89	Jombang (district)	-0.0334	.239	-0.0405	.737	-0.0031	.280	0.0021	.711	0.0056	.449	-0.0106	.197	-0.0025	.437

No	Districts or cities	average years in education		poverty severity index		(%) proper ventilation		(%) proper lighting		(%) floor area per capita < 8 m²		(%) smoker		(%) easy access to health facilities	
		β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value
90	Nganjuk (district)	-0.0345	.221	-0.0431	.719	-0.0030	.304	0.0019	.731	0.0058	.434	-0.0107	.191	-0.0027	.392
91	Madiun (district)	-0.0360	.201	-0.0462	.700	-0.0028	.336	0.0017	.758	0.0060	.414	-0.0108	.186	-0.0030	.346
92	Magetan (district)	-0.0383	.176	-0.0508	.675	-0.0025	.380	0.0015	.790	0.0064	.382	-0.0109	.185	-0.0033	.296
93	Ngawi (district)	-0.0393	.167	-0.0513	.672	-0.0025	.385	0.0013	.807	0.0064	.384	-0.0110	.180	-0.0032	.310
94	Bojonegoro (district)	-0.0358	.204	-0.0441	.713	-0.0029	.317	0.0017	.757	0.0058	.434	-0.0109	.182	-0.0027	.396
95	Tuban (district)	-0.0360	.203	-0.0429	.721	-0.0029	.308	0.0016	.763	0.0056	.446	-0.0110	.178	-0.0025	.429
96	Lamongan (district)	-0.0338	.233	-0.0397	.743	-0.0032	.276	0.0020	.721	0.0055	.459	-0.0108	.191	-0.0023	.466
97	Gresik (district)	-0.0331	.246	-0.0383	.753	-0.0033	.264	0.0021	.707	0.0055	.465	-0.0108	.197	-0.0022	.489
98	Bangkalan (district)	-0.0324	.261	-0.0362	.768	-0.0034	.249	0.0023	.693	0.0054	.473	-0.0107	.206	-0.0020	.529
99	Sampang (district)	-0.0319	.273	-0.0350	.778	-0.0035	.240	0.0024	.683	0.0054	.476	-0.0106	.215	-0.0019	.553
100	Pamekasan (district)	-0.0316	.280	-0.0342	.784	-0.0036	.235	0.0024	.677	0.0054	.478	-0.0106	.221	-0.0019	.568
101	Sumenep (district)	-0.0313	.288	-0.0332	.792	-0.0036	.230	0.0025	.672	0.0054	.481	-0.0105	.227	-0.0018	.588
102	Kediri (city)	-0.0338	.232	-0.0426	.722	-0.0030	.299	0.0020	.718	0.0058	.433	-0.0106	.197	-0.0027	.389
103	Blitar (city)	-0.0329	.246	-0.0418	.728	-0.0031	.289	0.0021	.701	0.0058	.434	-0.0104	.206	-0.0027	.396
104	Malang (city)	-0.0321	.263	-0.0390	.748	-0.0033	.264	0.0023	.684	0.0057	.450	-0.0104	.214	-0.0024	.457
105	Probolinggo (city)	-0.0315	.278	-0.0364	.768	-0.0035	.245	0.0025	.673	0.0056	.463	-0.0104	.223	-0.0021	.517
106	Pasuruan (city)	-0.0320	.268	-0.0373	.761	-0.0034	.252	0.0023	.682	0.0056	.462	-0.0105	.214	-0.0022	.498
107	Mojokerto (city)	-0.0330	.246	-0.0394	.745	-0.0032	.270	0.0021	.704	0.0056	.456	-0.0106	.200	-0.0024	.461
108	Madiun (city)	-0.0369	.191	-0.0478	.691	-0.0027	.352	0.0016	.771	0.0061	.403	-0.0108	.185	-0.0031	.327
109	Surabaya (city)	-0.0326	.256	-0.0376	.759	-0.0033	.257	0.0022	.696	0.0055	.466	-0.0107	.204	-0.0022	.500
110	Batu (city)	-0.0324	.256	-0.0394	.745	-0.0032	.267	0.0022	.691	0.0056	.451	-0.0105	.208	-0.0024	.453

No	Districts or cities	average years in education		poverty severity index		(%) proper ventilation		(%) proper lighting		(%) floor area per capita < 8 m²		(%) smoker		(%) easy access to health facilities	
		β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value	β	*p* value
Banten province															
111	Pandeglang (district)	-0.0503	.084	-0.2740	.097	0.0014	.655	-0.0030	.515	0.0050	.252	0.0065	.462	-0.0058	.079
112	Lebak (district)	-0.0502	.081	-0.2724	.094	0.0013	.657	-0.0030	.516	0.0050	.245	0.0064	.465	-0.0059	.072
113	Tangerang (district)	-0.0506	.079	-0.2684	.100	0.0014	.647	-0.0031	.505	0.0050	.244	0.0064	.468	-0.0058	.075
114	Serang (district)	-0.0506	.082	-0.2702	.102	0.0014	.646	-0.0031	.505	0.0050	.251	0.0065	.464	-0.0057	.082
115	Tangerang (city)	-0.0506	.078	-0.2677	.100	0.0014	.647	-0.0031	.505	0.0051	.241	0.0063	.469	-0.0058	.073
116	Cilegon (city)	-0.0507	.083	-0.2699	.105	0.0014	.643	-0.0031	.502	0.0050	.255	0.0065	.464	-0.0057	.087
117	Serang (city)	-0.0506	.082	-0.2700	.102	0.0014	.645	-0.0031	.504	0.0050	.251	0.0065	.465	-0.0057	.082
118	South Tangerang (city)	-0.0505	.077	-0.2680	.098	0.0014	.651	-0.0031	.508	0.0051	.238	0.0063	.470	-0.0059	.070

Note: β = adjusted regression coefficient; % = percentage; m = meter; bold = p < .05