



Available online at <http://scik.org>

Commun. Math. Biol. Neurosci. 2020, 2020:53

<https://doi.org/10.28919/cmbn/4804>

ISSN: 2052-2541

SPATIAL DISTRIBUTION OF TUBERCULOSIS DISEASE AMONG MEN AND WOMEN IN BANDUNG CITY, INDONESIA

I. GEDE NYOMAN MINDRA JAYA^{1,2,*}, BUDI NURANI RUCHJANA³, ATJE SETIAWAN ABDULLAH⁴,
TONI TOHARUDIN¹

¹Department of Statistics, Padjadjaran University, Bandung, Indonesia

²Faculty of Spatial Science, Groningen University, Groningen, Netherlands

³Department of Mathematics, Padjadjaran University, Bandung, Indonesia

⁴Department of Computer Science, Padjadjaran University, Bandung, Indonesia

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Abstract: Tuberculosis (TB) is still a serious health problem particularly in developing countries caused by bacteria (*Mycobacterium tuberculosis*) that most often affect the lungs. Tuberculosis is curable and preventable. In general, tuberculosis (TB) incidences rates are usually higher in men than in women, but it has similar spatial distribution with a very high positive correlation. This study evaluated the spatial distribution of Tuberculosis Disease among men and women in Bandung City, Indonesia by means Bayesian shared component model. We found the joint effects dominated the spatial variation of TB for men and women which indicates there are similar risk factors that influence the spatial distribution of TB for men and women. The factors could be a health facility, health behaviours, and environmental factors. By knowing, the spatial pattern of TB for men and women, the government may use this information to develop an effective and efficient strategy to control TB transmission.

Keywords: tuberculosis; Bayesian; spatial; Bandung.

2010 AMS Subject Classification: 92B20.

*Corresponding author

E-mail address: mindra@unpad.ac.id

Received June 25, 2020

1. INTRODUCTION

Tuberculosis (TB) is caused by bacteria (*Mycobacterium tuberculosis*) that most often affect the lungs. To date, it is still a serious health problem particularly in developing countries with low health facility and health behaviors [1]. Tuberculosis is curable and preventable. However, it is among the leading causes of death from infectious disease [2]. In 2018, a total of 1.5 million people died from TB and recorded as the one of the top 10 causes of death and the leading cause from a single infectious agent (above HIV/AIDS) [1]. The previous studies reported tuberculosis (TB) incidences rates are usually higher in men than in women [3] [4] [5] [6] [7]. Globally, men are more likely to be diagnosed with TB than women, with a male-to-female ratio of 1.6:1 [4].

TB transmission are commonly found occurs within a household or community, leading to heterogeneous spatial patterns [8]. A clear spatial clustering of TB could reflect ongoing transmission and causative risk factors. In order to develop efficiency and effective strategy to control and prevent TB transmission, identify the hotspot of TB and its spatial distribution by gender are required. It is important to evaluate the disease transmission considering gender to find more accurately the risk factors that have a significant effect in explaining the disease variation over space [9].

The ratio in Bandung was recorded 1.3:1. Several factors are suspected to contribute to the different number of cases based on gender such as healthy life behaviors. This study was conducted to evaluate gender differentials in TB for sub-districts in Bandung city. Data exploration shows in several sub-district the ratio higher than 1.3:1. However, there is a high positive correlation between the number of TB between men and women which indicates there are shared effects that influence by similar risk factors. The Bayesian shared component model reported the shared effect dominated the spatial variation of TB for men and women which is indicated by the standard deviation of the hyperparameter. The standard deviation estimate of the joint spatial effects is much higher than the standard deviation estimate of the individual spatial effects. In this study, we propose to use spatial joint modelling by mean Bayesian approach to explore the geographical variation of TB risk for men and women in Bandung, Indonesia. To data, the TB positive cases in

Bandung are still high with the ratio between men and women is 1.2:1. Bayesian shared component model is better to be used to strengthen inference and correct for any spatially structured sources of bias, when distinct data sources on one or more related diseases are available [10].

2. MATERIAL AND METHODS

Material

Bandung is a capital city of West Java, Indonesia with very dense population. In 2018, the population of Bandung are 2,452,179 inhabitants. TB is still becomes health issue because the number of incidences were still high. TB and population at risk data were collected from Bandung city health office. It can be accessed for free from <http://data.bandung.go.id/>.

Method

Based on the model that have been developed by Knorr-Held and Besag (2001) [11], we propose the following model:

$$y_{ji} \sim P(E_{ji}\theta_{ji}) \quad j = \{Men, Women\}, \quad i = 1, \dots, 30$$

where E_{ji} denotes the expected count for group j at location i which is defined as:

$$E_{ji} = N_{ji} \times \frac{\sum_{i=1}^{30} y_{ji}}{\sum_{i=1}^{30} N_{ji}}$$

and θ_{ji} is the relative risk for group j at location i . The relative risk θ_{ji} is commonly modeled using log linear model by defining the expected count E_{ji} as the offset variable.

$$\log(\theta_{ji}) = \eta_{ji} = offset(\log E_{ji}) + \alpha(j) + \gamma(j)\psi_i + \phi_{ji} + e_{ji}$$

where $\alpha(j)$ is the intercept (overall risk) for man and women, ψ_i is the joint spatial component and

$$\gamma(j) = \begin{cases} 1 & \text{if } j = \text{man} \\ \delta & \text{if } j = \text{women} \end{cases}$$

The last two components ϕ_{ji} and e_{ji} are the spatially structured and unstructured components.

For the spatially structured component is assumed follow iCAR prior [12] and for unstructured is exchangeable prior (iid). The model is estimated using R-INLA [13]

3. MAIN RESULTS

Data exploration

Tuberculosis (TB) was found in all sub-district in Bandung city. In 2018, the official health reported of 11,000 number of TB cases with the ratio between men and women is 1.2:1. The descriptive of statistics are presented in Table 1.

Table 1. Descriptive of statistics

Variables	Mean	Minimum	Maximum
TB of Men	20	5	57
TB of Women	16	1	40
Population at risk of Men	41,112	12,654	69,904
Population at risk of Women	40,627	12,158	67,173

The high incidences were found in the southwest, northern, and center regions of Bandung (see Fig.1).

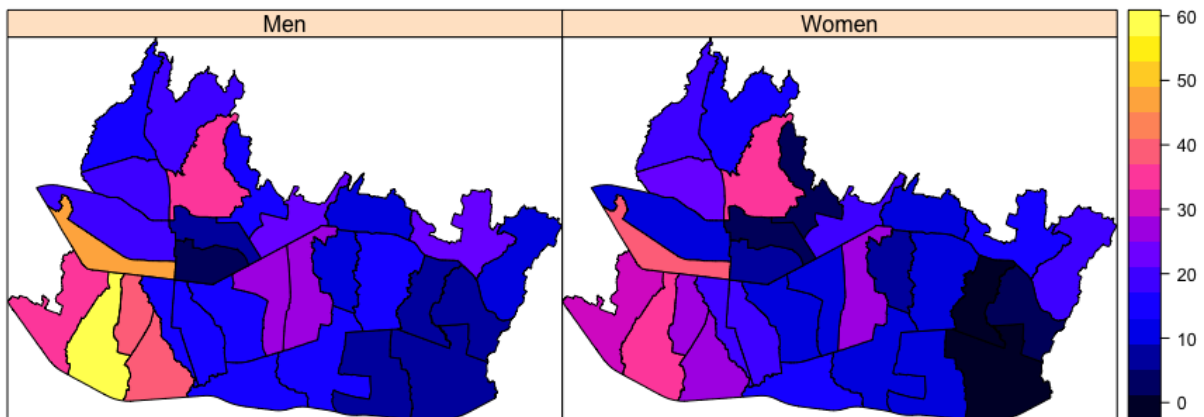


Figure 1. Number of Tuberculosis by Gender and sub-district

SPATIAL DISTRIBUTION OF TUBERCULOSIS DISEASE AMONG MEN AND WOMEN

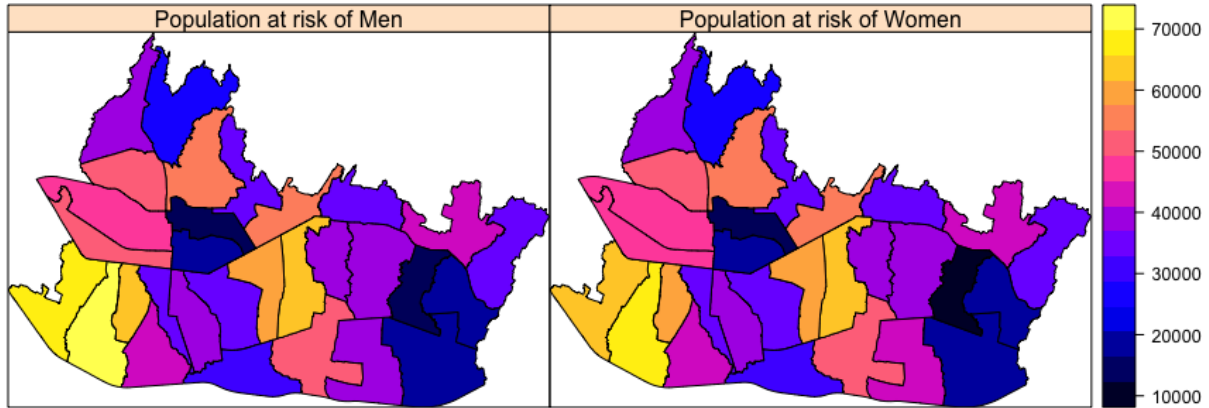


Figure 2. Number of Population at risk by gender and sub-district

Figure 2 shows the population at risk for men and women. There is a similar spatial pattern between the number of incidences and populations at risk. The southern regions have high number of incidence and population at risk.

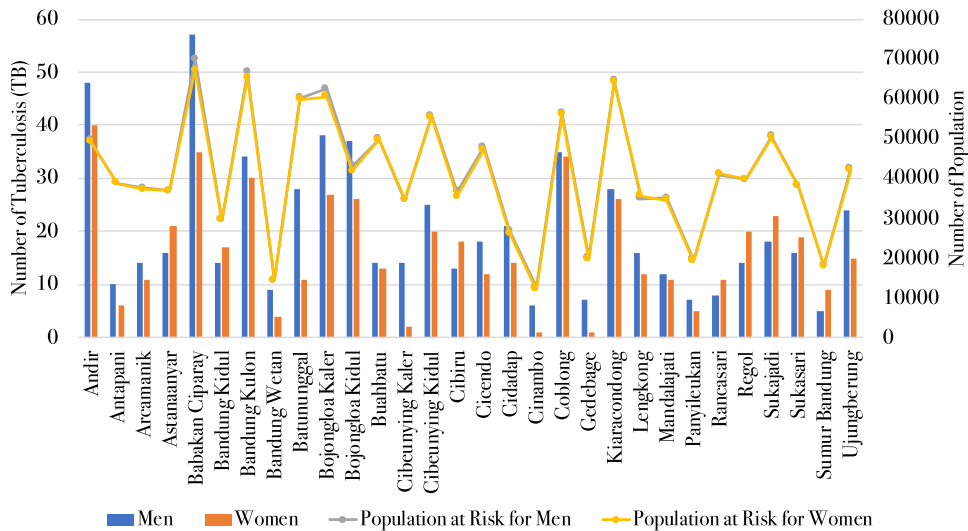


Figure 3. Number of Tuberculosis (TB) and Population at Risk per sub-district

Figure 3 presents the similar patterns are more clearly between the number of TB for men and women and the population at risk.

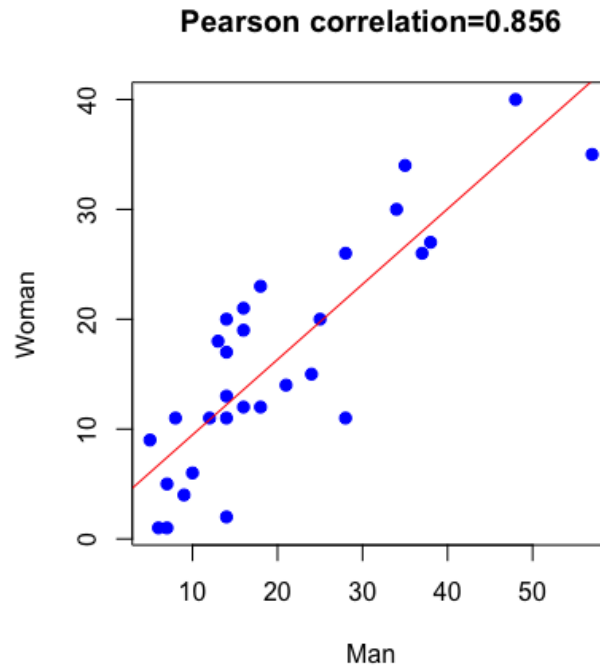


Figure 4. Number of Tuberculosis (TB) and Population at Risk per sub-district

The correlation between TB men and women based on sub-district observations of 0.856 which indicates there is a strong correlation. Figure 4 shows that there is evidence of a common spatial pattern in both gender.

Bayesian shared component model

In this section we present an advanced spatial analysis, in which both genders are analyzed simultaneously. In this case, the statistical model assumes a joint spatial effect that is shared between the two gender categories, men and women.

Table 2. Fixed effects estimates

	mean	S.E	0.025quant	0.5quant	0.975quant
Alpha Man	-0.078	0.046	-0.170	-0.077	0.012
Alpha Women	-0.099	0.053	-0.205	-0.098	0.004

Table 2 shows the intercept of the log-linear model. The exponential of the intercept is

represented the overall risk of TB for each gender. For men the overall risk is $exp(-0.078) = 0.925$ and for women $exp(-0.099) = 0.906$. The overall risk TB of men slightly higher than women. The density of both intercepts are presented in Figure 5.

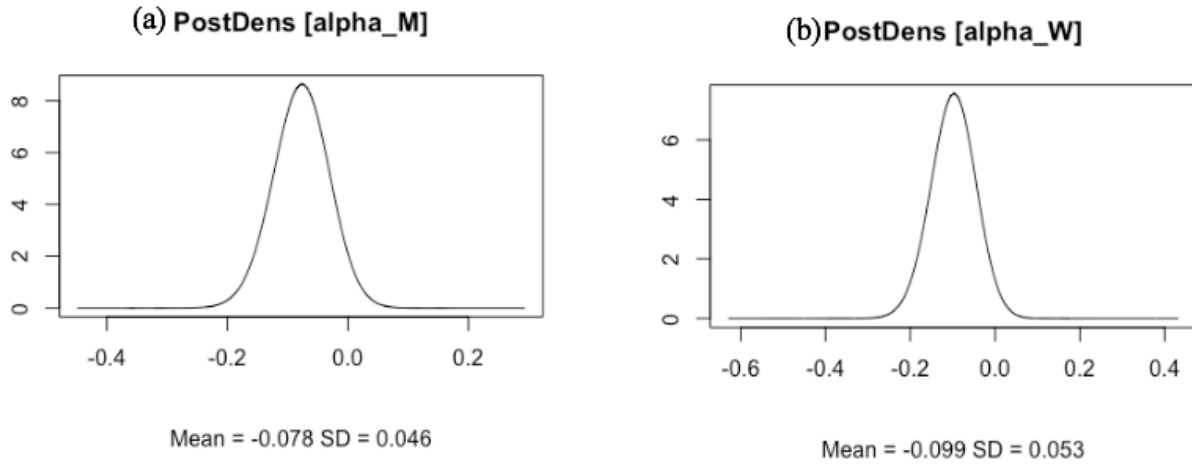


Figure 4. Intercept of (a) Man and (b) Woman Models

Table 3. Posterior mean of standard deviation (SD) of the random effects

Components	mean	S.E	q0.025	q0.5	q0.975
SD shared	0.430	0.098	0.260	0.422	0.644
SD spatial structured Men	0.044	0.031	0.013	0.035	0.127
SD spatial unstructured Men	0.055	0.047	0.014	0.040	0.183
SD spatial structured Women	0.065	0.061	0.016	0.045	0.231
SD spatial unstructured Women	0.080	0.089	0.017	0.051	0.319
Delta	1.208	0.253	0.739	1.195	1.729

Table 3 shows the standard deviation of the hyperprior parameter. The higher value of the standard deviation explains that the random effect component has higher effects in explaining the spatial variation of TB for each gender. Here we found the joint spatial effect is the most important component. The distribution of each component is presented in Figure 5.

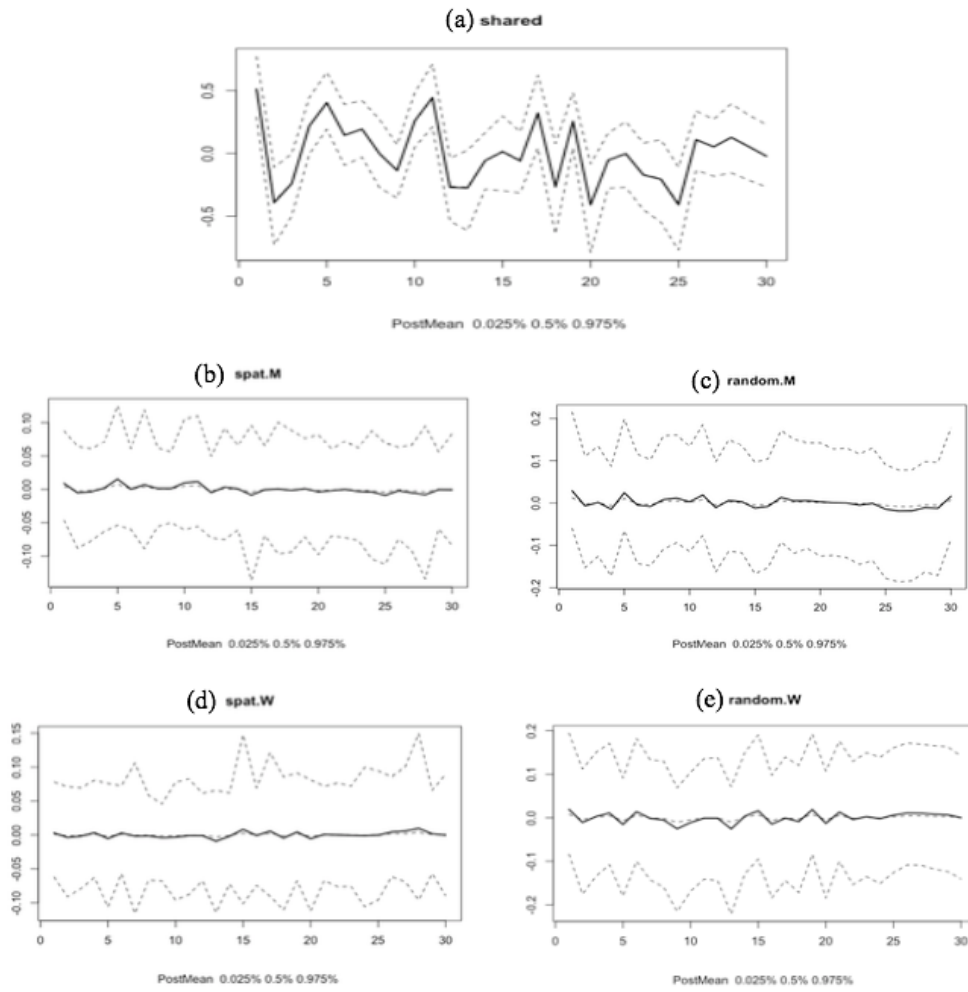


Figure 5. Spatial distribution of hyperparameters

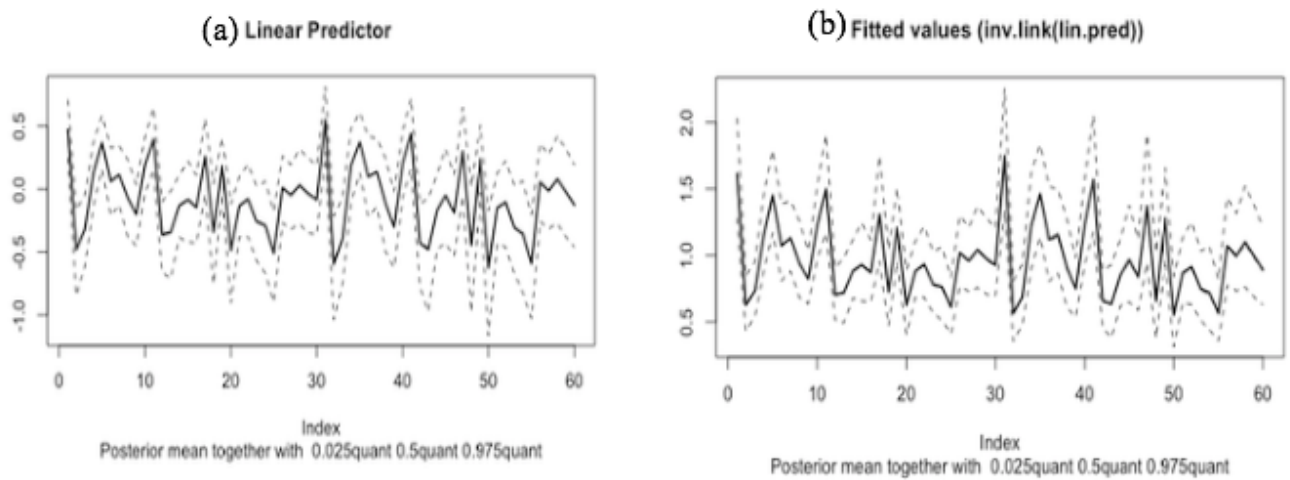


Figure 6. (a) Linear predictor and (b) fitted values of TB

SPATIAL DISTRIBUTION OF TUBERCULOSIS DISEASE AMONG MEN AND WOMEN

Figure 6 shows the linear predictor and fitted values of the Bayesian shared component model. Both of statistics have tight 95% credible interval which indicate the model is better fit to the data. For more advance model validation is presented in Figure 7.

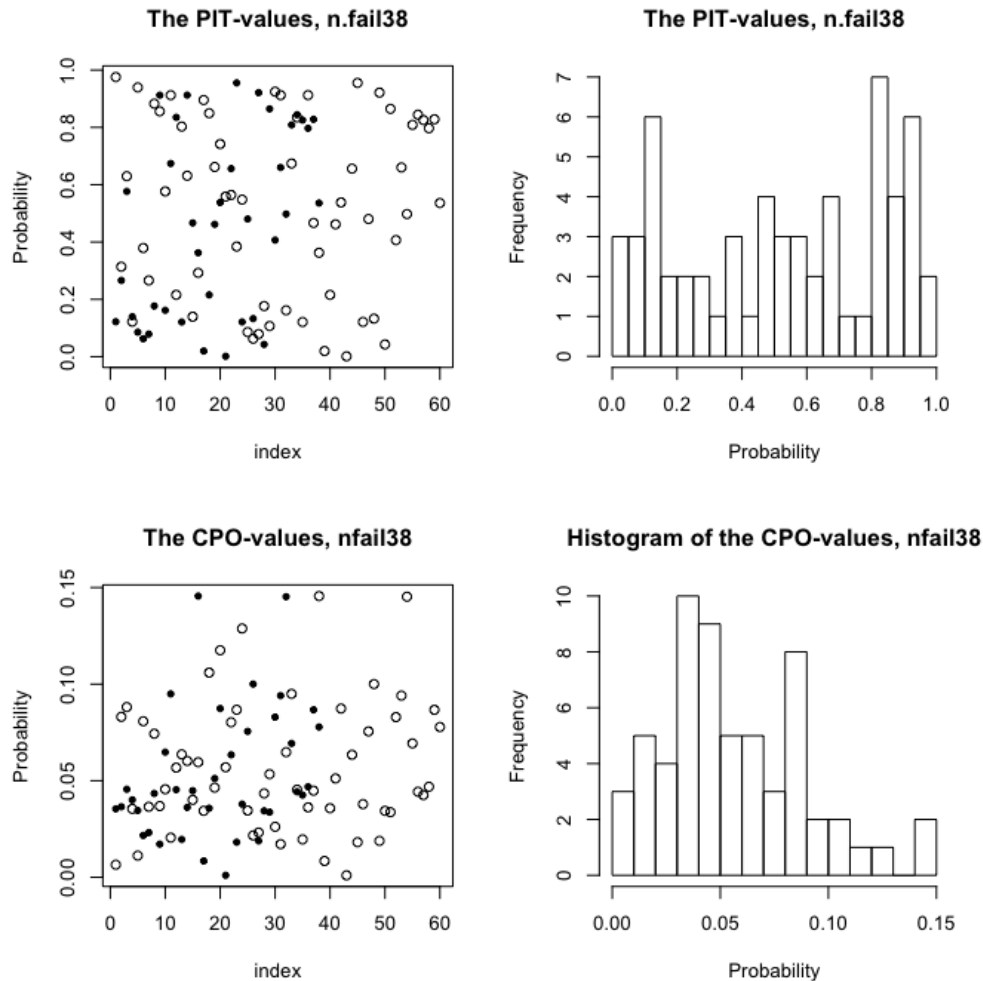


Figure 7. Model Validation

In Bayesian approach, predicted integral transform (PIT) and conditional predictive ordinate (CPO) are commonly used to evaluate model validity. Those statistics are the leave-one-out cross-validation. Figure 7 shows that the distribution of the PITs is close to a uniform distribution, suggesting that the model reasonably fits the data. Finally, based on Bayesian shared component

model we estimate the relative risk of TB for men and women presented in Figure 8.

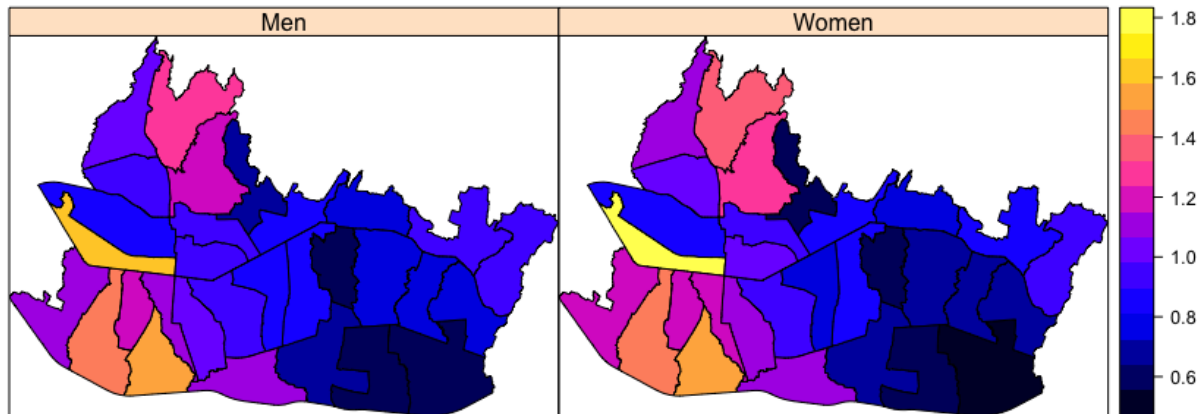


Figure 8. Relative Risk Estimate of TB (BTA+) for Men and Women

We found the spatial pattern of TB for both genders is similar. The high risks of TB were found in the southwest and northern region of Bandung while for the eastern of Bandung, the risk of TB is relatively low.

4. DISCUSSION

The differential issue of gender in tuberculosis (TB) have been discussed worldwide [4]. Globally, men are more likely to be diagnosed with TB than women, with a male-to-female ratio of 1.6:1 [4]. The ratio in Bandung was recorded 1.3:1. Several factors are suspected to contribute to the different number of cases based on gender such as healthy life behaviors. This study was conducted to evaluate gender differentials in TB for sub-districts in Bandung city. Data exploration shows in several sub-district the ratio higher than 1.3:1. However, there is a high positive correlation between the number of TB between men and women which indicates there are shared effects that influence by similar risk factors. The Bayesian shared component model reported the shared effect dominated the spatial variation of TB for men and women which is indicated by the standard deviation of the hyperparameter. The standard deviation estimate of the joint spatial effects is much higher than the standard deviation estimate of the individual spatial effects. Therefore, it can be

explained that the joint spatial effects have captured the spatial variability of the data. Moreover, the standard deviation estimate of the random effects for both men and women groups is small, which indicates that there is no other important source of variability in the data. The basic point of the proposed model is to observe the joint spatial pattern and to understand the effect of the individual spatial pattern of each gender. Based on the estimation of a statistic that measures the differences patterns between men and women we found there is a slight difference of 1.208. Based on the shared component model, we found the high-risk of TB for men and women are generally in southwest and northern of Bandung with the relative risk higher than its expected count. By knowing, the spatial pattern of TB for men and women is similar which indicates they have similar risk factors, the government may use this information to develop an effective and efficient strategy to control TB transmission.

5. CONCLUSION

In general, tuberculosis (TB) incidences rates are more likely higher in men than in women, but it has similar spatial distribution with a very high positive correlation. The spatial distribution of TB for men and women in Bandung city, Indonesia are dominated by the joint effects which indicates there are similar risk factors that influence the spatial distribution of TB for men and women. Although men are more likely to be infected with TB than women, risk factors related to space are found to be the same.

ACKNOWLEDGEMENT

We thank the Health Office of the city of Bandung for supplying the data on the spatiotemporal weather risk factors, Dengue incidence, and population size. Financial support was received from ALG Unpad contract: 1427/UN6.3.1/LT/2020.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

REFERENCES

- [1] WHO, Tuberculosis, WHO, 24 March (2020). [Online]. Available: <https://www.who.int/news-room/factsheets/detail/tuberculosis>. [Accessed 26 June 2020].
- [2] S. Nhamoyebonde, A. Leslie, Biological Differences Between the Sexes and Susceptibility to Tuberculosis, *J. Infect. Dis.* 209 (2014), S100–S106.
- [3] K.C. Horton, P. MacPherson, R.M.G.J. Houben, R.G. White, E.L. Corbett, Sex Differences in Tuberculosis Burden and Notifications in Low- and Middle-Income Countries: A Systematic Review and Meta-analysis, *PLoS Med.* 13 (2016), e1002119.
- [4] R. Marçôa, A. Ribeiro, R. Duarte, Tuberculosis and gender – Factors influencing the risk of tuberculosis among men and women by age group, *Pulmonol. J.* 24 (3) (2018), 199-202.
- [5] WHO, Tuberculosis and gender, WHO, 1 January (2020). [Online]. Available: <https://www.who.int/tb/areas-of-work/population-groups/gender/en/>. [Accessed 26 June 2020].
- [6] WHO, Gender and tuberculosis, WHO, 20 January (2020). [Online]. Available: <https://www.who.int/gender-equity-rights/knowledge/a85584/en/>. [Accessed 26 June 2020].
- [7] S. Rao, Tuberculosis and patient gender: An analysis and its implications in tuberculosis control, *Lung India*, 26(2) (2009), 46-47.
- [8] D. Shaweno, M. Karmakar, K.A. Alene, R. Ragonnet, A.C. Clements, J.M. Trauer, J.T. Denholm, E.S. McBryde, Methods used in the spatial analysis of tuberculosis epidemiology: a systematic review, *BMC Med.* 16 (2018), 193.
- [9] D. Westergaard, P. Moseley, F.K.H. Sørup, P. Baldi, S. Brunak, Population-wide analysis of differences in disease progression patterns in men and women, *Nat Commun.* 10 (2019), 666.
- [10] S. Ancelet, J.J. Abellan, D.R.V.J. Vilas, C. Birch, S. Richardson, Bayesian shared spatial - component models to combine and borrow strength across sparse disease surveillance sources, *Biometric. J.* 54(3) (2012), 385-404.
- [11] L. Knorr-Held, N. G. Best, A Shared Component Model for Detecting Joint and Selective Clustering of Two Diseases, *J. R. Stat. Soc., Ser. A, Stat. Soc.* 164 (2001), 73-85.
- [12] J. Besag, J. York, A. Mollié, Bayesian image restoration, with two applications in spatial statistics, *Ann. Inst. Stat. Math.* 43 (1991), 1-20.

SPATIAL DISTRIBUTION OF TUBERCULOSIS DISEASE AMONG MEN AND WOMEN

- [13] M. Blangiardo, M. Cameletti, *Spatial and Spatio-temporal Bayesian Models with R - INLA*, John Wiley & Sons, Chichester, 2015.