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# Spatial Analyses of Low Birth Weight Incidence, Indonesia

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**Abstract** The etiology of Low Birth Weight (LBW) in Murung Raya is still unclear. This study aimed to find out the relationship between environmental and health behavior risk factors of LBW in Murung Raya. 150 women were recruited through the incidence data 2013- 2014, and the questionnaires, medical records, and geographic data were measured by McNemar, ANOVA, logistic, IRR, MI, z (Gi), and NNI tests. Bivariate analysis showed significant correlation of LBW with TBA care OR= 10, drinking popa OR= 5, smoking OR= 6.1, and accessibility OR = 2.3, with adjusted OR for TBA care OR= 32.78, ANC OR= 27.52 revealing trend lines with ANOVA F=49, and clustering RR=7, MI >0 (four clusters), z (Gi) >1 (two high clusters), and NNI>1 (two high clusters). The spatial analysis provided greater statistical power to detect an effect that was not apparent in the case-control study. This study suggests that preventions, interventions and treatment for LBW not only be conducted by the current epidemiology approach but also by new modern geographic positioning analysis.

**Keywords:** Low birth weight, epidemiology, spatial analysis, Murung Raya, Indonesia

***Abstrak** Etiologi Berat Lahir Rendah (BBLR) di Murung Raya masih belum jelas. Penelitian ini bertujuan untuk mengetahui hubungan antara faktor risiko perilaku lingkungan dan kesehatan dari BBLR di Murung Raya. 150 wanita direkrut melalui data kejadian 2013-2014, dan kuesioner, catatan medis, dan data geografis diukur dengan McNemar, ANOVA, logistik, IRR, MI, z (Gi), dan tes NNI. Analisis bivariat menunjukkan korelasi signifikan BBLR dengan perawatan TBA OR = 10, minum popa OR = 5, merokok OR= 6,1, dan aksesibilitas OR = 2,3, dengan OR yang disesuaikan untuk perawatan TBA ATAU = 32,78, ANC ATAU = 27,52 mengungkapkan garis tren dengan ANOVA F = 49, dan pengelompokan RR = 7, MI> 0 (empat kelompok), z (Gi)> 1 (dua kelompok tinggi), dan NNI> 1 (dua kelompok tinggi). Analisis spasial memberikan kekuatan statistik yang lebih besar untuk mendeteksi efek yang tidak jelas dalam studi kasus-kontrol. Studi ini menunjukkan bahwa pencegahan, intervensi dan pengobatan untuk BBLR tidak hanya dilakukan oleh pendekatan epidemiologi saat ini tetapi juga oleh analisis posisi geografis modern yang baru.*

***Kata kunci:** Berat badan lahir rendah, epidemiologi, analisis spasial, Murung Raya, Indonesia*

## 1. Introduction

Newborns with LBW (<2,500 grams) are more likely to have poor health outcomes and are approximately 20 times more at risk to die than heavier babies [WHO, 2013]. There are about four million newborns babies worldwide every year. The level of LBW in developing countries is 16.5%, which is more than twice (7%) than in developed countries. In Indonesia in 2013 it was 10.2%, and according to recent research the incidence of LBW has not decreased to expected rates [Bappenas, 2015]. In Murung Raya, the rate of LBW is 6.7%, and it has climbed steadily since 2014 [Dinkes Mura, 2015]. This fact suggests that LBW remains a challenging public health issue in national and district levels. Beside maternal history of previous delivery, other widely known risk factors of LBW are environmental and behavioral factors [Aguilera et al., 2009]. The identification of clusters, buffer, autocorrelation, nearest neighbor, and general ord general G with higher LBW risk can hypothesize the pattern, function, and effect of risk and disease etiology [Grady and Enander, 2009]. However, the association between spatial level, personal and social risk factors with LBW is difficult to establish because the exposure of determinants can occur at different levels over long periods of time making causal relationships and non-stationary responses difficult to accurately diagnose.

The study of spatial analysis for a case-control of LBW in Murung Raya has never been done. This study aimed to determine the relationship between environmental and health behavior determinants of LBW, by analyzing spatial and epidemiological aspects. Murung Raya district was classified into several subdistricts based on their area levels to examine the disparity of LBW rates in potential area. Spatial statistics examining LBW were done using Scan Statistics, Geoda, and ArcGIS. Epidemiology aspects analyses were performed on Stata.

The outcomes gleaned from this study are necessary to understand the spatial and epidemiology data of LBW in Murung Raya and to find out the relation between the variables of area and health behavior as risk factors of LBW. These outcomes will provide public health data to establish a framework for planning health promotion

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programs, prevention and intervention activities. In order to be successfully implemented, the result will be targeted to specific geographic regions with high-risk populations.

## 2. The Methods

The research was an epidemiologic study with matched case-control design. The study was conducted from August to December 2015 in six subdistricts with the population involving all live births in Murung Raya District. The inclusion criteria of the subjects was all live births listed in the Health Departement of Murung Raya District database 2013-2014.

There were 150 subjects included in this study. The number of case-control subjects were 75 cases and 75 controls. Types of matching criteria were age, parity, and residence of the subjects. The case criterion was mother with live birth weight <2500 gram and the control criterion were lived birth weight ≥2500 grams. Patients of all ages were included in the study. The controls were selected from the Health Department database in Murung Raya District, compared with the data of the Primary Health Center (PHC) and midwife medical records. The health behavior risk factors were obtained by interviewing the mothers, for which most of them are Traditional Birth Attendance (TBA) care variables: antenatal (ANC) care history, drinking popa (traditional alcoholic beverage of Dayak's ethnic group), smoking, and access to the health facilities. The variable data of the area consisted of altitude and slope from Bappeda Mura, 2015, mercury exposure from BLH Mura, 2014, and mapping of coal and gold mining area from Distamben Mura, 2015.

The UGM Ethics committee provided approval ref: KE/FK/1142/EC/15, Medical and Health Research Ethics Committee Faculty of Medicine, Public Health and Nursing, Universitas Gadjah Mada.

LBW was measured by McNemar and OR tests. Data was further analyzed with ANOVA, conditional logistic regression OR, Poisson regression IRR, Moran index of autocorrelation, score z Gi Getis-Ord General G, nearest neighbor analysis (NNI) and P value of clustering and diagnostic of spatial dependence. The univariate analysis examined age, parity, and residence, and the bivariate analysis was used to determine the relationship between LBW and control for health behavior variables. McNemar statistical test was conducted with significance level of p <0.05 and calculation Odds Ratio (OR) on a 95% CI. Odds Ratio was calculated by ignoring the value of concordance (cell A and the cell D) for both cases and controls. The matching with McNemar statistic, and multivariate with unconditional logistic regression for OR and Poisson regression for IRR were performed on Stata version 12.

The scan statistical method based on the discrete Poisson probability model was employed in this study to detect districts with highly clustered LBW rates [Kulldorff, 2015]. GeoDa was used to find out MI/DF on diagnostic of spatial dependence [Anselin et al., 2004], ArcGIS to measure the distance buffer, Moran Index (MI) of spatial autocorrelation, z (Gi) score for Getis-Ord General G, and Nearest Neighbor Index (NNI) for nearest neighbor analysis [Esri, 2011].

## 3. Result and Discussion

The trend of live births from 2009 to 2014 in Murung Raya resulted in 6.71% that were LBW. As illustrated in Table 1, the yearly district LBW rate for male (mean=2.7%) was considerably higher compared to female births (mean=2.1%). In fact, births in isolated areas were more likely born LBW compared to un-isolated with a range from 12.9% to 14.4%. Among areas and other births, the LBW range was 6.6–7.5% and 7.4– 8.7%, respectively. The LBW rate by gender was similar, but the proportion of LBW among males was slightly higher (2.7%) than female births (2%).

As illus¬trated in Figure 1, the data points follow a linear trend with little fluctuation. Furthermore, the linear regres¬sion of LBW rate from year to year resulted in a fair highly 0.57 (p-value < 0.001), thus indicating a rather steady trend of decrease (slope = -0.28). When focused on average years 2009-2014 were found a positive decrease of change in the average annual rate. Only in 2014 was there an increase. Overall the prevalence of LBW in Murung Raya (6.7%) is in line with several areas in Central Kalimantan. This high incidence may be explained by the time gap between these studies and changes from year to year as birth weight may have yearly variations. The prevalence of LBW also may vary between and within geographical regions. It was clearly found that LBW rate in Murung Raya had been decreasing in both male and female infants from 2009 to 2014, regardless of gender and residence. During the period of interest in this analysis, the annual rates of LBW term in Murung Raya comparing the gender and residence rates in the first three years (2009–2011) and those in the last three years (2012–2014) suggests a significant gap which was not likely due to chance. Other reasons might include different areas, influence of different risk factors, and also different health service utilization. However, this study found a different mean of the temporal trend line in gender of LBW compared to gender and residence of mother.

### Case-Control Study

Referring to Table 2 the univariate analysis of the characteristics of mothers in the sample matching age, residence, and parity was done using the sum of samples 75 LBW and 75 control. The mothers with adequate TBA care were 32 cases (82.05%) and seven control (17.95%), non adequate ANC case 33 (71.74%) and control 13 (28.26%). However, total cases with drinking popa were 16 (84.21%) and control 3 (15.79%), similar to smoking 21 (82.21%) and control 9 (30%). The total of cases with difficulty of accessibility were 63 cases

Table 1. One-way analysis by sex and resident trend line of LBW in Murung Raya (2009-2014).

| | Variable | F | p |
|---|---|---|---|
| Total | | 49.00 | 0.002 |
| Sex | Male | 8.31 | 0.04 |
| | Female | 7.74 | 0.049 |
| Resident | Un-isolated area | 6.64 | 0.0615 |
| | Isolated area | 6.64 | 0.0615 |
| | | 8.80 | 0.041 |

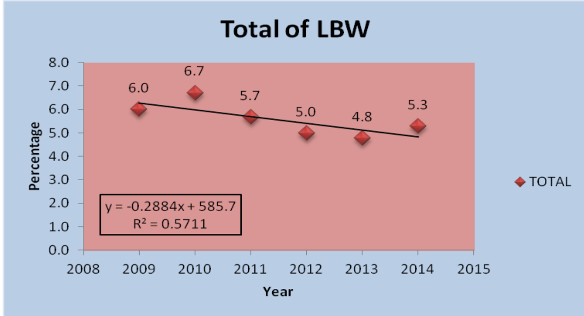

Figure 1. Temporal variation of the overall LBW rate in Murung Raya (2009–2014)

Table 2. Characteristics of mothers

| | Variable | LBW | | Control | |
|---|---|---|---|---|---|
| | | N=75 | % | N=75 | % |
| TBA care | Adequate | 32 | 82.05 | 7 | 17.95 |
| | Inadequate | 26 | 34.67 | 49 | 65.33 |
| ANC | Inadequate | 33 | 71.74 | 13 | 28.26 |
| | Adequate | 42 | 40.38 | 62 | 59.62 |
| Drinking popa | Ever | 16 | 84.21 | 3 | 15.79 |
| | Never | 59 | 45.04 | 72 | 54.96 |
| Smoking | Ever | 21 | 70 | 9 | 30 |
| | Never | 54 | 45 | 66 | 55 |
| Accessibility | Difficult | 63 | 55.75 | 50 | 44.25 |
| | Easy | 12 | 32.43 | 25 | 67.57 |
| Mercury exposure (mg/kg) | <0.0143 | 15 | 10.00 | 15 | 10.00 |
| | 0.0144/0.0172 | 24 | 16.00 | 24 | 16.00 |
| | 0.0173/0.0204 | 12 | 8.00 | 12 | 8.00 |
| | 0.0205/0.0362 | 6 | 4.00 | 6 | 4.00 |
| | 0.0363/0.0424 | 14 | 9.33 | 14 | 9.33 |
| | >0.0425 | 4 | 2.67 | 4 | 2.67 |
| | <5.000 | 35 | 23.33 | 33 | 22.00 |
| | 5.001-10.000 | 21 | 14.00 | 25 | 16.67 |
| | <10.000 | 17 | 11.33 | 17 | 11.33 |

(55.75%) and control 50 (44.25%). The characteristics of the mothers with environmental variables based on mercury exposure were at level 0.0144/0.0172 about 24 (16%), and at level>0.0425 (5.33%).

Bivariate analysis was used to determine the relationship between independent variables and the dependent variable and was equated with good parity in the case group and the control group as shown in Table 3. McNemar statistical test was used with significance level of p <0.05 and calculation Odds Ratio (OR) with 95% CI. Odds Ratio was calculated by comparing the value of concordance (a cell and the cell d) for both cases and controls exposed. Matching case-control ANC as predictor of LBW was found in discordance 24 and 4 with matching concordance 9 and 38. Statistical result was significant among ANC with 75 LBW with OR=6 (95% CI: 2.06-23.79). Interpretation of adequate ANC as a risk factor of LBW was six times greater compared with non LBW. TBA care as predictor of LBW was found in discordance 4 and 18 while matching concordance was 20 and 2. Statistical result was significant among TBA care with 75 LBW with OR=5 (95% CI: 1.41-26.94). Interpretation of adequate TBA care as a risk factor of LBW was ten times greater compared with control. Drinking popa as predictor of LBW was found in discordance 1 and 58 while matching concordance was 16 and 3. Statistical result was significant among drinking popa with 75 LBW with OR=2.22 (95% CI: 0.67-5.54). Interpretation of drinking popa as a risk factor of LBW was five times greater compared with non LBW. Smoking as predictor of LBW was found in discordance 34 and two while matching concordance

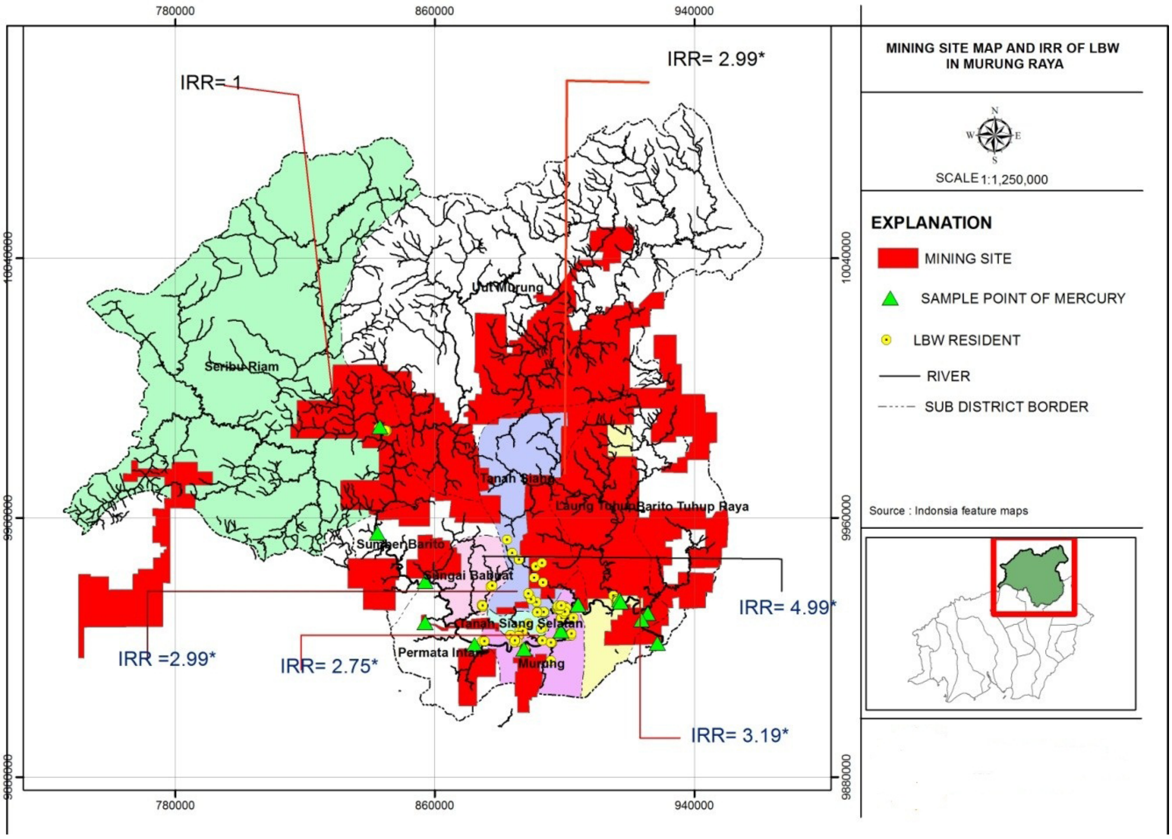


Figure 2. Map of coal and gold mining areas connected with Mercury exposure

Table 3. Bivariate analysis with McNemar statistics matching case-control LBW as predictor.

| Variable | Control | | | | | | |
|---|---|---|---|---|---|---|---|
| | E + | E - | $X^2$ | P | OR | P | OR |
| TBA care | | | | | | | |
| Adequate TBA care(+) | 4 | 20 | | | | | |
| Inadequate (-) | 2 | 18 | 14.73 | 0.0001 | 10 | 2.43- | 88.24 |
| ANC | | | | | | | |
| Inadequate ANC (+) | 9 | 24 | | | | | |
| Adequate ANC(-) | 4 | 38 | 14.29 | 0.0002 | 6 | 2.06- | 23.79 |
| Drinking popa | | | | | | | |
| Drinking popa(+) | 1 | 16 | | | | | |
| No (-) | 3 | 56 | 8 | 0.005 | 5 | 1.41- | 26.94 |
| Smoking | | | | | | | |
| Smoking (+) | 3 | 18 | | | | | |
| No (-) | 6 | 48 | 6 | 0.01 | 3 | 1.14- | 9.23 |
| Accessibility | | | | | | | |
| Difficult accessibility (+) | 40 | 23 | | | | | |
| Easy accessibility(-) | 10 | 2 | 5.12 | 0.024 | 2.3 | 1.05- | 5.41 |

was 6 and 33. Statistical result was significant among smoking with 75 LBW with OR=3 (95% CI: 1.14-9.23). Interpretation of smoking as a risk factor of LBW was three times greater compared with control. Accessibility as predictor of LBW was found in discordance 23 and 10 with matching concordance was 40 and 2. Statistical result was significant among accessibility with 75 LBW with OR=3 (95% CI: 1.14-9.23). Interpretation of difficult accessibility as a risk factor of LBW was 2.3 times greater compared with control.

The result of multivariate analysis is shown in Table 4. Model 1 showed that there was a statistically significant relationship between LBW's risk factors such as TBA care with adjusted OR=19.26 (CI=2.85-130.39) and ANC adjusted OR=16.87(CI=1.61-176.47). Analysis showed a significant relationship between TBA care variable and ANC with the cases of LBW by controlling the smoking and accessibility variables. The result was that mothers with adequate TBA care have 19.26 times greater risk of LBW than control. Mothers with inadequate ANC have 16.87 times greater risk of LBW than control. Accessibility variable was not statistically significant contrary with generally accepted practice. Smoking variable was protective. In model 2 after controlling, drinking popa, TBA care and ANC variables were still significant. Drinking popa variable did not influence the variables of TBA attendance, ANC, smoking and accessibility, which could be seen from the difference in value of -2 log likelihood of 1.49. This value is lower than the table χ2 11.07 with a degree of freedom 5. It means that the contribution of drinking popa variable against LBW cases was not significant. This model produces a value of to 0.54 which means that the variables of TBA care, ANC, smoking and accessibility can predict LBW 54% in this study by adjusting for drinking popa, which can predict LBW using this research model.

**Environmental exposure risk factor**

The incidences of low birth weight were influenced by environmental pollution as the environmental factors [Brauer et al., 2008], [Urquia et al., 2010] and also geographical factors [Asundep et al., 2013], [Kruk et al., 2009]. This study shows that all districts have significant Mercury contaminated incidence ratio. Following the pattern along the river, the pollution at the lower course of the river was higher than the upper course in subdistricts of Murung, Laung Tuhup, Sei Babuat, Tanah Siang Selatan, and Tanah Siang. Only one area had low incidence rate of LBW in Seribu Riam, which is located at the upper course. This finding supports a relationship between exposure to MeHg and birth weight [van Wijngaarden et al., 2014]. There were evidences for associations of B-Hg with increases in birth weight [Taylor et al., 2016]. LBW was more likely to happen among women who reside within 8 kilometers with fish consumption [Burch et al., 2014]. The process of environmental exposure was because of the increase of pollutants and waste runoff carried by the rainfalls [Nyaken, 2008]. Topography aspects also affected the water quality. The water qualities at the lower course of the polluted river indicate the sources of pollution at the upper course region because there are the coal and gold mining sites. Runoff from the steep slope will bring together existing pollutants in the ground level that accumulate on the flat areas and drainage toward the river. Pollutants that accumulate on the flat area will be absorbed and contaminate soil and groundwater. Contamination of pollutants in humans occurs when water is used as a source of water consumption. Fish consumption is also a major human exposure pathway for Mercury. The result of this research indicates that hair or blood concentrations of Mercury are relatively higher among those who consume more fish rather than infrequent fish consumption.

Table 4. Conditional Logistic Regression analysis showing relationship of health behavior with LBW

| Variables | Model 1. OR (CI) | Model 2. OR (CI) |
|---|---|---|
| TBA care | 19.26(2.85-130.39)* | 32.78(2.95-364.42)* |
| ANC | 16.87(1.61-176.47)* | 27.52(1.43-531.08)* |
| Smoking | 0.18 (0.02-1.42) | 0.06 (0.00-1.20) |
| Accesibility | 4.34(0.77-24.50) | 7.53 (0.80-70.65) |
| Drinking popa | - | 15.08(0.39-587.62) |
| 2 Log-likelihood (Deviance) | 15.42 | 13.93 |
| $X^2$ score (df) | 30.15 | 33.13 |
| $X^2$ table | 9.49 | 11.07 |
| P value | 0.00 | 0.00 |
| $R^2$ | 0.49 | 0.54 |

The slope of surface 4-6% was significant as a risk factor for LBW in subdistricts Seribu Riam and Saripoi, since both of the areas are located at high slope surface [Allamano et al., 2009]. The environmental characteristics are influenced by the slope, and are also positively correlated with LBW. These factors also contribute to the role of maternal place of residence as a mediator of maternal stress and adverse reproductive outcomes among women [Miranda et al., 2009]. One study found evidence of the associations between B-Hg with birth weight increases [Taylor et al., 2016]. Mothers who lived in the highlands were at risk for hypoxic fetus that caused neonatal asphyxia. Oxygenation interference / lower oxygen levels affect the fetus and cause LBW conditions.

The behavior of smoking for pregnant women affects the incidence of LBW. The exposure factor to toxic substances contained in smoking is a risk for pregnant women. This study found that smoking mothers are three times more at risk of LBW, after adjusting for other variables but in multivariate analysis they were not significant. Another study found that 2.5% of mothers had smoked throughout their pregnancy with 7.7% classified as LBW [Miyake et al., 2014], between 20-40 years of age, and 254 (33.8%) smokers with (10.0%) births at LBW [Silva et al., 2011]. Smoking as a contributing factor was found in the United States which 20-40% of them had cases of LBW infants which were generally associated with 150-200g infant birth weight [Aaronson and Macnee, 1989]. Smoking during pregnancy was the most important predictor of an infant's low birth weight. The effort to reduce smoking during pregnancy might significantly contribute to reduce LBW in economically and educationally disadvantages populations. Social support had been constantly associated with reduced cigarette use and avoidance of smoking during pregnancy.

Drinking popa had five times greater risk of LBW. According to [Buescher and Ward, 1992], [Kramer, 1987], [Wimmer and Pihlstrom, 2008], [Tu et al., 2012], [Meng et al., 2013], drinking alcohol during pregnancy was a risk factor of LBW. From 2.1% who abused alcohol during pregnancy, 26.3% among these had LBW children [Silva et al., 2011]. A recent study found that overall maternal alcohol consumption during pregnancy was not associated with LBW but average consumption from one or more beverage in early or late pregnancy seemed to be associated with adverse birth outcomes in a study in Rotterdam, Netherlands [Jaddoe et al., 2007]. Another study report in Cantabria, Northern Spain found that alcohol consumption during weekdays of 12 g/day or more, elevated the risk of LBW [Mariscal et al., 2006]. But there are still controversies about the consequences of mild to moderate alcohol use in pregnancy linked to LBW [start.org, 2005]. In this research, there are no significant relationships that were observed between maternal alcohol consumption during pregnancy and the risk of LBW. Our study results suggest that the reduction of maternal alcohol consumption made more significant contribution to reduce the risk of LBW in economically and educationally disadvantaged communities.

Access to health service not only related to the physical aspects to reach out for the services and travel time, but also about the perception of the clients and the information that they had ever received [Thang and Ahn, 2002]. This study found that accessibility was statistically significant. It was appropriate with the statement of Goddard and Smith [2001] that access to the health service also should be assessed with the combination of the available health care quality service, reasonable cost, as well as adequate information. So in principle, access to health service includes structural characteristics of the health service, and the desire or the necessity to seek medical care as needed [Aday, 1993]. The problem of spatial access to PHC especially in Canada, gave us new perspectives that Indonesia is a largely rural and remote country from a geographical perspective and one that is committed to the health equity. The attention recently has been drawn to the mismatch between the spatial distribution of inhabitants and PHC providers [Schuurman et al., 2010]. The spatial accessibility indicated that 205 sub-districts show great disparities in health care access throughout the country. The research in Bhutan indicates that in 2013, 24% of Bhutan's populations had poor access to primary health care service, 66% had medium-level access, and only 10% had good access [Jamtsho et al., 2015].

**Spatial autocorrelation analysis**

It has been estimated that there were linkages between subdistricts with high $0 < MI \leq 1$, and p-value >0.05 to the regional LBW rate relationship. To determine the relationship between subdistricts' linkages we used Moran's Index method (Figure 4). It was indicated the presence of spatial autocorrelation within neighboring areas are more similar (positive). It can be concluded that the similar characteristics between the cases have a value or indicate that LBW among the cases in Murung Raya subdistricts had a positive correlation among the near locations. The occurrence of spatial autocorrelation was highly dependent on the aggregation level [Overmars et al., 2003]. The number of LBW in Murung sub-district, obtained in Tanah Siang Selatan/ Sei Babuat MI= 0.759648 p value<0.05 Index, Laung Tuhup MI= 0.023460 p value<0.05, and Saripoi MI= 0.200778 p value<0.05. Subdistrict Murung MI= 1.008612 p value<0.05 in the range MI >1. Spatial autocorrelation for variables ANC, TBA care, drinking popa, smoking and access were all clustered with MI > -1 p value<0.05 (Table 5). It is contrary with subdistrict Seribu Riam that has a very low high $0 < MI \leq 1$, p value>0.05, which is also a neighboring area, and was not similar. It was indicated that this variable has the fewest and weakest external neighborhood effect of those examined. It was also because this subdistrict has a very extensive region located at the upper end and the residents of the communities were not in one area but in spread out areas. Different with the variables of ANC, TBA care, drinking popa, smoking, and access provided important evidence regarding variability in the strength of external neighborhood effect across analyzed risk factors of LBW. For example as an alternative, the spatial autocorrelation is high 0 < MI ≤ 1, p <0.05), indicating that this variable has an intermediate external neighborhood effect [Griffith, 2009]. The external effects of the other examined variables were a bit varied between medium to extreme. As mentioned earlier, the spatial pattern of this external might be shared by more than one variable.

**Getis-ord General G Analysis**

Getis-ord general G analysis found that the cases of LBW in every subdistrict had spatial cluster features with either high or low values. In subdistricts Murung and Seribu Riam, z-score < 0, p-value >0.05, was statistically not significant, with negative z-score, meaning that the smaller the z-score the more intense of the clustering of random value (cold spot). Contrasted with the subdistricts Tanah Siang Selatan, Sei Babuat and Tanah Siang showed the value of the z-score= -2.521007 with p-value > 0.05.

In subdistrict Laung Tuhup and Tanah Siang z-score 0 0, p-value <0.05 was statistically significant, with positive z-score, meaning that the larger the z-score, the more intense of the clustering of higher value (hot spot). The positive z-score showing higher values are randomly clustered in the area of the research. While in the subdistrict of Tanah Siang Selatan, Sei Babuat showed the value of the z-score> 0, p value >0.05 was statistically significant, meaning that the smaller of the z-score the more intense the clustering of low values (cold spot). Variables ANC, TBA care, drinking popa, and access also indicate z value (Gi) >2 p value

Table 5. The results of spatial autocorrelation with ArcGIS case of LBW in Murung Raya in 2013-2014.

| Variable | Moran's Index (I) | Expected Index (EI) | z-score | p-value | Result |
|---|---|---|---|---|---|
| ANC | 0.514 | -0.016 | 14.595 | 0.000 | clustered |
| TBA care | 0.439 | -0.011 | 14.786 | 0.000 | clustered |
| Drinking popa | 0.558 | -0.056 | 4.967 | 0.000 | clustered |
| Smoking | 0.587 | -0.036 | 5.535 | 0.000 | clustered |
| Accessibility | 0.505 | -0.009 | 19.127 | 0.000 | clustered |

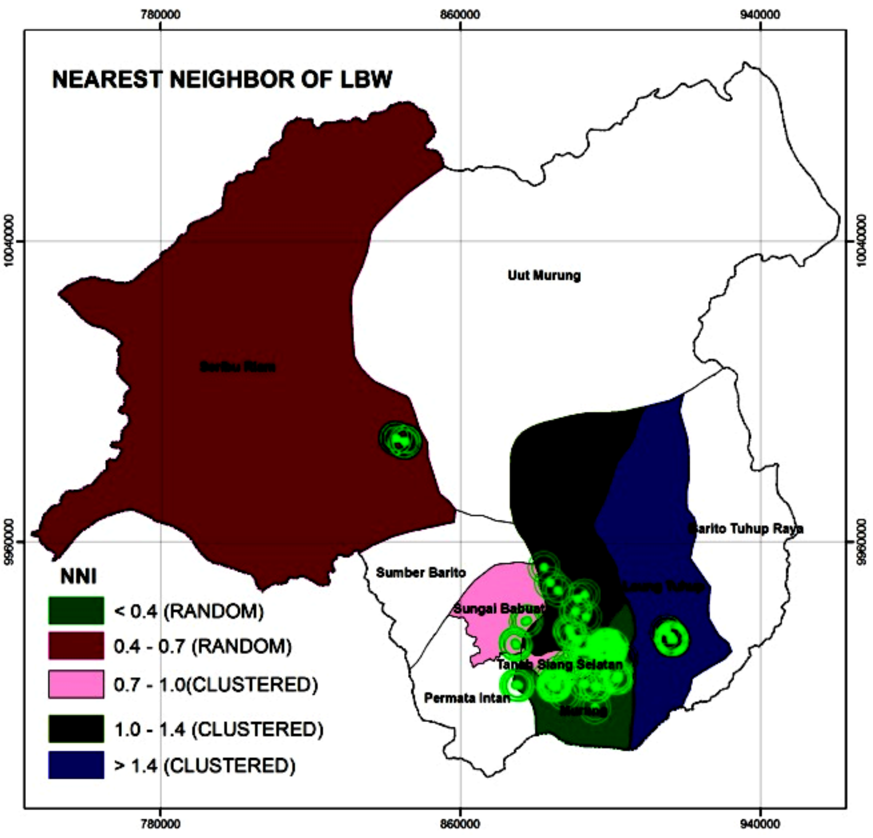


Figure 3. Nearest Neighbor Index (NNI)

Table 6. The results of the analysis of spatial statistical models Getis-Ord General G with ArcGIS in districts Murung Raya

| Variable | Observed General G | Expected General G | z-score | p-value | Result |
|---|---|---|---|---|---|
| ANC | 0.230 | 0.230 | 3.017 | 0.003 | Highly Clustered |
| TBA care | 0.175 | 0.175 | 3.926 | 0.00008 | Highly Clustered |
| Drinking popa | 0.211 | 0.211 | 2.636 | 0.008 | Highly Clustered |
| Smoking | 0.145 | 0.145 | 1.913 | 0.056 | Highly Clustered |
| Accessibility | 0.152 | 0.152 | 4.336 | 0.00002 | Highly Clustered |

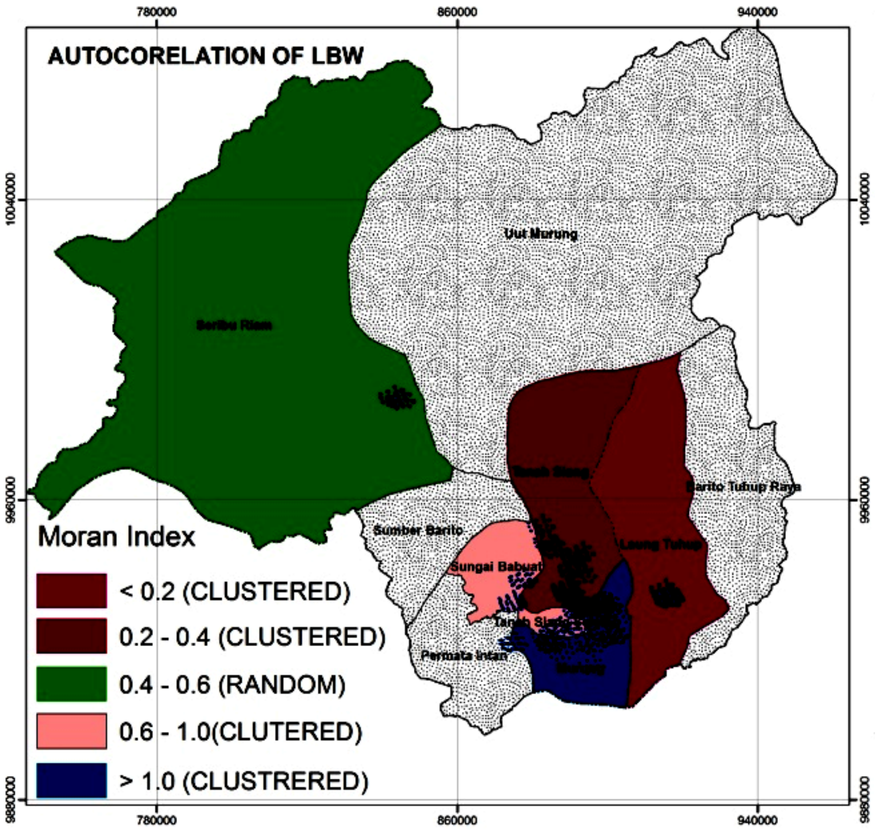


Figure 4. Spatial autocorrelation with Moran

< 0.05 which was showing a positive local significant relationship tending to be highly clustered. Only the variable smoking (Gi)< 2 tended to be random (Figure 5). Subdistrict Tanah Siang Selatan, Sei Babuat, Tahan Siang, and Laung Tuhup had a clustered case pattern with NNI > 0.07, p value <0.05 (Figure 3). LBW variable for ANC, TBA care, drinking popa, smoking, and access had a clustered pattern with NNI > 0 with p value < 0.05. It was indicated by the distance between one LBW case with other nearest cases. The z-scores were given to all variables. There was less than 1% likelihood that this clustered pattern could be the result of random chance (Table 7). In relation with that fact, each case was considered as a dot in the study area with clustered patterns [Maneewongvatana and Mount, 2002 ].

**Clustering Analysis**

There were statistically not significant clusters with p-value >0.05 in two subdistricts in Murung Raya identified in 2013-2014 from a purely spatial analysis scanning for higher rate using the Poisson model. From 3 cases of LBW in the subdistrict Murung there were observed 0.79 expected value. The cluster had a highly relative risk of 14.13. Another statistically not significant cluster (p-value>0.05) was identified in Tanah Siang Selatan and Sei Babuat with most likely cluster. This cluster had 2 cases of LBW with 0.44 expected case and high relative risk of 4.50 (Table 9). It was also identified in another secondary cluster area. Although the other clusters were presented statistically not significant, but their relative risks were high. A statistically significant cluster (p = 0.031) was found only in one community

Table 7. The results of the nearest neighbor analysis with ArcGIS in Murung Raya district

| Variable | Observed Mean Distance | Expected mean Distance | Nearest Neighbor Ratio | z-score | p-value | result |
|---|---|---|---|---|---|---|
| ANC | 0.008 | 0.032 | 0.259 | -11.168 | 0.000 | clustered |
| TBA care | 0.003 | 0.027 | 0.117 | -15.846 | 0.000 | clustered |
| Drinking popa | 0.023 | 0.041 | 0.555 | -3.713 | 0.002 | clustered |
| Smoking | 0.017 | 0.042 | 0.398 | -6.199 | 0.000 | clustered |
| Accessibility | 0.004 | 0.024 | 0.198 | -16.304 | 0.000 | clustered |

Table 8. Diagnostic for spatial dependence

| Subdistrict location | | | |
|---|---|---|---|
| Test | MI/DF | Z | p value |
| Spatial Error Correction | | | |
| Moran's I | 0.034 | 2.25 | 0.024 |
| Lagrange Multiplier | 1 | 0.823 | 0.36 |
| Robust Lagrange Multiplier | 1 | 0.20 | 0.65 |
| Spatial Lag Dependence | | | |
| Lagrange Multiplier | 1 | 0.97 | 0.32 |
| Robust Lagrange Multiplier | 1 | 0.35 | 0.55 |

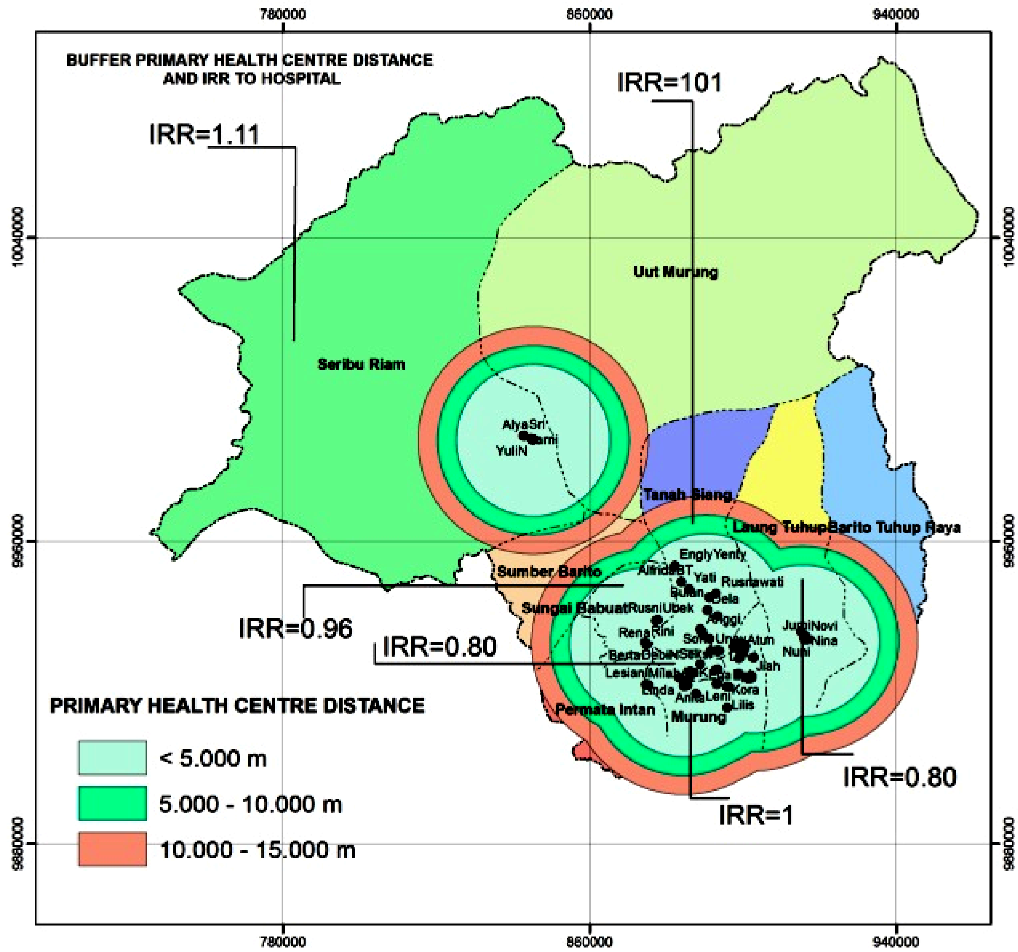


Figure 7. Buffer and IRR of the distance of PHC

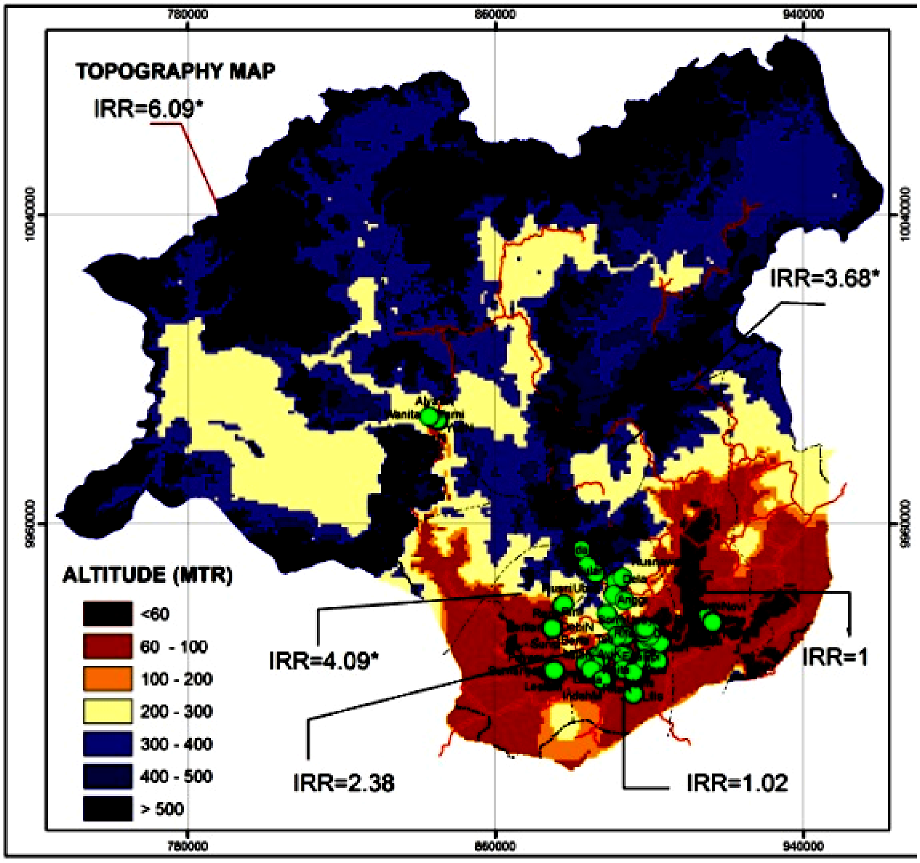


Figure 8. IRR of LBW according to altitude Figure

identified in 2005 in Osuwem council area. This cluster had 2 cases of under-five mortality with 0.04 expected value and had very high relative risk of 84.87. Another stastically not significant cluster was identified in 2006. Clustering resulted from other variables as a risk factor was found in some groups of ANC, TBA Care, drinking popa, smoking, and accessibility. Although only smoking variable indicates significant cluster, but the relative risk was still high.

Clustering analysis was needed to discover any information to create work plans for resource and health services mobilization [Coleman et al., 2009]. In 2013-2014, clustering result had evaluated the influences of district variation to LBW cases. It was also able to establish the geographical consequences to the nearest district [Klug et al., 2009]. Spatial analysis is useful to detect clustering and produce hypotheses results regarding disease disseminating factors, social economic status factors, and proximal factors [Awini et al., 2010]. Spatial clustering results, which describe and trace the LBW spatial pattern were important to produce mechanical hypotheses, targeting the highly environmental risks to observe and apply the intervention to mother and child health, and create the prevention plan and accurate evaluation of the health services provision. The study result indicated the distance of nearest spatial cluster is along the river similar to previous environmental factor research [Grady and Enander, 2009].

**Buffering analysis**

Buffer analysis was used to identify the distance of health care facilities with the residence of LBW cases based on the spatial element, in this case was the distance to PHC, altitude, and slope surface. It was an important aspect to measure the spatial accessibility to PHC using the distance of health care place [Jamtsho and Corner, 2014]. In this study, the unit of buffering was the point of PHC and the residence of the health functionary at the village. Buffer operation refers to the creation of a specific zone with specified distance around coverage features (3 levels radius of distance). This study found that 35 (68%) cases live near the defined buffer zone < 5000 meters and only 17 (30%) live in zone < 10.000 meters (Table 2). According to the research in Costa Rica, this buffering was used to measure the distance between incidences of LBW. The average distance to an outpatient care outlet was less than 1 km away and to the hospital was 5 km away. In terms of equity, 12 – 14% of the populations were underserved because the distance to the outpatient outlet is within 4 km and to the hospital within 25 km [Rosero-Bixby, 2004]. The potential spatial access to PHC depended on the patient's travel cost (time/distance) [Schuurman et al., 2010].

**Diagnostic for spatial dependence**

Diagnostic of spatial dependence used Geoda's software with several tests of spatial dependence, such

Table 9. Clustering LBW

| area | year | type | Number of cases | Distances (km) | Expected case | RR | p-value |
|---|---|---|---|---|---|---|---|
| Murung | 2013-2014 | Most likely | 2 | 3.21 | 0.50 | 6.00 | 0.91 |
| | | Secondary cluster | 5 | 1.63 | 0.52 | 5.71 | 0.98 |
| TSS / Sei Babuat | 2013-2014 | Most likely | 2 | 7.17 | 0.44 | 4.50 | 0.308 |
| | | Secondary cluster | 2 | 0.032 | 0.67 | 3.00 | 0.811 |
| Joloi | 2013-2014 | Most likely cluster | 2 | 0.02 | 1.20 | 1.67 | 0.66 |
| Tanah Siang | 2013-2014 | Most likely | 3 | 4.37 | 0.55 | 3.67 | 0.248 |
| | | Secondary cluster | 2 | 5.72 | 1.64 | 1.83 | 0.931 |
| Laung Tuhup | 2013-2014 | Cluster 1 | 2 | 0.33 | 0.44 | 4.50 | 4.50 |
| | | Cluster 2 | 2 | 0.25 | 0.67 | 3.00 | 0.915 |
| | | Cluster 3 | 2 | 0.28 | 0.89 | 2.25 | 0.995 |
| Variable ANC | 2013-2014 | Cluster 1 | 3 | 0.41 | 0.55 | 5.45 | 0.382 |
| | | Cluster 2 | 2 | 0.23 | 0.27 | 7.50 | 0.779 |
| | | Cluster 3 | 2 | 0.26 | 0.27 | 7.50 | 0.779 |
| TBA Care | 2013-2014 | Cluster 1 | 11 | 11.02 | 4.30 | 2.56 | 0.065 |
| | | Cluster 2 | 3 | 0.19 | 0.44 | 6.77 | 0.285 |
| | | Cluster 3 | 7 | 0.72 | 2.91 | 2.41 | 0.812 |
| | | Cluster 4 | 2 | 0.29 | 0.30 | 6.77 | 0.916 |
| | | Cluster 5 | 8 | 16.08 | 3.98 | 2.01 | 0.984 |
| Drinking popa | 2013-2014 | Cluster 1 | 2 | 0.020 | 0.32 | 6.33 | 0.105 |
| | | Cluster 2 | 2 | 0.032 | 0.53 | 3.80 | 0.861 |
| | | Cluster 3 | 4 | 12.23 | 2.11 | 1.90 | 0.983 |
| Smoking | 2013-2014 | Cluster 1 | 3 | 0.51 | 0.41 | 7.25 | 0.034 |
| | | Cluster 2 | 2 | 0.20 | 0.21 | 2.42 | 0.957 |
| | | Cluster 3 | 4 | 21.72 | 1.66 | 2.42 | 0.957 |
| Accesibility | 2013-2014 | Cluster 1 | 13 | 7.00 | 5.93 | 2.19 | 0.220 |
| | | Cluster 2 | 3 | 0.020 | 0.47 | 6.35 | 0.396 |
| | | Cluster 3 | 9 | 14.68 | 4.07 | 2.21 | 0.850 |
| | | Cluster 4 | 2 | 0.15 | 0.37 | 5.40 | 0.996 |
| | | Cluster 5 | 2 | 0.20 | 0.37 | 5.40 | 0.996 |

as: Moran's I (error), Lagrange multiplier (lag), Robust LM (lag), Lagrange multiplier (error), Robust LM (error), Lagrange multiplier (Sarma). The test results (spatial lag models - maximum likelihood estimation) showed Moran's I obtained MI<1, p-value <0.05 (Table 8), which means that LBW significantly followed the pattern of spatial distribution. LBW was associated with factors that exist in the area or spatial distribution of LBW. The test results of Lagrange multiplier p-value < 0.05 indicate that the spatial correlation does follow a spatial pattern. The p-value >0.05 at the spatial lag models was to conclude that there was a dependency of spatial lag. It means that since there is a dependency between LBW cases in one area to other LBW cases in another area, so it can be continued to establish the SAR models. Lagrange multiplier test on spatial model error provided p values >0.05, which indicate that there was no spatial error so it was not necessary to format the Spatial Error Model (SEM). The model conclusion of alleged SAR produces better parameters of the SER model in the case of spatial dependency in modeling of LBW in Murung Raya.

**Incidence of LBW by spatial analysis**

The ratio of observed LBW cases was plotted according to Poisson regression. The number of cases in each area was weighted by Incidence Rate Ratio at-risk of LBW. This weighting can be interpreted in terms of residence in the LBW location. Referring to Figure 2, Mercury exposure variable is significant compared to LBW with all levels (<0.0143 and >0.0425) in subdistricts Tanah Siang Selatan (IRR=2.99), Sei Babuat (IRR=4.99), Murung (IRR= 2.75) Laung Tuhup (IRR= 3.19), and Saripoi (IRR= 2.99). Slope surface variable with p-value >0.05 significant correlated to LBW with the slope surface (2-4%, 4-6%, and >10%) in subdistrict Joloi (IRR=3.18) and subdistrict Saripoi (IRR=2.07). Altitude variable with p-value >0.05 was significantly correlated to LBW with the all geographic altitude levels (>100 meters) in subdistricts in Tanah Siang Selatan (IRR=2.38), Sei Babuat (IRR=2.07), Joloi (6.09), and Saripoi (3.68) (Figure 8).

This investigation identified several established risk factors for LBW in addition to the neighborhood relationship, geographic proximity to environmental exposure and health behavior variables. At the same time, the spatial analysis determined that residence of the mothers living in coal and gold mining sites proximity to Mercury exposure constitute a significant risk for LBW. It should be noted that this risk was not detected in the case-control study at the individual level of analysis. The sensitivities of the case-control studies and spatial analysis to different measures of risk provide improved reliability over the traditional type of study. Thus, the combination of case-control study with spatial analysis should be considered with the environmental epidemiology studies in general to improve exposure assessment.

To expand the analysis beyond environmental risk factors, the authors included geographic location as a potential risk factor. Environmental exposures were mapped in relation to case patients and control patients with spatial analysis, and the results found that the environmental exposure (elevation, altitude, Mercury exposure) to residence was spatially correlated with the number of LBW cases in the subdistricts area.

The result of the spatial analysis indicated the association between the health behavior and the environmental exposure to the incidence of LBW in the surrounding communities. It is important to note that spatial analysis detected the following: first the spatial pattern with autocorrelation found that Moran's I of LBW among cases in subdistricts Murung Raya had a positive correlation among the near locations. Variables of health behavior were significant indicating positive and strong clustering of the rates. The lower course of the river indicates that this variable had the fewest and the weakest external neighborhood effect of those examined cases. The second showed that the Z-score of all variables (ANC, TBA care, drinking popa, and accessibility) indicated a positive local significant relationship and tended to be highly clustered. Only the smoking variable tended to random clustering. The third showed that the pattern of nearest neighbor according to the residents of LBW were approached to grouped (clustered), while in the subdistricts Murung and Seribu Riam were approached to more random pattern or spread pattern (dispersed).

According to the function of spatial analysis with detected clustering that is statistically not significant, an identified cluster is most likely a random cluster or a secondary cluster area. Although the other clusters presented statistically not significant, their risks were relatively high. Analysis of spatial dependency using Geoda software obtained the result that incidences of LBW were significant following the pattern of spatial distribution. LBW was associated with the factors that exist in the area or spatial distribution of LBW.

To detect the incident of LBW, Poisson regression was used to generate the number of cases expected in each environmental exposure. An absolute measure of LBW risk was given by the Poisson regression, while the relative risk measures were produced in logistic regression analysis because the risks were dependent on the IRR of environmental area variables. The Poisson regressions were used for the spatial analysis in this study because the probabilities of LBW in several subdistricts at the event were rare. The spatial analysis detected effects that did not appear in the case-control study. The logistic regression employed independent variables for each of the six subdistricts that were included in the study. Table 2 listed the number of case patients and control patients who lived in the same coal and gold mining area. There were no effects of residence in the area, but it was detected in the case-control study. Conclusively, it is clear that the spatial analysis study provided greater power to detect the geographic effect than the case-control study did.

## 4.Conclusion

The spatial analysis detected an effect that was not apparent in the case-control study. The logistic regression employed indepen¬dent variables for each of the seventy-five cases that were included in the spatial analysis, which were the number of case and control subjects that lived in different areas (isolated or un-isolated area). The effect of residence on every variable as a level area was not detected but howev¬er it was detected in the case-control study. It is apparent that the spatial analysis study provided greater power to detect the geographic effect than the case-control study. The spatial distribution of LBW in Murung Raya is far from even. In several cases the frequency of LBW in its neighborhoods exceeds the statistical probabilities that could have arisen through random variation. This high incidence of LBW has also shown a significant relation to the spatial distribution of LBW. It was not entirely explained by variations in health behavior variables or by environmental exposures characteristics. The crucial connection between epidemiology and spatial mapping is particularly key. The evidence and theories examined indicate the primary cause of the difference in LBW rates between the districts is the relative mix of environmental exposures and health behavior factors.

Limitations

However, our findings should be interpreted in light of several limitations. First, our sample size may have been too small to detect risk factor of LBW between environmental exposure and health behavior, although our case-control study was similar in size to one previous study assessing socioeconomic factors. Second, there were a relatively small number of live births of low birth weight with the range in area of Murung Raya was quite wider, precluding our ability to evaluate more clinically relevant end points using a spatial approach. Third, in our findings we found statistically significant results for an association between Low birth weight and Mercury exposure and mining area during pregnancy. However, studies have not continued to explore the extent to which maternal health may influence the relationship between fish consumption during pregnancy and birth weight. Finally, we had no way to ascertain the duration of exposure for each respondent (i.e., length of residence in her neighborhood); hence, the type, direction and magnitude of misclassification bias on this key exposure variable are unknown and the best way addressed through matching case-control of age, resident and parity.

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