Spatial modelling of particular matter 10 distribution in Bandung City

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Abstract. Air pollution is a significant problem that occurs in urban areas. Bandung city, as a metropolitan city, continues to experience an increase in population growth, which has led to an increase in the built-up area. The increased built-up area will lead to a decrease in the area of green, which was causing a decrease in air quality. The study aims to analyze the spatial distribution of PM 10 in Bandung city and its relationship with the distribution of land surface temperature, building density, and vegetation density. The research used pollutant levels data and Landsat 8 Imagery in the dry month of 2018. The analysis used were IDW interpolation, LST, NDBI, NDVI, correlation, and statistical regression tests. This research concluded that high pollutant levels are in the characteristics of the region with high surface temperature and index density, and a low index of vegetation density while low pollutant levels are in the characteristics of the region with surface temperature and density index value low buildings, and a high index value of vegetation density. Correlation results indicate an association with each variable. Based on the Pearson coefficient, the relationship between variables is at a moderate level. The regression results state that there is a significant influence between land surface temperature, vegetation index, and building index on the distribution patterns PM 10 in the Bandung city.

1. Introduction

Air pollution is a critical problem. Besides being able to threaten the air quality needed for health, air polluted directly inhaled through breathing. The World Health Organization (WHO) report at the Global Conference on Air Pollution and Health (2018), states that 91% of humans in the world breathe unhealthy air [1]. The results carried out by air pollution monitoring stations of the Meteorology and Geophysics Agency in several major cities such as Jakarta, Bandung, and Surabaya, indicating that the level of threshold of dust pollution continues to rise since 1980 [2].

The source of air pollution in urban areas can divide into two sources, namely immovable sources such as industrial activities, households, and waste combustion, and mobile sources (such as transportation activities that use fuel), both air pollutant sources will experience changes in number both in terms of the intensity of frequency of use and in the spatial terms more and more its existence in urban areas and its surroundings [3].

Bandung city is the area studied in the study. Bandung city as a metropolitan city continues to experience an increase in population growth, which leads to an increase in the area of land built and a decrease in the area of green, resulting in a decrease in air quality. On average, each year, the threshold of dust pollution reaches 130 µg / m³ in parts of Bandung City [2]. The dust particles believed to be the trigger for
respiratory infections because solid particles PM 10 can settle in the respiratory tract. The physical condition of the city of Bandung in the form of a basin made it difficult for the wind to hit the concentration of pollutants. Those are because the pollutants move horizontally. The topographic wall will be blocked if the intervention layer is blocked vertically [4].

Air is a resource that is always available on the face of the earth that is vulnerable to pollution [5]. Air quality is affected by air pollution. Types of air pollutant parameters according to Government Regulation Number 41 of 1999, covering SO2, CO, NO2, O3, Hydrocarbon, PM 10, PM 2.5, TSP, and Pb. Land cover in urban areas continues to change [6]. Changes in land cover to built land have a role in influencing the dispersion process of air pollutants [7]. Changes in land cover are caused by an increase in the physical development of cities, directly affecting changes in microclimates, especially an increase in surface temperatures [8,9]. The existence of buildings around the receiving area of pollutants has a role in influencing the dispersion process of air pollutants [10]. Air pollutant is an increase in material or physical or chemical substrate into the standard air environment that reaches a specific number, so that it can detect by humans or which can be calculated and measured, and can effect on humans, animals, vegetation and materials [11]. In this research, the substances measured is PM 10. PM 10 particles came from road dust, agricultural dust, riverbed, construction sites, mining operations, and similar activities [3].

This research focuses on PM 10. pollutants. Information about pollutant distribution in this study is predicted by utilizing IDW interpolation techniques and using Landsat 8 multispectral images. Landsat image to determine the value of land surface temperature, vegetation density index, and value of building index values of Bandung City buildings. Because of the limited spatial information regarding spatial patterns of research, it aims to produce a spatial model of PM 10 pollutant distribution in Bandung so that it can predict areas that have high levels of air pollution and those with lower levels of pollution than others. Analyzing the relationship and influence of land surface temperature patterns, building density index values, and vegetation density index values on the distribution of PM 10.

2. Research Method

The research area is Bandung City, located between 1070 36' East Longitude and 6055' South Latitude. Spatial approaches carried out using interpolation methods and statistical correlation methods (Figure 1. Describing the distribution of surface temperature, vegetation index, and building values obtained from processing Landsat Image 8, the image was corrected using the FLAASH Atmospheric Correction method. Processing data in this study carried out using ArcGIS10.4 software, ENVI 5.1, and modeling the concentration of air pollutants from each point air quality monitoring and sample point using IDW interpolation techniques. From the results of the levels of pollutants in each sample point, a spatial model made using IDW interpolation techniques. In predicting IDW method data based on the assumption that the attribute value of the data estimated at points that not recorded is a function of distance from the average value of the points that are around it [12].

Furthermore, correlation and regression tests carried out to determine the relationship and influence between surface temperature, vegetation index values, and buildings with concentrations of air pollutants. Then a statistical model is produced to determine the levels of pollutants. This research was conducted in 2018, covering dry months, namely June, July, August, and September. For testing CO and PM 10 in the field, samples taken at 57 sample points. The following is a strength interval table 1, according to [13].

| Table 1. Pearson Coefficient Interval |
|---------------------------------------|
| Coefficient Interval | Strength of Relationship |
|----------------------|--------------------------|
| 0                    | No Correlation            |
| 0.00 – 0.25          | Very weak correlation     |
| 0.25 – 0.50          | Moderate correlation      |
| 0.50 – 0.75          | Strong correlation        |
| 0.75 – 0.99          | Very strong correlation   |
| 1                    | Perfect correlation       |
3. Result and Discussion

The spatial pattern of the concentration value PM 10 saw in Figure 2, distribution. Where the value of Particular Matter 10 concentration that dominates the city of Bandung is 4.2 – 4.4 µg / m³, which is widespread in the southeast, south, southwest, and north of Bandung City. While the magnitude of 4.4 – 4.6 µg / m³ and >4.6 µg / m³ the distribution is random in the east, northeast, west, and southwest of Bandung City in June, July, August, and September, Bandung City.

Figure 1. Research Flow Chart

Figure 2. Spatial Model of PM 10 Distribution in Bandung City
Figure 3 shows the land surface temperature in June and September dominated by temperatures of 25-30 °C, and July and August dominated by temperatures >30 °C. Figure 3 building density patterns in the city of Bandung. Index value -1 - 0, non-built area spreads north and southeast. The index value of 0 – 0.1 moderate density building scattered in the central and southern parts. The index value >0.1 states that the high-density building is centered southwest and east. Figure 4 vegetation density patterns in the city of Bandung. Where the NDVI index value ranges from 0.5 - 1 fairly dense vegetation spread in the north, medium vegetation with NDVI values 0 – 0.5 scattered randomly in the northeast and southeast. Whereas non-vegetation areas with NDVI values ranged from -1-0 widely distributed in the eastern, central, and western parts of Bandung City.
Table 2. Correlation Results of NDVI, NDBI, Pollutants, and LST in June

|       | PM 10  | PM 10          | PM 10          |
|-------|--------|----------------|----------------|
| NDVI  | Pearson| -0.543         | NDBI           |
|       | Sig.   | 0              | Pearson        | 0.273         |
|       | Sig.   | 0              | LST            |
|       | Sig.   | 0.04           |                |
|       |        |                |                |

Table 2 states the significance value is less than the confidence level (0.05), then pollutants have a relationship with NDVI, NDBI, and LST. Based on the Pearson coefficient, NDVI, NDBI, and LST have a moderate correlation with PM 10 distribution.

Table 3. Results of Pollutant Regression, NDVI, NDBI, and LST in June

| Regression of PM 10 June |
|--------------------------|
| \( t_{table} = 2.00404 \) |
| NDVI                     |
| \( t_{result} = -2.932 \) |
| (+) 25.7%                |
| NDBI                     |
| \( t_{result} = -2.608 \) |
| (-) 74.3%               |
| LST                      |
| 2.656                    |

The regression equation in June is, \( Y \ PM 10 = 3.296 -0.559 \text{NDVI} + 0.218 \text{NDBI} + 0.057 \text{LST} \). Regression results state that the value of \( t_{result} \) NDVI, NDBI, and LST is greater than \( t_{table} \) of 2.00404 so it can conclude that "There is a significant effect of independent variables are land surface temperature, building density, and vegetation density on the pattern of distribution of pollutants in the city of Bandung." \( R^2 \) states that the independent variable affects the distribution of PM 10 by 25.7%. Table 4. show the significance values of variables less than the confidence level (0.05). The pollutants have a relationship with NDVI, NDBI, and LST. Based on the Pearson coefficient, NDVI, NDBI, and LST have a moderate correlation with PM 10 distribution.

Figure 5. Vegetation Index in Bandung City
Table 4. Correlation Results of NDVI, NDBI, Pollutants, and LST in July

|          | PM 10   |          | PM 10   |          | PM 10   |
|----------|---------|----------|---------|----------|---------|
| NDVI     | Pearson | -0.403   | NDBI    | Pearson | 0.484   |
|          | Sig.    | 0.002    |         | Sig.    | 0       |
| LST      | Pearson | 0.343    |         | Sig.    | 0.009   |

Table 5. Results of Pollutant Regression, NDVI, NDBI, and LST in July

| Regression of PM 10 July |
|-------------------------|
| \( t_{result} \)        |
| NDVI                    |
| -2.331                  |
| NDBI                    |
| -2.818                  |
| LST                     |
| 2.651                   |
| \( R \) Square = 0.257  |
| (+) 24.2\%              |
| (-) 75.8\%              |

The regression equation in July is, \( Y_{PM\ 10} = 4.159 - 0.066_{NDVI} + 1.360_{NDBI} + 0.017_{LST} \). Regression results state that the value of \( t_{result} \) NDVI, NDBI, and LST is greater than \( t_{table} \) of 2.00404 so it can be concluded that "There is a significant effect of independent variables are land surface temperature, building density, and vegetation density on the pattern of distribution of pollutants in the city of Bandung." \( R \) square states that the independent variable affects the distribution of PM 10 by 24.2\%.

Table 6. Correlation Results of NDVI, NDBI, Pollutants, and LST in August

|          | PM 10   |          | PM 10   |          | PM 10   |
|----------|---------|----------|---------|----------|---------|
| NDVI     | Pearson | -0.483   | NDBI    | Pearson | 0.422   |
|          | Sig.    | 0        |         | Sig.    | 0.001   |
| LST      | Pearson | 0.38     |         | Sig.    | 0.004   |

The following is Table 6. It states that the significance value is less than the confidence level (0.05), then pollutants have a relationship with NDVI, NDBI, and LST. Based on the Pearson coefficient, NDVI, NDBI, and LST have a moderate correlation with PM 10 distribution.

Table 7. Results of Pollutant Regression, NDVI, NDBI, and LST in August

| Regression of PM 10 August |
|---------------------------|
| \( t_{result} \)        |
| NDVI                    |
| -2.812                  |
| NDBI                    |
| 2.069                   |
| LST                     |
| 3.296                   |
| \( R \) Square = 0.257  |
| (+) 23.5\%              |
| (-) 76.5\%              |

The regression equation in August is \( Y_{PM\ 10} = 4.431 - 0.552_{NDVI} + 0.67_{NDBI} + 0.10_{LST} \). Regression results state that the value of \( t_{result} \) NDVI, NDBI, and LST is greater than \( t_{table} \) of 2.00404 so it can be concluded that "There is a significant effect of independent variables are land surface temperature, building density, and vegetation density on the pattern of distribution of pollutants in the city of Bandung." \( R \) square states that the independent variable affects the distribution of PM 10 by 23.5\%.

Table 8. Correlation Results of NDVI, NDBI, Pollutants, and LST in September

|          | PM 10   |          | PM 10   |          | PM 10   |
|----------|---------|----------|---------|----------|---------|
| NDVI     | Pearson | -0.518   | NDBI    | Pearson | 0.533   |
|          | Sig.    | 0        |         | Sig.    | 0       |
| LST      | Pearson | 0.441    |         | Sig.    | 0.001   |
The following is Table 8. states the significance value is less than the confidence level (0.05), then pollutants have a relationship with NDVI, NDBI, and LST. Based on the Pearson coefficient, NDVI, NDBI, and LST have a moderate correlation with PM 10 distribution.

Table 9. Results of Pollutant Regression, NDVI, NDBI, and LST in September

| Regression of PM 10 September |
|-----------------------------|
| $t_{\text{table}} = 2.00404$ | NDVI | NDBI | LST |
| $t_{\text{result}}$ | -2.83 | 2.023 | 2.702 |
| R Square: 0.257 | (+) 30.1% | (-) 69.9% |

The regression equation in September is $Y_{\text{PM 10}} = 4.074 - 0.259_{\text{NDVI}} + 0.910_{\text{NDBI}} + 0.19_{\text{LST}}$. Regression results state that the value of $t_{\text{result}}$ NDVI, NDBI, and LST is greater than $t_{\text{table}}$ of 2.00404 so it can be concluded that "There is a significant effect of independent variables are land surface temperature, building density, and vegetation density on the pattern of distribution of pollutants in the city of Bandung." R square states that the independent variable affects the distribution of PM 10 by 30.1%.

4. Conclusion
PM 10 distribution model in the dry month of 2018, high pollutant levels are in the characteristics of the region with high surface temperature and index density, and a low index of vegetation density while low pollutant levels are in the characteristics of the region with surface temperature and density index value low buildings, and a high index value of vegetation density. Correlation results indicate an association with each variable. Based on the Pearson coefficient, the relationship between variables is at a moderate level. The regression results state that there is a significant influence between land surface temperature, vegetation index, and building index on the distribution patterns PM 10 in the Bandung city.

5. References
[1] Godlee F 2018 Distant Voice, WHO Global Conference on Air Pollution and Health Geneva 30 October 2018
[2] Resosudarmo B 2017 Dampak Kebijakan Memperbaiki Kualitas Udara pada Pendapatan Masyarakat di Indonesia
[3] Husen I 2015 Distribusi Polutan Udara di DKI Jakarta (Studi Kasus Tahun 2013-2014) Thesis Undergraduate (Depok: Universitas Indonesia)
[4] Sumaryati 2011 Polusi Udara Di Kawasan Cekungan Bandung Berita Dirgantara 12 (3) (Indonesia: Lembaga Penerbangan dan Antariksa Nasional)
[5] Setiawan I B 2010 Pencemaran Udara Dalam Antisipasi Teknis Pengelolaan Sumberdaya Lingkungan Journal of SMARTek 8 pp 120 – 129
[6] Government Regulation (PP) Nomor 41 Tahun 1999 Tentang Pengendalian Pencemaran Udara Indonesia
[7] Zheng S, Zhou X, Singh P R, Wu Y, Ye Yanmei and Wu Cifang 2017 The Spatiotemporal Distribution of Air Pollutants and Their Relationship with Land-Use Patterns in Hangzhou City, China MDPI Journal Atmosphere 8 pp 110
[8] Nor Siti Afzan Buyadi, Mohd Wan Naim Wan Mohd & Misni Alamah. 2013. Impact of Land Use Changes on the Surface Temperature Distribution of Area Surrounding the National Botanic Garden, Shah Alam Social and Behavioral Sciences 101 pp 516 – 525
[9] Rasul G F I 2017 Urban Land Use Land Cover Changes and Their Effect on Land Surface Temperature: Case Study Using Dohuk City in the Kurdistan Region of Iraq Journal Climate 5 pp 13
[10] Apriani K 2018 Pemodelan Spasial Kualitas Udara di Kota Bekasi Proceeding Seminar Nasional Geografi dan Pembangunan Berkelanjutan 2018 pp 19
[11] Mukono H J 2008 Pencemaran Udara dan Pengaruhnya Terhadap Gangguan Saluran
Pernapasan (Surabaya: Airlangga University Press)

[12] Syaeful B H 2013 Metode Interpolasi Spasial Dalam Studi Geografi (Ulasan Singkat dan Contoh Aplikasinya) Jurnal Geomedia Volume 11

[13] Sarwono, J 2009 Statistik Itu Mudah: Panduan Lengkap Untuk Belajar Komputasi Statistik Menggunakan SPSS 16 (Yogyakarta: Penerbit Universitas Atma Jaya Yogyakarta)