Spatial Regression Modelling Impact of Population Movement Intensity and Land Use to Air Temperature in Semarang City, Indonesia

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Abstract. The built-up area and the number of population mobility are used to indicate urban growth. Many research’s found that number of population mobility which use motorized vehicle has contributed in increasing exhaust emissions in the air, and have an impact on air temperature, and so does the built-up area. The built-up area made the ability of the environment to absorb heat decreased. This phenomenon is also occurred in Semarang. Spatial regression modelling is used to describe the relationship between land use and population movement to Land Surface Temperature (LST) in Semarang City. Based on the spatial regression analysis, a spatial model of the effect of population movement and land use to land surface temperature can be formulated as follows, $LST = 25.2 + 0.03X_1 + 0.065X_2 + 0.000093X_3 - 0.001340X_4 + 0.000901X_5 - 0.000702X_6$. The increasing of population movement ($X_1$), industrial area ($X_2$) and residential area ($X_3$) will affect to increase the land surface temperature. Meanwhile, vacant land ($X_4$), vegetated land ($X_5$), and water bodies ($X_6$) contribute to lowering air temperature. It means the air temperature in the city of Semarang become hotter in the future if the government doesn’t provide an enough open space as an instrument to reduce the increasing of air temperature.

Keywords: Land use, Air Temperature, Movement Intensity

1. Introduction

Urban development which are characterized by the number of population mobility and the growth of built-up land cover. The amount of population mobility through motorized vehicle transportation activities has the potential to increase exhaust emissions in the air which have an impact on air quality [1]. Meanwhile, urban physical development with increasing intensity of built land use will also have the potential to reduce the ability of the environment to absorb heat [2,3].

The city of Semarang has a rapid urban physical growth which are indicated by the growth of settlement activities in the periphery and the use of land intensively at the downtown area. The physical development of Semarang City is followed by the growth of transportation activities. Settlement activities in the periphery provide a significant contribution to the number of population movements in the city of Semarang [4].

Transportation activities which use fossil-fuelled vehicles produce exhaust emissions which will affect air quality and also the land surface temperature. Research conducted in cities of China [5] showed that transportation activities have contributed to the increasing of land surface temperature. The ease of movement and connectivity between regions drives the distribution process of consumer
goods and raw materials easily. The transport activities have an impact on regional economic and drive the urbanization.

Urbanization which is indicated by land use change has an impact on the environment. Land use change contributed to the increasing of air temperature. Decreasing area of vegetated land due to land use change caused the diminishing ability of the earth's surface to absorb heat [6,7]. Based on data from the Directorate General of Highways, the movement of motorized vehicles on the main roads of Semarang City has significant growth, from 27 thousand vehicles per day in 2010 to 53 thousand vehicles per day in 2019. The growth of transportation and land use activities has been offset by increasing of air temperatures. The increasing of air temperature in the city of Semarang is around 1.08°C in the last ten years [8].

This research found that transportation activities and built-up land use are affected to the increasing of land surface temperature which is represent the air temperature in Semarang City. In other hand, the unbuilt land use has a contribution to reduce the increasing of land surface temperature in Semarang City. The contribution of transport activity and land use to land surface temperature is measured using spatial regression model. This model can describe the contribution of each factors affecting the land surface temperature spatially.

2. Data and Methods

This research used spatial regression model to explore the relationship dan contribution of transport activity and land use pattern to land surface temperature. The spatial regression model uses the same principles as classical regression [9–11] it is assumed that the independent variable and the dependent variable are interrelated, and any changes in the independent variable will affect the value of the dependent variable. In this case, any change in the value of the independent variables (land cover area and traffic volume) will have an effect on changes in air temperature in every part of the city space.

The independent variables used in this study were the number of community movements (X1), area of industrial land use (X2), area of residential land use (X3), area of vacant land (X4), area of vegetation land (X5), and area of water bodies (X6). Mathematically the Land Surface Temperature (LST) model in the city of Semarang can be symbolized as follows:

\[ \text{LST} = C + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 \]

Through the spatial regression model, it is expected that the contribution of the total population movement of Semarang City and each type of land use to LST in Semarang City can be measured with certainty. This model is expected to be a meaningful input for the physical planning of urban spatial planning and transportation that is more environmentally friendly.

The data used in this research were derived from Landsat 8 imagery and sentinel-2 imagery which were obtained through the USGS website. Population travel intra urban data were obtained from previous research by [4]. The sentinel-2 imagery is used for the land cover classification, while the Landsat 8 imagery, particularly the infrared thermal sensor, is used to create a land surface temperature map. A radiometric correction process is carried out before the process of land cover classification and a land surface temperature. The whole process of data processing and analysis used the Geographic Information System software.

3. Results and Discussion

Semarang City is one of the main economic activity centers in Central Java Province. Its role as one of the main economic centers makes Semarang City attractive for investment, as indicated by more than 22% of PMDN investment in Central Java. Semarang City, in Central Java Semarang City is ranked 2nd investment destination in Central Java after Cilacap Regency. The investment trend which is quite significant in the last five years has also tended to increase even though it decreased in 2019, but increased again in 2020.
Investment trends have a significant role in attracting people to move to Semarang City due to job opportunities. The attractiveness of migration will affect population dynamics in the city of Semarang. And it contributes to population growth and increased land demand in Semarang. The population of Semarang City has increased by around 78 thousand people in the last five years since 2015, and of course this has made the demand for housing increases. Based on the land cover map derived from sentinel 2 imagery, it can be seen clearly that residential activity is growing rapidly, especially on the periphery of Semarang City (see Figure 1).

![Figure 1. Land Use of Semarang City 2020 (Source: Sentinel-2 Imagery, USGS, 2020)](source)

The population growth in Semarang City not only contributes to the increasing demand for housing in the periphery but also contributes to the number of residents mobility from the periphery to the city center and vice versa. The mobility of population in the city of Semarang is dominated by the mobility from residential. The number of mobility from residential is higher than the mobility from industrial and trading activities. The highest number of mobility comes from the eastern side of the city of Semarang (Figure 2). The growth of residential areas in the periphery and the increased mobility of motorized vehicles will certainly also affect exhaust emissions and greenhouse gas emissions that will arise from transportation activities and residential activities in the city of Semarang.

![Figure 2. Mobility Pattern in Semarang City (Source: Analysis, 2020)](source)
Based on previous research in Jakarta and cities in China, the existence of built-up land use and the mobility of the population using motorized vehicles makes a significant contribution to increase the land surface temperature [12–14]. So does in Semarang City, areas which has a wider residential and industrial land use and higher population mobility tend to have a higher surface temperature than areas with undeveloped land (empty land, land with vegetation, and water bodies). The results of Landsat 8 imagery processing in 2015 and 2020 show an empirical fact that there has been an expansion of areas that have a higher land surface temperature level (Figure 3).

![Figure 3. Spatial Pattern of Land Surface Temperature in the City of Semarang in 2015 and 2020 (Source: Analysis, 2021)](image)

This phenomenon provides a significant indication that population mobility and land use types have a strong correlation with the increasing value of land surface temperature in Semarang City. The positive correlation is shown by the mobility and use of residential and industrial land, where areas with high mobility and residential and industrial land have high temperatures. Meanwhile, the negative correlation is shown by the non-built land which tends to have a lower surface temperature.

The results of the spatial regression analysis prove that the magnitude of population mobility and the use of residential and industrial land has a positive effect on the increase in land surface temperature, on the contrary, on land that is not built either in the form of vacant land, vegetated land or water bodies. The results of spatial regression analysis using the ordinary least squares method through geographic information system software produce the following calculation output (see Table 1).

| Variable   | Coefficient [A] | Stderror | T-Statistic | Probability [B] |
|------------|-----------------|----------|-------------|-----------------|
| Intercept  | 25,183865       | 0,002574 | 9785,433636 | 0,000000*       |
| Mov_Int (X1)| 0,028278        | 0,000053 | 532,248017  | 0,000000*       |
| Ind_Area (X2)| 0,065287        | 0,00727  | 8,98028     | 0,000000*       |
| H_Area (X3) | 0,000093        | 0,000008 | 11,127619   | 0,000000*       |
| Vac_Area (X4)| -0,00134        | 0,002077 | -0,645109   | 0,518857        |
| Veg_Area (X5)| -0,000091       | 0,000006 | -14,401957  | 0,000000*       |
| Wat_Area (X6)| -0,000702       | 0,00121  | -5,792713   | 0,000000*       |

Notes: * An asterisk next to a number indicates a statistically significant p-value (p < 0,01)

Based on the output of the spatial regression analysis, the effect of population mobility and various types of land use on land surface temperature in Semarang City can be formulated mathematically as follows.

$$LST = 25,18 + 0,028278X1 + 0,065287X2 + 0,000093X3 - 0,00134X4 - 0,000091X5 - 0,000702X6$$

(2)
This means that if the variables X2 to X6 are considered constant, then for every 1 unit increase in the intensity of population movement, the land surface temperature will increase by 0.028°C, likewise every one hectare increase in industrial and residential land area will have an effect on the increase in surface temperature. Land is 0.065°C and 0.0000930°C, whereas if the area of non-built land is empty land, vegetated land and water bodies increase, there will be a chance of a decrease in soil surface temperature.

This result is in line with the analysis carried out in previous studies [15,16] which shows that land cover diversity contributes to soil surface temperature dynamics. The contribution of non-built land (vacant land, vegetated land, and water bodies) to the decrease in soil surface temperature cannot be separated from the process of plant metabolism and the evaporation process which has an influence on the character of the surrounding microclimate. Plant metabolic processes and evaporation processes that produce oxygen and water vapor encourage a decrease in surface temperature, heat generated by built-up land activities and transportation can be reduced by oxygen and water vapor produced by plant metabolic processes and evaporation [17,18]. Spatially, the prediction of land surface temperature generated from the regression model from equation 2 shows a similarity pattern to the spatial character of land surface temperature measured through thermal infrared sensors (TIRS) from Landsat 8 imagery. Built up land uses tend to have higher surface temperatures than areas with lower activity intensity. The comparison between the results of measured land surface temperature and the predicted land surface temperature using equation 2 can be seen at Figure 4.

4. Conclusion

Based on the analysis, it can be concluded that the quality of urban air temperature will be significantly influenced by the transportation activities using motorized vehicles and the type of land use. The higher of transportation activity using motorized vehicles, it will make air temperature in the city of Semarang increase. So does the increasing area of industrial and residential areas will increase the air temperature in the city of Semarang. The growth in the use of motorized vehicles as well as the development of settlements and industry is a normal mechanism in line with economic growth in the city of Semarang. So, to reduce the impact of the growth of transportation activities and the growth of residential and industrial estates on air temperature, the Semarang City Government needs to formulate a mechanism that can control the use of motorized vehicles and control the physical development of space more environmentally. Mass public transport policies and encouraging the development of green open space policies that have been carried out by the Semarang City Government are positive steps to reduce the negative effects of the city's physical development and urban transportation activities. This effort must be more strengthened so that in the future Semarang City will become a more comfortable city to live in.
5. **Acknowledgements**

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