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Effect of Land Use Change to the Increasing Land-Based Emission and Urban Heat Island Phenomenon in Bandung City

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Abstract. In order to fulfill the needs of built areas in Bandung encouraged land use changes in several areas. This land use change is one of the contributing factors to the increasing levels of carbon emissions in the air, which will have a further impact on the increasing urban temperature and Urban Heat Island phenomenon. Thus, this study was aimed to identify the effect of land use change on the increase of land-based emissions and temperatures in Bandung, as well as the trend in the future. This study utilized stock difference analysis method and the value of land-based emissions by using simple regression method. In addition, this study identified the effect of increase in emissions to the increase in temperature. The equation model produced from the regression was applied to identify the trend in 2031. Based on the results of the analysis, it was identified that land use change that occurred in 2003, 2011, 2014 and 2016 had an influence on increasing levels of carbon emissions in Bandung and had a significant influence on the increase in temperature. This temperature trend is projected to increase by an average of 1°C in 2031.

Keywords: land use change, land-based emission, temperature surface temperature

1. Introduction
Bandung is a significantly developed city in West Java Province since it was first planned by Thomas Karsten in 1941[1]. Bandung city continues to grow in response to population growth each year. Identified in 2011 to 2015, the population of Bandung City increased by 56,152 people. This had an impact on natural land use that changed into built-up area to respond the number of population.

Land use change as a respond to urbanization might improve emissions, due to the reducing amount of vegetations [2]. The increase in emissions is related to the increase in temperature due to the amount of gas exhausts in the atmosphere resulting them to gather up which cover the Earth, reflecting heat radiation and trapping them inside. The increase in temperature will occur in urban areas due to the concentration of human’s productive activities, such as trade and services, also transportation in urban areas. In addition, buildings and roads affect radiation and will often produce heat island effect, i.e. Urban Heat Island (UHI).

The UHI phenomenon also began to occur in Bandung City, indicated by the average annual temperature increase. The average annual air temperature in the Bandung city increased by 0.15 °C, from 23.38 °C in 2011 to 23.53 °C in 2016[3]. The trend of increasing average temperature turned out to be in line with the land use change. From 2003 to 2014, the percentage of the built area continued to
increase, which originally amounted to 72%, proceeded to develop to 88% [3]. With changes in land use, the increase of emissions in the air was projected to incline due to land use change.

Indications of the relationship between land use change, emission, and air temperature have not been specifically identified for the case of Bandung City. This study is expected to greatly contribute the intervention that will be carried out in the future spatial plan. Therefore, this study was aimed to identify the effect of land use change on increasing emissions and urban temperatures as an indication of the existence of the urban heat island phenomenon.

2. Methods

This study is an explanatory research with a causal approach, exploring the effects of land use change on the increasing land-based emissions and the UHI phenomenon, as well as providing the predictions for the future. The land uses observed in this study are the land use data in Bandung City in 2003, 2011, 2014, and 2016 in accordance with the availability of data. This study utilized the three main methods of analysis, such as: (1) method of calculating surface temperature changes, (2) methods of calculating land-based emissions, and (3) method of correlation.

2.1. Method of calculating land surface temperature changes

In this study, the phenomenon of the urban heat island was identified by using observations from Temperature Land Surface (LST) to measure the surface heat emitted by the land. LST was measured by applying the remote-sensing techniques, estimating the brightness level of the uppermost layer in the atmosphere, which was captured based on its brightness in the Landsat image [4]. The value of this LST represented the value of urban temperature by converting Digital Number to spectral radiation, which has its brightness temperature valued. LST will be measured based on Landsat 7 with band 6, conducted by using the following formulas and stages of:

1. Changing the DN values into spectral radiance by using the conversion formula on Landsat 7 as follows [5], [6]:

\[
L_{\lambda} = \left( \frac{L_{\lambda_{\text{max}}}-L_{\lambda_{\text{min}}}}{QCAL_{\text{max}}-QCAL_{\text{min}}} \right) \times (Qcalc - QCAL_{\text{min}}) + L_{\lambda_{\text{min}}}
\]

\(L_{\lambda} \): Spectral radiance (Watts/(m² * srad * μm))
\(L_{\lambda_{\text{max}}} \): Maximum spectral radiance in scale of QCALmax. \(L_{\lambda_{\text{max}}} \) for Landsat 7 with band 6 is 17.040
\(L_{\lambda_{\text{min}}} \): Minimum spectral radiance in scale of QCALmin. \(L_{\lambda_{\text{min}}} \) for Landsat 7 with band 6 is 0
\(QCAL_{\text{max}} \): Maximum pixel value. QCALmax for Landsat 7 with band 6 is 255
\(QCAL_{\text{min}} \): Minimum pixel value. QCALmin for Landsat 7 with band 6 is 1
\(Qcalc \): Quantized and calibrated standard product pixel values, Digital Number which used (thermal band)

2. Calculating the Brightness Temperature by converting \((L_{\lambda})\) spectral radiance then converting it to TB value into temperature with unit Kevin (K). This used thermal constants provided in metadata landsat 7 ETM+ files [6]:

\[
T_B = \frac{K_2}{\ln \left( \frac{K_1}{K_2} + 1 \right)}
\]

\(T_B \): At-satellite brightness temperature (K)
\(L_{\lambda} \): Spectral radiance (Watts/(m² * srad * μm))
K1 : Band-specific thermal conversion constant from The metadata (K1_CONSTANT_BAND_x, where x is the band number), with the constant for Band 6 of Landsat 7 is 666.09
K2 : Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the band number), with the constant for Band 6 of Landsat 7 is 1282.71

3. Calculating the LST by converting the estimation results of $T_B$, which have kelvin units to centigrade by reducing each result of the calculation with a value of 273.15.

$$T = T_B - 273.15$$

$T$ : Temperature in Celsius (°C)
$T_B$ : At-satellite brightness temperature (K)

2.2. Method of calculating land-based emission
Calculation of land-based emissions was carried out by identifying the value of carbon stocks from a land use. In this study, the approach applied the stock difference approach, that identifies an increase or a decrease in carbon stocks, due to changes in land cover biomass as a representation of land use change [2]. This method was carried out by calculating the total carbon stock from each type of land cover. The value of carbon stocks used in this study refers to the value of aboveground carbon stocks for each type of land cover issued by the National Development Planning Agency (Bappenas) in the framework of preparing Regional Action Plans for the reduction of Greenhouse Gases (RAD-GRK). The calculation carried out for each type of land use change, including the realization of the spatial pattern plan contained in the Bandung City Spatial Plan (RTRW) with the basic formula as follow [2], [7]:

$$EV = AD \times FE$$

$EV$ : Emission Value, the amount of greenhouse gases released into the atmosphere from a landscape (ton CO$_{eq}$)
$AD$ : Activity Data, area of land cover changes (ha)
$EF$ : Emission Factor, the amount of carbon stored from a biomass in land cover (ton CO$_{eq}$)

From the results of the calculation of carbon stock values, the amount of emissions produced was gathered from the difference in the carbon stocks value from two different periods. If the value of the carbon stock difference is greater than 0 (emission value > 0), carbon release into the air was present, which means there was an increase in the level of emissions in the air. If the value of the carbon stock difference is less than 0 (emission value < 0), carbon storage or sequestration was present. If the value of the difference in carbon stock is equal to 0 (emission value = 0), then there is no change in the carbon content in the air [7].

2.3. Method of correlation
This study identified the correlation through the effect of changes in the value of land-based emission toward LST and its consequences for the UHI phenomenon. This correlation was identified by using a simple regression analysis between each change in the value of land-based emission with each change in the value of LST in a location experiencing changes in land use. Aside to identify the influence, this analysis was also utilized to build an equation model of the influence, which will be used to estimate the conditions that will occur in the future, when the spatial pattern plan for Bandung City RTRW in 2031 is realized. The hypothesis of the equation that was proven as follows:

$$Y = a + bX$$
\[ Y = \text{dependent variable of LST for each pixel land use change} \]
\[ X = \text{independent variable of land-based emissions as a consequence of land use changes calculated from each pixel change in land use} \]
\[ a = \text{constant} \]
\[ b = \text{coefficient estimator of X} \]

This method was carried out through 3 (three) main tests, namely: (1) Pearson correlation test, (2) F-test, and (3) t-test.

Pearson correlation was applied to find out the strength and direction of the influence between changes in land-based emission to the changes in LST. The closer Pearson correlation value to 1, the greater the relationship formed and conversely, the farther it is to 1, the smaller the relationship formed. If the correlation value is positive (+), then the direction of the relationship between changes in land-based emission are in line with changes in LST or in other words the greater the changes in land-based emission, the greater the LST changes that occur. Conversely, if the correlation value is negative (-), then the relationship between changes in land-based emission is inversely proportional to changes in LST or in other words the more changes in land-based emission that occur, the smaller the LST changes that occur.

The F-test was performed to determine whether the independent variable changes in land-based emission (X) had a joint effect on the dependent variable LST (Y). This F-test proves that the model generated from regression analysis can / cannot predict temperature conditions in 2031. The hypotheses tested are:
- **Ho**: Land-based emissions do not have a joint effect to predict temperature / model or the equation formed cannot be used to predict temperature.
- **H1**: Land-based emissions have a joint effect to predict temperature / model or the formed equation can be used to predict temperature.

The test criteria are as follows: **Ho**: accepted (H1 rejected) if the significance is \( F \geq 0.05 \) and **H1**: rejected (Ho accepted) if the significance is \( F \leq 0.05 \)

The t-test essentially shows how far the effect of 1 (one) variable changes in land-based emission in explaining LST variables. The hypotheses tested are:
- **Ho**: Variable of land-based emissions have no effect on LST.
- **H1**: Variable of land-based emissions have the effect of predicting LST.

The test criteria are as follows: **Ho**: accepted (H1 rejected) if the significance is \( t \geq 0.05 \) and **H1**: rejected (Ho accepted) if the significance is \( t \leq 0.05 \)

### 3. Result and Discussions

#### 3.1. Temperature Changes as a consequence of Land Use Change in the City of Bandung

The results of processing by converting brightness levels to landsat 7 images into temperature values indicated that the city of Bandung had a high LST value in the city center, while for areas far from the city center tended to have a low LST. Changes in the LST of Bandung City from 2003-2016 experienced fluctuations. The highest LST is in the built area, which is marked by red, marking the heat due to the prolonged and existing heat absorption in building during the day [8].

In 2003, the highest LST was found in the northern part of Bandung; in Cibeunying Sub-district, and in the airport at Cicendo Subdistrict. On other areas, the average LST was only 25-26°C and the lowest was in the East of Bandung. In 2011, the highest LST was in the city center to the North and South with an average surface temperature of 32°C. The increase of LST from 2003 to 2011 was quite high, because almost all areas of Bandung City in 2011 had high LST. In 2014, the LST of the city of Bandung decreased to 6-14°C at the lowest, while the highest was 24-26°C. The highest LST was spread in the central part of the city to the northern part, from the District of Bojongloa Kidul to Sukasari District. In 2016, the LST of the city of Bandung experienced an increase compared to 2014. The lowest LST ranged from 13-16°C, and the highest was 27-34°C. The highest LST were only
scattered in the central part of the city and in the North such as Cibeunying District, and Cicendo District. For some parts such as North Bandung, the average low LST ranged only from 13-16°C due to the large area of vegetation in the area. The distribution of LST changes in the city of Bandung is depicted in Figure 1.

3.2. Land-Based Emission as Consequences Land Use Change

Emission calculations were carried out by using data on land use change in 2003, 2011, 2014, 2016, along with spatial pattern of the RTRW in 2031. With these data, the carbon stock change process was carried out by using the difference approach of two different-time periods. The processing results showed that emissions due to land use change, continued to increase. This increase was influenced by the reduction in non-built land changing into built-up land, as the consequence of the increasing population.

Figure 1. LST Changes in 2003-2016
Source: Analysis Result, 2018

Figure 2 presents the information that the change in total emission values is striking between the changes in 2011-2014 and 2003-2011. In 2011-2014, the largest increase of carbon stocks (sequestration) was identified, which was in contrast to the conditions in the changes from 2003-2011 producing the largest emissions from the range of years during the research. However, this condition does not work consistently, as in 2016, the drive to rebuild the city was unstoppable, with changes in rice fields, as well as in residential areas. This has an impact on the emissions resulting from changes in 2016 (increase). The fluctuations in land use change were anticipated in the spatial pattern of the Bandung City Plan (RTRW) 2031 to restore better condition of Bandung City, by producing greater sequestration. In terms of distribution, changes in the value of emissions marked land use changes in the eastern part of Bandung, such as Gedebage and Ujingberung, with a large amount of non-built land available in 2003, as target for urban development allocation (Figure 2).

3.3. Corellation of Land-based Emission Change and LST Change as Consequences of Land Use Change

Changes in land-based emissions during the period of 2003-2016 were essentially in line with the condition of the LST of the city of Bandung at the same period. This was identified from the value of emissions in 2011-2014, which resulted in the largest sequestration value with the average LST at the
lowest value among all years of research. On the contrary, in 2003-2011 and 2014-2015, a large land-based emission value had a high average LST. The existence of conditions that are in line between changes in emissions was due to changes in land use with LST (indicating a relationship between the two) [8]. As for proving this correlation, a correlation analysis was performed by using a simple regression analysis between changes in land-based emission with changes in LST on each type of land use change. This analysis was carried out separately for each type of land use change to identify the linkages more specifically. From this simple regression analysis, the threetest results were obtained, including $R^2$, F test, and t test.

![Figure 2. Distribution of Land-based Emission 2003-2031](source: Analysis Result, 2018)

From the results of the analysis, it was identified that changes in any land use change that produced a certain emission value, turned out to have an effect on the existing LST conditions with a positive relationship (Table 3). Even though it has a relationship, the relationship formed is relatively small when seen for each of these changes. From these results, it was identified that the value of $R^2$ which gave the most influence was the use of station land by 1.1%, while the value of $R^2$ was the smallest for sports areas of 0.001%. This identified that the change in land use into a built area such as a station had a relatively large effect compared to other land use changes with the green land cover.

**Table 1.** $R^2$ Value dan t-test for Each Type of Land Use Change

| No | Changes From Using Any Land to Being | $R^2$ | Information | t-stat | Sig. t-test | Information t-test |
|----|--------------------------------------|-------|-------------|--------|-------------|-------------------|
| 1  | Airport                              | 0.044 | Corellated  | 2.609  | 0.01        | Corellated        |
| 2  | Military Area                        | 0.015 | Corellated  | 1.909  | 0.057       | Corellated        |
| 3  | Forest                               | 0.047 | Corellated  | -2.772 | 0.006       | Corellated        |
| 4  | Religion Facility                    | 0.003 | Corellated  | 1.856  | 0.064       | Corellated        |
| 5  | Industry                             | 0.015 | Corellated  | 7.161  | 0.000       | Corellated        |
| 6  | Health Facility                      | 0.015 | Corellated  | 2.609  | 0.009       | Corellated        |
| 7  | Sport Facility                       | 0.001 | Corellated  | 1.165  | 0.244       | Not Corellated    |
| 8  | Education Facility                   | 0.012 | Corellated  | 4.996  | 0.000       | Corellated        |
| 9  | Government Office                    | 0.007 | Corellated  | 2.373  | 0.018       | Corellated        |
| 10 | Trading Facility                     | 0.005 | Corellated  | 7.567  | 0.000       | Corellated        |
Based on the t-test statistic related to the influence of the variable changes in land-based emission (X) and LST (Y), the value of Sig. was less than 0.05 for each land use except for sports facilities, because the use of the land had not changed. Based on the t test, there was a significant effect on the increase in LST (Y) in the city of Bandung, due to an increase in land-based emission (X). Each use of land except sports facilities produced changes in land-based emission (X) with the highest concentration value from the agricultural land use with a t value of 11,798 with a significant value of 0.00. Thus, it is concluded that there is an increase in land-based emission (X) from the area built into an agricultural area. Land use with the concentration of land-based emission (X) becomes the lowest for forest land uses with a t value of -2.7772. This explains that there is a change in land-based emission (X) to be sequestration due to changes in land use into forest areas.

The corellation between variables X and Y as a single unit model was understood by the F / Anova correlation test using the formula in equation (5). From the results of the analysis, it was explained that the model of the relationship between changes in land-based emission and changes in LST formed for each type of land use change were all insignificant. Of the 15 patterns of land use change that occurred, it was identified that the change became sports facilities, giving a significance value greater than 0.05, identifying that the model of the relationship equation formed cannot be used to predict conditions in the future. Meanwhile, 14 other land-use change patterns provided conditions that the model from this simple regression analysis was significant to predict future conditions (Table 4).

### Table 2. F-test Value for Each Type of Land Use Change

| No  | Changes From Using Any Land to Being | R²  | Information | t-stat | Sig. | Information | Arti Model Persamaan |
|-----|-------------------------------------|-----|-------------|-------|------|-------------|----------------------|
| 1   | Airport                             | 6,808 | 0.01 | Corelated | Y = 24,245+0.002 (x) | Every increase in emissions by 1% causes a LST increase of 0.002°C |
| 2   | Military Area                       | 3,644 | 0.057 | Corelated | Y = 24,667+0.044 (x) | Every increase in emissions by 1% causes a LST increase of 0.044°C |
| 3   | Forest                              | 7,683 | 0.006 | Corelated | Y = 22,847+0.006 (x) | Every increase in emissions by 1% causes a LST increase of 0.006°C |
| 4   | Religion Facility                   | 3,445 | 0.064 | Corelated | Y = 0.659+25.273 (x) | Every increase in emissions by 1% causes a LST increase of 0.659°C |
| 5   | Industry                            | 51.274 | 0.000 | Corelated | Y = 23,165+0.39 (x) | Every increase in emissions by 1% causes a LST increase of 0.39°C |
| 6   | Health Facility                     | 6,808 | 0.009 | Corelated | Y = 25,376+1,346 (x) | Every increase in emissions by 1% causes a LST increase of 1.346°C |
| 7   | Sport Facility                      | 1,358 | 0.244 | Not Corelated | Y = 24,801+0.01 (x) | Every increase in emissions by 1% causes a LST increase of 0.01°C |
| 8   | Education Facility                  | 24,959 | 0.000 | Corelated | Y = 24,549+0.039 (x) | Every increase in emissions by 1% causes a LST increase of 0.039°C |
| 9   | Government Office                   | 5,630 | 0.018 | Corelated | Y = 25 +0.29 (x) | Every increase in emissions by 1% causes a LST increase of 0.29°C |
| 10  | Trading Facility                    | 57,256 | 0.000 | Corelated | Y = 24,188+0.001 (x) | Every increase in emissions by 1% causes a LST increase of 0.001°C |
| 11  | Residential Area                    | 53,088 | 0.000 | Corelated | Y = 23,509+0.002 (x) | Every increase in emissions by 1% causes a LST increase of 0.002°C |
| 12  | Stasion                             | 41,169 | 0.000 | Corelated | Y = 25,088+0.493 (x) | Every increase in emissions by 1% causes a LST increase of 0.493°C |
| 13  | Park                                | 12,706 | 0.000 | Corelated | Y = 23,250+0 (x) | Every increase in emissions does not cause an increase of LST |
3.4. Effect of Spatial Planning in Reducing Emissions and UHI Phenomena

The equation model obtained from simple regression analysis on each land use change is utilized to predict the distribution of LST in Bandung in 2031 with the spatial pattern plan (the Bandung City Spatial Plan (RTRW) 2031). As for changes to sports facilities, it is assumed to remain constant because the equation model formed from the results of simple regression analysis showed no effect.

From the results of calculations with the equation formed in Table 4, it was identified that the average LST of Bandung in 2031 would increase by 0.92°C (close to 1°C) or at an average of 24°C. This average LST is predicted to increase compared to the average LST in 2016 (23.02 °C) due to changes in the value of emissions in vegetation area that becomes built area, resulting in high emissions of 10,235 CO₂eq in which a 1% increase in emissions causes the increase in LST of 0.6°C.

When compared to the land-based emission produced, it showed that a sequestration leads to the absorption of carbon stocks with higher LST. This means that the increase in the allocation of protected areas and parks in the Bandung Spatial Plan (RTRW) 2031 has not been able to reduce the overall LST. This also means that the composition of protected areas and parks in Bandung is not enough to reduce the rising temperature of settlements as a result of the construction of the built area. The prediction of changes in LST in 2031 will occur a lot in eastern and northern part of Bandung, which currently has a tendency to change into a built up area (Figure 3).

![Figure 3. Comparation of LST Distribution 2016 and 2031](source: Analysis Result, 2018)

4. Conclusion

This tendency of increasing LST indicates that the UHI phenomenon occurred in Bandung. The increasing value of LST indicated the increasing value of air temperature as the existence of the UHI phenomenon in urban areas [4]. The value of this LST was converted into UHI values in urban areas. For the case of Bandung City, the increase in the UHI phenomenon was caused by the increase in land-based emission with response to the development needs of Bandung City contributing to the occurrence of the UHI phenomenon.

The Bandung City Spatial Plan (RTRW) 2031, which has allocated protected areas and parks, has not been able to control and reduce the UHI phenomenon. The allocation of sufficiently good space needs to be complemented by detailed directions on each type of land use change that can later be followed up in zoning regulations in a detailed spatial plan. The detailed form of directives included...
the determination of a large green coefficient in the built area, the use of materials that can absorb heat, and the selection of the right type of vegetation for absorbing heat and absorbing emissions.

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