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RESEARCH ARTICLE

Association between Surface Air Temperature and Land Use On The Campus Scale

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Abstract

The increasing trend of global temperature is related to the land use change in the form of urbanization. The impact of land use change to surface air temperature in Indonesia especially in smaller scope in Indonesia have not researched yet. The study area is located on newly built campus and the development of land use change inside campus can be managed carefully. This research aim is to determine which land use affecting high-temperature by using multiple linear regression method with least square approach so that temperature increase can be controlled in which some land uses must be preserved in urbanization. Land use data is interpreted from the photo map of 275 hectare campus. Temperature data is measured by using the digital thermometer three times a day. The method idea is to obtain distinctive contribution of every land use to every temperature measurement point. The contribution follows the inverse distance weighted concept. Surface air temperature measurement points are located with 150 meter interval and centroids of land use polygons are used for association calculation. Temperature measurement shows values between 25.5°C and 35.4°C. Land use with more anthropogenic activities and rubber plantation are the top contributors to high surface air temperature within a day. In the non-built-up land use category, water body increases the temperature in the daytime. Anthropogenic activities and vegetation density within land use is the main factor in increasing the surface air temperature so that it is suggested to plant farm-like vegetation around every built-up land use.

Keywords: Temperature, Land Use, Multiple Linear Regression, Least Square

1. Introduction

Surface air temperature which is temperature of the air near the surface of the earth shows increasing trends globally over the years (Jones et al., 1999; Shrestha et al., 2017; Foster et al., 2017). The temperature increase can be significantly measured in global scale (Hansen et al., 2006), country scale (Li et al., 2020; Fujibe, 2009; Domroes and El-Tantawi, 2005; Tang et al., 2010), or a city scale (Rahman, 2011; Ludwig et al., 2004; Martinez-Austria et al., 2016; Sharovsky et al., 2004). The factors that affect the temperature are latitude, surface type, elevation, relationship to large bodies of water, and cloud cover (Ackerman and Knox, 2006). The temperature increase is affected by the change of those factors. In a smaller scale, one of the factors that lead to the temperature increase is surface type or land use (Baldocchi and Ma, 2013), vegetation characteristics, building spatial distribution, and surface material (Bonan, 2000; Stone and Norman, 2006; Middel et al., 2014).

Land use change — highly associated with urbanization (Dadashpoor et al., 2019; Alphan, 2003) — affect the temperature increase (Kalnay and Cai, 2003). It is associated with how well the land use or surface type in absorbing or reflecting solar energy such as grassland absorbs more energy than aluminium–based building which affects the temperature (Frick and Suskiyatno, 1998). The example of country with high urbanization is Indonesia (equatorial region). The high intensity of urbanization in Indonesia (Rahmawati, 2020) affects the land use change and increase the temperature. The land use changes due to urbanization in Indonesia are researched in many area such as Banten (Saifullah et al., 2017), Central Sulawesi (Veldkamp et al., 2009), and Jakarta (Hutabarat, 2010). The association between surface air temperature and land use have been researched in global scale (Rasul, 2020), country scale (Yang et al., 2009; Deng et al., 2015a; SadiqKhan et al., 2020; Saavedra et al., 2020), and city scale (Amorim et al., 2020; Dissanayake, 2020). Most of the researches involve large area (over 1000 hectare) and the temperature sampling method is in sparse interval. Moreover, the specific impact of land use change to surface air temperature especially in Indonesia have not researched yet.

This research focuses on association between land use and temperature on the campus scale in Indonesia The area of campus is 275 hectare (Fig. 1) and it is good location to be researched since the campus is newly built campus (Institut Teknologi Sumatera, 2013; Alif et al., 2019a; Alif et al., 2018) and the development of land use change inside campus can be managed carefully based the result of this research. Smaller area means the sampling method is not sparse and factors that affect the temperature beside land use and elevation are neglected. This research aim is to determine which land use affecting high-temperature by using multiple linear regression method with least square approach so that temperature increase can be controlled in which some land uses must be preserved in urbanization.

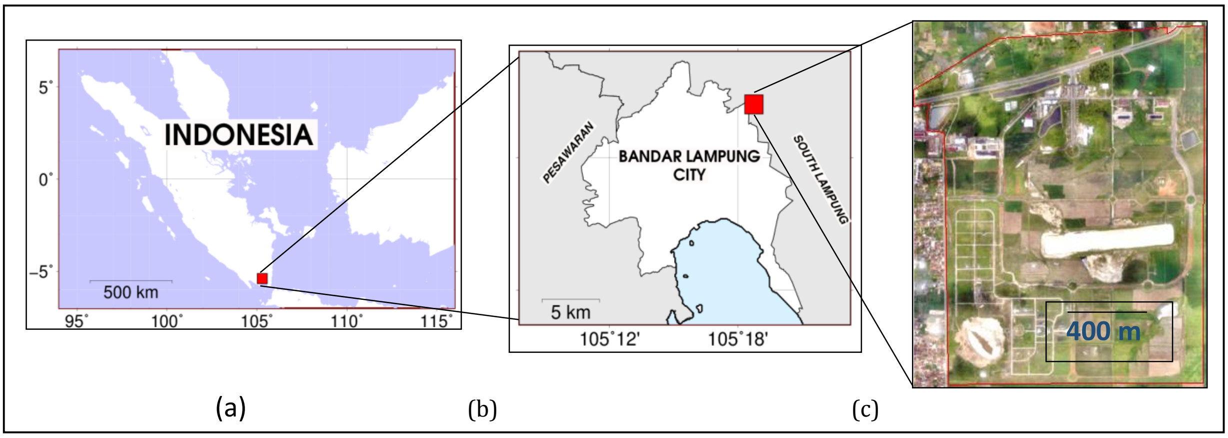

Fig. 1. Research location delineated by red lines (c) and is shown by red rectangle in (a) and (b). Black lines connect figure (a), (b), and (c).

2. Temperature and Land Use Data

Land use data is interpreted from the photo map of 275 hectare campus. The the photo map is obtained from the photogrammetry measurement in 2019. The the photo map has 4.8 cm accuracy in 1:1000 scales. Land use is interpreted visually using nine interpretation keys (Hodgson et al., 2007) as follows: pattern, tone, texture, shadow, site, shape, size, association, and resolution).

The classification is based on SNI of land use classification (Badan Standardisasi Nasional, 2014) resulting in 10 kinds of land use found on the area, delineated by polygons,and validated directly on site. Those land uses are public facilities (canteen, sports field, and clinic), student and lecturer dormitory, classroom building, settlement, road network, vacant land, farm, rubber plantation, paddy field, and water body. The validation is conducted on every land use resulted in 91% overall accuracy.

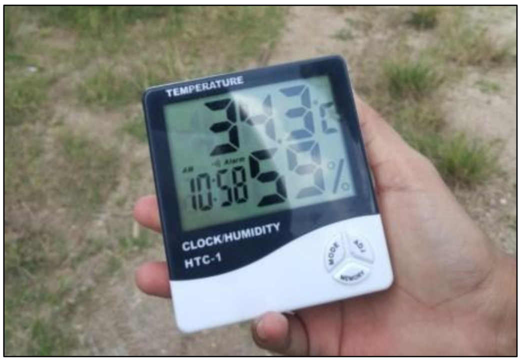

Fig. 2. The digital thermometer used to measure surface air temperature.

Temperature data is measured by using the digital thermometer three times a day (Fig. 2). The thermometer has a resolution 0.1°C and can measure temperature from -10°C until 50°C. The temperature is measured on April 11th, 2019 in monsoon transition (Chang et al., 2005) with partly cloudy weather. The temperature is measured in the morning (06.30-07.30), noon (12.00-13.00), and afternoon (16.00-17.00) due to fluctuation of temperature in a single day (Lakitan, 2002). The temperature is measured on point called in this research as temperature measurement points (TMP).

Elevation data is obtained from The digital Elevation Model processing resulted from campus the photo map. The elevation has 3 meter resolution with geoid as vertical datum. The elevation is classified into three classes (Di Gregorio, 2005; Alif et al., 2019b): low, medium, and high. The elevation is taken into account as the other factor affecting surface air temperature besides land use.

3. Association Calculation Method

Temperature data are overlaid with either land use data or elevation data to understand association among the parameters. The method idea is to obtain distinctive contribution of either every land use or every elevation class to every TMP. The contribution follows the inverse distance weighted concept (Lu and Wong, 2008) – the further the particular land use to the TMP, the less contribution the particular land use to the temperature on TMP.

Surface air temperature measurement points are located with 150 meter interval and centroids of land use polygons are used for association calculation. The numbers of TMP are 72 points based on number of minimum sample point formula for map with 1:1000 scales (Badan Informasi Geospasial, 2014). The distribution of TMPs is shown on Fig. 3.There are total 99 land use points (LUP) for association calculation derived from centroid of every land use polygons. The point samples of every elevation class (ECP) are located in ~150 meter interval and the number for every class depends on the area of every class. There are a total of 41 ECPs used for association calculation.

Association calculation is conducted by applying distance from either LUP or ECP to TMP into multiple linear regression method. The distance is two-dimensional Euclidean distance (Johnson and Wichern, 2002) by using Universal Transverse Mercator coordinates of points as input. The distance is calculated from every TMP to every either LUP or ECP. The distance value is used in multiple linear regression calculation.

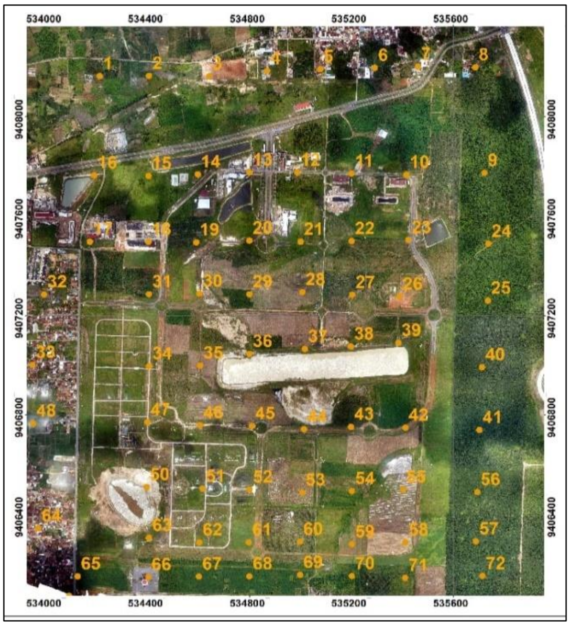

Fig 3. Surface air temperature measurement point shown by orange dots. Number mark close to every dot is the number of the measurement points.

Multiple linear regression method using least square approach is started by completing the mathematical equation of multiple linear regressions as shown on Eqn. 1 (Kahar, 2007). Least square approach is usually used in calculating reference frame for topography mapping (Kahar, 2007), statistics (Pratomo and Astuti, 2015), meteorology (Estiningtyas and Wigena, 2011), and transportation (Cong et al., 2016; Kresnanto, 2010; Alif and Silaen, 2020). Least square approach is also used in surface air temperature or land use related research (Kalota, 2017; Marchetti et al., 2015; Deng et al., 2015b; Untari, 2012).

$$
\begin{aligned}
a_0 + a_1x_{11} + a_2x_{12} + a_3x_{13} + \ldots + a_ux_{1u} &= f_1 \\
a_0 + a_1x_{21} + a_2x_{22} + a_3x_{23} + \ldots + a_ux_{2u} &= f_2 \quad (1) \\
&\vdots \\
a_0 + a_1x_{n1} + a_2x_{n2} + a_3x_{n3} + \ldots + a_ux_{nu} &= f_n
\end{aligned}
$$

Where a is association parameter of TMP and either LUP or ECP which is the only independent variable in the equation, u is the number of either LUP or ECP used in the equation, n is the number of TMP or equation used which is 72 equations, x is the inversion of distance between TMP and either LUP or ECP, and f is the value of surface air temperature on every TMP.

One mathematical equation from Eqn. 1 describes one TMP which is the quantification of surface air temperature value and inversion of distance between TMP and either LUP or ECP. Eqn. 1or association calculation formula is used 11 times: one to calculate the association between temperature and elevation, 10 times to calculate association between temperature and every land use. The equation with those data can be calculated since the unknown parameters are always less than the known measurements (Kahar, 2007) or 72 data. The association parameters of land use polygons are averaged to obtain the association parameter of land use. The association parameter of TMP and every land use compared with each other to understand the contribution of land use location to the temperature.

Eqn. 1 can be solved by converting the equation into matrices in Eqn. 2 and the matrices are calculated in Eqn. 3.

$$
B = \begin{bmatrix} 1 & x_{11} & \cdots & x_{1u} \\ \vdots & \vdots & \ddots & \vdots \\ 1 & x_{n1} & \cdots & x_{nu} \end{bmatrix} \quad A = \begin{bmatrix} a_1 \\ \vdots \\ a_u \end{bmatrix} F = \begin{bmatrix} f_1 \\ \vdots \\ f_n \end{bmatrix} (2)
$$

$$
A = (B^T B)^{-1} B^T F \qquad (3)
$$

Where B is design matrix in multiple linear regressions, F is surface air temperature value matrix, and A is association parameter matrix used to understand the association between surface air temperature and either land use or elevation.

4. Result and Discussion

Land use polygon (Fig. 4) and elevation class (Fig. 5) are determined and validated before association calculation. The dominant land use in the area is farm and vacant land. The high elevation class in the area is located on the northwest which is dominated by farm and classroom building land use.

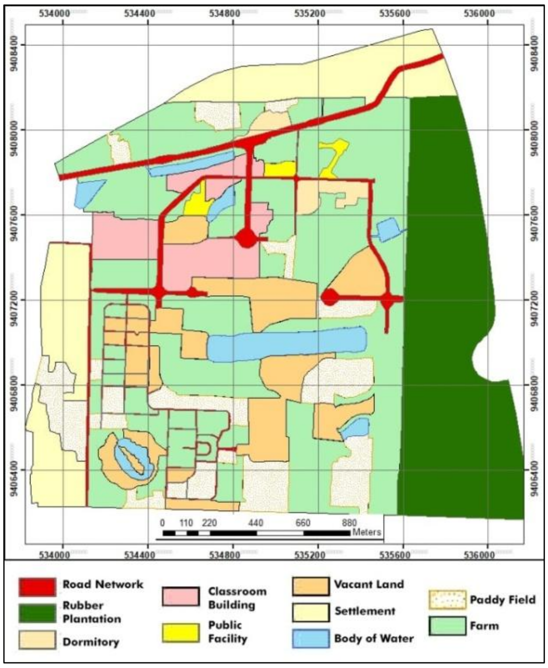

Fig. 4. Land use polygon is shown by various colors with the legend inside the figure.

Before understanding the association between surface air temperature and land use, the contribution of elevation to the temperature is calculated. In a larger scale, the temperature is decreasing with height (Anthony, 2015). From this research result with campus scale, it can be inferred that elevation is not on the line with the theory. In the morning, a high elevation class is the lowest contributor to the high-temperature. In the noon, low elevation class is the lowest contributor to the high-temperature. In the afternoon, the high elevation class is the lowest contributor to the high-temperature.

Temperature measurement in the morning shows values between 25.5°C and 26.1°C with the highest value located on the northern side of the campus. The area is close to the main road network connecting toll road entrance and the city. It is suggested that the traffic on the road contributes more to the highest temperature in the morning. The other area with high-temperature is located close to the southwest water body. On the contrary, the area with the lowest temperature located in central-eastern and which is on farm and rubber plantation land use with less anthropogenic activities in the morning.

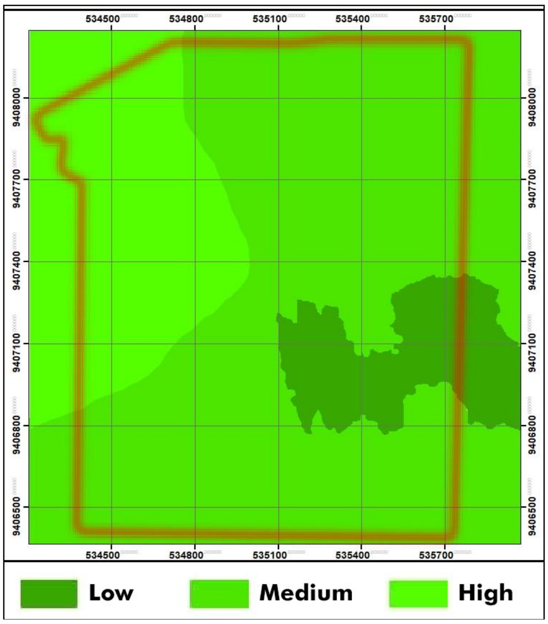

Fig. 5. Elevation class is shown by various colors with the legend inside the figure. Red lines show the boundary of the campus.

Land use with the highest contribution to the temperature in the morning from the calculation is settlement. The contribution percentage of surface air temperature is shown in Table 1. Besides traffic that contributes more to the highest temperature, other land uses with anthropogenic activities contribute more than road networks which are: settlement, dormitory, public facilities. It is suggested that in the morning anthropogenic activities in those land uses especially settlement are more than anthropogenic activities in road network. Top five high-temperature contributors in the morning are land uses with anthropogenic activities while the top six high-temperature contributors relatively have little vegetation. It is in line with the bottom four high-temperature contributors are land uses with relatively having much vegetation.

Table 1 Contribution of land use to the surface air temperature in the morning

Rank	Land Use	Percentage (%)
1	Settlement	22.2
2	Dormitory	22.1
3	Public Facilities	15.1
4	Road Network	12.3
5	Classroom Building	7.1
6	Water body	6.7
7	Vacant Land	5.6
8	Rubber Plantation	4.2
9	Paddy Field	3.3
10	Farm	1.4

Temperature measurement in the noon shows values between 33.8°C and 35.4°C with the highest value located in the southwestern side of the campus close to the southwest water body. The location has various land uses that have little vegetation such as settlement, road network, water body, and vacant land. It is suggested in the southwest water body, the temperature of the solar is reflected by the water and increase the temperature of its surrounding, moreover, the land uses surrounding it relatively has little vegetation. On the contrary, the area with the lowest temperature located in the most north of campus in farm land use. It is highly suggested the absorption of solar energy at the noon in farm land use (Frick and Suskiyatno, 1998) is related to the temperature.

Land use with the highest contribution to the temperature in the noon from the calculation is dormitory. The contribution percentage of surface air temperature is shown in Table 2. The typical land uses that contribute more to high-temperature in noon resembles morning results which are land uses with more anthropogenic activities except one thing. Rubber plantation which contributes less in the morning contributes more to high-temperature more than public facilities and classroom building. It means — unlike the other vegetation — the vegetation in rubber plantation give bad impact on the local environment (Majumder et al., 2014). The road network in the noon contributes more than itself in the morning. It is suggested that the traffic at the noon is more than the traffic in the morning including road network inside campus, especially road close to the southwest water body. Water body contributes more than classroom building since it reflects solar energy into the surroundings. Farm and paddy field is still the bottom two high-temperature contributors.

Temperature measurement in the afternoon shows values between 29.4°C and 30.3°C with the highest value located in the southwestern side of the campus close to the southwest water body similar to measurement in the noon.

Table 2 Contribution of land use to the surface air temperature in the noon

Rank	Land Use	Percentage (%)
1	Dormitory	23.8
2	Settlement	17.3
3	Road Network	15.2
4	Rubber Plantation	15.1
5	Public Facilities	9.0
6	Water body	6.0
7	Classroom Building	5.8
8	Vacant Land	3.8
9	Paddy Field	2.3
10	Farm	1.7

The other area with high-temperature is located east side of the campus in rubber plantation land use. On the contrary, the area with the lowest temperature scattered inside the campus which is mostly on farm land use with less anthropogenic activities in the afternoon.

Land use with the highest contribution to the temperature in the afternoon from the calculation is settlement. The contribution percentage of surface air temperature is shown in Table 3. The land uses with more anthropogenic activities plus rubber plantation are the top six high-temperature contributors. Moreover, rubber plantation bad impact on the local environment in the afternoon worse than its impact in the noon. Water body land use in the afternoon contributes less than itself in the noon.

Table 3. Contribution of land use to the surface air temperature in the afternoon

Rank	Land Use	Percentage (%)
1	Settlement	23.3
2	Rubber Plantation	17.4
3	Dormitory	16.7
4	Road Network	14.7
5	Public Facilities	10.8
6	Classroom Building	6.9
7	Water body	4.2
8	Vacant Land	2.3
9	Paddy Field	2.1
10	Farm	1.6

In a day, land use with more anthropogenic activities and rubber plantation are the top contributors to high-temperature in campus scale. The rank difference of those land uses from morning to afternoon is shown in Fig. 6. Built-up land use with more anthropogenic activities and less vegetation are the top contributors to high-temperature in all-time as well as rubber plantation in noon and afternoon. Class building is the least contributor among built-up land use while water body is the biggest contributor after rubber plantation among non-built-up land use. It reflects the sunlight especially the one close to temperature highest peak hour (between noon and afternoon) (Lakitan, 2002) and increases the temperature of its surrounding. Settlement contributes more than dormitory at all times except at the noon. Road network contribution to high-temperature depends on the traffic (Ha et al., 2020). The traffic is less in the morning and more in the noon and the afternoon (Alif and Silaen, 2020) in the same boat with the road network ranking in all day.

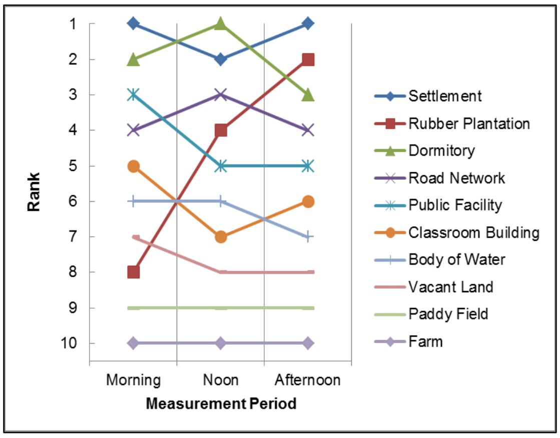

Fig. 6. Land use contributor rank to high-temperature in three measurement periods with legend inside the figure.

Built-up land use contributes to high surface air temperature depends on anthropogenic activities and its vegetation density (Fauzi et al., 2019). It confirms that residential areas are the top contributors to high-temperature (Ha et al., 2020). In brief, the Built-up land uses have strong positive correlation with surface air temperature (Rasul, 2020). The construction of new build up land use in campus development is suggested to be more vertical development than horizontal development.

Farm-like vegetation is the best land use to minimize the surface air temperature while water body is one of the worst. Farm-like vegetation increase the temperature less than grass-like vegetation (Yang et al., 2009). In this research, farm is the least contributor to high-temperature among non-Built-up land use. The result confirms that water body increases the temperature in the daytime (Ha et al., 2020; Saavedra et al., 2020). Water body is good in enhancing the beauty of the scenery but is bad in decreasing the surface air temperature. Rubber plantation as discussed before is increasing the temperature though it is a type of vegetation. The conversion from non-built land use into build use in campus development will increase the temperature (Sadiq Khan et al., 2020) and it is suggested to plant more farm-like vegetation around the area without rubber-like vegetation or water body.

5. Conclusion

Land use that contributes the most to high-temperature is settlement in built-up land use category and rubber plantation in the non-built-up land use category. The result is calculated by using multiple linear regression method with least square approach. Anthropogenic activities and vegetation density within land use is the main factor in increasing the surface air temperature of its surrounding. In campus development, it is suggested to construct more vertical Built-up land use than the horizontal one and plant farm-like vegetation around every Built-up land use. This research which focuses on the association between land use and temperature shows the elevation difference on the campus scale does not vary the temperature like the other parameter which is not included in the research such as latitude, relationship to large bodies of water, and cloud cover. The inclusion of those parameters in other research with a larger scope with similar measurement interval will help to understand more in larger scope development. The inclusion of vegetation characteristics, building spatial distribution, and surface material for calculation in the future research will also help to understand more detailed factor that affects the temperature.

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