THE GREEN OPEN SPACE'S SIZE AND FORM EFFECT ON MICROCLIMATE IN THE CAMPUS: A CASE STUDY IN UNIVERSITY OF INDONESIA AND IPB UNIVERSITY

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ABSTRACT: Green Open Space (GOS) has long been known as one of the solutions to reduce the effects of Urban Heat Island (UHI). The ability of vegetation to reduce absorb carbon dioxide and carry out evapotranspiration makes the surrounding air temperature decrease. The ability of GOS to ameliorate the climate is greatly influenced by the size and shape of GOS. This study aims to compare the effect of the shape and size of GOS on the two public campuses in Indonesia, University of Indonesia and IPB University. By using the Land Surface Temperature (LST) data obtained from Landsat 8, the ability of each GOS shape and size to influence the microclimate can be predicted. Also, by using the normalized difference vegetation index (NDVI) data, the correlation between the greenness index and the microclimate could be correlated. The results showed that shape and size is not the only factors those have ability to ameliorate the microclimate.

1. BACKGROUND

The accelerated population growth in urban areas, associated with the increase of impermeable concrete surfaces, industrial pollution, and destruction of natural habitats, negatively changes the urban microclimate (Watson and Johnson, 1987; Akbari *et al.*, 2001; Grimmond, 2007). In some cities, the urbanization may contribute up to more than 80% of the local warming, and has become the most determinative factor of the urban climatic environment (Li *et al.*, 2015). Sustainable development cannot be achieved without significantly transforming the way we build and manage our urban spaces.

Green Open Space (GOS) has long been known as one of the solutions to reduce the effects of Urban Heat Island (UHI). The ability of vegetation to reduce absorb carbon dioxide and evapotranspiration makes the surrounding air temperature decrease. Vegetation structures in the form of trees that have the ability to shade the surrounding area can increase their ability to carry out microclimate amelioration.

GOS can be differentiated based on the type of vegetation that compose it, its size and shape. Types of vegetation that can make green open space consist of trees, shrubs and grass. The size of green open space can be categorized into small, medium, and large. Meanwhile, the form of green open space can be divided into several categories such as square, linear, round, irregular, etc.

Based on the research of Zain *et al*. (2015), trees have the best ability to reduce air temperature compared to other vegetation structures such as shrubs and grasses. Research by Monteiro *et* *al*. (2016) explains that on average, small greenspaces can lower the air temperature from 0.4 to 0.8 °C over approximately 30–120 m and medium greenspaces can lower the air temperature by an average of 0.6–1.0 °C over approximately 180–330 m. This shows that the larger size of green open space, the greater its ability to reduce air temperature.

Concerns about the worsening of the microclimate in urban areas have made several campuses in the world begin the green campus movement. There are several green campus ranking systems for universities in the world. The ranking has been used to become a standard reference for the development of universities in the academic field. In America there is a rating system that includes information about reforestation under the name of the United States Green Report Card. There are 322 universities that are members of the United States Green Report Card.

In 2010, the official UI GreenMetric was established by the University of Indonesia, which is a world ranking university based on Green Campus performance. In 2011, UNEP issued a Greening Universities Toolkit that designed to provide universities with the basic strategies and tactics necessary to transform themselves into green, low carbon institutions with the capacity to address climate change, increase resource efficiency, enhance ecosystem management and minimise waste and pollution (Dave *et al.*, 2014). IPB University and University of Indonesia (UI) are two of many campuses in Indonesia that take part in the UIgreenmetric ranking every year. In 2018, UI was ranked 27th while IPB University was ranked 40th on the international level. The two campuses are ranked in the top two of UIgreenmetric for national campuses and have a great commitment to go to green campus.

Until now, not much information is known about the effect of the shape and size of green open space on the surrounding air temperature. Also, there have been no studies comparing the microclimate conditions on IPB University and University of Indonesia. Most of the research on the effect of the size and shape of green open space was carried out in subtropical areas using Land Surface Temperature (LST) calculations via remote sensing. Based on this, a study was conducted to see the effect of the shape and size of green open space on its effect in reducing air temperature in those two campuses.

2. METHODS

2.1. Study Location

This research was held at IPB University, Bogor, West Java and the University of Indonesia, Depok, West Java in September 2020. These two campuses were chosen as research locations because they have many green open spaces in various shapes and sizes. In addition, these two campuses are the two national campuses in Indonesia that have the highest ranking of UIGreenMetric, an international ranking of environmental friendly campuses.

The location of data collection was carried out at 3 GOS at IPB University and 3 GOS at the Univ of Indonesia (Figure 1 and Figure 2). The six locations were selected based on their size, which is above 1 hectare. The name, shape and size of green open space at each location can be seen in Table 1.

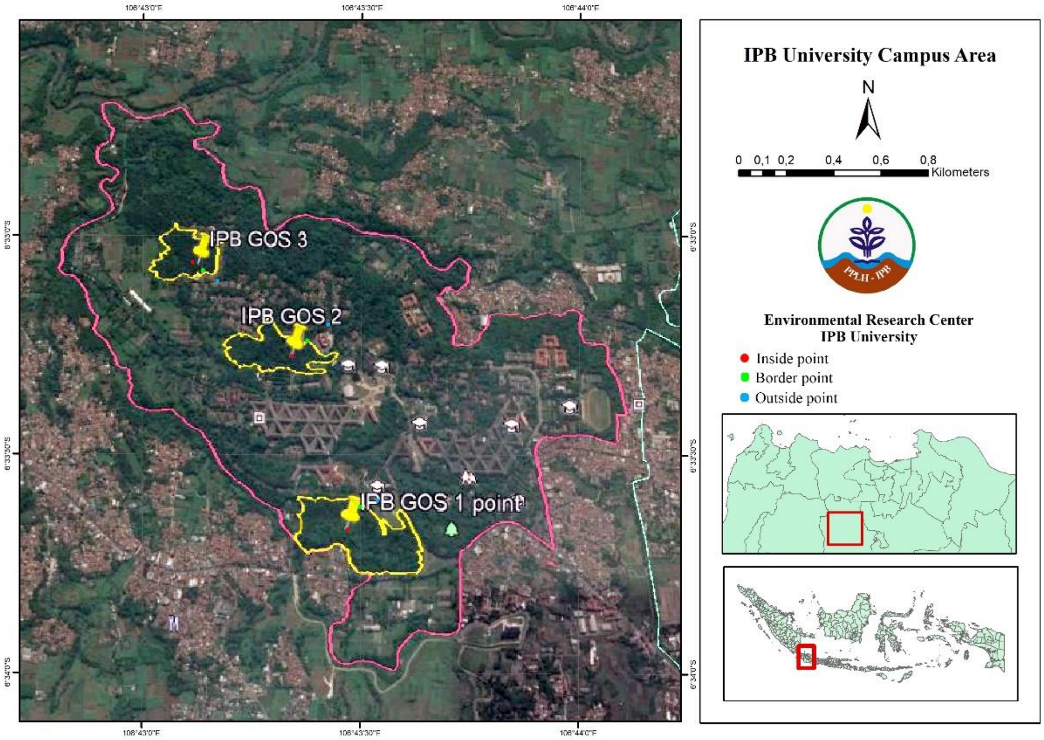

Figure 1. Study location in IPB University, Bogor

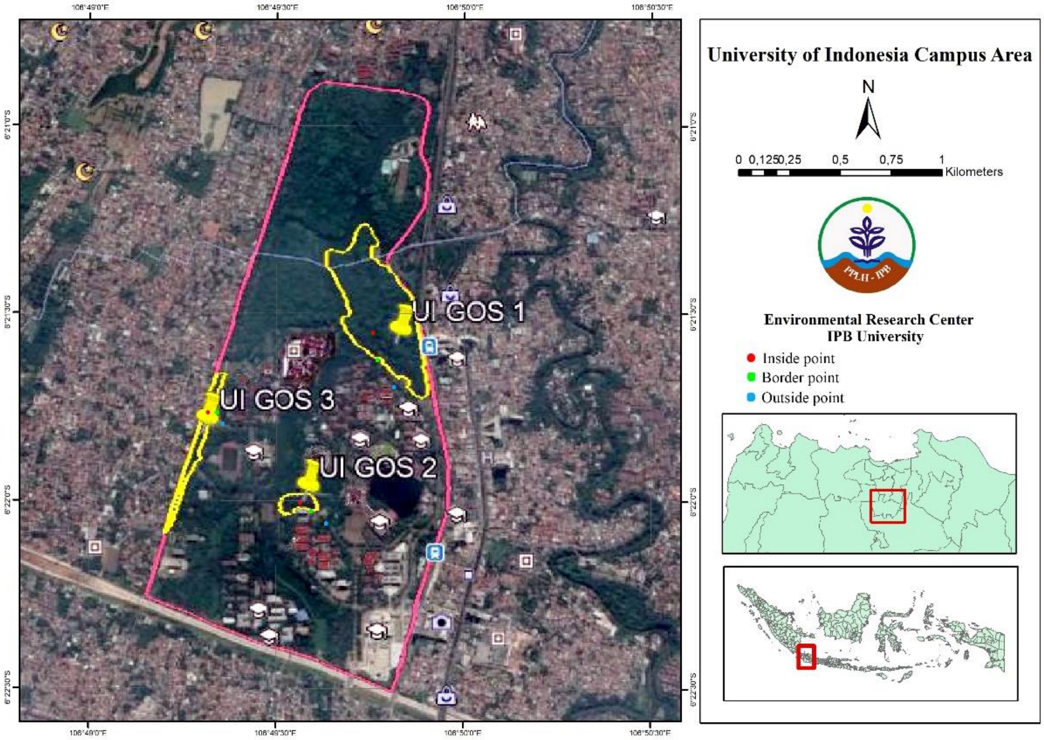

Figure 2. Study Location in University of Indonesia, Depok

Table 1. Name, Form, and Size of Each GOS in 2 Campuses

No	Initial	GOS Name	Form	Size (Hectares)
1	GOS 1 IPB	Bamboo Arboretum	Irregular	9,5
2	GOS 2 IPB	Sylvasari Experimental Forest	Irregular	4,4
3	GOS 3 IPB	Rubber Experimental Plantation	Irregular	5,4
4	GOS 1 UI	UI Wood	Irregular	20
5	GOS 2 UI	GOS near Faculty of Pharmacy	Irregular	1,2
6	GOS 3 UI	Linear GOS in front of Faculty of Engineering	Linear	2,8

2.2. Data Measurements

Microclimate measurements were carried out using a dry wet thermometer to measure air temperature and relative humidity. The tool was placed 150 cm above the ground. Data was collected during the rainy season. Ground measurement was conducted in Univ. of Indonesia on 18-20 September 2020 and IPB University on 29 September-1 October 2020. At each location, data collection was carried out three times a day, in the morning (07:00-10:00), during the day (11:00-14:00) and in the evening (15:00-18:00). In each location, data collection was carried out three times on 3 days in a row.

Air temperature data collection was carried out on inside, border, and outside of GOS area. The distance between the inside, edge and outside points of the GOS ranges from 50-100 meters. The air temperature in the morning, afternoon, and evening for 3 days of data collection will be determined the average.

2.3. Data Analysis

QGIS software was used to obtain total area of each GOS sample. This software was also used to obtain the NDVI and LST value. NDVI value were used to analyze the relationship between vegetation coverage with LST.

In this study, microclimate condition in those two campuses in 2020 will be compared using Landsat 8 satellite data. Two satellite images of IPB University and Univ. of Indonesia (Path 122 Row 65) in September 18, 2020 were collected from USGS webpage. Satellite data imagery was used to analyze NDVI and LST value. Normalized Difference Vegetation Index (NDVI) was used widely to monitor the quality and distribution of vegetation. NDVI was, in fact, often referred to as a greenness index. This index can be computed with a simple formula

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

The range of NDVI values is between -1.0 and +1.0. Values greater than 0.1 usually indicate an increase in the degree of greenness and intensity of the vegetation. Values -1 indicates deep water, values between 0 and 0.1 are generally characteristic of rocks and vacant lots, and values less than 0 may indicate ice clouds, water vapor clouds and snow. The vegetation surface ranges from NDVI values of 0.1 for savanna land (grasslands) to 0.8 for tropical rain forest areas.

The Land Surface Temperature (LST) is the radiative skin temperature of ground. It depends on the albedo, the vegetation cover and the soil moisture. In most cases, LST is a mixture of vegetation and bare soil temperatures. LST can be analysed using Bands 10 and 11 from the Thermal Infrared Sensor (TIRS) of the Landsat 8 satellite. Guha to *et al.* (2018) stated that NDVI shows a strong negative correlation with LST. According to Kaplan *et al.* (2018), UHI can be extracted using following formula:

$$UHI = \mu + \frac{\sigma}{2} \quad (2)$$

in which μ is the mean LST value of the study area, and s is the standard deviation of the LST.

3. RESULTS AND DISCUSSIONS

3.1.Form and Size of Green Open Spaces

Most of the GOS form found on both campuses are irregular. This happens because both campuses have irregular land forms and GOS is usually located on the outer edge or as a boundary zone. However, there is also GOS that has a linear shape which is located at the median of the road or the border between the road and the guardrail. The 3 GOS in each campus were randomly selected to see the effect of the shape and size of green open space on the microclimate.

Based on the size and availability of the facilities, GOS can be categorized into 7 categories (GIGL, 2020)

1. Regional Parks: 400 Ha
2. Metropolitan Parks: 60 Ha
3. District Parks: 20 hectares
4. Local Parks and Open Spaces: 2 hectares
5. Small Open Spaces: Under 2 hectares
6. Pocket Parks: Under 0.4

Based on its size, some GOS located at IPB University are in the category of local park and open spaces. IPB University's GOS is mostly used for research activities. Different with IPB University, Univ. of Indonesia utilizes most of the GOS for sports activities such as jogging and cycling. The size of GOS in this campus is more variable than in IPB University. The size of GOS 1 in UI can be classified into district parks while 2 others can be classified into small open spaces and local parks. However, the six locations which have been selected for data collection had minimal influence from human activities so that temperature and humidity measurements were free from anthropogenic factors.

3.2. Microclimate Data based on Ground Measurement

By comparing the inside, border, and outside point of GOS at each location, it can be seen that almost all inside points have the lowest air temperature compared to the border and outside points. This shows that the presence of vegetation can reduce air temperature while the outside area of GOS that does not have a shade has a higher temperature. According to Aram *et al.* (2019), green infrastructure (trees, parks, forests, and green roofs) has a higher level of thermal comfort than other urban spaces. This is especially true for larger parks and urban forests which can have up to 0.94 °C lower daytime temperatures.

Table 2. Microclimate data of 3 GOS in IPB University based on ground measurement

Variable	Air Temperature of GOS 1 (°C)			Air Temperature of GOS 2 (°C)			Air Temperature of GOS 3 (°C)		
	Inside	**Border**	**Outside**	**Inside**	**Border**	**Outside**	**Inside**	**Border**	**Outside**
Tr	26,96	27,71	29,25	27,17	27,71	27,75	28,21	28,33	28,67
RHr	83,16	79,33	77,34	85,24	78,42	82,98	82,15	82,72	79,90
THI	26,05	26,56	27,92	26,36	26,51	26,80	27,20	27,35	27,51
THI Category	Quite Comfortable	Quite Comfortable	Uncomfortable	Quite Comfortable	Quite Comfortable	Quite Comfortable	Uncomfortable	Uncomfortable	Uncomfortable

Table 3. Microclimate data of 3 GOS in University of Indonesia based on ground measurement

Variable	Microclimate of GOS 1			Microclimate of GOS 2			Microclimate of GOS 3		
	Inside	**Border**	**Outside**	**Inside**	**Border**	**Outside**	**Inside**	**Border**	**Outside**
Tr	28,79 °C	31,04 °C	31,75 °C	30,21 °C	32,08 °C	33,50 °C	30,46 °C	31,40 °C	32,75 °C
RHr	75,92%	68,44%	61,86%	71,25%	63,14%	58,51%	68,21%	63,13%	53,83%
THI	27,40	29,08	29,33	28,47	29,71	30,72	28,52	29,08	29,73
THI Category	Uncomfortable	Uncomfortable	Uncomfortable	Uncomfortable	Uncomfortable	Uncomfortable	Uncomfortable	Uncomfortable	Uncomfortable

Based on Table 2 and Table 3, University of Indonesia had warmer temperature (Tr) and dryer humidity (RHr) than IPB University. Air humidity has a value that is inversely proportional to air humidity. The higher the air temperature, the lower the humidity and vice versa. University of Indonesia is surrounded by built area and high traffic condition. These anthropogenic factors could be triggered the warmer temperature in this campus.

According to Emmanuel (2005), THI criteria are divided into 3 categories. The comfort category is at 21-24, quite comfortable category is at 25-27, while the uncomfortable category is above 27. Based on the THI calculation at each sampling point, almost all points in IPB University were in the quite comfortable category while most of sampling location in Univ. of Indonesia were categorised into uncomfortable.

3.3. NDVI and LST

Figure 3 shows the Greenness Index and LST on both campuses. It can be seen that NDVI and LST have a negative correlation. Areas with high levels of greenness have low temperatures and vice versa. Based on the LST value, the air temperature range in IPB ranges from 24.52 to 30.47 °C while the LST UI value shows a range between 24.62 to 30.51°C. This shows that IPB has a lower air temperature based on LST analysis although the difference is not significant. The Table 4 shows the difference in air temperature based on ground measurement and LST analysis.

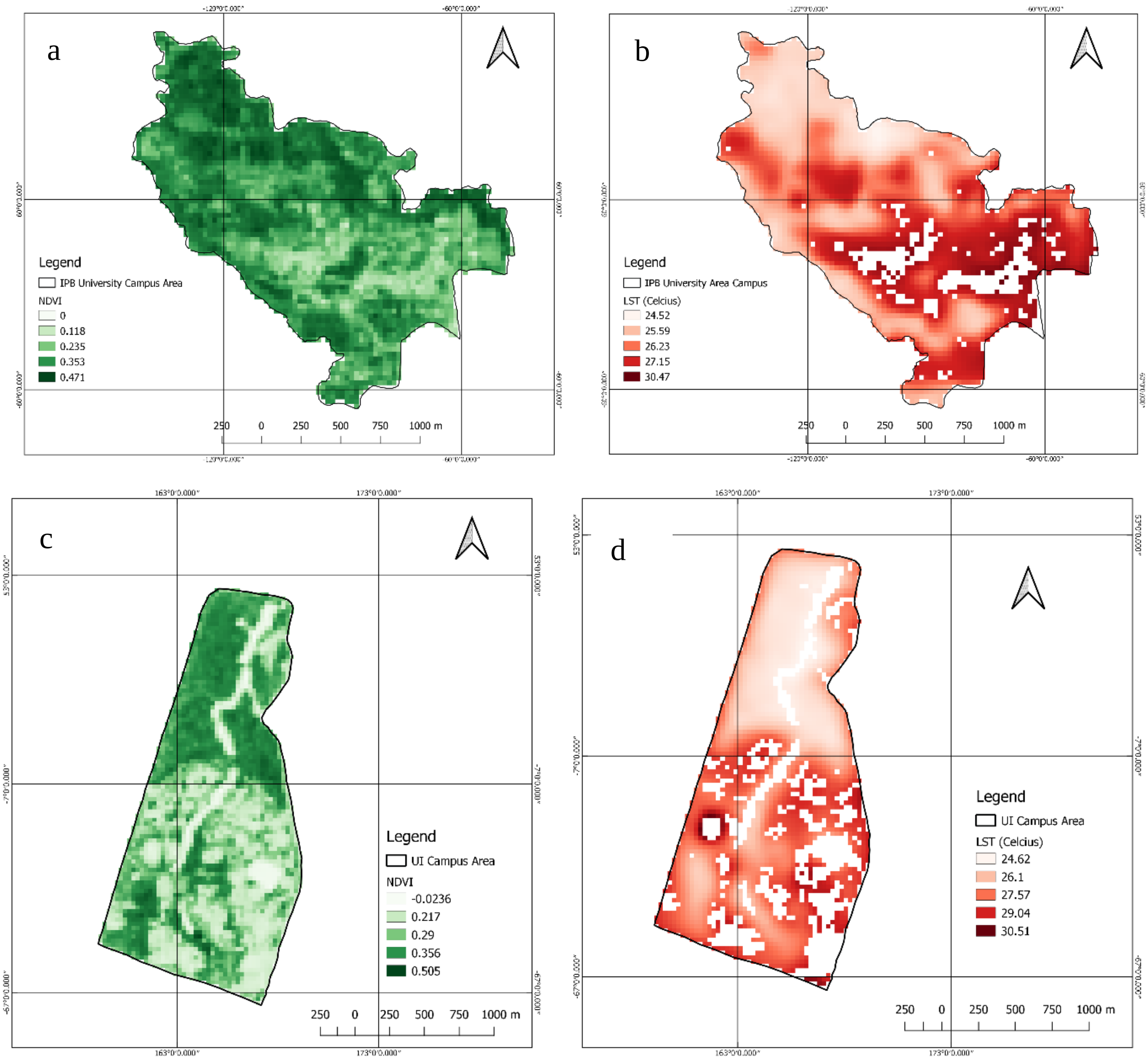

Figure 3. NDVI Map of IPB University (a), LST Map of IPB University (b), NDVI Map of Univ. of Indonesia (c), and LST Map of Univ. of Indonesia (d)

Table 4. Comparison of Air Temperature from Ground Measurement and LST Analysis

No	Location	Ground Measured Temperature (°C) T_1	Land Surface Temperature (°C) T_2	$T_1 - T_2$
1	GOS 1 IPB	26,96	25,47	1,49
2	GOS 2 IPB	27,17	25,9	1,27
3	GOS 3 IPB	28,21	25,63	2,58
4	GOS 1 UI	28,79	27,88	0,91
5	GOS 2 UI	30,21	26,95	3,26
6	GOS 3 UI	30,46	27,52	2,94

Based on Table 2, there are differences in air temperature based on ground measurement and LST analysis. The air temperature from the LST analysis tends to be lower than the ground measurement. The difference in air temperature of the two types of methods ranges from 0.91-3.26 °C.

LST is one of the most important climate system variables on a variety of time scales, exerting control over the partitioning of energy into latent and sensible heat fluxes, and a strong indicator of surface warming trends from climate change (Schneider and Hook, 2010). LST is also more sensitive to changes in vegetation density and captures additional information on the biophysical controls on surface temperature, such as surface roughness and transpirational cooling (Mildrexler et al., 2011a; Oyler et al., 2016).

The differences between LST and Ground measured temperature could be affected by several factors. According to Wang (2020), LST may have rapid temporal variation so that ground measurement must be well matched to satellite measurement. In this case, LST data retrieved 10 days before the ground measurement. LST is also coupled with surface emissivity in the satellite sensed signal. Based on this condition, LST should be evaluated by using ground measured data. The validation of the satellite LST products is rather hard, mainly due to the variety, heterogenity, and emission isotropy of land surface. The success of this application lies in the best of validation of the remote sensed LSTs.

3.4.Correlation between GOS Size and LST

Table 5. Form, Size, and Ground Measured Temperature in IPB University

No	Initial	Location	Form	Size (Hectares)	Ground Measured Temperature (°C)
1	GOS 1	Bamboo Arboretum	Irregular	9,5	26,96
2	GOS 2	Sylvasari Experimental Forest	Irregular	4,4	27,17
3	GOS 3	Rubber Experimental Plantation	Irregular	5,4	28,21

IPB University and Univ. of Indonesia are located in different cities with different conditions of surrounding areas. Based on this condition, correlation of size and temperature should be made in each of campuses. GOS 1 in IPB University has the largest size of the two other GOS. Air temperature based on ground measured temperature and LST in this GOS also shows the lowest value. Even though it has a lower area, GOS 2 has a lower temperature than GOS 3. Besides the size, vegetation density plays important role in air temperature amelioration. GOS 2, which is an experimental forest, has a higher density than the rubber experimental plantation.

Table 6. Form, Size, and Ground Measured Temperature in Univ. of Indonesia

No	Initial	Location	Form	Size (Hectares)	Ground Measured Temperature (°C)
1	GOS 1	UI Wood	Irregular	20	28,79
2	GOS 2	GOS near Faculty of Pharmacy	Irregular	1,2	30,21
3	GOS 3	Linear GOS in front of Faculty of Engineering	Linear	2,8	30,46

Similar to IPB University, GOS 1 UI which has the largest area has the lowest air temperature. However, GOS 2 has a lower air temperature than GOS 3 which has a larger area. In general, GOS in UI has fairly uniform vegetation density and types. The GOS with linear form tends to make low ability to ameliorate air temperature. Based on Li (2020), the linear park category contributes with a less cooling effect.

4. Conclusion

Based on the results and discussion, IPB University has lower air temperatures and higher humidity compared to University of Indonesia. The air temperature in the inside of GOS shows a lower value compared to the border and outside areas. LST analysis shows different results with a ground measured temperature. This difference can be caused by several factors. The difference of data collection days schedule between LST and ground measurement can be an important factor. Moreover, LST requires a validation process in its application. The success of this application lies in the best of validation of the remote sensed LSTs. Comparison of shape, size, and ground measured temperature at the six locations shows that GOS size plays an important role in microclimate amelioration. However, the size of the GOS is not the only factor affecting air temperature. Plants, water bodies, slope direction, height difference, spatial morphology are also have the important roles in order to improve the microclimate comfort in portion of sites (Suming *et al.*, 2017).

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