Urban Heat Signature Impact on University Campus

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Abstract. Global environmental change, as IPPC reported, its indication with air temperature getting a rise every year within 0.74 ºC since the beginning of the 20th century. The consequence of that condition, every human will live with global environmental change. Urban Heat Signature is temperature behavior of land cover types as a representation of an urban environment. University Campus, as part of an urban environment, had an Urban Heat Signature. The research objective assessments of Urban Heat Signature impact on urban universities campus. Study area located in urban at University of Malaya (UM) and the University of Indonesia (UI). This research used spatial-temporal analysis to analysis Urban Heat Signature effect on a university campus with employed image satellite generated land surface temperature, ground trough collected air surface temperature and an online survey of human perception. This result saw that both UM and UI campuses found maximum Urban Heat Signature between 30–33.0 ºC and the UHS effect on air temperature with max >33.0 ºC then impact on human perception is very hot with uncomfortable sensation will getting a headache and lethargic then decreasing capacity and achievement of work or study at two urban universities. This result concluded that UHS impact on the university campus with air temperature more than 33.0 ºC and heat intensity would impact on human health and work activity, especially on study achievement. This result is significant to an understanding of UHS impact on human well-being in university campus as urban an environment.

1. Introduction

The IPCC 2007 report on the “Science of Climate Change” showed a small increase in temperature and rainfall for the Southeast Asia Region in the last 50 years [1]. Asian cities are the most rapidly growing regions of the world nowadays and will be located in Asia by the year 2015 [2]. The rapid growth of a city has concluded that the urbanized areas had significantly higher day-time surface temp as compared to those of the surrounding rural with vegetated areas [2, 3]. In Singapore, the primary root of heat island in cities is due to the absorption of solar radiation by mass building structures, roads, and other hard surfaces during daytime [4]. In Singapore, some factors contribute to the occurrence and intensity of heat island, and city functions [5]. In February 2002, the mean rural temperatures in Bangkok, Manila and Ho Chi Minh City were 29.5 ºC, 26.5 ºC, and 30.0 ºC [2].

The studies of urban heat relate to rapid development in the urban area has been done in many places. Those are Seoul [6], Singapore [4], Tokyo [7], and Hong Kong [8]. Urban heat studies also took place in several cities in Indonesian like Bandung, Surabaya, Semarang, and Jakarta, where remote sensing data such as Landsat imagery was employed. The result showed that area with high surface temperature
The temperature is representing the heat from the land which generate Landsat imageries. Image processing use/land is chosen as signature. This research is focusing on 2. (UM) a Heat Signature impact on urban universities campus. Study area located in urban at University of Malaya of an urban environment, had an Urban Heat Signature. The research objective assessments of Urban sustainability has become a global concern for univers they carefully monitored the impact of university activities on the natural environment. Saga University, Japan conduct urban heat studies in Guangzhou, which is a typical subtropical city in China, suffered heat stroke during the intense training period for a college student. Based on that fact of the university campus, people are considering to conduct urban heat studies in the university complex. The urban heat study has conducted at the National University of Singapore. Another university is National Formosa University in Taiwan, The South China University of Technology in Guangzhou, China, Shenyang University, China and Saga University, Japan.

The recent major issue of climate change mitigation is also considered by university leaders as they carefully monitored the impact of university activities on the natural environment. Campus sustainability has become a global concern for university management. University Campus, as part of an urban environment, had an Urban Heat Signature. The research objective assessments of Urban Heat Signature impact on urban universities campus. Study area located in urban at University of Malaya (UM) and the University of Indonesia (UI).

2. Material and method
This research is focusing on the analysis of land surface temperature (LST), determine urban heat signature (UHS) and its distribution and observation on the impact of urban quality. University campus is chosen as a study area, where the rate of urbanization is very rapid, hence the dynamic change of land-use/land-cover were seen. The method saw in Figure 1.

Image processing
This paper used indirect data collecting by employing satellite Landsat OLI-TIRS. The list of Landsat imageries showed in Table 1. The pixel size is determined at 100 x 100 meters, accordance with [4,6,7] who measured UHI in Japan. The grid size is also determined based on land-cover. Land surface temperature is representing the heat from the land which generated by radiated sun energy [4,7,10].

| Path/row  | 2013          | 2014          | 2015          | 2016          |
|-----------|---------------|---------------|---------------|---------------|
| 127/058   | 22 April      | 4 February    | 7 & 23 February| 9 & 25 January|
| (UM)      | 27 July       | 8 & 24 March  | 11 & 27 March | 26 February   |
|           | 12 August     | 25 April      | 12 April      | 13 & 29 March |
|           | 31 October    | 11 & 27 May   | 30 May        | 14 April      |
|           | 16 November   | 12 & 28 June  | 17 July       | 3 & 19 July   |
|           | 3 November    | 15 & 31 August| 3 & 19 September| 29 September |
| 122/064   | 22 June       | 22 April      | 14 & 30 July  | 23 January    |
| (UI)      | 8 & 24 July   | 9 & 25 June   | 15 & 31 August| 23 February   |
|           | 25 August     | 28 August     | 2 & 18 October| 11 & 27 April |
|           | 10 & 26 September | 13 & 29 September | 3 November | 13 May        |
|           | 12 October    | 15 & 31 October | 5 December    | 30 June       |
|           |               |               |               | 16 July       |
LST generate through several steps. The thermal band of Landsat imagery is the main “ingredient” of LST. First, the digital number (DN) of the thermal than converted to spectral radiance. The formula represented in equation 1 and 2 (Eq. 1 applied for Landsat TM and ETM+, eq.2 applied for Landsat OLI-TIRS)\[4,7].

\[ L\lambda = \frac{(LM\lambda_{MAX} - LM\lambda_{MIN})}{(QCAL_{MAX} - QCAL_{MIN})} \times (QCAL - QCAL_{MIN}) + LM\lambda_{MIN} \]
\[ L\lambda = (M \times DN) + A \]

Where \( L\lambda \) is spectral radiance (\( \text{Wm}^{-2}\text{sr}^{-1}\text{\mu m}^{-1} \)), \( M \) is Multiplicative digital number value at the thermal band, \( DN \) is a digital number of Landsat’s thermal band, and \( A \) is the additive value of spectral radiance at the thermal band. Second, the spectral radiance resulted from equation one is being converted to estimate land surface temperature. The formula is represented in equation 2 \[7,10,12,13\].

\[ T = K2/\ln((K1/L\lambda) + 1) \]

Where \( T \) is the temperature at the satellite sensor (Kelvin), \( K1 \) is the calibration constant 1 for Landsat, \( K2 \) is the calibration constant 2 for Landsat, and \( L\lambda \) is the spectral radiance of band. The utilization of remote sensing imagery to collect urban heat signature have performed in several studies \[4,10,11,12,13\]. Finally, the estimate of LST is being transformed from Kelvin to Celsius by the following formula \[10,14\].

\[ LST \text{ (celcius)} = T - 272.15 \]

Based on the equation the low value of LST will be seen in maximum vegetation cover, while minimum vegetation cover overlay with high-temperature value \[8,15,16,17\]. Urban Heat Signature is LST value within temporal data acquisition based on land cover types in the urban area.

**Air Surface Temperature**

The direct collect of air surface temperature used survey by the rapid 10-15 minute in daylight in March, June 2013, October 2014, and March 2015. The air temperatures measured each value saved on a picture (smartphone or camera) then stored manually in database acquired used mobile temperature and humidity tool \[4,7,20\]. Field visits were conducted 2013-2015 in the two universities, with data collecting during 10-12 hour, do June 2013, October 2014 and March 2015. Sampling data for air surface temp based on land use cover, e.g., building covered, paved open space, water bodies, open vegetated covered and densely vegetated covered. This method already used at the National University of Singapore campus, conducted on a typical day \[14, 21\] and related studied at Saga University in Japan \[15\]. The sample location used grid size \[7, 23\] and mobile tools Hioki 3641 with specification two
channel, range temperature measurement about -20.0°C to 70.0°C when using the internal temperature sensor and humidity range measurement about 0.0% - 100% RH when using internal humidity sensor, and temperature accuracy is ± 0.50°C (at 0.0 to 35.0°C) and humidity accuracy is ± 5 RH (at 25°C).

**Intensity Perception Study Index**

The perception among these respondents was investigated to identify the level and type of impact [23] of natural hazard. The respondent is students from both universities with 120 respondents at each university campus. The study using an online survey, and they answer the questions about perception of heat, landscape feature and potential impact on human activity. This survey collects on human quality impact with landscape feature with category thermal sensation on warm and comfort sensation on uncomfortable sensation; this condition will impact on psychology with increasing stress caused by sweating and blood flow and health condition with increasing danger of heat stroke [24]. Those all data used the index called Universal Thermal Climate Index (UTCI) for assessment UHS behavior on 2013-2016. The UTCI used to detect the UHS on UI Campus. Then detect the UHS as Urban Heat Hazard in University Campus used the ETI with a level sensation of temperature and comfort within the sensation of temperature level had a very Hot until Neutral and the level sensation of comfort had very uncomfortable until comfortable [24].

3. Result and discussion.

3.1. Land Cover at UM and UI Campus

Land cover as the localized urban environment at UM Campus and UI Campus saw in Table 2. The comparative land cover on UM and UI founded two urban campuses had a similar land cover but with differentiation of total percentage area. Land covered in UM campus is building covered is 20.9% bigger than UI campus with build-covered only 10.9%. The UM campus covered by a dense vegetated is 59.1% and the other hand it was smallest than UI campus covered by 65.3%. The spatial distribution of land cover in UM and UI campuses saw in Figure 2.

| No | Land cover                        | UM Campus | Percentage (%) | UI Campus | Percentage (%) |
|----|-----------------------------------|-----------|----------------|-----------|----------------|
| 1  | Building Covered (Faculties,      | 67.3      | 20.9           | 33.0      | 10.9           |
|    | Colleges, Administrative Buildings) |          |                |           |                |
| 2  | Paved Open Space Covered          | 52.9      | 16.4           | 35.8      | 12.6           |
| 3  | Water bodies Covered              | 3.0       | 0.9            | 22.9      | 7.5            |
| 4  | Open Vegetated Covered            | 23.3      | 7.2            | 19.3      | 6.4            |
| 5  | Dense Vegetated Covered           | 189.0     | 59.1           | 197.4     | 65.3           |

![Figure 2. Spatial Pattern of Land Cover at UM and UI Campuses](image)
3.2. Temporal analysis
Comparative Temporal Trend UM and UI Campus based on 2013-2016 average temp on UM trend is positive from 23°C become 26°C, and the other hand UI Campus with trend negative average temp from 28°C become 27°C. In general temp of UHS comparative between UM Campus and UI Campus found UHS on UM Campus lowest than UHS on UI Campus (Figure 3). This result saw trend temporal UHS Behavior on UM and UI Campus since 2013-2016 had fluctuated on solar radiation and land use cover with positive trend temporal.

![Figure 3. Temporal Trend of UHS Behavior at UM and UI Campus 2013-2016](image)

Land cover as a representation of UHS within difference month of high and low temp. The similar relation between land cover types and UHS Profile and Spatial Pattern on UM Campus and UI Campus found that both campuses had similar relationship saw in Table 3. The spatial patterns of UHS had similar to the spatial pattern of land cover on both campuses. The spatial pattern of UHS related to the spatial pattern of land cover, each land cover types related to a high and low temp of UHS. Both UM Campus and UI Campus found UHS related to vegetation covered and building covered. The vegetation-covered had UHS with the lowest temperature, and the other hand building covered had UHS with high temp.

**Table 3. UHS on UM and UI Campuses 2013-2016**

| Land Cover Type          | UHS UM Campus (°C) | UHS UI Campus (°C) |
|--------------------------|--------------------|--------------------|
|                          | 2013   | 2014   | 2015   | 2016   | 2013   | 2014   | 2015   | 2016   |
| Paved Open Space         | 31     | 39     | 33     | 36     | 35     | 34     | 33     | 34     |
| Building Surface         | 31     | 39     | 33     | 36     | 33     | 33     | 31     | 33     |
| Open Vegetated Surface   | 31     | 37     | 32     | 35     | 35     | 35     | 33     | 35     |
| Water Bodies             | 30     | 36     | 31     | 35     | 32     | 31     | 30     | 31     |
| Dense Vegetated Surface  | 31     | 39     | 33     | 34     | 34     | 33     | 32     | 23     |

3.3. Air Surface Temperature
The UHS effect on environmental at UM and UI campus show in Table 4. Those land cover had a temperature impact on UHS with maximum air temp >30.0°C. This UHS effected the Air temp both UM and UI campus shown in Table 5. The UM Campus had air temp. >30.0°C started from 10 am until 3 pm, max air temp 33.9°C (3 pm) and min air temp is 27.3°C (07 am). Comparative with UI campus the result air temp >30.0°C started from 10 am until time 3 pm, max air temp is 33.5°C (01 pm) and min temp is 27.1°C (06 am). This result gave the new understanding about different land use cover were a representation of differentiated of air behavior on a comparative spatial-temporal analysis between UM Campus and UI Campus. The result also found UHS Behavior related with UM Campus had building covered more than UI Campus, in general, air temp had min temp (27.3°C) on 07 am show in Figure 4.
Table 4. UHS on UM and UI Campuses 2013-2016

| Land Cover Types               | UHS UM Campus (°C) | UHS UI Campus (°C) |
|--------------------------------|--------------------|--------------------|
|                                | Min | Max | Av. | Min | Max | Av. |
| Paved Open Space               | 25  | 39  | 32  | 25  | 35  | 30  |
| Building Surface               | 25  | 38  | 32  | 26  | 33  | 30  |
| Open Vegetated Surface         | 25  | 37  | 31  | 22  | 35  | 29  |
| Water Bodies                   | 27  | 36  | 31  | 25  | 32  | 29  |
| Dense Vegetated Surface        | 26  | 34  | 30  | 22  | 34  | 28  |

Figure 4. Temporal Trend of AST Behavior at UM and UI Campus 2013-2015

Table 5. Air Surface Temperature on UM and UI Campuses 2013-2015

| Land Cover Types               | AST UM Campus(°C) | AST UI Campus(°C) |
|--------------------------------|-------------------|-------------------|
|                                | 2013  | 2015  | Avg.  | 2014  | 2015  | Avg.  |
| Paved Open Space               | 34.4  | 34.3  | 34.4  | 35.7  | 33.9  | 35.0  |
| Building Covered               | 34.5  | 34.8  | 34.6  | 36.7  | 34.1  | 35.4  |
| Open Vegetated Covered         | 34.4  | 33.2  | 34.0  | 38.4  | 33.3  | 35.8  |
| Water Bodies Covered           | 33.9  | 35.2  | 34.6  | 38.0  | 33.3  | 35.6  |
| Dense Vegetated Covered        | 34.1  | 34.1  | 34.1  | 36.7  | 33.1  | 34.9  |

3.4. Human Perception of UHS Impact on University

3.4.1. Human Perception of Temperature and Comfort
Based on respondent on perception intensity study in UM and UI Campus answering that Paved Open Space as an area with hot perception, Water bodies with dominant warm perception and dense vegetation as a neutral perception on hot levels. Perception intensity study in UM and UI Campus the comfort with a land cover that answering that Paved Open Space as an area with uncomforted perception, and dense vegetation as a comfort perception.

Table 6. Perception of Heat and Comfort for Temp. 32-34°C in UM and UI Campuses

| Hot Level     | UM (%) | UI (%) | Comfort Level | UM (%) | UI (%) |
|---------------|--------|--------|---------------|--------|--------|
| Neutral       | 1.4    | 0.6    | Very Comfort  | 4.2    | 2.8    |
| Slightly Warm | 8.3    | 4.2    | Comfort       | 34.7   | 22.2   |
| Warm          | 33.3   | 20.8   | Slightly Comfort | 37.5 | 43.1 |
| Hot           | 33.3   | 22.2   | Uncomfortable | 13.9   | 9.7    |
| Very Hot      | 23.7   | 52.8   | Very Uncomfortable | 9.7 | 22.2 |
|               | 100.0  | 100.0  |                | 100.0  | 100.0  |

Table 6 mention of the level of perception of heat intensity impact perception of hot and comfort level between UM and UI. The perception both campuses had answering when temperature more than >30°C,
especially $>34^\circ$C, this conclusion very hot and very comfortable. Its mean both university had the same perception of heat intensity impact on human well-being.

3.4.2. Human Perception of Hot and Comfort and Health and Work

Based on data perception intensity study related to ETI, the heat intensity impact on human health and working activity. UM, the community had perception within a level in hot is neutral and very comfort did not ask the respondent to allow respondent to answer the perception oh heat intensity. The result of perception heat intensity will impact on their health especially getting tired and lethargic when temperature intensity very hot and very comfort condition. The condition also impacts work activity on condition very hot and very comfort will decreasing working or study achievement. The rest all respondent perception saw in Table 7. The conclusion on UM community heat intensity will impact on human well-being as a risk on UM community. Table 7 mention of the level of perception of heat intensity impact perception of health and working/study activity between UM and UI. The perception both campuses had answering when temperature more than $>30$ °C, especially $>34$ °C, this conclusion very hot and very comfort will impact on Getting Tired and Lethargic then decreasing of working/study achievement as perception within heat intensity impact on human well-being.

Table 7. Perception of Health and Work on Temp. 32-34°C in UM and UI Campuses

| Health                  | UM (%) | UI (%) | Work/Study               | UM (%) | UI (%) |
|-------------------------|--------|--------|--------------------------|--------|--------|
| Skin Moisture Problem   | 12.9   | 13.7   | Decreasing Health        | 4.2    | 2.8    |
| Getting Headaches       | 33.9   | 19.0   | Decreasing Work/Study Capacity | 34.7 | 22.2 |
| Throat Discomforts      | 17.7   | 20.7   | Decreasing Work/Study Achievement | 37.5 | 43.1 |
| Eye Function            | 6.5    | 13.8   |                          |        |        |
| Tiredness and Lethargic | 29.0   | 32.8   |                          |        |        |
|                         | 100.0  | 100.0  |                          | 100.0  | 100.0  |

4. Conclusion

This result concluded that UHS impact on the university campus with air temperature more than 32°C and heat intensity would impact on human health and work activity, especially on study achievement. This result is significant to an understanding of UHS impact on human well-being in university campus as urban an environment.

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