Spatial-temporal analysis of changes in land-cover and land surface temperature (LST) within Universiti Putra Malaysia campus area

I P A Shidiq¹²*, M H Ismail¹, S Supriatna² and A Wibowo²*

¹Department of Forest Management, Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
²Department of Geography, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, 16424 Depok, Indonesia

E-mail: gs35277@siswa.upm.edu.my, iqbalputut@ui.ac.id, adi.w@sci.ui.ac.id

Abstract. The urban forest is one of the typical vegetation-covered space in an urban area. The existence and development of the urban forest commonly found within the university campus site. The ecological and environmental characteristics in a university campus site usually resemble and similar to the urban area. The physical environment of the campus area is gradually changing due to development and improvement purposes, and it is impacting the land-cover on the surface. Changing the physical element of the surface will affect the absorption of the sun radiation, and further, it is changing the dynamic of the micro-climatic condition or temperature within the surrounding area. The primary focus of the research is to observe the impact of land-cover change on the land surface temperature (LST) within the campus area. Universiti Putra Malaysia is one of the largest campuses located in the urban area of Serdang district, state of Selangor. The dynamic changes in this site observed through multi-temporal Landsat 8 OLI-TIRS level 1 imageries. Datasets from 2013 to 2015 were collected to employ spatial-temporal analysis on land-cover changes, as well as the LST algorithm to monitor the surface temperature. The result shows that there was an increasing surface temperature during 2013-2015, which corresponds with the inclining built-up area. The research concluded that changes in land-cover would affect the spatial-temporal land surface temperature at University Putra Malaysia.

1. Introduction
The ENSO, monsoons, and the Indian Dipole Oscillation (IOD) circulation systems are generally triggering extreme weather and influencing the changing behavior patterns of hydro-meteorological and geomorphological events in the surrounding region [1]. Some impacted areas are cities, especially in the Asia-Pacific region. Asian cities are the most rapidly growing regions of the world nowadays, and 16 of the world’s 24 megacities will be located in Asia by the year 2015 [2,3]. Urbanization, including residential, commercial, and industrial developments, initiated one of the most dramatic human-induced changes of a natural ecosystem. The natural environment converted to a built-up area, a largely
impervious landscape made up of rigid, and also sharp-edged roughness elements [2]. This phenomenon might establish new kinds of a threatening situation for the urban population. There are three billion people (48% of the world population) living in urban areas, they directly exposed to urban heating problems and more people will be vulnerable to these problems as the number of people living in urban areas is expected to grow to five billion by 2030 [3].

The accelerated rate of urban growth in tropical cities is changing more outdoor spaces for leisure and recreation activities of citizens [4]. 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 the daytime. The loss of green areas in the urban environment as a consequence of rapid population has led to demands for converting natural areas to public housing [5]. In Malaysia, several factors contribute to the occurrence and intensity of heat island, and these include weather, geographic location, time of day and season, city form, and city functions [6].

The urban forest is one of the typical vegetation-covered space in an urban area. The existence and development of the urban forest commonly found within the university campus site. The ecological and environmental characteristics in a university campus site usually resemble and similar to the cities of the urban area. The development of the university campus might have changed the land cover, and it will increase the land surface temperature (LST). The built-up area is usually related to the high-temperature zone on LST. The objective of the research is to examine the spatial-temporal of land cover change and its effect on LST, especially in the Universiti Putra Malaysia (UPM) campus area.

2. Material and method
2.1. Image processing

This paper used indirect data collecting by employing satellite data from Landsat 8 OLI-TIRS. The list of Landsat imageries used in this study shown in Table 1. The thermal band from each data were collected and processed to generate LST. The pixel size is determined at 100 x 100 meters, accordance with [7], who measured the urban heat island (UHI) in Japan. The grid size is also determined based on the spatial representation of land-use and land-cover. Land surface temperature is representing the heat from the land which generated by radiated sun energy [5,8,9,10].

| Year | Path/row | Acquisition date | Remote sensing imagery |
|------|----------|------------------|------------------------|
| 2013 | 127/058  | 22 April         | Landsat OLI-TIRS       |
| 2013 | 127/058  | 25 June          | Landsat OLI-TIRS       |
| 2013 | 127/058  | 29 September     | Landsat OLI-TIRS       |
| 2013 | 127/058  | 18 December      | Landsat OLI-TIRS       |
| 2015 | 127/058  | 27 March         | Landsat OLI-TIRS       |
| 2015 | 127/058  | 30 May           | Landsat OLI-TIRS       |
| 2015 | 127/058  | 3 September      | Landsat OLI-TIRS       |

LST generated through several steps. The thermal band of Landsat imagery is the main “ingredient” of LST. First, the digital number (DN) of the thermal band needs to converted to spectral radiance. The formula is represented in equation 1 [11].

$$L\lambda = (M \times DN) + A$$  \hspace{1cm} (1)

Where $L\lambda$ is spectral radiance (Wm$^{-2}$sr$^{-1}$μm$^{-1}$), M is Multiplicative digital number value at 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\[12,13,14\].

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

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 signatures have performed in several studies\[5,10,11,12,13,14\]. Finally, the estimate of LST is being transformed from Kelvin to Celsius by the following formula\[10,15\].

\[LST (celsius) = T - 272.15\]  

Based on the equation, the low value of LST will be seen in maximum vegetation cover, while minimum vegetation cover will be overlaid with high-temperature value\[8,16,17,18\].

2.2. Land cover change detection using Google Earth Data

Data collection and extraction start from downloading the satellite imagery data via Google Earth and use it as data resources\[19,20\]. Then the satellite image data from Google Earth is mosaicked using ArcGIS software. The result of the mosaicked images does not have geographic references. A georeferenced tool is used to the mosaicked images to get a georeferenced image based on Universal Transverse Mercator (UTM) projection. Land-use type from the Google Image was digitized based on a square grid and the attribute on every land use types also being collected. Those data land cover types save in geodatabase storage and accessible next processed summary of a total area each land cover type.

3. Result and discussion.

3.1. Spatial-temporal analysis of LST

Based on the temporal data, the maximum LST tends to increase from June to December. In April 2013, then maximum LST reached 29.41 °C (Table 2). In June 2013, it was decreasing to 27.31 °C and rising back in September 2013 (28.84 °C), as well as in December 2013 (30.67 °C). On the other hand, the distributions of urban heat signatures (UHS) were varied each year. In order to describe the distribution, this study classifies UHS into three classes, high, moderate, and low, which based on the range of LST value (Figure 1). This study also calculates and observes the extent of the high-temperature zone each month (Table 3). The area of Low UHS tends to decrease each month. It was occupying 99.53 % of the area of UPM campus in April 2013, and the coverage was decreasing to 92.63 % in June 2013. The extent was rising back in September 2013 (99.33 %), but it was decreasing again in December 2013 (89.08 %). On the contrary, the area of High UHS tends to increase, with 0.10 % in April 2013. It was rising to 0.41 % in June 2013. Finally, the High UHS area covered 2.80 % of the UPM campus in December 2013 (Table 3).

| LST     | April (22/4/13) | June (25/6/13) | September (29/9/13) | December (18/12/13) |
|---------|----------------|---------------|---------------------|---------------------|
|         | (°C)           | (°C)          | (°C)                | (°C)                |
| Maximum | 29.41          | 27.31         | 28.84               | 30.67               |
| Average | 23.84          | 23.71         | 18.22               | 24.97               |
| Std. deviation | 2.15   | 1.97          | 6.13                | 3.16                |

Sources: Data Processing
Figure 1. The land surface temperature of UPM Campus from April until December 2013

Table 3. The coverage of each UHS in April, June, September, and December 2013 on UPM campus

| Class | April* (Ha) | April* (%) | June** (Ha) | June** (%) | September*** (Ha) | September*** (%) | December* (Ha) | December* (%) |
|-------|-------------|------------|-------------|------------|------------------|-----------------|----------------|----------------|
| Low   | 1031.78     | 99.53      | 960.34      | 92.63      | 1029.71          | 99.33           | 923.40         | 89.08          |
| Medium| 3.77        | 0.36       | 72.09       | 6.95       | 4.49             | 0.43            | 84.17          | 8.12           |
| High  | 1.08        | 0.10       | 4.30        | 0.41       | 2.49             | 0.24            | 29.04          | 2.80           |

Sources: Data Processing
* Low (<28), Medium (28-29), High (>29) are in Celsius degree
** Low (<26), Medium (26-27), High (>27) are in Celsius degree
*** Low (<27), Medium (27-28), High (>28) are in Celsius degree
The distributions of LST were also varied each month in 2015. The maximum LST in March 2013 reached 32.03 °C (Table 4). It was decreasing to 29.53 °C in May 2013 and rising back to 32.17 °C in September 2013. Based on the collected data, September was the warmest month in 2015, with an average LST of 28.91 °C. In order to describe the distribution in 2015, this study also classifies UHS into three classes, high, moderate, and low, which based on the range of LST value (Figure 2). The area of Low UHS tends to decrease each month. It was occupying 46.22 % of the area of UPM campus in March 2015, and the coverage was increasing to 91.57 % in May 2015 (Table 5). The extent was declining back in September 2015 (21.74 %). On the contrary, the area of High UHS tends to increase, with 25.33 % in March 2015. It was declining to 0.62 % in May 2015. Finally, the High UHS area covered 47.84 % of the UPM campus in September 2015 (Table 5).

Table 4. LST in March, May, and September 2015 on UPM Campus

| LST       | March (27/3/15) (°C) | May (30/5/15) (°C) | September (3/9/15) (°C) |
|-----------|----------------------|--------------------|-------------------------|
| Maximum   | 32.03                | 29.53              | 32.17                   |
| Average   | 28.04                | 26.53              | 28.91                   |
| Std. deviation | 1.48            | 1.04               | 1.18                    |

Sources: Data Processing

In general, 2015 was warmer than 2013. It evidenced by the higher maximum and average LST values found in 2015. The range of average value in 2013 was found between 18.22 to 24.97 °C, whereas the

Table 5. The coverage of each UHS class in March, May, and September 2015 on UPM campus

| Class | March | May | September |
|-------|-------|-----|-----------|
|       | Ha    | %   | Ha        | %       | Ha  | %   |
| Low   | 478.41| 46.22| 948.50    | 91.57   | 225.19| 21.74|
| Medium| 294.47| 28.45| 80.93     | 7.81    | 315.09| 30.42|
| High  | 262.20| 25.33| 6.43      | 0.62    | 495.63| 47.84|

Sources: Data Processing

In general, 2015 was warmer than 2013. It evidenced by the higher maximum and average LST values found in 2015. The range of average value in 2013 was found between 18.22 to 24.97 °C, whereas the
higher range of average value found in 2015. It was between 26.53 to 28.91 °C (Table 4). A similar result also is shown in maximum LST value. This study the same month to compare the maximum LST between those two years. The maximum LST in September 2015 found at 32.17 °C. It is higher than the maximum LST in September 2013 (28.84 °C).

3.2. Land-cover change
Google Earth Data archived could be used to identify a land cover change in a specific area. The detection of land-cover changes found easier when using Google Earth data because it supports satellite data for a specific location from the previous period. Figure 3 shows the land-cover changes in the surrounding area, as the image shows data from 5 October 2013 and 2 September 2014. The yellow line highlights the location of the changes. It is quite a significant change from the original cover (vegetation) to the built-up area.

![Figure 3](image)

**Figure 3.** Land cover Change on UPM Campus from October 2013 until September 2014

![Figure 4](image)

**Figure 4.** Land cover Change on UPM Campus from September 2015 until September 2019
Figure 4 also shows land-cover changes in the surrounding area, as the image shows data from 9 September 2015 and 25 March 2019. The yellow line highlights the location of the changes. It is quite a significant change from natural cover (vegetation) to the built-up area.

4. Conclusion
The result shows that there was an increasing surface temperature during 2013-2015, the maximum LST in September 2015 was found at 32.17 °C, it is higher than the maximum LST in September 2013 (28.84 °C). The result shows that there was an increasing surface temperature during 2013-2015, which corresponds with the inclining built-up area. The research concluded that changes in land-cover would affect the spatial-temporal land surface temperature at University Putra Malaysia.

5. References
[1] Khairulmaini O S and Ghaffar F A 2008 Vulnerability and adaptation to climate change threat: Issues and challenges for Malaysia Proceedings of the 3rd Regional Symposium on Environment and Natural Resources: Conservation for a green future, Kuala Lumpur pp 1-22
[2] Tran H, Uchihama D, Ochi S and Yasuoka Y 2006 Assessment with satellite data of the urban heat island effects in Asian megacities International Journal of Applied Earth Observation and Geoinformation 8 (1) pp 34-48
[3] Memon R A, Leung D Y and Liu C H 2009 An investigation of urban heat island intensity (UHII) as an indicator of urban heating Atmospheric Research 94 (3) pp 491-500
[4] Makaremi N, Salleh E, Jaafar M Z and Ghaffarian H A 2012 Thermal comfort conditions of shaded outdoor spaces in the hot and humid climate of Malaysia Building and Environment 48 pp 7-14
[5] Wong N H and Yu C 2005 Study of green areas and urban heat island in a tropical city Habitat International 29 (3) pp 547-558
[6] Ishak A, Hassan Z N C, Edros N H, Zamberi M H and Rahman M N A 2011 The Effect of Local Climate on Urban Heat Island Trend; A Case Study in Urban Areas of Ipoh and Kuantan. Malaysian Meteorological Department (MMD) Ministry of Science, Technology and Innovation, Kuala Lumpur, Malaysia
[7] Suzuki C 2008 Improvements in the heat island monitoring network in Tokyo Geography Tokyo University 43 pp 33-40
[8] Srivanit M and Hokao K 2013 Evaluating the cooling effects of greening for improving the outdoor thermal environment at an institutional campus in the summer Building and Environment 66 pp 158-172
[9] Mirzaei P A and Haghighat F 2010 Approaches to studying urban heat island–abilities and limitations Building and Environment 45 (10) pp 2192-2201
[10] Wibowo A, Raditya A, Harmantyo D and Semedi J M 2015 Land Surface Temperature as Urban Hazard in Education Area (A Case Study: University of Indonesia) Proceeding the First International Conference of Indonesian Society for Remote Sensing
[11] USGS 2014 Landsat 5 History. Accessed on March 21, 2016. http://landsat.usgs.gov/about_landsat5.php.
[12] Tursilowati L 2002 Urban heat island and their contribution to climate change and relationship with land-use change Proceeding on National Seminar on Global Warming and Global Change: Fact, Mitigation, and Adaptation ISBN: 978-979-17490-0-8
[13] Ichinose T, Matsumoto F, and Kataoka K 2008 Urban thermal environment and its mitigation through the urban planning process Geographical Reports of Tokyo Metropolitan University 43 pp 33-40
[14] Hernina R, Ismullah I H and Wikantika K 2008 The Analysis of Urban Heat Island Using Satellite Image (Case Study Bekasi West Java) Jurnal Geografi 1 (2) pp 73-80
[15] Wibowo A and Semedi J M 2016 Spatial Temporal Analysis of Air Surface Temperature Behavior on Small City Proceeding the 13th International Asian Urbanization Conference,
Acknowledgments
The authors would like to thank Faculty Forestry, Universiti Putra Malaysia, and Department of Geography, Faculty of Mathematics and Natural Sciences, the University of Indonesia, for the support of the research.