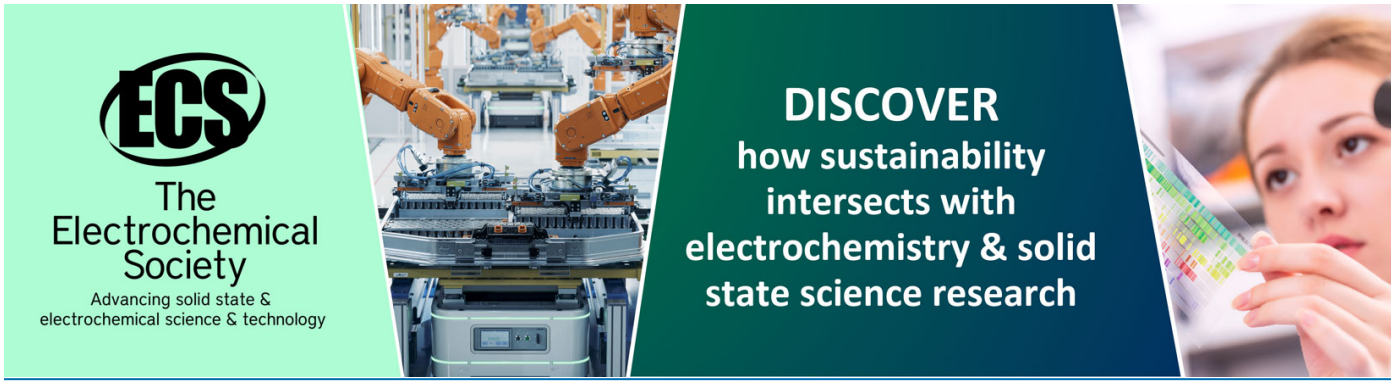
Land use changes and relation to urban heat island (case study Semarang City, Central Java)



Land use changes and relation to urban heat island (case study Semarang City, Central Java)

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Abstract. The population in Semarang City has been more and more increased while the demand for land for built-up area has also steadily increased. These conditions have increased the surface temperature which triggered the phenomenon of Urban Heat Island (UHI). This study aims to determine the impact of land use changes to the UHI phenomenon in the Semarang City. The data used in this study included remote-sensing satellite images of Landsat TM5 in 2008 and Landsat8 OLI in 2018. The methods used were Top of Atmosphere (ToA) correction, spatial analysis, and Land Surface Temperature (LST). The results showed that in the period of 2008-2018, there was an increased built-up area by 13% while the use of forest and plantations area was decreased by 7%. In the period of 2008-2018, the surface temperature rised from 18-33^{0}C to 22-40^{0}C. The land use that has a highest surface temperature was on built-up area, reaching as much as 26-30^{0}C in 2008 and 30-34^{0}C in 2018 while the lowest was on water bodies as much as 22-26^{0}C in 2008 and 24-26^{0}C in 2018. The changes of land use into built-up area have led to increase surface temperatures which have caused the UHI phenomenon in Semarang City.

Keywords: Landuse Changes, Remote Sensing, UHI.

1. Introduction

Population growth in Indonesia is faster compared to other Asian countries. Indonesia's population in 2025 is estimated at 273.2 million. While the issue of global warming is also a major problem in the world today including Indonesia. Population growth causes many new buildings and properties with the conversion of open land to built-up areas all of which are required to support various human activities [1]. This effects the rise in surface temperature that triggers the phenomenon of *Urban Heat Island* (UHI).

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Urban Heat Island is influenced by several factors including urban land use, minimal vegetation, and surface temperature [2]. The condition of the urban air temperature is higher compared to the temperature around it. During the day the hot air temperature in the city can be higher around 3-10 °C compared to the surrounding air temperature [3]. The study of the phenomenon of urban heat island in Semarang is important to do considering that this phenomenon affects the conditions of air quality, human health, and energy use, to climate change in the long run. Also, this study will help in the process of land use planning and spatial distribution areas that will influence the formation of urban heat islands in large cities.

2. Material and Method

2.1 Research sites

This research was conducted in Semarang City, Central Java. It was carried out for 4 months starting April 2019 until July 2019. The following is a map of the research location showed in figure 1.

Figure 1. Map of research location

2.2. Data types and sources

The data used in this study consisted of primary and secondary data. Primary data was obtained through field validation tests, while the secondary data in the form of digital data Landsat TM 5 of 2008 year and Landsat 8 OLI of 2018 year path images 120 rows 065.

2.3. Materials and tools

The materials used in this study include the Semarang City administration map, land use maps and regional spatial plan maps, while the tools used consist of computers or laptops with ArcGis 10.2 and Erdass Imagine 2014 software.

2.4. Method of collecting data

Data collection methods include; field observations and literature studies. In this study observations were carried out as validation tests of land use observed. Other secondary data are obtained from various sources, through literature studies in several related institutions including in Semarang City.

2.5. Data analysis method

2.5.1. Analysis of changes in land use. Land use data for 2008 was obtained from *BPN*, and the data of land use in 2018 from satelite images Landsat 8 OLI 2018 with the visual classification analysis. Furthemore, a spatial analysis techniques will be conducted to find out how much changes in land use and cover in the period 2008 to 2018.

2.5.2. Urban Heat Island analysis. The thermal band contained in the image data is used to estimate surface temperature [4,5]. Data on satellite image Landsat TM5 in 2008 thermal bands are in band 6, while on Landsat 8 in 2018, thermal bands are in band 10 and band 11. Data on the band is converted from raw image or DN (Digital Number) value to the TOA (Top of Atmosphere) spectral radiance value. To be able to extract surface temperature data, there are two steps; change the Digital Number (DN) value to the TOA spectral radiance value, then the TOA spectral radiance value is extracted to the value of surface temperature (units of Kelvin), using the following equation:

$$L_\lambda = ML * Q_{cal} + A_L \quad (1)$$

Where, L_λ : TOA spectral radiance
M_L : Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x)
A_L : Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x)
Q_{cal}: Quantized and calibrated standard product pixel values (level 1 pixel value in DN)

Next, Land Surface Temperature (LST) is a condition that is controlled by the balance of surface energy, atmosphere, thermal properties of the surface and sub-surface media. The surface temperature of a region can be defined from Landsat satellite images extracted from thermal bands. The TOA spectral radiance value is transferred to the Urban Heat Island surface temperature value using the equation:

$$T = \frac{K_2}{ln\left(\frac{K_1}{L_\lambda}+1\right)} \quad (2)$$

Where, T : At satellite brightness temperature (K)
L_λ : TOA spectral radiance
K_1 : Band-specific thermal conversion constant (K1_CONSTANT_BAND_x)
K_2 : Band-specific thermal conversion constant (K2_CONSTANT_BAND_x)

Estimation of surface temperature values of Urban Heat Island is in Kelvin degrees, for better classification and process, then converted to Celsius, obtained through equations:

$$^oCelcius = {}^oKelvin - 273,15 \quad (3)$$

2.5.3. Analysis of Urban Heat Island distribution in each land use. Analysis of the distribution of Urban Heat Island in each land use was carried out using spatial analysis between land use maps with Urban Heat Island maps in each observation year. Results obtained from the distribution of Urban Heat Island and average temperatures for each land use.

3. Results and Discussion

3.1. Land use

The results of land use data for 2008 was obtained from Bappeda/BPN and interpretation of Landsat 8 OLI in 2018 resulted in 8 classes of land use including: forests, plantations, field, built-up area, bare land, rice fields, shrubs and water bodies (table 1), maps land use are presented in figure 2 and figure 3. In general, land use in Semarang is dominated by built up land (43%), plantations (15%), and rice fields (12%).

Table 1. Land use in Semarang

Land use	in 2008		in 2018		Change	
	Ha	%	Ha	%	Ha	%
Forest	2,061	5	290	1	-1,772	-5
Plantation	6,944	18	5,838	15	-1,106	-3
Field	2,751	7	3,651	9	899	2
Built-up Area	11,775	30	16,683	43	4,909	13
Bare Land	1,168	3	1,638	4	470	1
Rice Fields	6,715	17	4,490	12	-2,225	-6
Shrubs	3,077	8	2,142	6	-935	-2
Water Body	4,340	11	4,100	11	-241	-1

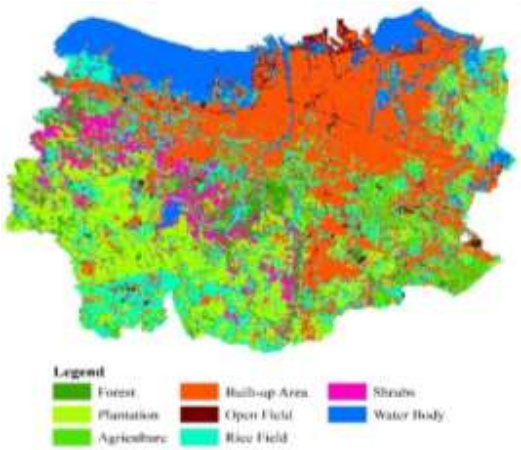

Figure 2. Map of land use in 2008

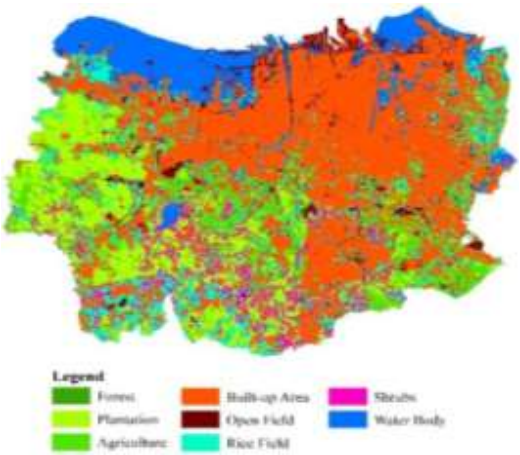

Figure 3. Map of land use in 2018

3.2. Changes in land use

The need to increase the extent of certain types of land use causes the surrounding land to be dynamically changed [6]. Changes in land use are created from interactions between humans and nature [7] and involve complex mechanisms and processes [8]. Changes in land use that occurred in the city of Semarang in the period 2008-2018 are presented in table 1. The total area of change in land use during the period was 12,556 ha or 32% of the total area of Semarang.

Based on land use changes that occur shows that the use of agriculture land, built-up area, and open land is a type of land use that has increased area. Built-up area has increased in area in that period which is 4,909 ha (39%), agriculture are 899 ha or (7%), and open land is 470 ha (4%) of the total land use change. The trend map of changes in land use during the observation period is presented in figure 4.

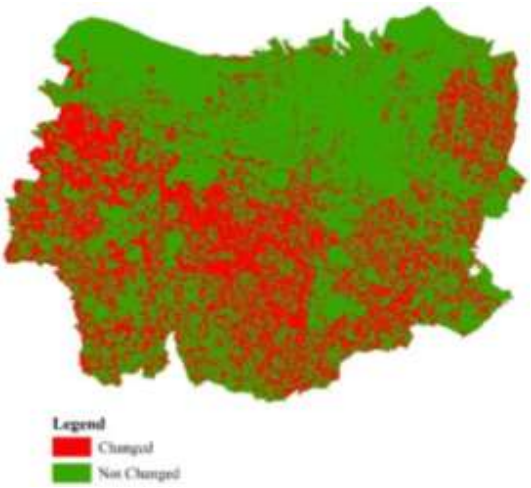

Figure 4. Map of trends in land use change in 2008-2018

3.3. Urban Heat Island (UHI) of Semarang

Surface temperature research is intended to determine changes in surface temperature in 2 years of observation. Classification of surface temperature in Semarang in 2008 is divided into eight classes, while for 2018 it is divided into 9 classes of surface temperature (table 2). In 2008 Semarang was dominated by surface temperatures ranging from 26-28 °C, which was 36%, while in 2018 it was dominated by surface temperatures of 30-32 °C, which was 31%. The surface temperature in Semarang has increased in the observation year period, from the surface temperature range of 18-33 °C in 2008 to 22-40 °C in 2018. The spatial distribution of surface temperatures in Semarang is presented in figure 5 and figure 6.

Table 2. Spatial distribution of surface temperatures in Semarang

UHI Class (°C) in 2008	Large		UHI Class (°C) in 2018	Large	
	Ha	%		Ha	%
18-20	1	0,0	-	-	-
20-22	30	0,1	-	-	-
22-24	2,952	7,6	22-24	186	0
24-26	12,263	31,6	24-26	2,337	6
26-28	14,246	36,7	26-28	5,483	14
28-30	8,977	23,1	28-30	10,811	28
30-32	357	0,9	30-32	12,114	31
32-33	1	0,0	32-34	7,413	19
-	-	-	34-36	474	1
-	-	-	36-38	6	0
-	-	-	38-40	3	0

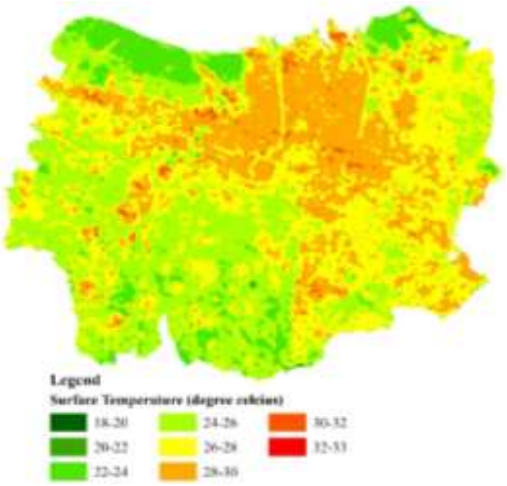

Figure 5. Map of UHI in 2008

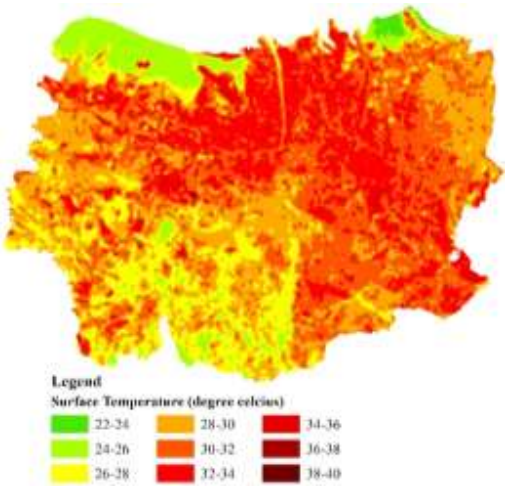

Figure 6. Map of UHI in 2018

3.4. Linkages between land use change and UHI

The results of the analysis show that in 2008 and 2018, land use classification that had the highest surface temperature values were built-up areas and bare land, which were 26-30 °C in 2008 and 30-34 °C in 2018 respectively (table 3). The results of the analysis were also showed that in addition to the water body, other land uses had increased surface temperatures during the period of observation. Forest land use classification have increased surface temperatures, from the range of 24-28 °C in 2008 to 26-30 °C in 2018, plantation use in the range of 24-28 °C in 2008 to 26-30 °C in 2018, as well as field use range from 24-28 °C in 2008 to 28-32 °C in 2018.

Table 3. Land use with UHI in Semarang

Land use	In 2008		In 2018		Temperature Change Status
	Temperature (°C)	%	Temperature (°C)	%	
Forest	24-28	5	26-30	1	Increase
Plantation	24-28	18	26-30	15	Increase
Field	24-28	7	28-32	9	Increase
Built-up Area	26-30	30	30-34	43	Increase
Bare Land	26-30	3	30-34	4	Increase
Rice Field	24-28	17	28-32	12	Increase
Shrubs	24-28	8	26-30	6	Increase
Water body	22-26	11	24-26	11	Not change

The surface temperature of built-up areas and bare land ranged from 26-30 °C in 2008 to 30-34 °C in 2018, rice field and field ranged from 24-28 °C in 2008 to 28-32 °C in 2018, water body ranged 22-26 °C in 2008 to 24-26 °C in 2018, while forest, plantation and shrub land use ranged from 24-28 °C in 2008 to 26-30 °C in 2018 (figure 7 and 8).

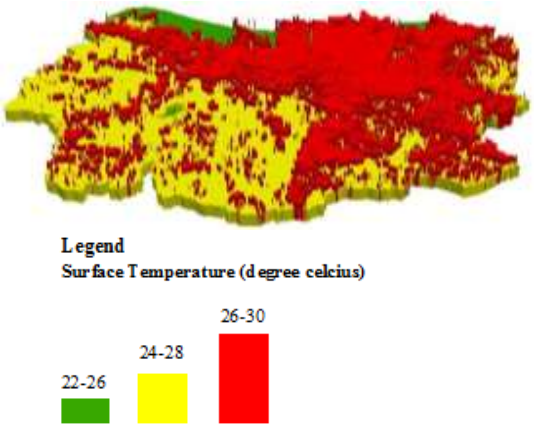

Figure 7. Surface temperature based on land use in 2008

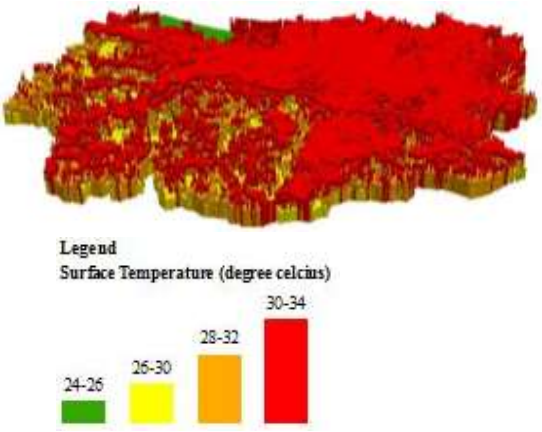

Figure 8. Surface temperature based on land use in 2018

Based on the relationship with changes in land use that occur shows that the wider the change in land leads to built-up area activity causing the surface temperature also increases. Sun *et al*. [9], Kershaw [10], Takkanon [11] concluded that urbanization has contributed significantly to rising surface temperatures.

4. Conclusion

The conclusion of this study is

- The total area change in land use in Semarang during the period 2008-2018 was 12,556 ha or 32%. Massive land development has increased in area in that period by 4,909 ha (39%).
- The surface temperature in Semarang has increased in the period 2008-2018, from 18-33^{o}C in 2008 to 22-40^{o}C in 2018.
- The highest surface temperature values were in the landuse of built-up area and bare land, which were 26-30^{o}C in 2008 and 30-34^{o}C in 2018, respectively.

5. References

[1] Limas A V 2014 Discussion of the effects of urban heat island and alternative solutions for the city of Jakarta *Jati Undip*. **9** 29-34
[2] Fawzi N I 2013 *Urban Heat Island Study in Yogyakarta City-Relationship Between Land Cover and Surface Temperature* (Yogyakarta: Gadjah Mada University)
[3] Khomarudin M R 2004 Detect heat islands with remote sensing satellite data *Warta Lapan.* **6** 74-81
[4] Rushayati S B, Hermawan R 2013 Characteristics of Urban Heat Island Conditions in DKI Jakarta *Media Conservation*. **18** 96-100
[5] Noviyanti E, Pamungkas A, Santoso E B 2016 The concept of UHI management in the CBD area of the city of Surabaya *Journal of Geography Research and Development*. **4** 2
[6] Munawir, Barus B, Sudadi U 2019 Spatial analysis of dynamics land conversion in Gowa district, South Sulawesi *Tataloka*. **21** 237-252
[7] Vitousek P M, Mooney H A, Lubchenco J 1997 Human domination of earth's ecosystems *Science*. **277** 494-499
[8] Sohl T L, Claggett P R 2013 Clarity versus complexity: land-use modeling as a practical tool for decision-makers *Journal of Environmental Management*. **129** 235-243

[9] Sun Y, Zhang X, Ren G 2016 Contribution of urbanization to warming in China *Nat. Clim. Chang*. **6** 706-709
[10] Kershaw T 2017 Climate change resilience in the urban environment (London) *IOP Science*. **4** 1-44
[11] Takkanon P 2017 UHI and thermal performance of office buildings in Bangkok *Procedia Engineering*. **180** 241-251