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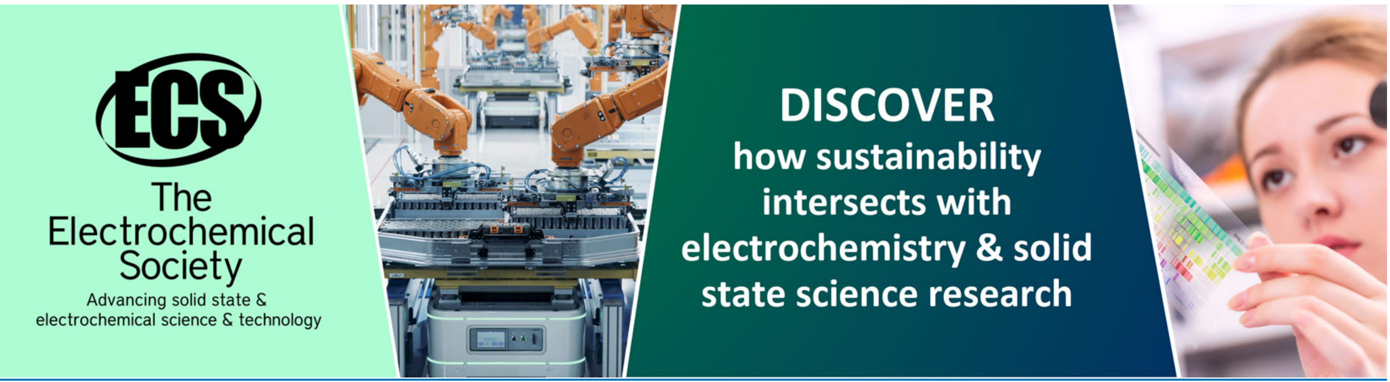

Spatial planning for green infrastructure in Yogyakarta City based on land surface temperature

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Abstract. Green infrastructure (GI) planning has developed as an important approach that aids the creation of functional, sustainable, and liveable cities. GI can play a role in climate change adaptation and mitigation through reducing air and surface temperature by providing shading and enhancing evapotranspiration. The aim of this study is to introduce a spatial analysis approach by identify priority areas thus GI can be strategically placedto improve local temperature regulation. We used a method to evaluate the local temperature regulation by green cover at land use unit level using information on land cover and LST, the mean of LST was calculated for each land use and land cover classes. LST map result shows that across the study area, LST values increased from the outskirts towards the centre of urban areas with surface ranging from 30ºC to 42ºC with average temperature 36.3ºC. The results was shown that land use unit such as industrial, health buildings, offices, and tourism areas with built up areas land cover are become priority areas for GI planning. Awareness of this environmental issues is crucial as it can serve as a tool for cities to adapt and mitigate climate change to improve green infrastructure planning strategies.

Keywords: climate change, green infrastructure, land surface temperature, urban heat island

1. Introduction

In cities worldwide, hard surfaces can now comprise as much as 67% of land area, while 'green' areas can fall as low as 16% in some cities [1]. Urban growth, by altering cities and the surrounding countryside, presents numerous challenges for the maintenance of urban green space, and consequently also for human health and well-being [2]. Yogyakarta is one of the cities in Indonesia that experienced rapid growth and development, eventually green space has turned into built up area. Land use of Yogyakarta in 2014 is dominated by settlements that covering 1333.75 ha or 40.58% of the total area [3]. Development of Yogyakarta in the middle of DIY Province has potential to give a negative impact on the phenomenon of Urban Heat Island (UHI). UHI phenomenon is a major issue in every developing city in the world against global warming. Land Surface Temperature (LST) derived from remote sensing data is unique source of information in order to define surface UHI and it has been widely used as indicator for UHI research [4]. LST information is available from a series of satellite sensors that covering various earth surfaces. Compared with the air temperature obtained from the climatological station, the thermal image provides full spatial coverage at various temporal scales [5].

Over the past decade GI planning has developed as an important approach to green space planning that aids the creation of functional, sustainable and livable cities [6]. Green urban infrastructure can play a role in climate change adaptation through reducing air and surface temperature by providing shading and enhancing evapotranspiration, which leads to two benefits: reduced energy use and improved thermal comfort, them also affects air quality through the absorption of pollutants [7,8]. Local temperature regulation by green areas is an important urban ecosystem service, because it can reduce UHI effect so it will improve the quality of life [9, 10]. Therefore, the aim of this study is to introduce a spatial analysis approach by identify priority areas thus GI can be strategically placed to improve local temperature regulation.

2. Data and Methods

To identify priority areas for Yogyakarta GI planning, three main methodological steps were taken. First, by identifying spatial distribution LST of Yogyakarta. Secondly, by classifying land cover map. Third, estimating spatial priority areas for GI planning to improve local temperature regulation. To identifying spatial distribution LST of Yogyakarta, the method used is Split Window Algorithm. The main data used is Digital Satellite Landsat-8 OLI (Operational Land Imager) path 120-row 65was obtain from United States Geological Survey website. The satellite image was collected on 17 May 2017when the atmospheric condition was highly clear. UHI are generally stronger during the daytime, the selection of a daytime image in the summer is recommended [9]. The 2014 land use map was obtained from previous research by Ratnasari (2015) (Figure 1). DIY (Special region of Yogyakarta) province map is obtained from the Indonesian Topographic Map 2004 in the scale of 1: 25,000 by Geospatial Information Agency used as the administrative boundary and the study area.

2.1. Estimated Land Surface Temperature Distribution

The first step is determining subset area. Second, converting the Digital Number into spectral radiance. Band 10 and band 11, band 4, and band 5 converted from raw image to Top of Atmospheric spectral radiance using radiance rescaling factors [12]. The calculation formula is as follows:

$$L\lambda = M_L * Q_{cal} + A_L$$

Where: Lλ is Top of Atmospheric Spectral Radiance (Watts/ (m2*srad*µm)); $M_L$is band-specific multiplicative rescaling factor (0.0003342); $A_L$is band-specific additive rescaling factor (0.1); Q_{cal} is band 10/ band 11 image.

Third, TIRS band 10 and band 11 were taken to estimate Brightness Temperature (BT) on Kelvin by converting spectral radiance to BT for both TIR bands [12], supported by the following formula:

$$BTi = \frac{K2}{Ln\left(\left(\frac{K1}{L\lambda}\right) + 1\right)}$$

Where: K1 and K2 are band-specific thermal conversion constant from metadata; L λ is Top of Atmospheric Spectral Radiance (Watts/ (m2 * srad * µm)).

Then, estimate the value of Normalize Difference Vegetation Index (NDVI). Band 4 and band 5 are used to obtain NDVI values with the following formula [11]:

$$NDVI = \frac{NIR\ (band\ 5) - R\ (band\ 4)}{NIR\ (band\ 5) + R\ (band\ 4)}$$

Where: NIR is near-infrared band (Band 5) and R is red band (Band 4).

FVC values can be estimated using previously obtained NDVI values, as well as NDVI soil and NDVI veg values [13]. The pixel was considered as bare soil when the NDVI values are<0,2; while it would be considered as full vegetation when the NDVI values are > 0,5 [11]. FVC function is to estimate the fraction of a vegetation covered area, with the following formula:

$$FVC = \frac{NDVI - NDVIsoil}{NDVIveg - NDVIsoil}$$

Where: NDVI soil is NDVI value of soil = 0.2; NDVI veg is NDVI value of vegetation = the maximum value of NDVI (more than 0.5).

Using the average value and the difference value on Land Surface Emissivity (LSE) to estimate the LST. Estimating LSE requires the emissivity value of soil and vegetation from both TIRS band 10 and band 11 [14], with the following formula:

$$LSE = \varepsilon s*(1\text{-}FVC) + \varepsilon v*FVC$$

Where: εs and εv are soil and vegetation emissivity values.

The combination of LSE band 10 and band 11 generates mean of LSE (ε) and difference of LSE value (Δm) [14], with the following formula:

$$\varepsilon = \frac{\varepsilon 10 + \varepsilon 11}{2}$$

Where: $\varepsilon$is mean of LSE; $\varepsilon 10$ and$\varepsilon 11$ is the emissivity of band 10 and band 11.

$$\Delta\varepsilon = \varepsilon 10 - \varepsilon 11$$

Where:$\Delta\varepsilon$ is difference of LSE; ε_{10} andε_{11} is the emissivity of band 10 and band 11.

The final step, estimate LST use an algorithm with the following formula [13]:

$$LST = TB_{10}+C_1(TB_{10}\text{-}TB_{11})+C_2(TB_{10}\text{-}TB_{11})^2+C_0+(C_3+C_4W)\ (1\text{-}\ \varepsilon)+(C_5+C_6W)\Delta m$$

Where: C_0 - C_6isSplit-window coefficient value; $\varepsilon$is mean of LSE band 10 and band 11; W is Atmospheric Water Vapour Content = 0.013 [14]; Δm is difference of LSE band 10 and band 11.

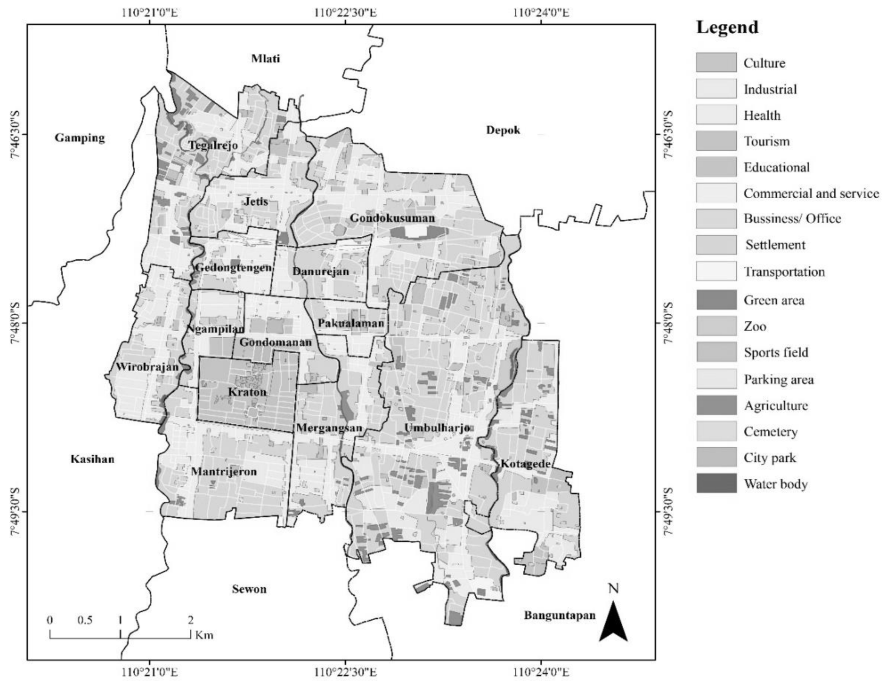

Figure 1. Land use map of Yogyakarta 2014 [3].

2.2. Land cover map classification

Procedures for image classification by supervised classification method and to classify land cover class is used sub-menu of image classification with maximum likelihood classification method in ArcMap

10.4. In land cover map analysis, the first thing to do is combining 3 bands that suitable with the spectral characteristics of each band and adjusted for research objective, in this study bands 4, 3 and 2 (natural color) was used. Then, pan sharpening process is done to sharpen the appearance of objects on the image in conducting visual analysis. The sharpening of this object is done by combining the multiband image (1, 2, 3, 4, 5, 6, 7 and 9) which has a resolution of 30m x 30m and a panchromatic band (band 8) that has a spatial resolution of 15m x 15m [15]. After that, we clipping the image that has been compiled with the administrative boundary map of Yogyakarta. The next step is to create a training area as polygons in each class that will be classified. Training area was spreaded and evenly distributed to each class that covering the entire study area. Four types of land cover identified are, (1) vegetation (including forest, street trees), (2) agriculture land, (3) bare land, and (4) built up area (commercial buildings, settlements, offices, industrial areas, etc.) In this study, the accuracy of land cover classification is classified using the reference point generated by using stratified random sampling technique. This evaluation tests visual accuracy level of the supervised classification. Accuracy is done by making contingency matrix (confusion matrix). Accuracy that can be calculated is, user's accuracy, producer's accuracy and overall accuracy.

2.3. Identify GI priority areas to improve local temperature regulation

In this study, we use method to evaluate the local temperature regulation by green cover at the land use unit level using information on land cover and surface temperature. The mean of LST was calculated for each land use and land cover classes. Based on index proposed by Schwarzet al. [10], has been developed index that establishes the influence of green cover on surface temperature for each land use unit (i):

$$index\ (i) = \frac{Mean\ temperature\ Land\ Use}{Mean\ temperature\ Green\ Cover}\ x\ \ percent\ Green\ Cover$$

3. Result and Discussion

3.1. Spatial distribution of land surface temperature

Based on the results of Land Surface Temperature distribution analysis, the class of temperature distribution is grouped into 12 classes (**Figure 2**). The spatial distribution of land surface temperature by land use unit exhibits the general pattern of urban heat islands, wherein temperatures tend to decrease as the radial distance from the city centre increases, with surface ranging from 30°C to 42°C. The map shows that high temperatures occur in the built up areas, while the lower temperatures occurring vegetated areas. Xiong et al. found that high temperature anomalies are closely related to built-up areas, densely populated zones, and highly dense industrial areas [16]. Land cover factors have the greatest impact on spatial distribution of UHI in Yogyakarta City. High LST values generally occur in built up areas due to the increasing population density every year in Yogyakarta, the development spread to the sub urban areas surrounding the city, some part of Sleman and Bantul Regency [13].The highest temperature occur in Gondomanan District with an average temperature of 38.4°C and the lowest temperature is in Tegalrejo District with an average temperature of 35.7°C.

3.2. Land cover map

The classification result of land cover map of Yogyakarta is shown in Figure 3. It can be seen that most of urban area is dominated by built up area, with overall presentation of vegetated area covering 25.27 ha (0.8%), bare land 450.99 ha (13.7%), agriculture land 263.82 ha (8%), and built up area 2556.86 ha (77.5%). Land use in Yogyakarta is dominated by residential areas that occupy almost half of the total area [3]. After the land cover map is classified, accuracy test obtain with overall accuracy results is 91.25%, and kappa accuracy 88.33%.

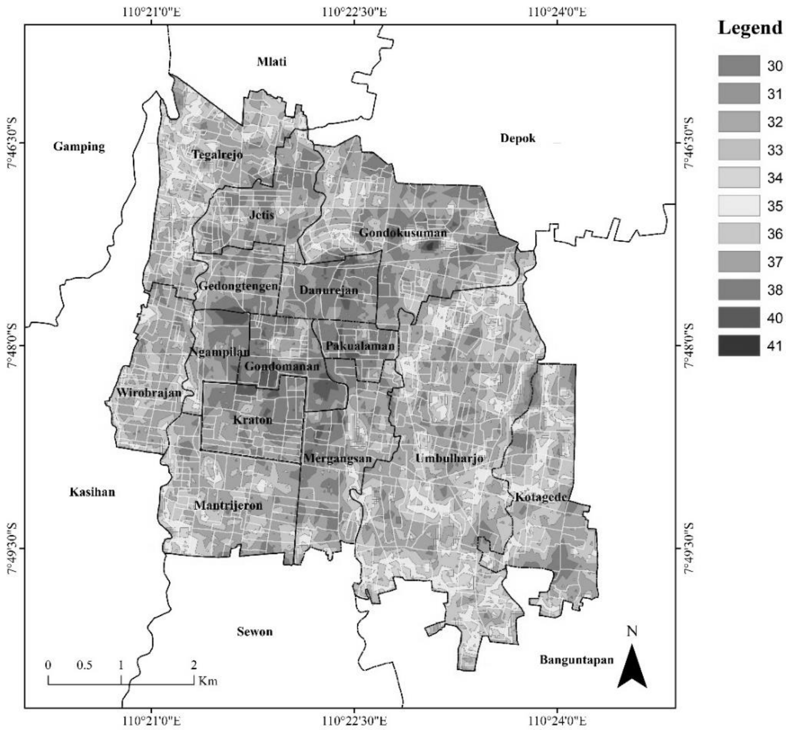

Figure 2. Land Surface Temperature map (° C) of Yogyakarta 2017.

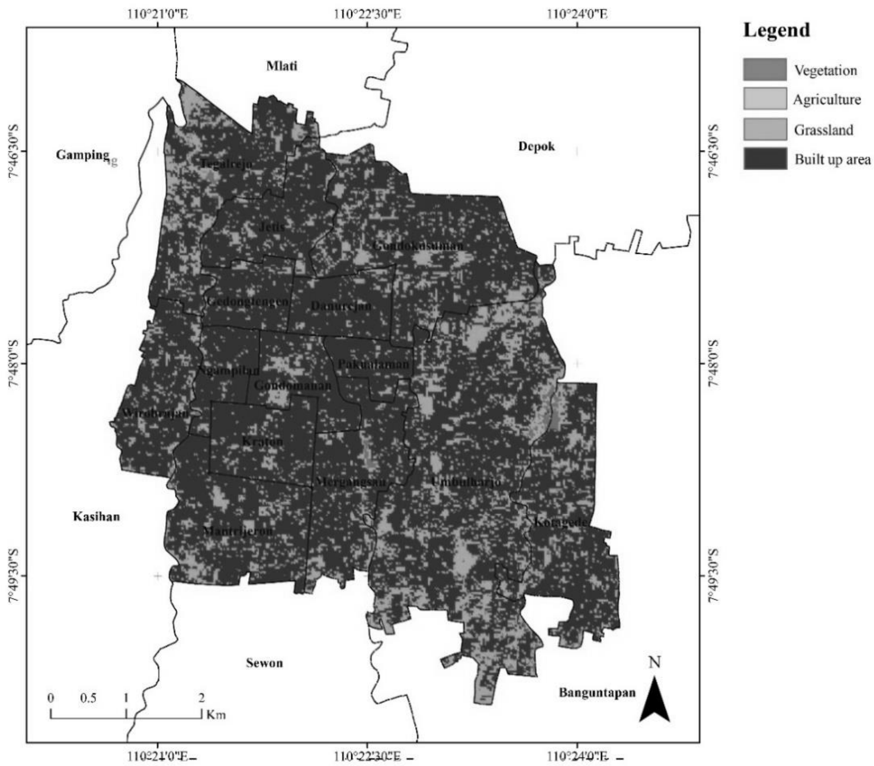

Figure 3. Land cover map of Yogyakarta 2017.

3.3. Spatial priority areas for GI planning

Table 1 summarizes surface cover information for each land use classes and means of surface temperatures for all land use and land cover classes. The results show that, the lowest average temperature in the land use class is 33.1°C in the zoo area and the highest average temperature reached 38°C occurred in health buildings area that lack of vegetation. The results confirm the expected relationship between land use/land cover characteristics and surface temperature. The land use/land cover classes related to urban fabric exhibit the highest temperature, while the lowest values occur at green covered surfaces [10]. The distribution of temperatures in urban areas is complex and depends on factors such as the pattern of urban land use, with densely built up areas being considerably warmer while green-covered surfaces are relatively cool areas [17].

Table 1. Areal percentage of each land cover class for each land use class, and list for all land use and land cover classes.

Land use classes	Land cover classes (%) Green cover classes				Built area/ impervious surfaces (%)	LST Mean (ºC)
	Agricultural	Tree covered	Bare land	Total green		
Industrial	31.6	1.0	67.4	17.5	82.5	36.6
Culture	41.1	4.6	54.3	25.9	74.1	37.6
Health	23.7	1.4	74.9	17.7	82.3	38.0
Tourism	31.5	0.9	67.7	8.2	91.8	37.8
Education	39.6	1.0	59.4	29.3	70.7	36.7
Business	28.3	1.1	70.6	16.5	83.5	36.8
Office	38.5	1.0	60.5	30.2	69.8	36.7
Housing	37.2	2.4	60.4	20.9	79.1	36.2
Transportation	26.9	4.2	69.0	29.7	70.3	37.6
Agriculture	53.7	1.1	45.1	61.0	39.0	35.0
Water body	53.5	21.6	24.9	49.2	50.8	35.2
Cemetery	27.6	0.3	72.0	38.6	61.4	36.7
Green area	42.7	8.8	48.5	57.1	42.9	35.5
Zoo	39.4	45.9	14.7	83.4	16.6	33.1
Yard	18.6	0.6	80.8	50.8	49.2	37.0
Parking area	24.0	0.2	75.8	32.0	68.0	37.4
Urban park	24.1	1.4	74.5	50.9	49.1	38.0
LST Mean (ºC)	36.1	35.1	36.9	36.0	36.3	

The result from Table 1 was inputted to the equation to determine the land cover index of surface temperature unit (i). The index classification is divided into 7 classes with a class interval value is 13.60 by using Sturges interval formula to determine the priority class. After classification obtained, the classes then translated into spatial forms as a priority areas map for GI planning that classified as class 1 (low priority area) that represented in green color, while class 7 (high priority area) is represented in red (Figure 4). The results shown that land use unit such as industrial, health buildings, offices, and tourism areas with built up areas land cover classes are become priority areas for GI planning. From central of the city and spreaded to the north and the south are the most urbanized areas and the most areas that need more GI.

4. Conclusion

LST spatial distribution results are ranging from 30 °C to 42°C. The highest temperature occurred in Gondomanan District with an average temperature of 38.4ºC and the lowest one is in Tegalrejo District with an average temperature of 35.7ºC. The lowest average temperature in the land use class is 33.1°C and the highest reach up to 38°C. The results shown that land use unit such as industrial, health buildings, offices, and tourism areas with built up areas land cover classes are become priority areas for GI planning. From central of the city then spreaded to the north and the south are the most urbanized areas and the most areas that need more GI.

Awareness of this environmental issues is crucial as it can serve as a tool for cities to adapt and mitigate climate change to improve green infrastructure planning strategies. By raising public awareness of the green infrastructure importance, will make people want to learn to improve knowledge and skills in building green spaces. Further research on community perceptions and preferences on GI will strengthen the GI planning decision support tools.

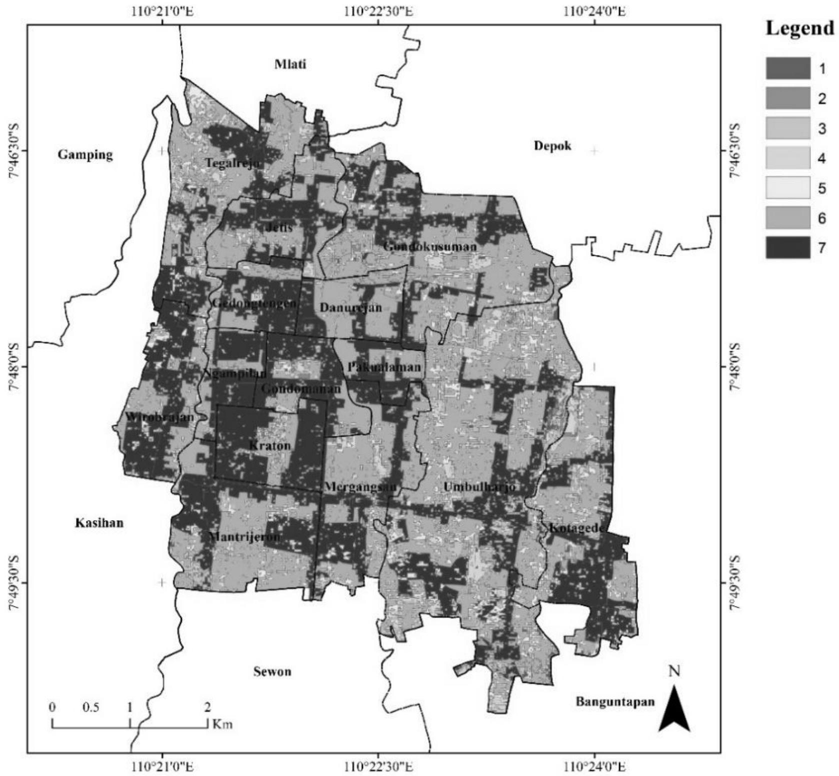

Figure 4. Priority areas of green infrastructure planning.

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