Conference Paper

Spatial Model of Green Open Space Needs for Mitigation of Urban Heat Island Phenomenon in Semarang

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Abstract

Increasing population of the can be effect to an increase in space requirements. Fulfilling space needs means that what happens is a land use changes. green land becomes a need for development land and is the cause of the effect of rising air temperatures in cities. These changes are very important to studying for make plans on city. This study intends to examine the needs of Green Open Space spatially based on the phenomenon of increasing temperature in a location within the city compared to its surroundings or called Urban Heat Island (UHI). Remote Sensing is used to detect UHI spatially. This UHI location will be used as spatial modeling data to assess how large and where is need green space. The expected processing results are a spatial model simulation of the adequacy of Green Open Space requirements that will be a mitigation of the UHI phenomenon that is presented spatially in the form of thematic maps as one of the data that can be used as consideration in the city design planning of Semarang in the long term.

Keywords: land use changes, green open space, remote sensing, urban heat island

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1. Introduction

The city as a unity of the network of human life is characterized by high population density and is characterized by heterogeneous socio-economic strata and materialistic features. Urban society consists of native people of the area and migrants. Increasing city dwellers also means increasing space requirements. Meeting the needs of space then means that what happens is the change in land use of green land into land development needs. Reduced green space causes many negative effects. Urban plans in the city design must be to study this. In the developing of urban areas must be considering the degradation of vegetation, because it will be have bad effect for the climate in city. The heat produced by the industrial process of factories, building air conditioners and motorized vehicles in urban areas also contributes to the increase in heat. [1 - 4].

Indonesia have major city and Semarang is one of them that is still developing to the City of Metropolis. City infrastructure developing can result in land-use dominated by built-up land and a reduction in vegetation cover. Development in big cities changes natural things into artificial one, and this can degradate of the microclimate condition [5]. Thermal comfort in human life will affected because of it. The city of Semarang experiences Urban Heat island (UHI) [6], this shows spasial spread of thermal condition. Changes in microclimate with periodic increases in temperature resulting degradation of comfort temperature and causes increasing energy consumption in use of air conditioning and also affecting in Increasing in pollution of fresh air, increasing CO2 gas, and the end wil be affecting human health[7 - 9].

The use of Remote Sensing method in developing spatial models can be done quickly, effectively, and efficiently. This method is more interesting than conventional methods such as data obtained in the form of digital data, the measurement covers a more distributed area compared to conventional measurements which only form certain points (samples) [10 - 12].

This study intends to examine the needs of Green Open Space (GOS) spatially based on the phenomenon of rising temperatures in a location within the city compared to its surroundings or called Urban Heat Island (UHI). Remote Sensing can be used to detect UHI spatially. This UHI location will be used as spatial modeling to assess how much and where there is a need for GOS. In the end, the adequacy of the needs of green space will be a mitigation of the UHI phenomenon.

2. Methods and Equipment

2.1. Methods

2.1.1. Radiometric Correction

Radiometric Transformation is performed to improve the visual quality of the image while improving pixel values that do not match the reflectance value or the actual spectral beam of the object, formula (1) is used for the transformation of digital numbers into radians, and formula (2) is used for transforming digital numbers into reflectance [13].

$$L\lambda = MLQcal + AL \quad (1)$$

Lλ: Radiance Value

ML: Radians Radiometric rescaling grup MULT

Qcal: DN Thermal Band.

AL: Radians Radiometric rescaling grup ADD

Convert Digital Number (DN) to Reflectant value

$$\rho\lambda' = M\rho * Qcal + A\rho \tag{2}$$

ρ': Spectral reflectance value (without sun angle correction)

Mρ: Re-scaling constant (REFLECTANCE MULTI BAND x)

Qcal: Pixel value (Digital Number)

Aρ: Adder constants (REFLECTANCE ADD BAND x)

To get the reflectance value, it's must correct the angle of the sun with the following equation (3) [13]:

$$\rho\lambda = (\rho\lambda')/(\cos(\Theta sz)) = (\rho\lambda')/(\sin(\Theta se)) \tag{3}$$

ρλ': Reflectance value (without sun angle correction)

ρλ: Reflectance value (corrected by the sun's angle)

ϴsz: Zenith Corner. ϴsz = 90°- ϴse

ϴse: Angle of sun elevation when recording

2.1.2. Emisivity

Surface emissivity is an object's ability to radiate the energy it has [14]. The energy is the thermal energy possessed by the object, both in cold and hot conditions. Even when it is snowing cold, objects still radiate energy. The power of objects to emit this energy is called emissivity. some are able to emit all of its energy or just a part of it. This is based on remote sensing thermal systems that use the basis that any object with temperatures above absolute zero (0° Kelvin or -273.15° C) emits radiation that is in the infrared wave.

Emissivity is symbolized by epsilon (ε) Emissivity has a value between 0 to 1, perfect black objects have an emissivity equal to 1 while the actual object has an emissivity of less than one. Emissivity is a dimensionless unit, the more coarse material and black the object, its emissivity increases to 1 [15]. The surface emissivity equation for heterogeneous earth surface conditions can be seen in the following equation (4):

$$\varepsilon = \varepsilon \upsilon P\upsilon + \varepsilon s(1 - P\upsilon) + d\varepsilon P\upsilon(1 - P\upsilon) \tag{4}$$

ε: surface emissivity

εv: Vegetation emissivity value (0.985)

εs: soil emissivity value (0.960)

$d\varepsilon$: form factor (0.06)

According to [16], `Pv' is a vegetation fraction with values varying from 0 to 1. The value of Pv can be obtained from the scaling of NDVI to minimize disturbances from moist soil conditions and surface energy fluxes. The PV value equation can be seen in formula (5) [16]:

$$\text{Pv} = \left(\frac{|NDVImaks| - NDVImin}{NDVImaks - NDVImin}\right)^2 \quad (5)$$

NDVI: Vegetation index processing results

NDVImin: Minimum value of vegetation index processing results

NDVImaks: Maximum value of the vegetation index processing

2.1.3. Surface Temperature

The surface temperature is the temperature of the outer portion of an object. Definition of surface temperature for exposed soil is the temperature in the outer layer of the soil surface. According to [17], surface temperature is not the same as air temperature. The value of the two can be very different depending on space and time. Surface temperature affects the heat flux felt (sensible heat), especially during the day, because the surface temperature of objects is higher than air temperature. Surface temperature is the first element that can be identified from thermal satellite imagery, through the use of remote sensing, surface temperature can be defined as the average surface temperature of a surface, which is depicted in the coverage of a pixel with various different surface types. The estimation equation of Land Surface Temperature and parameters for processing atmospheric correction according to [18] can be seen in Equations (6).

$$Ts = \gamma\left[\frac{1}{\varepsilon}(\psi1 * L_{sen} + \psi2) + \psi3\right] + \delta \quad (6)$$

$\gamma = 1 \frac{T_{sen}}{K_2 L_{sen}}$

$\delta = -T_{sen} - \left(\frac{T^2{}_{sen}}{K_2}\right)$

$\psi1 = \frac{1}{\tau}$

$\psi2 = -L\downarrow - \frac{L\uparrow}{\tau}$

$\psi3 = L\downarrow$

Ts: Surface Temperature

γ dan δ: Parameters that depend on the Planck function ψ1. $\psi 2$ dan ψ3: Atmospheric correction

L_{sen}: Top of Atmosfer Radians

T_{sen}: Brightness temperature value

$L\uparrow$: Upwelling radiance

L↓: Down-welling radiance

τ: Trans emissivity

ε: Emissivity

K2: Radiation Constant (in meta-data)

2.1.4. Temperature Humidity Index

Life comfort level in an area is asses using Temperature Humidity Index (THI). This method is often used in expressing the comfort level of an area. Generally people from the tropics feel comfortable at values of 20-26°C and already feel uncomfortable at THI above 27° C. Comfort is a term used to express the influence of physical or atmospheric physical environmental conditions on humans. Comfortable conditions if some of the human energy is freed for productive work and efforts to regulate body temperature are at a minimal level. This method produces an index to determine the effect of heat conditions on human comfort that combines temperature and humidity. In equation (7) Temperature Humidity Index is build from the value of air temperature (°C).

$$\text{THI} = 0.8Ta + \frac{(\text{RH } x \text{ Ta})}{500} \tag{7}$$

THI: Index of Temperature Humidity

Ta: Air Temperature (°C)

RH: Relative Humidity (%)

The range of classification of THI using four class of temperature range [19] and [20], here's the classification:

Table 1: Temperature Humidity Index (THI) Value Range.

THI Value Range (°C)	Information
< 20	Un comfort (too cool)
20 to 24	Comfort
24 to 26	Quite comfort
> 26	Un comfort (too hot)

The Urban Heat Island (UHI) is identification by thresholding of Surface Temperature (LST) result, UHI value getiing from LST subtracting by UHI threshold value according to [21], The equation descript in eq. (8) below:

$$T > \ + 0.5\alpha$$

$$0 < T \leq \ + 0.5\alpha \quad (8)$$

2.2. Equipment

This research is conducting in the city of Semarang Central Java - Indonesia. This study uses a combination of several data, the data is: SPOT-6 captured on February 2019 imagery for the detection of green open space. Landsat 8 captured on July 25th 2019, this imagery is used to construct and measure surface temperature with air temperature and land cover, Semarang Sub-district administrative boundaries to limit the study, as well as validation data of green open space coordinate distribution and air temperature and dew point temperature data from meteorological agencies in Semarang City.

3. Results

Radiometric transformation aims to reduce the effect of errors or inconsistencies in image brightness values that can limit a person's ability to interpret the appearance of the earth's surface. Radiometric calibration consists of radiometric corrections carried out by changing the Digital Number value into the radians TOA value and the reflectance TOA value.

Table 2: Radiometric transformation result on Landsat-8 Image.

Image	Band	Digital Number		Radians		Reflectance	
		Max	Min	Max	Min	Max	Min
	B2	25115	0			0.537	0.080
	B3	27407	0			0.598	0.053
Landsat 8	B4	29378	0			0.651	0.033
	B5	32792	0			0.742	0.016
	B10	32926	0	11.104	8.479		

Land-cover in this study is divided into 3 land cover classes. namely vegetation, non-vegetation and water bodies Figure 1(left). Vegetation density NDVI class is divided into 5 namely water, sparse vegetation, fairly tight, tight and very tight Figure 1(right).

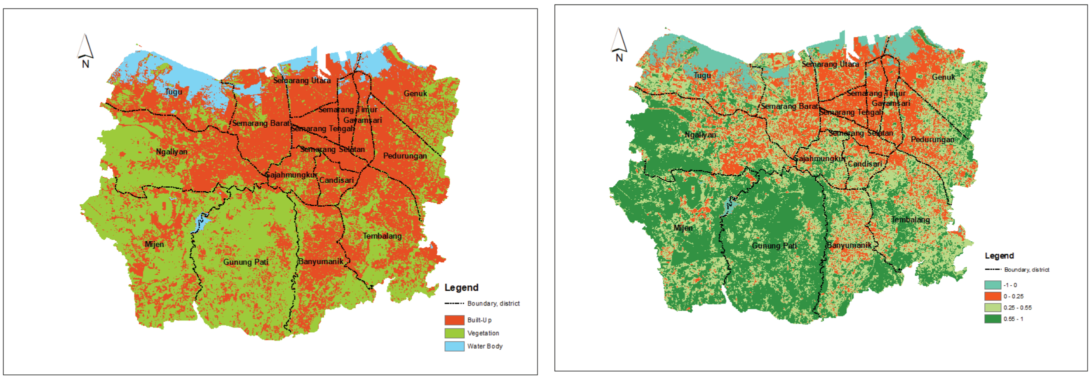

Figure 1: Land-cover (left) and Vegetation density index (right).

The most extensive land cover class is the non-vegetation class. Non-vegetation class has an area of 5774.265 Ha or 50.11% of the area of Semarang City. The second largest land cover class is the vegetation class, which is 815.645 Ha or 44.02% of the area of Semarang City. Water body class has the smallest area of 560.180 Ha or 5.87% of the area of Semarang City Figure 1. Vegetation density class which has the largest area is sparse vegetation (0.25 -- 0.55) class that is equal to 3459.158 Ha. Examples of sparse vegetation density classes are settlements and vacant land. Vegetation class is rarely higher than other classes. meaning that the area of settlement and vacant land is greater than the area of plants.

The LST (Land Surface Temperature) processing results divide into 5 temperature classes. The distribution of surface temperatures can be seen in Figure 2.

The highest surface temperature in Semarang is around 35-40, this known as Urban Heat Island (UHI) and the lowest is around 15-20. Surface temperature in the city of Semarang is dominated by temperatures ranging from 30-35, with an area of 5722.008. The extent of land surface temperature classes in each district can be seen in Table 3.

Table 3: Land Surface Temperature classes in each district.

District	Land Surface Temperature (LST) Classes				
	15-20 (Ha)	20-25 (Ha)	25-30 (Ha)	30-35 (Ha)	35-40 (Ha)
Candisari			36.11848	625.217	
Gajah Mungkur			263.047	678.339	
Semarang Barat	0.062	3.431	494.100	1888.837	27.888
Semarang Selatan			20.112	592.863	1.550
Semarang Tengah			8.685	526.610	
Semarang Timur			80.256	481.476	
Semarang Utara		34.005	455.393	928.666	5.268

Table 3 shows that the surface temperature class is dominated by a 30-35 temperature range, with the largest area in the Semarang Barat district. The second largest surface temperature class is in the range of 25-30, with the largest area in the Semarang Barat District of 494.100 Ha. Temperature classes ranging from 20-25 only exist in the districts of Semarang Barat and Semarang Utara. Temperature Class ranges 35-40 are found in 3 districts namely Semarang Barat, Semarang Selatan and Semarang Utara. 15-20 temperature class only exists in the District of Semarang Barat. Air temperature is the degree of hot and cold air in the atmosphere. The temperature is divided into 5 classes. The distribution of air temperatures in Semarang City Center can be descript in Figure 3.

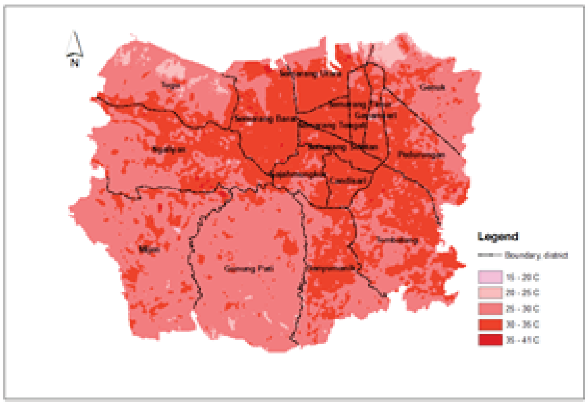

Figure 2: Land Surface Temperature (LST) spatial distribution.

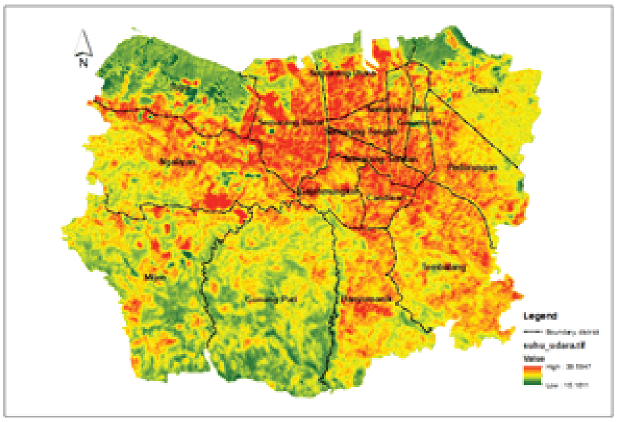

Figure 3: Air Temperature spatial distribution.

From Figure 3 derived Table 4, and it is shows that air temperature is dominated by the class of 20-25 C. The largest district in the class of 20-25 C is Semarang Barat District, with an area of 1304.467 Ha. Class 30-35 is dominated by Semarang Barat Sub-district, with an area of 1069.982 Ha. Classes from 20-25 C are located in Gajah Mungkur District, Semarang Barat, Semarang Timur, Semarang Utara, this class is dominated by Semarang Utara District, with an area of 81.212 Ha. Class 15-20 C is only found in the District of West Semarang, with an area of 0.695 Ha. Class distribution of 35-40 C is only found in Semarang Barat District, with an area of 6.600 Ha.

Table 4: Air Temperature classes in each district.

District	Air Temperature Classes				
	15-20 (Ha)	20-25 (Ha)	25-30 (Ha)	30-35 (Ha)	35-40 (Ha)
Candisari			414.108	247.227	
Gajah Mungkur		1.064	761.027	179.295	
Semarang Barat	0.695	31.151	1304.467	1069.982	6.600
Semarang Selatan			317.949	296.576	
Semarang Tengah			346.740	188.556	
Semarang Timur		6.960	442.455	112.317	
Semarang Utara		81.212	843.166	496.717	

Comfortable is a term used to express the influence of atmospheric or climatic physical environmental conditions on humans. Comfortable conditions if some of the human energy is freed for productive work and efforts to regulate body temperature are at a minimal level. Generally people from the tropics feel comfortable at 20-26°C and already feel unc omfortable at THI above 27°C. THI classification consists of 3 classes, namely comfort (too cold), quite comfort. and un-comfort (too hot) The extent of THI class for each district can be seen in Figure 4 Table 5.

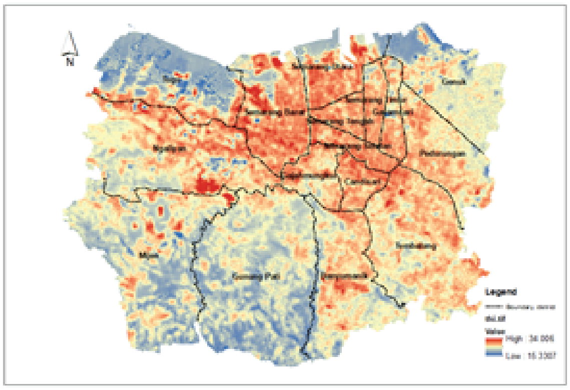

Figure 4: Temperature Humidity Index (THI) spatial distribution.

Table 5: Temperature Humidity Index (THI) classes in each district.

District	THI classes		
	<20 °C	20-26°C	>26 °C
Candisari		146.1297	515.2059
Gajah Mungkur		481.0354	460.3509
Semarang Barat	1.2584	711.6988	1700.085
Semarang Selatan		65.7651	548.7603
Semarang Tengah		85.3574	449.9382
Semarang Timur		173.7627	387.9691
Semarang Utara		606.7098	814.3857

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Table 5 shows that Semarang City Center is dominated by THI class values which are more than 26 C, meaning that in Semarang City Center there are many uncomfortable areas. Classes> 20 C are only found in the District of Semarang Barat with an area of 1.2584 Ha. Classes 20-26 are located in all sub-districts in Semarang City Center, with the largest area in Semarang Barat Sub-District, covering 711.6988 Ha. Class distribution> 26oC is located throughout the Central Semarang District, with the largest area in the Semarang Barat area of 1700.085 Ha.

4. Discussion

This research conducted a green open space analysis in the Semarang City Center consisting of 7 districts Candi sari, Gajah Mungkur, Semarang Barat, Semarang Selatan, Semarang Tengah, Semarang Timur and Semarang Utara. Green Open Space is a place to grow plants, both those that grow naturally and those that are intentionally planted. Classification of green space in this study is green space border river green residential area, green space office area and public facilities, green space trade and services, green space education area, green space recreation and sports area, green space cemetery area, green space parks and fields, green space lane road, green space lane border railroad, green space special military area, green space of airport area, green space of coastal area, green space of seaport area, green space of train station, forest and green space of industrial area.

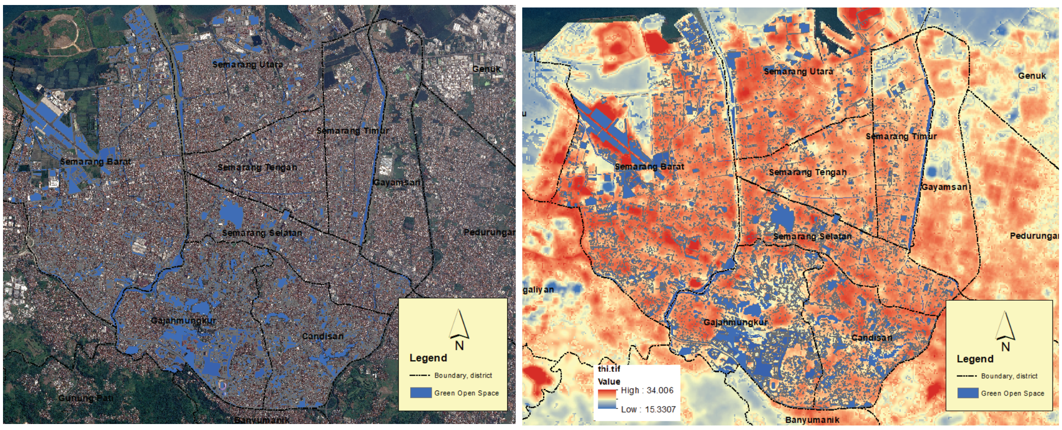

Figure 5: Green Open Space spasial spatial distribution(left) and GOS overlay with THI.

Green open space spasial distribution can be seen on Figure 5 and this area can be found on Table 6. 7 sub-districts are the focus here because they seem to be most affected by UHI's warming up and entering uncomfortable classes, can be seen on Figure 5.

Table 6: Green Open Space Classes in 7 district.

No	Green Open Space Classes	Candisari (Ha)	Gajah Mungkur (Ha)	Semarang Barat (Ha)	Semarang Selatan (Ha)	Semarang Tengah (Ha)	Semarang Timur (Ha)	Semarang Utara (Ha)
1	GOS Cemetery	8.010	5.792	17.784	31.088	0.310	0.240	1.139
2	GOS education	4.419	110.377	27.997	14.375	3.980	3.208	3.098
3	GOS trade service	4.905	4.433	30.895	5.972	5.815	7.101	6.187
4	GOS residential	84.785	92.766	125.062	13.655	7.706	10.668	29.564
5	GOS recreation sport	0.961	9.047	5.911	2.281	2.685	1.069	0.160
6	GOS border river	2.754	19.217	.,436	5.665	4.156	0.011	0.950
7	GOS Park and field	6.472	4.567	41.031	7.881	1.628	22.870	0.755
8	Forest	17.358	52.425	7.361	6.928	5.515	2.479	12.672
9	GOS road lane	10.327	14.771	82.077	10.625	4.151	5.244	2.130
10	GOS Airport	0	0	15.513	0	0	0	34.760
11	GOS seaport	0	0		0	0	0	1.326
12	GOS Office area	5.766	4.451	10.417	0.406	0	2.030	1.453
13	GOS Military	10.020	0	9.123	0	0	0	30
Total Area		155.777	317.846	377.995	98.875	35.947	54.919	98.069

Areas affected by UHI and temperature discomfort are in the northern region or the northern part of Semarang City, as discussed in previous studies [6], [22]. North of the city as the heart of the city is available a variety of infrastructure supporting local and regional and national economies as a busy region, north of the city as the heart of the city that is available a variety of infrastructure supporting local and regional and national economies as a busy area, but the support of vegetation in green open space is not in line and may be very minimal. North, Central and East Semarang districts have very little green open space. The comparison the less green open space the more affected by UHI and temperature discomfort, can be found on Figure 5. In this study, an example was taken in North Semarang sub-district, recommendations for adding vegetation as part of the green open space in Figure 5. The recommendations are Green Parking Lot, Green Roof / Green Wall, and Planting Trees arround residential buildings.

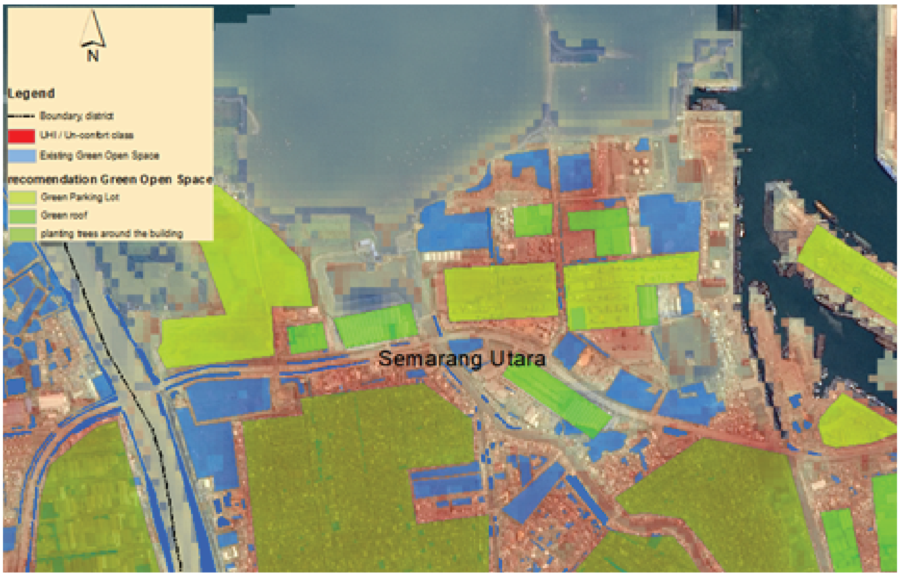

Figure 6: Green Open Space recommendation on UHI area.

5. Conclusion

Urban Heat that causes residential discomfort in the city of Semarang occurs and can be proven by Remote sensing technology. The phenomenon of rising temperatures shows a direct relationship with the amount of vegetation in a city called Green Open Space. This level of discomfort is directly proportional to the temperature rise but inversely proportional to the amount of vegetation. The northern area of Semarang City was identified as the hottest and uncomfortable environmental area based on Temperature Humidity Index class distribution. The recommendation to add Green Open Space needs to be done, but it is not possible to replace the buildings that have been built there. Green Parking Lot, Green Roof / Green Wall, and Planting Trees on residential buildings are the most likely to be done. The implementation of this recommendation can be done by conducting socialization in the housing community and issuing regional regulations on the obligation to make green roofs and green walls in buildings that have been and will be built.

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Conflict of Interest

The authors have no conflict of interest to declare.

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