ESTIMATION OF LAND SURFACE TEMPERATURE-ASSESSMENT WITH REMOTE SENSING DATA FOR URBAN HEAT ISLAND IN BATAM MUNICIPALITY

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ARTICLE INFO

Article History
Received : 19/08/21
Revised : 11/01/22
Accepted : 27/06/22

Citation:
Anurogo, W., Sidabutar, R.T.C., Lubis, M.Z., Panuntun, H., Nugroho, C.B., & Sufwandika, M., (2023) Estimation Of Land Surface Temperature-Assessment With Remote Sensing Data For Urban Heat Island In Batam Municipality. GeoEco. Vol. 09, No. 1.

ABSTRACT

Urban Heat Island (UHI) is a phenomenon where the surface temperature in urban areas is higher than in the surrounding area or in open air areas. Hilly city that continues to increase every year. Because of that, it needed an effort at the city-level urban heat island on Batam Island. Through the Thermal Landsat 8 channel image recording May 24, 2018 sensing data can be used to complete the heat calculation of the urban heat Island on Batam Island. This research aims to determine the variation of Urban Heat Island (UHI) effect on land cover in the research area. This research uses LST and maximum likelihood multispectral classification for land cover area and NDVI transformation. The results of the processing are obtained with R2 value of 0.872324 with UHI intensity of 0-8.06˚C. This shows the amount needed by Urban Heat Cities in Batam Island specifically in urban areas such as Batu Ampar District, Batam Kota, Bengkong, Batu Aji, Lubuk Baja, Sagulung, and Sekupang.

Keywords: *Remote Sensing; Land Surface Temperature; Urban Heat Island; Batam*

INTRODUCTION

It Urban Heat Island (UHI) is a phenomenon where the surface temperature in urban areas is higher than in the surrounding area or in open-air areas. This is due to changes in vegetation land turned into built land resulting in increased human activity in development in urban areas or densely populated buildings (Luan et al. 2020). Other factors causing UHI are due to the use of air conditioning (AC) in urban areas, emissions from motor vehicles and industrial activities, building materials in urban areas, such as asphalt, concrete, and others. This rising temperature will have a negative impact on uncontrolled city growth (Fawzi 2017).

This research on Urban Heat Island was carried out because of the increasing development that is constantly increasing on Batam Island which will cause inconvenience to the community. Based on BPS data (2018) the temperature in January to December, Batam has a tropical climate with minimum temperatures in 2017 ranging from 20.00 ˚C - 23.60 ˚C and maximum temperatures ranging from 32.40 ˚C - 34.60 ˚C, while the average temperature throughout 2017 is 27.00 ˚C - 27.90 ˚C. According Sari et al, 2017, the temperature of the heat in the Batam area has never reached 33 degrees Celsius. This is the highest temperature ever in Batam. This hot weather will also result in areas becoming a potential for forest or land fires.

Remote sensing applications can be used to interact with objects that are on the surface of the earth (Anurogo et al. 2017) including surface temperature (Fawzi 2017; Sari, Anurogo, and Lubis 2018). This research uses Landsat 8 satellite imagery with thermal infrared channels. This Landsat 8 image will be used to determine the phenomenon of Urban Heat Island (UHI) in the study area so that the results obtained in the research of thermal channel capabilities of remote sensing data in mapping Urban Heat Island (UHI) (Kaplan, Avdan, and Yigit Avdan 2018; Keeratikasikorn and Bonafoni 2018) on Batam Island.

The development of an area and the increasing population causes the change of vegetation land into built land is increasing every year (Anwar, et al., 2018; Taiwo, 2018; Wilonoyudho et al., 2017), therefore urban areas have increased surface temperatures (Fawzi 2017; Sari et al. 2018). This is usually caused by building materials in urban areas, such as asphalt, concrete, and so forth. The closer the building causes the temperature in urban areas to be higher and vice versa (Fawzi 2017). This research aims to determine the variation of Urban Heat Island (UHI) effect on land cover in the research area using remote sensing data.

MATERIALS AND METHODS

This research is located in Batam Island at 1º05′ North Latitude and 104º02′ East Longitude. The city boundary of Batam is bordered by the Northern Side of the Singapore Strait, the Southern Side of the Senayang District, the Eastern Side of the North Bintan District, the West of the Karimun Regency and the Moro of the Karimun Regency. This research consists of three stages, the pre-processing stage, the processing and the post-processing stage. The first data collection technique in the pre-processing stage is by downloading Landsat 8 image data which will be used as a processing reference data, then the data is then performed in two stages of correction, geometric correction and radiometric correction.

Geometric correction uses the placement of a Ground Control Point (GCP) to adjust the coordinates of the image with the map projection system. In this study geometric correction using the Batam City RBI map scale of 1: 25000 with a standard deviation value (Root Mean Square Error) must be less than 1. If the RMSE value is more than 1 then it will be repeated until it meets the requirements for geometric correction. Radiometric calibration is performed to eliminate or minimize atmospheric noise during the image recording process (Purwanto and Andrasmoro., 2021; Purwanto & Eviliyanto, 2022). The disturbance in question is the reflection of the recording results that are not in accordance with the existing surface of the earth so that it needs to be done radiometric correction by changing the value of the digital number (DN) into a reflectance value (Anurogo, Sari, et al. 2018). The radiometric correction processing uses equations:

DN to Radiance

$$L_\lambda = \left(\frac{L_{max} - L_{min}}{QCAL_{max} - QCAL_{min}}\right) x \; (Q_{cal} - QCAL_{min}) + L_{min}$$

L_λ = spectral radians (W/(m^2 .sr.µm).

Q_{cal} = digital number (DN).

$QCAL_{min}$ = the minimum pixel value that refers to LMINλ (DN).

$QCAL_{max}$ = the maximum pixel value that refers to LMAXλ (DN).

L_{min} = the minimum radian spektral (W/(m^2 .sr.µm).

L_{max} = the maximum radian spektral (W/(m^2 .sr.µm).

Radiance to reflectance

$$\rho\lambda = \frac{\pi . L\lambda . d^2}{ESUN\lambda \, . \cos \theta_s}$$

$\rho\lambda$ = reflectance value.

π = mathematical constant (3,14159).

d^2 = distance of the sun - earth (astronomical unit).

$ESUN\lambda$ = average exoatmospheric solar irradiance (W/m^2.sr.µm).

θ_s = sun zenith angel (degree).

Dark pixel substraction

$$RC = R - Rsi$$

RC = surface reflectance.

R = TOA reflectance.

RSI = spectral value used for offset.

The next stage is an image processing classification. The digital classification of an image is a process in which pixels with the same spectral characteristics are assumed to be the same class. The method used at this stage is to use the Maximum Likelihood Classification (MLC) method for the classification of land cover. In this research, the classification of land cover is carried out into several classes namely built-up land, vacant land, vegetation, and water bodies. This class division is often called prior probability, where the results of the classification of land cover imagery can be calculated. If this opportunity is not known then the magnitude of the opportunity is stated to be the same for all classes with one per number of classes created.

The next step is to find the value of vegetation cover density with Normalized Difference Vegetation Index or NDVI, in principle, is a method to find the appearance of vegetation in an area. NDVI values have a range between -1 (minus) to 1 (positive). Values representing vegetation are in the range of 0.1 to 0.7 if NDVI values above this value indicate better levels of vegetation cover (Hidayati, Suharyadi, and Danoedoro 2018; Milanović et al. 2019; Rendana et al. 2020). The NDVI equation formula;

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

NIR = Band Near Infrared Landsat 8.

RED = Band Red Landsat 8.

In remote sensing, the ground surface temperature can be defined as the average surface temperature of a surface, which is depicted in the coverage of a pixel with different surface types. This research uses land surface temperature (LST) to obtain surface temperature in Landsat 8 images with the Brightness Temperature algorithm (Hidayati et al. 2018; Lubis et al. 2017). The Conversion of Spectral TOA Radians into Kelvins using the formula :

$$\mathbf{T} = \frac{K2}{In(\frac{K1}{L\lambda} + 1)}$$

Tb = Brightness Temperature.

(K) K1 = Spectral radians calibration constant.

K2 = Absolute temperature calibration constant (K).

$L\lambda$ = Radian spectral Convert temperature in units.

Kelvin becomes Celcius: TCelcius = TKelvin -273

Urban Heat Island (UHI) can be known after obtaining vegetation cover and LST produce surface temperature to the land cover. From those, it can be seen the surface temperature of the area in Batam City. Quantification of UHI quantities that occur can be determined using the equation between the highest temperature and the lowest temperature (Aris et al. 2019; Fawzi 2017).

$$\Delta T_{\mu-r} = T_{\mu} - T_{r}$$

T_{μ} = surface temperature in a city or region that is warmer than its surroundings.

T_{r} = village surface temperature or around the area measured T_{μ}.

$T_{\mu-r}$ = the UHI effect.

RESULTS AND DISCUSSION

NDVI vegetation index transformation is the first transformation processing that is done after the image data is corrected. NDVI transformation is used to see the value of vegetation density in the image. For this reason, geometric and radiometric correction images of band 4 and band 5 are used. Band 4 is a red color image channel and band 5 is near-infrared (NIR) **(Figure 1)**.

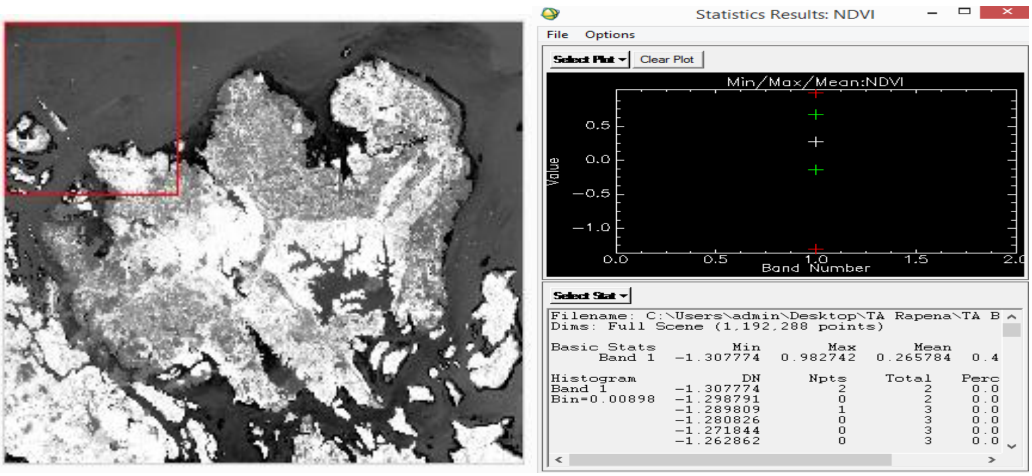

Figure 1. Image processing results of NDVI transformation (left), static results of NDVI images (right).

In the NDVI image intervals can be seen interval range of -1 to 0.9. For values close to minus one, they can be classified as objects of water bodies **(see**

Figure 2). Values close to zero are classified as objects of land and rocks. Whereas the maximum value is classified as an object of vegetation.

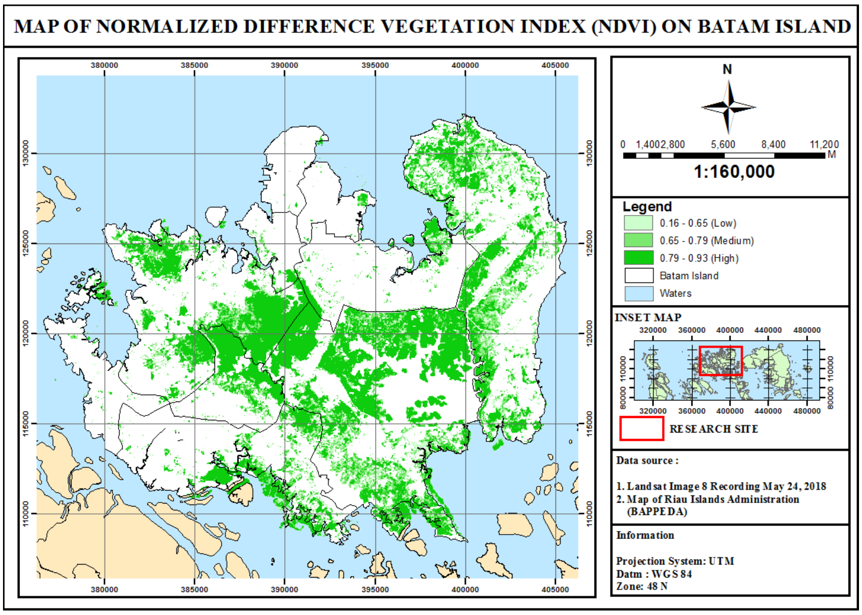

Figure 2. Map of NDVI vegetation index transformation

The NDVI transformation data is then correlated with the canopy density data in the field to produce a canopy density map. The canopy density map is shown in **Figure 3.**

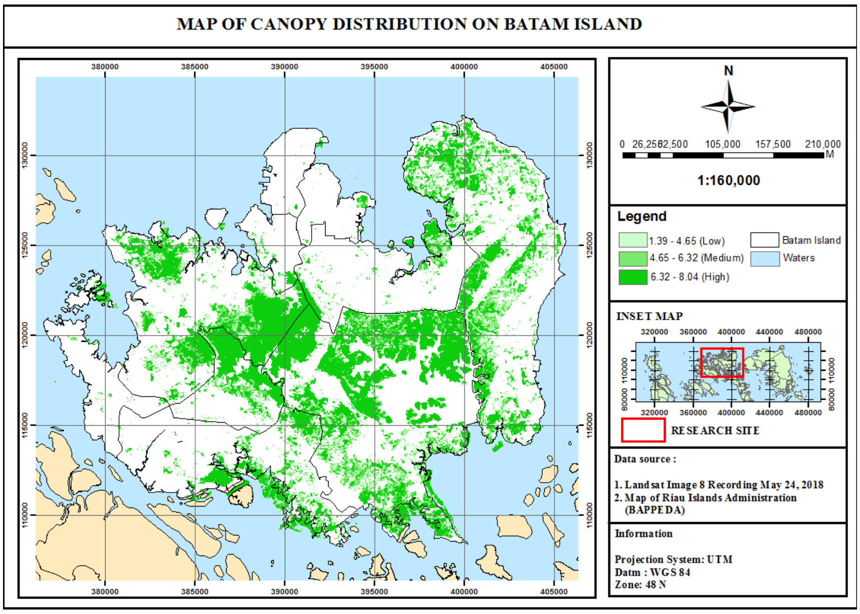

Figure 3. The canopy density map

Land Surface Temperature transformation uses the image of the thermal channel radiance, the channels used are band 10 and band 11. The value

p-ISSN 2460-0768 e-ISSN 2597-6044
https://doi.org/10.20961/ge.v9i1.54510

of each LST formula is obtained from the Landsat 8 image metadata which then selects and matches the radiance image band. The results of this processing produce temperature LST values in kelvin units. To change the LST image from Kelvin to Celsius in the formula band minus 273 degrees. With this processing, the temperature value in Celsius is obtained.

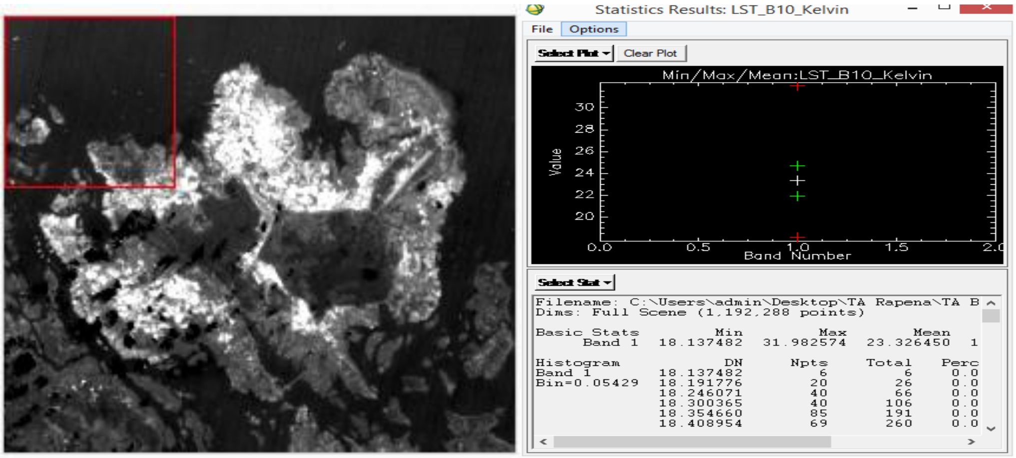

Figure 4. Image processing results of LST thermal channel (left) and the static result of the thermal channel (right)

The result of processing the surface temperature of the thermal image recording at 08.43 in the morning is at an interval of 180C-310C **(see Figure 4).**

Sample modeling and interpretation accuracy tests were carried out to determine the value of the accuracy of the results of research conducted in image processing of the original phenomenon in the field. The LST image was taken as many as 37 samples in the research area in Batam Island, then we divided the sample into two parts to be used as data modeling in the interpretation accuracy test. For data modeling 19 data samples were taken and 18 data samples were taken for accuracy testing. Simple linear regression modeling is done to find out the relationship between two variables, the first variable is the data from the remote sensing image extraction while the second is the measurement data from the field. This is done to find out correlation analysis and regression analysis on the data. Correlation analysis aims to determine the direction and strength of the relationship between the variable x with the variable y, while the regression analysis is carried out to be able to find out the magnitude of the effect caused by changes in each unit of variable y. The data used are LST image data as variable x and temperature from the results of the field survey as variable y **(Figure 5)**.

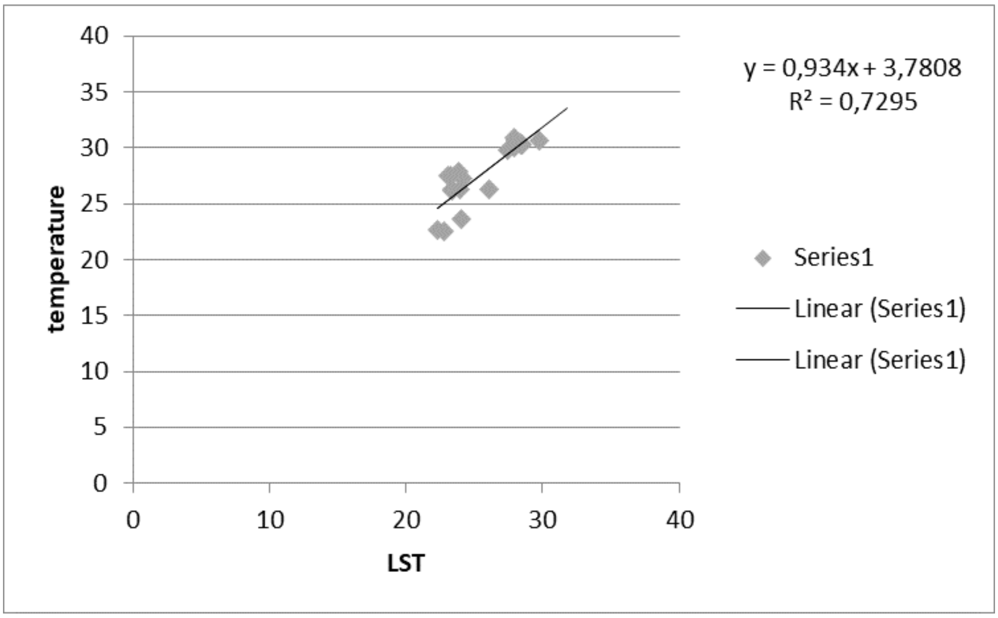

Figure 5. Linear regression between temperature and LST transformation

An accuracy test was conducted to determine the error of remote sensing data in research in presenting urban heat island on Batam Island. The total sample used was 18 sample units for accuracy testing by finding the root of the square of the total value of the difference between the actual data in the field with the result data of all samples divided by the number of accuracy test samples. The magnitude of the total error (RMSE) on LST and field temperature is 0.872324.

The value of the urban heat island on Batam Island is obtained from the equation process of the results of the regression analysis and then entered in the image to get the spatial distribution of the actual surface temperature in the field. The spatial distribution of UHI values is obtained from formula 6 by inputting the formula input into the actual LST image distribution. The results of the UHI distribution are then classified into 3 classes to determine the distribution of UHI distributions. The analysis shows that the temperature changes that occur in the UHI process are different. Temperature changes between dense settlements and suburban settlements are ± 1.90C while for temperature changes between residential areas and non-UHI land uses around ± 3.70C. Urban Heat Cities in Batam Island specifically in urban areas such as Batu Ampar District, Batam Kota, Bengkong, Batu Aji, Lubuk Baja, Sagulung, and Sekupang especially for residential areas against non UHI areas. The UHI distribution pattern is shown in **Figure 6.**

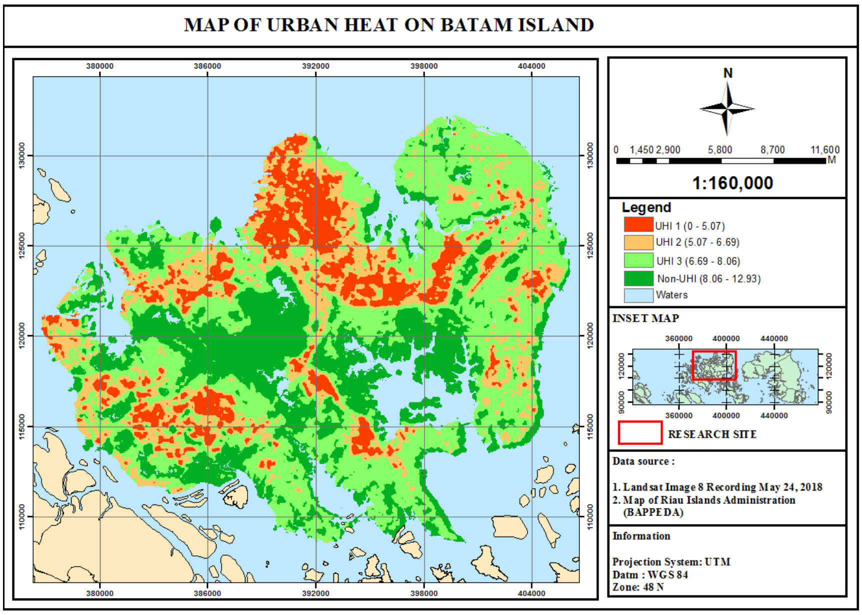

Figure 6. The UHI distribution pattern

CONCLUSIONS

The urban heat island value of Batam is divided into 3 levels to determine the distribution of UHI. Analysis shows that the temperature changes that occur during UHI are different. The temperature change between dense residential areas and suburban residential areas is ± 1.90C, while the temperature change between residential areas and non-UHI land uses is approximately ± 3.70C. The R2 value obtained as a result of the treatment is 0.872324, and the UHI intensity is 0-8.06℃. This shows the number of hot cities in Batam, especially in urban areas such as Batu Ampar District, Batam Kota, Bengkong, Batu Aji, Lubuk Baja, Sagulung and Sekupang. The next step of research and development is to combine it with building density to obtain the variance of UHI change.

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