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Analysis of Vegetation Height Relationship with Land Surface Temperature Using Lidar Data and Landsat 8 Oli/Tirs Imagery

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ABSTRACT

In recent years there have been global warming events in most areas of the hemisphere. The effects of global warming can result in changes in climate patterns in a certain time, which makes changes in the composition of the global atmosphere and increases air temperature. Increased infrastructure development and reduced vegetation that functions to absorb heat cause an increase in surface temperature. With the development of remote sensing technology, it can be used for study and research purposes. This research was conducted in Grobogan Regency which is one of the regions that is currently quite developed. This study aims to determine the relationship between vegetation height and land surface temperature (LST) and the relationship between vegetation density levels based on NDVI values with vegetation height using correlation and regression analysis methods. Data was used to determine vegetation height parameters using Airborne LiDAR while determining land surface temperature and NDVI using Landsat 8 OLI/TIRS C1 Level 1 Satellite Imagery. The result of Airborne LiDAR data is a canopy height model (CHM) where the lowest parameter of vegetation height is 1 meter, and the highest parameter of vegetation height is 28 meters. The results of the Landsat 8 OLI/TIRS C1 Level 1 Satellite Image are in the form of temperature and NDVI variation maps where there is a temperature range of 22.8°C - 27.2°C. After analyzing the correlation of vegetation height with ground surface temperature and vegetation density based on NDVI values with vegetation height, it can be concluded that vegetation height with ground surface temperature has a very low relationship with a value range of 0.00 - 0.20 and vegetation density based on NDVI values with vegetation height has a low relationship with a value range of 0.21 - 0.40.

Keywords: LST, LiDAR, NDVI, Remote Sensing, Grobogan District

1. Introduction

In recent years there has been a global warming event in most regions in the hemisphere. The effects of global warming can result in changes in climate patterns at a certain time which makes changes in the composition of the global atmosphere and increases air temperature [1]. Global warming is associated with an increase in the average temperature of the Earth's surface. Human influence has become the dominant cause of accelerated global temperature increase. About 60% of the global urban population is currently warming 2 times more than the world average and temperatures in cities are projected to increase by another 2°C by 2050 [2]. Increased infrastructure development and reduced vegetation that functions to absorb heat cause an increase in surface temperature. The increase in residential land cover will affect the density of vegetation in the city. The reduction of green land will lead to changes in the spatial pattern of the area, which has an impact on significantly increasing urban air temperatures [3].

Remote sensing has made it possible to study temperature variations over large areas and the factors that influence them. Land surface temperature (LST), which has a major influence on air temperature, can be estimated using thermal imagery. The composition and configuration of land cover at the city level can be calculated directly using remote sensing techniques or acquired geospatial data. Thermal imagery in the Landsat satellite series has been widely used to estimate LST at medium resolution [4].

LiDAR (Light Detection and Ranging) is an active remote sensing technique and is widely used to estimate surface elevation, including vegetation. Some recent research findings have looked at the effect of vegetation height on urban summit temperatures. Vegetation volume estimated using LiDAR data, and greenness (NDVI) were the best predictors of summer night temperatures [5]. Vegetation height has a comparable effect on LST reduction [2]. With the increased availability of remote sensing data from different sensors and the improvement in the field of competence, the study of LST dynamics has taken a big leap.

However, the effect of vegetation height on temperature has not been widely studied. Therefore, this study examines the relationship between surface temperature and vegetation height. This study was conducted in Grobogan Regency, Central Java Province. The reason this study was conducted in Grobogan Regency, Central Java Province, is one of the areas that is dense with buildings and has a population density that is growing rapidly with the change of land from vegetation to non-vegetated open land. So, this research was conducted to test whether vegetation height can affect the temperature in Grabogan Regency, Central Java Province.

2. Research method

2.1. Areas and Types of Research

The location of this research is in Grobogan Regency, Central Java with a research area of 100 hectares with the area located at coordinates 7° 3' 42.82" - 7° 6' 24.31" N and 110° 53' 37.35" - 110° 56' 20.11" WEST. Grobogan Regency has regional boundaries where the west is directly adjacent to Semarang and Demak Regencies. The north is directly adjacent to Demak, Kudus and Pati regencies. The east is directly adjacent to Blora Regency. The south is directly adjacent to Ngawi, Sragen, and Boyolali regencies.

Figure 1. Research area

In this study, the type of research conducted was descriptive with a quantitative approach. Descriptive research is research conducted to determine the value of independent variables, either one or more variables without making comparisons or connecting with other variables. Quantitative is used to examine populations or samples using measuring instruments or research instruments, data analysis is quantitative or statistical to test hypotheses that have been made [6].

2.2. Vegetation Height Extraction Based on LiDAR Data

LiDAR data acquisition was carried out on February 1, 2020, by PT. Waindo specterra has been calibrated and georeferenced to the Geospatial Information Agency CORS station. From the LIDAR data, it produces vegetation height by subtracting DSM from DTM. The method of calculating the height of the building uses the formula shown in equation (1).

$$\text{vegetation height} = DSM - DTM \tag{1}$$

There are two stages in processing LiDAR data, namely point cloud classification and vegetation height extraction. Point cloud classification is carried out to divide the class of the point cloud according to the actual naming. In this study, the classification is divided into two classes, namely ground and vegetation. Classification is carried out using the slope-based method where which method works based on TIN (Triangulation Irregular Network) calculations by paying attention to the largest slope angle and the lowest point in an area whose size has been determined. Vegetation height extraction is done to determine the height of vegetation starting from the ground surface to the end of the vegetation height surface.

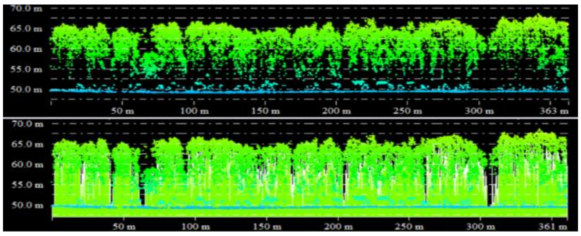

Figure 2. Vegetation height extraction result

2.3. Land Surface Temperature

Landsat-8 OLI/TIRS satellite image data was obtained by downloading images from the website earthexplorer.usgs.gov. Landsat image processing generally involves geometric correction. However, for Landsat-8 images with Level-One Terrain-Corrected specifications, no correction is needed because they are free from sensor, satellite, and earth errors. So the first step taken in processing Landsat-8 OLI/TIRS images is DN to spectral radian, which aims to convert band 10 pixels in the form of calibrated Dn into spectral radian according to the formula shown in equation (2). Second, the spectral radian to kelvin aims to convert the spectral radian value into the Kelvin Radian value according to the formula shown in equation (3). The third is the last stage, namely converting Kelvin to centigrade, which aims to convert Kelvin values into centigrade Radian values according to the formula shown in equation (4).

$$L\lambda = ML * Qcal + AL \quad (2)$$

$$T = K2/\{alog(K1/L\lambda + 1)\} \quad (3)$$

$$C = K - 273.15 \quad (4)$$

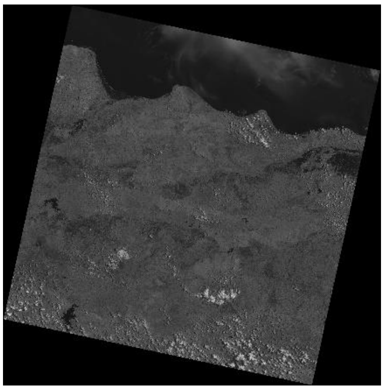

Figure 3. Landsat-8 OLI/TIRS Imagery

2.4. Normalized Difference Vegetation Index (NDVI) Processing

NDVI processing is used to analyze the level of vegetation density using Landsat 8 satellite image data which produces information in the form of a comparison of the greenness of vegetation in satellite images. For vegetation monitoring, the process of comparing the brightness levels of the redlight channel and the near-infrared light channel is carried out using the NDVI algorithm, resulting in a vegetation density map (5).

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad (5)$$

2.5. Correlation and Regression Analysis Methods

The method used in determining the relationship between vegetation height and land surface temperature is the Correlation method. Correlation is the relationship between two variables that have different parameters, especially in quantitative variables. A high correlation will determine a close unidirectional or opposing covariation between variables. The covariation is one of the indications to conclude about the possible relationship between vegetation height and land surface temperature and the relationship between vegetation density based on NDVI values and vegetation height. To determine the relationship between vegetation height and land surface temperature and the relationship between vegetation density based on NDVI values and vegetation height, Pearson correlation and regression analysis were conducted. The formula for Pearson correlation analysis is shown in equation (6) and regression analysis is shown in equation (7).

$$r = \frac{\sum(xi - x)(yi - y)}{\sqrt{\sum(xi - x)(yi - y)}} \quad (6)$$

$$\bar{Y}\text{t} = \alpha X + \text{b} \quad (7)$$

3. Results and discussion

Based on the previous methodological process to determine whether vegetation height has a relationship with land surface temperature and vegetation density based on NDVI values with vegetation height in Grobogan Regency, Central Java Province with a research area of 100 hectares. The temperature and NDVI analysis process was identified using Landsat 8 OLI/TIRS thermal infrared data and vegetation height was acquired using Airborne LiDAR. So that the data gets results and discussions that are described in the following subchapters.

3.1. Height Variation Based on Canopy Height Model (CHM)

Based on the results of processing LiDAR data acquired on February 1, 2020, the classification of the point cloud has been carried out. Point clouds that have vegetation class and ground class and continued with the extraction of the two classes, resulting in a Canopy Height Model (CHM) with a total of 5,041 vegetation, classified into three classes, namely low vegetation, medium vegetation, high vegetation which can be seen in the following figure.

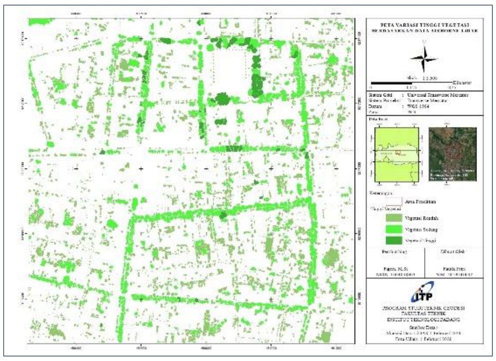

Figure 4. Canopy height model

3.2. NDVI Variation Based on Landsat 8 OLI/TIRS Image on February 4, 2020

Based on the results of processing the Landsat 8 OLI/TIRS image recorded on February 4, 2020, the NDVI classification is made into 4 classes of very low greenness, low greenness, medium greenness, high greenness. The very low greenness class is symbolized by dark green with a value range of -0.03 - 0.15. Low greenness is symbolized by a light green color with a value range of 0.15 - 0.25. Medium greenness is symbolized by orange with a value range of 0.26 - 0.35. High greenness is symbolized by red with a value range of 0.36 - 1.00 class which can be seen in the following figure.

Figure 5. NDVI variation map

3.3. Land Surface temperature Variation Based on Landsat 8 OLI/TIRS Image on February 4, 2020

Based on the results of processing the Landsat 8 OLI/TIRS image recorded on February 4, 2020, in Figure 4.5, it shows that the value of vegetation temperature variation is classified into 3 classes with the lowest temperature value of 22.8°C and the highest value of 27.1°C.

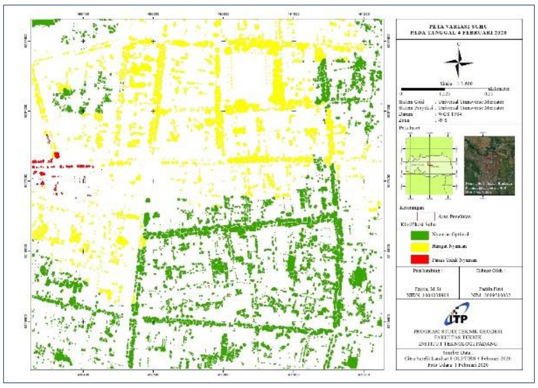

Figure 6. Temperature variation maps

3.4. Spatial Distribution of CHM and LST

The distribution of the canopy height model (CHM) and Land Surface Temperature (LST) in Grobogan Regency, Central Java Province has a varied LST. So, it is necessary to flatten the data which will be used for the next stage of analysis. Average LST is divided according to vegetation height classes such as low, medium, and high. The average of the three temperature variations can be seen in the following figure.

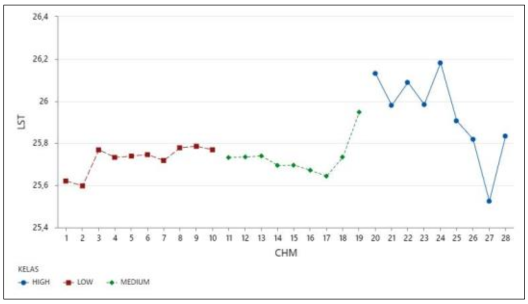

Figure 7. Average temperature on February 4, 2020

On February 4, 2020, the average temperature obtained in the low class with a value of 25.72 ° C, the average temperature obtained in the medium class with a value of 25.73 ° C, the average temperature obtained in the high class with a value of 25.82 ° C. so that it is known that the temperature increase from the low class to the medium class with a value of 0.01 ° C and an increase from the medium class to the high class with a value of 0.09 ° C.

3.5. Relationship Between Ground Surface Temperature and Vegetation Height

The results of the correlation analysis, LST and CHM on February 4, 2020, get a correlation coefficient value of 0.016 which means that vegetation height and ground surface temperature have a very low relationship with a value range of 0.00 - 0.20. The P-Value on February 4, 2020, between vegetation height and ground surface temperature shows a value of 0.245 which means that there is no significant effect between vegetation height and ground surface temperature based on a 5% significant level. Then the results of the P-Value value are not significant because the value of 0.245>0.05.

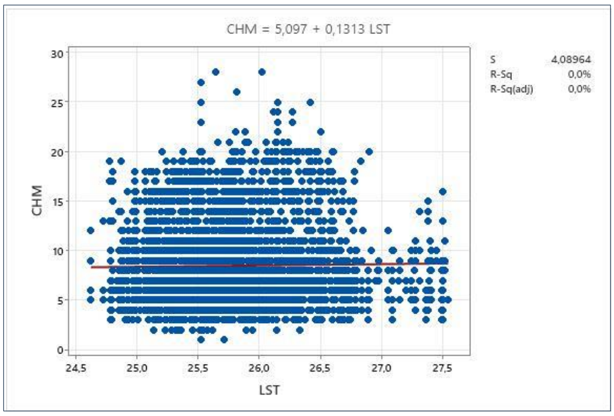

Figure 8. Graph of the relationship between vegetation height and surface temperature

In the regression analysis of vegetation height data with temperature, results can be drawn based on the value of the equation, where the value of the equation Y = 0.1313 + 5.097 X which means that if X is zero then Y is 0.1313. X is positive 5.097 the effect is positive between variable X (tree height) and variable Y (LST). When X increases by 1, Y will increase by 5.097. The coefficient of determination is 0.03%. This means that tree height only affects surface temperature by 0.03%, the remaining 99.97% is influenced by other factors not tested in the study.

3.6. Relationship Between NDVI Vegetation Density Level and Vegetation Height

The results of the correlation analysis of the NDVI vegetation density level and vegetation height on February 4, 2020, obtained a correlation coefficient value of 0.222, which means that the NDVI vegetation density level and vegetation height have a low relationship with a value range of 0.21 - 0.40. The P-Value on February 4, 2020, between the level of NDVI vegetation density and vegetation height shows a value of 0.000 which means that there is a significant influence between NDVI vegetation density and vegetation height based on a 5% significant level. Then the result of the P-value is significant because the value of 0.000 <0.05.

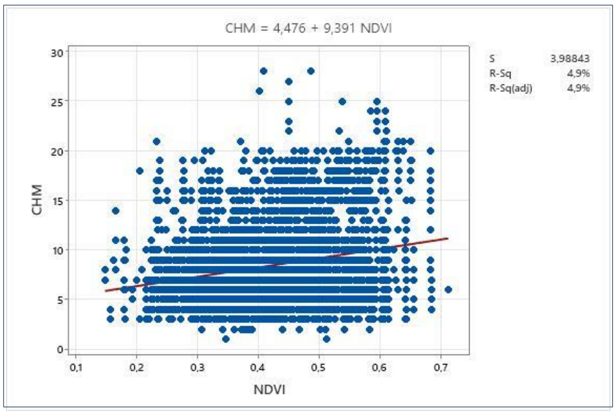

Figure 9. Graph of NDVI vegetation density relationship with vegetation height

In the regression analysis of NDVI vegetation density data and vegetation height, results can be drawn based on the value of the equation, where the value of the equation Y = 0.3817 + 0.005233 X which means that if X is zero then Y is 0.3817. X is positive 0.005233 so the effect is positive between variable X (tree height) and variable Y (NDVI vegetation density). When X increases by 1, Y will increase by 0.005233. The coefficient of determination is 4.9%. Which means that vegetation density only affects vegetation height by 4.9%, the remaining 95.1% is influenced by other factors not tested in the study.

4. Conclusions

The relationship between the level of vegetation density based on NDVI values and vegetation height in Grobogan Regency, Central Java Province using Airborne LiDAR and thermal infrared data in this study obtained a correlation value of 0.222 which means that the level of NDVI vegetation density with vegetation height has a low relationship with a value range of 0.21 - 0.40. Spatial distribution of ground surface temperature in Grobogan Regency, Central Java Province using thermal infrared data in the optimal comfortable range with interval values of 22.8 ° C to 25.8 ° C, almost comfortable 25.8 ° C to 27.2 ° C, uncomfortably hot > 27.2 ° C. The relationship between vegetation height and ground surface temperature in Grobogan Regency, Central Java Province using Airborne LiDAR and thermal infrared data in this study obtained a correlation coefficient of 0.016 which means that vegetation height with ground surface temperature has a very low relationship with a value range of 0.00 - 0.20.

Declaration of competing interest

The authors declare that they have no recognized non-financial or financial competing interests in any materials discussed in the current work.

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