Advances in Social Science, Education and Humanities Research (ASSEHR), volume 208
1st International Conference on Social Sciences and Interdisciplinary Studies (ICSSIS 2018)

Impact of NDVI Change to Spatial Distribution of Land Surface Temperature: A Study in Medan City, Indonesia

1st Riki Rahmad
Department of Geography Education
Universitas Negeri Medan
Medan, Indonesia
rikirahmad@unimed.ac.id

2nd Ali Nurman
Department of Geography Education
Universitas Negeri Medan
Medan, Indonesia
alinurman@unimed.ac.id

3rd Kamarlin Pinem
Department of Geography Education
Universitas Negeri Medan
Medan, Indonesia
kamarlin.pinem@unimed.ac.id

***Abstract*—This study aims to determine: (1) spatial-temporal variations in land surface temperature in Medan City, (2) spatial-temporal variations in vegetation index values (NDVI) in Medan City, (3) the relationship between LST and NDVI in Medan City. The design of this research is correlational and population research conducted with a spatial and temporal approach to analyse data spatially in different years of image recording. The variables in this study are land surface temperature and vegetation density. Data collection is done by image interpretation, observation, and documentation methods — data analysis techniques in image interpretation in the form of image transformation LST, NDVI, and spatial statistics. The results showed that the lowest land surface temperature of Medan City in 2011 was 20.72° C and the highest was 31.82° C with an average temperature of 26.05° C.The lowest temperature found in Medan Labuhan, and the highest temperature found in Medan Denai. For 2018 shows the lowest temperature is 19.32° C in Medan Belawan Sub-district, while the highest temperature is 34.43° C in Medan Denai Sub-district. The average temperature for 2018 is 28.1° C. Accuracy test shows there is a strong relationship between LST and temperature measurement. NDVI transformation results show that in 2011 the vegetation density of Medan City was dominated by medium density classes and in 2018 dominated by low-density class. This result shows a decrease in the level of vegetation density in Medan City.**

***Keywords*—LST, NDVI, Landsat, GIS**

I. INTRODUCTION

Land surface temperature in an area is influenced by the condition of vegetation density, building density, and the number of people who inhabit the place [1]. The lack of vegetated land has a negative impact on human life, such as rising surface temperatures. Objects on the surface will absorb the incoming radiation. Built land such as settlements, offices, and industrial estates will absorb solar radiation higher than vegetated land [2].

The Normalized Difference Vegetation Index (NDVI) is an algorithm that is applied to multi-channel imagery to identify vegetation density [3]. NDVI is the best known and often used vegetation index. NDVI was developed based on the difference between maximum absorption in red waves and maximum reflectance in infrared waves based on leaf cell structure [4]. NDVI was chosen because this algorithm has been widely known in remote sensing for vegetation studies. Although simple, it is proven that it can highlight phenomena associated with vegetation density by suppressing other sources of spectral variation. High NDVI values indicate greener plants (more tightly) and vice versa [5]. NDVI transformation has a high sensitivity to chlorophyll content in plants, so it is very good to identify vegetation not only in areas with high-density vegetation but also areas with low density[6].

The use of remote sensing data in recent years is overgrowing as technology develops. Remote sensing technology makes it possible to obtain spatial data in a relatively short time and a large area with considerable accuracy compared to conventional methods [7]. Remote sensing imagery provides the needs related to the temperature of the earth with infrared thermal channel technology that can record spectral values to identify temperatures [8].

One of the sensors developed in a remote sensing system is an infrared thermal sensor. Thermal infrared sensitivity to surface temperature allows extraction of temperature from a remote sensing image. This extraction outlines two stages, namely the calculation of spectral reflection and calculation of temperature [9]. Urban vegetation can help decrease Land surface temperature (LST) to mitigate urban heat island (UHI) effects [5]. The more vegetation cover, the LST will be cooler and vice versa [10]. The relationship between LST and urban vegetation amount has been extensively documented.

Analysis of changes in vegetation and development of heat islands from year to year requires a geography study in order to provide a visual description of the distribution of heat islands and their relationship to the presence of vegetation in the city of Medan. The acquisition of spatial data on terrestrial surface temperatures requires a lot of costs, time, and energy, making it difficult to do it regularly for temporal monitoring. [11].

The increase in population is of course also accompanied by the development process. Conversion of land use from the vegetation area to non-vegetation, such as settlements, for example, will affect the surface temperature in the area. Also, this will directly or indirectly affect the occurrence of global warming. The study of Land Surface Temperature is important because it will help in the process of land use and utilisation planning. And can know the spatial distribution area that affects the increase in surface temperature. The analysis used is by remote sensing technology through data information from land cover detection and surface temperature.

Community activities in Medan city produce much heat, for example, industrial activities, infrastructure development, and transportation. Large areas of built-up land also contribute to heat because radiation that reaches the surface will be absorbed more by the built-up land. The area will form Urban Heat Island (UHI), which is the centre of the hot surface in the middle of the city and decreases while on the edge of the city.

II. METHODS

The design of this research is correlational. The research is aimed at extracting primary data on land surface temperature and vegetation density with remote sensing and provides analysis of spatio-temporal variation of heat islands and their relationship to vegetation density. The study was conducted using a spatial and temporal approach. The spatial approach is intended to analyse data obtained from remote sensing technology spatially. The temporal approach is intended to analyse data obtained from remote sensing technology from different years in the study.

This research is population research. The analysis technique used is a digital image processing technique using the LST (Land Surface Temperature) algorithm to extract the value of land surface temperature, NDVI (Normalized Difference Vegetation Index) to extract the value of vegetation density.Spatial correlation analysis of the results was carried out to study the heat island which was seen from the distribution of land surface temperature and its relationship to vegetation density in Medan City as the study area.

Data analysis was carried out to follow up the data acquisition results from the transformation of remote sensing digital images. Data analysis in this study consisted of four sequences.

A. Image Processing for Extraction of Land Surface Temperature

The extraction of land surface temperature from remote sensing satellite imagery is needed for further analysis of the spatial-temporal characteristics of urban heat island in Medan City. The emission of ground surface heat measures temperature due to solar radiation. Ground surface heat emission is captured by satellite image sensors in the range of thermal infrared spectra. The sensor converts heat emission to different brightness on an image band. Landsat 8 is one image that has a thermal infrared band; the channel is TIRS (*Thermal Infrared Red Sensor*) on channels number 10 and 11 recording in 2011 and 2018.

All imagery used has a close range of recording time, namely the morning time in the range of April - October which is estimated to still be in the season range that adjusts the implementation schedule of the research, to reduce the ambiguity of temperature anomalies recorded on the image.

Before the Landsat image is formed into an LST, the original Digital Number (DN) image is converted to a Radiance Spectral. TIRS Landsat 8 DN conversion step to Spectral Radiance value uses Equation 1[12].

$$L\lambda = ML * Qcal + AL \qquad (1)$$

Where:
Qcal = pixel value (DN)
ML = Radiometric rescaling group on mult band radians in Metadata file (.MTL)
AL = Radiometric rescaling group on the "add radians band" in the Metadata file
L λ = Spectral Radiation.

Furthermore, the radiance values obtained are converted to LST temperature values, the temperature values have Kelvin units. LST is obtained by applying the Planck algorithm as shown in Equation 2[13]. The LST temperature value in units of Kelvin (K) is converted to units of degrees Celsius (C) using Equation (4). The reason for using Celsius is because it has a better range for clarity in image interpretation.

$$T(C) = T(K) - 273.15 \qquad (3)$$

Where :
T (C): LST temperature in degrees *Celsius*,
T (K): LST temperature in *Kelvin*degree and value 273.15 is the conversion constant of Kelvin to *Celsius*.

Furthermore, the LST values obtained from the 10 and 11 TIRS bands on average use Equation 5 to obtain more fixed LST values in each image recording.

$$TY = Mean\ (T(C)\ Band10 + T(C)\ Band11) \qquad (4)$$

Where:
TY: Average LST temperature in the recording
T (C) Band10: LST temperature of Band 10
T (C) Band11: LST temperature of Band 11

B. Image Processing for Vegetation Index Value Extraction

Extraction of vegetation index values is intended to review vegetation density in the study area. Image processing for this purpose uses the NDVI (Normalized Difference Vegetation Index) formula, which connects the pixel values of the red and near-infrared(NIR) channels.NDVI calculationis formulated as follows:

$$NDVI = \frac{(BV_{near\ infrar}}{(BV_{near\ infrar}} \qquad (5)$$

C. Relationship Analysis of LST and NDVI

To analyze the relationship between land surface temperature and vegetation density index, a quantitative analysis was carried out in the form of statistical calculations. Statistical analysis is used to determine the strengths and forms of influence between the variables tested. Statistical analysis was used in the form of Pearson Product Moment correlation test to determine how much the relationship between vegetation density to land surface temperature.

$$r_{XY} = \frac{n(\Sigma XY)-(\Sigma X.\Sigma}{\sqrt{\{n\Sigma X^2-(\Sigma X)^2\}\{n\Sigma Y^2}}$$

(6)

Where:

r= correlation coefficient

n= number of samples

X= independent variable

Y= dependent variable

III. RESULT AND DISCUSSION

A. Transformation of Land Surface Temperature (LST)

The acquisition of land surface temperature information in this study through the stages of digital image transformation. The images used are images from Landsat 5 ETM + satellites for 2011 data requirements and Landsat 8 OLI / TIRS for 2018. The basis for the selection of the image year is based on the condition of cloud cover in the image. If there are too many clouds, the image transformation process to the surface temperature of the land becomes less valid.

The image transformation process begins with the conversion of the Digital Number (DN) to spectral radians to be converted to a temperature value. LST analysis uses ArcGIS Model Builder tools to facilitate the work in GIS analysis because many processes are carried out repeatedly for Medan City with various bands/channels in each digital image. Land surface temperature analysis takes the thermal band to analyse objects in Medan City. On Landsat 5, band 6was used for LST analysis for August 2011. Band 6 has a spatial resolution of 60x60 meters. Slightly different for August 2018, where the TIRS channel on Landsat 8, which is band 10 and band 11, has a spatial resolution of 100x100 meters.

After the band selection is done, the cropping scene process is done according to the Medan City administrative boundaries.Thisis done so that the analysis process runs faster because the computer only performs the transformation process for the Medan area.

After a series of image, transformation steps are taken, LST data will be obtained that can be used as a basis for spatial-temporal analysis of land surface temperature. Spatial-temporal temperature analysis is performed for each pixel in the output and also for the temperature based on the sub-district.

B. Spatial-Temporal Analysis of Land Surface Temperature

From the LST transformation process, obtained the spatial distribution of land surface temperatures for 2011 and 2018. The results showed that for 2011, the lowest temperature was 20.72 o C and the highest was 31.82 o C with an average temperature of 26.05 o C.The lowest temperature is found in Medan Labuhanand the highest temperature is in Medan Denai. Medan Area Subdistrict, Medan Denai, and Medan Perjuangan have relatively higher temperatures compared to other sub-districts, while Medan Belawan, Medan Labuhan and Medan Marelan in the northern region have the lowest temperatures compared to other sub-districts.

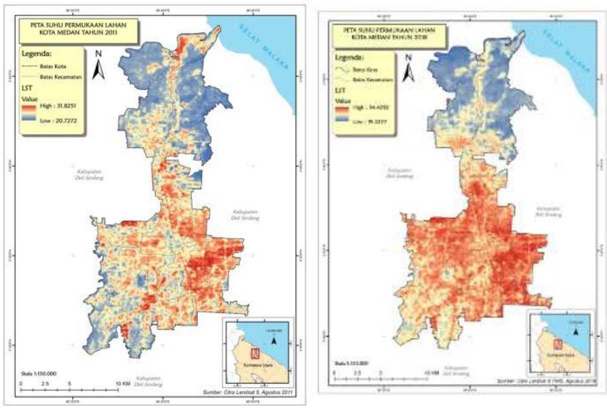

Fig.1. Land Surface Temperature Map of Medan City 2011 and 2018

Image transformation results for 2018 show the lowest temperature is 19.32º C in Medan Belawan, while the highest temperature is 34.43º C in Medan Denai. The average temperature for 2018 is 28.1ºC. Sub-districts that have high temperatures are Medan Area, Medan Perjuangan, Medan Denai, and Medan Sandpaper. Judging from its position, sub-districts in the eastern part of Medan City tend to have higher temperatures compared to other regions. This is because the city centreis located in the sub-districts above. Sub-districts that recorded significant temperature increases were Helvetia, West Medan, Medan Amplas, and Medan Petisah. These districts experienced a temperature rise of more than 3ºC. The opposite happened in Medan Belawan which had a temperature decrease from 24.94º C to 23.84ºC.

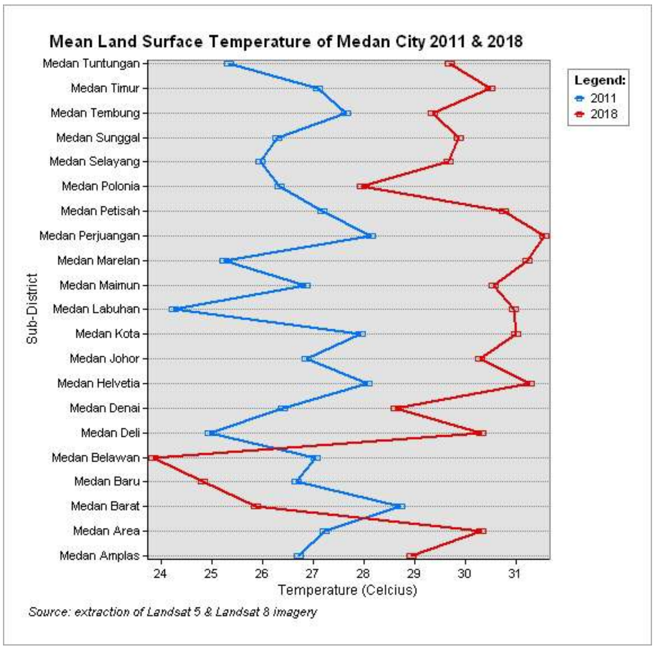

Fig.2. Graph of Increased Land Surface Temperature in Medan City

In addition to the distribution of temperatures by pixel and sub-district, land surface temperature classes can also see spatial-temporal distribution. Giving temperature class conducted by *reclassifying* raster on a GIS that serves to determine the temperature class that we want to be subsequently converted to shapefile format for later calculated the area of each class of temperature.The results showed that the temperature classes for 2011 were <22, 22-24, 24-26, 26-28, 28-30, and 30-32. Whereas for 2018 has a more extended range from <22 to>34 with 8 classes.

TABLE I. COMPARISON OF LAND SURFACE TEMPERATURE OF MEDAN 2011 AND 2018

No	Temp (C)	2011		2018	
		Areas (km²)	%	Areas (km²)	%
1	< 22	0.06	0.02%	3.14	1.11%
2	22 - 24	51.12	18.08%	38.08	13.47%
3	24 - 26	95.45	33.76%	31.81	11.25%
4	26 - 28	84.13	29.75%	47.08	16.65%
5	28 - 30	49.09	17.36%	70.05	24.77%
6	30 - 32	2.91	1.03%	75.49	26.70%
7	32 - 34	0	0.00%	17.03	6.02%
8	> 34	0	0.00%	0.08	0.03%
Total		282.77	100%	282.77	100%

Source: Research Results, 2018

C. Transformation of the Normalized Difference Vegetation Index (NDVI)

NDVI transformation is done to see the distribution of vegetation density in Medan City. This data was analysed using bands 3 and 4 on Landsat 5 and bands 4 and 5 on Landsat 8 OLI. The results of image transformation in 2011 showed that 36.71 km^2 or 12.98% of the area of Medan was moderately vegetated, while 12.85% had a rare density level, and 8.29% had tight vegetation. Spatial distribution of vegetation density in Medan City in 2011 can be seen in Figure 4.

NDVI transformation results for the 2018 image indicate the rate of decline in vegetation density in Medan City. The area of non-vegetation land increased to 75,83 % of the total area.The density of vegetation is only 2,06 km^2 or 0.73% of the total area.

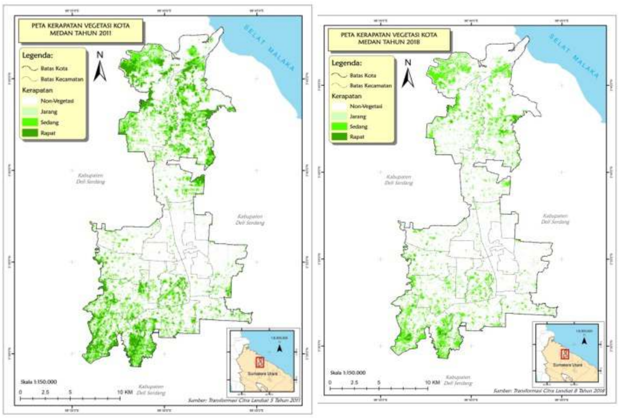

Fig. 3.NDVI Map of Medan City in 2011 and 2018

D. Relationship Between LST and NDVI

Landsat 8 TIRS satellite images provide information on the spatial distribution of Land Surface Temperature in Medan City. This information is in the form of pixels that have values as surface temperatures in units of degrees Celsius, where there is a tendency for these pixels to cluster in the range of high values. The results of the LST and NDVI transformations indicate that there are groupings of pixel points on high LST values which indicate the presence of urban heat islands that are close to spatial similarities by grouping pixel points on very low NDVI values. The visual comparison of the map shows the similarity in the direction of the development of pixel dots of LST and NDVI in 2011 and 2018. Drawings of scatter diagrams connect between LST values on the x-axis and NDVI values on the y-axis (Figure 5). The results of the NDVI and LST values that are read from the diagram are the tendency of lower surface temperature along with the increasing value of the vegetation index. On the contrary, this diagram shows the tendency to increase land surface temperature as the vegetation index decreases.

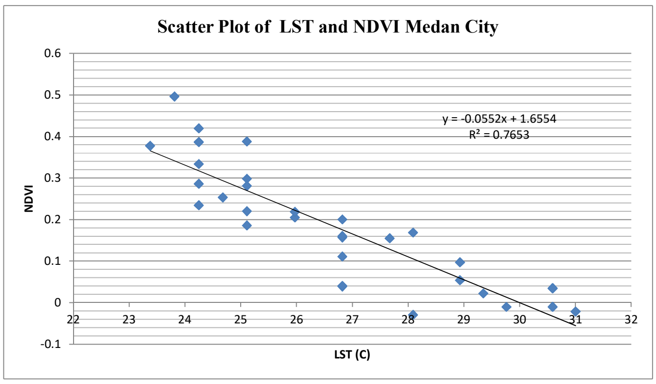

Fig. 4. Scatter Plot of LST and NDVI of Medan City

Figure 4 shows the trend of forming trend lines with the value of spatial correlation between LST and NDVI of -0.7653. Translation of spatial correlation is based on the Moran index where the value of I<0 indicates a strong positive relationship, I = 0 indicates a random relationship, and I> 0 indicates a strong negative relationship. The value of spatial correlation between LST and NDVI which is less than 0 indicates that there is a strong negative relationship between land surface temperature and vegetation density. This negative relationship means that the higher the surface temperature of the land in Medan, the lower the vegetation density, and the lower the surface temperature of the land in Medan, the lower the vegetation density.

IV. Conclusions

Based on the results and discussion, the conclusions of this study are:

1. The lowest surface temperature of Medan City in 2011 was 20.72^{o} C,and the highest was 31.82^{O} C with an average temperature of 26.05^{o} C.The lowest temperature is found in Medan Labuhanand the highest temperature is found in Medan Denai. For 2018 shows the lowest temperature is 19.32^{o} C in Medan Belawan, while the highest temperature is 34.43^{o} C in Medan Denai.The average temperature for 2018 is 28.1^{o} C.Accuracy test shows there is a strong relationship between LST temperature and measurement temperature in the field.
2. NDVI transformation results show that in 2011 the vegetation density of Medan City was dominated by medium density classes and in 2018 dominated the medium density class. Thisresult shows a decrease in the level of vegetation density in Medan City.

References

[1] I. Prasasti, N. M. Sari, and N. Febrianti, "Analisis Perubahan Sebaran Pulau Panas Perkotaan (Urban Heat Island) di Wilayah DKI Jakarta dan Hubungannya dengan Perubahan Lahan , Kondisi Vegetasi dan Perkembangan Kawasan Terbangun Menggunakan Data Penginderaan Jauh," pp. 383–391, 2015.

[2] M. Ranagalage, R. C. Estoque, and Y. Murayama, "An Urban Heat Island Study of the Colombo Metropolitan Area, Sri Lanka, Based on Landsat Data (1997–2017)," *ISPRS Int. J. Geo-Information*, vol. 6, no. 7, p. 189, 2017.

[3] P. Macarof and F. Statescu, "Comparison of NDBI and NDVI as Indicators of Surface Urban Heat Island Effect in Landsat 8 Imagery: A Case Study of Iasi," *Present Environ. Sustain. Dev.*, vol. 11, no. 2, 2017.

[4] K. C. Tan, H. S. Lim, M. Z. MatJafri, and K. Abdullah, "A comparison of radiometric correction techniques in the evaluation of the relationship between LST and NDVI in Landsat imagery," *Environ. Monit. Assess.*, vol. 184, no. 6, pp. 3813–3829, 2012.

[5] R. Zhibin, Z. Haifeng, H. Xingyuan, Z. Dan, and Y. Xingyang, "Estimation of the Relationship Between Urban Vegetation Configuration and Land Surface Temperature with Remote Sensing," *J. Indian Soc. Remote Sens.*, vol. 43, no. 1, pp. 89–100, 2015.

[6] M. Rathinasamy, V. M. Bindhu, J. Adamowski, B. Narasimhan, and R. Khosa, "Investigation of the scaling characteristics of LANDSAT temperature and vegetation data: a wavelet-based approach," *Int. J. Biometeorol.*, vol. 61, no. 10, pp. 1709–1721, 2017.

[7] H. Urqueta *et al.*, "Land surface temperature as an indicator of the unsaturated zone thickness: A remote sensing approach in the Atacama Desert," *Sci. Total Environ.*, 2018.

[8] V. Bento, I. Trigo, C. Gouveia, and C. DaCamara, "Contribution of Land Surface Temperature (TCI) to Vegetation Health Index: A Comparative Study Using Clear Sky and All-Weather Climate Data Records," *Remote Sens.*, 2018.

[9] F. Zhang, H. Kung, V. C. Johnson, B. I. LaGrone, and J. Wang, "Change Detection of Land Surface Temperature (LST) and some Related Parameters Using Landsat Image: a Case Study of the Ebinur Lake Watershed, Xinjiang, China," *Wetlands*, vol. 38, no. 1, pp. 65–80, 2018.

[10] R. H. Jatmiko, "Penggunaan Citra Saluran Inframerah Termal untuk Studi Perubahan Liputan Lahan dan Suhu sebagai Indikator Perubahan Iklim Perkotaan di Yogyakarta," Universitas Gadjah Mada, 2015.

[11] I. N. Hidayati, R. Suharyadi, and P. Danoedoro, "Kombinasi Indeks Citra untuk Analisis Lahan Terbangun dan Vegetasi Perkotaan," *Maj. Geogr. Indones.*, vol. 32, no. 1, pp. 24–32, 2018.

[12] B. Sasmito and A. Suprayogi, "Model Kekritisan Indeks Lingkungan dengan Algoritma Urban Heat Island di Kota Semarang," *Maj. Ilm. Globe*, vol. 19, no. 1, pp. 45–52, 2017.

[13] K. Zanter, "Landsat 8 (L8) Data Users Handbook," *Survey, Department of the Interior U.S. Geological*. 2015.