Land surface temperature distribution and development for green open space in Medan city using imagery-based satellite Landsat 8

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Abstract. Green open space (GOS) is one of the requirements where a city is comfortable to stay. GOS might reduce land surface temperature (LST) and air pollution. Medan is one of the biggest towns in Indonesia that experienced rapid development. However, the early development tends to neglect the GOS existence for the city. The objective of the study is to determine the distribution of land surface temperature and the relationship between the normalized difference vegetation index (NDVI) and the priority of GOS development in Medan City using imagery-based satellite Landsat 8. The method approached to correlate the distribution of land surface temperature derived from the value of digital number band 10 with the NDVI which was from the ratio of groups five and four on satellite images of Landsat 8. The results showed that the distribution of land surface temperature in the Medan City in 2016 ranged 20.57 - 33.83 °C. The relationship between the distribution of LST distribution with NDVI was reversed with a negative correlation of -0.543 (sig 0.000). The direction of GOS in Medan City is therefore developed on the allocation of LST and divided into three priority classes namely first priority class had 5,119.71 ha, the second priority consisted of 16,935.76 ha, and third priority of 6,118.50 ha.

1. Introduction
Medan city is one of the big cities in Indonesia which have rapid development. Urban developments are usually accompanied by the extensive development of settlements as well as industries and services that result in the reduction of green open space (GOS). Reduced green open space in an urban area could lead to an increase in land surface temperature (LST). The land cover is a reflection of human intervention that may affect LST [1].

Land cover in an urban area is related to LST. LST provides information on land conversion that could lead to an increase in LST through information on land use changes and human activities that may affect the environment [2-4]. Reduced GOS leads to heat islands in the areas of settlement, industrial, office centers, and commercial centers.

Remote sensing is one of the indirect methods that can be used to determine LST [5]. Landsat 8 satellite images are containing a thermal band that can be used to predict LST distribution. The lack of up-to-date information on LST distribution and GOS development guidance in Medan City makes this research critical. The purpose of this research is to know the spread of LST and its relation with NDVI in Medan City.
2. Materials and Method

2.1. Study area
This study was conducted in Medan City, North Sumatera Province with the total area of 28,174 ha. Medan City Administration is divided into 21 subdistricts and 151 villages. The geographical location of Medan City lies between 3°30’- 3°43’ North Latitude and 98°35’- 98°44’ East Longitude. Medan City is adjacent to Deli Serdang Regency and Malacca Strait (Figure 1).

![Figure 1. Map of site research](image)

2.2. Analysis of land cover and normalize different vegetation index (NDVI)
Satellite imagery used in this study is Landsat 8 path/row of 129/057 acquisition date 11 March 2016 obtained from USGS (http://glovis.usgs.gov/). Medan administration data obtained from Central Agency on Statistics in 2010.

The analysis of land cover classification was conducted by using the supervised classification with Maximum Likelihood Classifier method. Validation of land cover is done by confusion matrix to get the overall accuracy and kappa precision. While the value of NDVI obtained by following the formula:

\[
NDVI = \frac{\text{Band 5} - \text{Band 4}}{\text{Band 5} + \text{Band 4}}
\]

Where :
Band 4: digital number (DN) of red band
Band 5: digital number (DN) of near infrared

2.3. Analysis of land surface temperature
Estimated LST value is done by using Arc Gis 10 to convert pixel values. The value of the pixel in the form of DN then transformed into the value radiance. The conversion of DN value to brightness value is done by using the formula as follows:

\[
\lambda = +
\]
Where:

\(L_\lambda\): Radiance spectral TOA (watts/m\(^2\) Srad μm)

ML: \((\text{Radiance}_{\text{mult\_band}} \times x), x = \text{DN of band 10 in Landsat 8}\)

AL: \((\text{Radiance}_{\text{add\_band}} \times x), x = \text{DN of band 10 in Landsat 8}\)

Qcal: Quantized and calibrated standard product pixel values (DN)

The radiance value is then converted to a Kelvin scale temperature value (°K). In this study, the LST distribution is expressed in Celsius (°C) obtained by converting the LST value from °K to °C. The conversion of spectral radiance to temperature is as follows:

\[ T_S = \frac{K_2}{\ln \left( \frac{K_1}{L_\lambda} + 1 \right)} \]

Where:

TR: Radian temperature (°K)

K1: Band calibration constant 10 (Landsat 8))

K2: Band calibration constant 10 (Landsat 8))

\(L_\lambda\): Radiance spectral TOA (watts/m\(^2\) Srad μm)

2.4. Analysis of development priority of GOS

Map of GOS development location obtained from the classification of LST. The map of surface temperature distribution in 2016 is used as a base map in determining the priority location of green open space development. The LST distribution map is classified into three classes: first priority, second priority, and third priority. The priority interval of GOS development in Medan City is as follows:

First Priority: \(x \geq \mu + SD\)

Second Priority: \(\mu - SD < x \leq \mu + SD\)

Third Priority: \(x \leq \mu - SD\)

Where:

\(x\): Surface temperature (°C)

\(\mu\): Average surface temperature (°C)

3. Results and Discussion

The result of the land covers analysis in Medan City based on Landsat 8 satellite imagery. Figure 2a shows the area of land cover settlement 14,834.03 ha (52.65%), agriculture 6,692.38 ha (23.75%), mixed garden 3,267.89 ha (11.60%), mangrove 1,658.39 ha (5.89%), water body 1,200.50 ha (4.26%), grass 283.86 ha (1.01%) and cloud 236.91 ha (0.84%). The validation test of land cover in Medan City showed overall accuracy 89.20 % and kappa accuracy 85.6 %, respectively. This result demonstrates the classification of land cover in Medan city based on Landsat 8 satellite imagery in 2016 which produced is good enough.

Estimation of NDVI shows the values range between -0.09 to 0.57 (Figure 2b). The NDVI value close to 1 indicates a dense vegetation cover, whereas the NDVI approaching the number 0 indicates an open area. Comparison of Figures 2a and 2b show that land cover on the settlement has a low NDVI value while mangrove cover, mixed garden and agriculture show higher NDVI values.
The statistical characteristics of LST value of Medan City in 2016 (Table 1) shows that there is a correlation between land cover and LST. Settlement land cover has the highest LST, and Mangrove land cover has the lowest LST. The LST average value of settlement land cover is 29.53 °C, and the LST average value of mangrove land cover is 25.55 °C. Vegetation land cover has lower LST averages compared to non-vegetation land cover (settlement). This study shows that the existence of vegetation land cover has the advantage of decreasing LST in Medan City.

| Land cover 2006 | Land Surface Temperature (°C) |
|----------------|-------------------------------|
|               | min   | max   | mean  | Standard deviation |
| Settlement    | 22.77 | 33.83 | 29.53 | 1.81               |
| Mixed garden  | 25.01 | 31.33 | 27.31 | 1.33               |
| Grass         | 24.19 | 29.35 | 27.40 | 1.42               |
| Agriculture   | 20.57 | 32.30 | 27.18 | 1.52               |
| Mangrove      | 24.52 | 27.32 | 25.55 | 0.53               |

The LST distribution of Medan City in 2016 ranges between 20.57 °C to 33.83 °C, with the average LST, is 28.53 °C. High LST values mostly found in urban centers. The land covers dominant in urban centers is settlements. In contrast, low LST values found in sub urban. The area comprises dominant in sub urban is ground cover with vegetation of agriculture, mixed garden, and mangrove (Figure 3a).

The correlation between land cover and LST distribution expressed by the value of Pearson correlation. The result of Pearson correlation between NDVI value with LST value in this research is -0.543 (sig 0.000). This result shows that the direction of the relationship between NDVI and LST has a negative correlation. The present study well corresponds with other reports [6-8] which indicated that urban vegetation areas were useful for decreasing LST. Cities with small LST are more comfortable to live in than those with higher LST.
We developed the priority to facilitate the development of GOS. It is classified the priority of GOS development based on LST distribution in Medan City. The top priority is showing red color which is a high priority covered 5.119.71 ha has a great LST value range (LST > 30.62 °C). The second priority with yellow included 16.935.76 ha which is an area with LST value varies 26.42 to 30.62 °C. Whereas third priority indicating with green color consists of 6.118.50 ha which is a sector with LST less than 26.42 °C (Figure 3b).

Figure 4 shows the most of GOS development of beginning priority located in settlement land cover (92.62%), then followed by agriculture (6.67%), mixed garden (0.69%), and grass (0.02%). The second priority consists of settlement land cover (52.36%), agriculture (31.49%), mixed garden (12.96%), grass (1.15%), and mangrove (0.58%). Furthermore, the third priority consists of mangrove cover (25.49%), settlement (20.04%), mixed garden (16.95%), agriculture (16.63%), and grass (1.45%). The settlement predominated land cover in GOS development major priority and second priority in Medan City. The settlements are the largest contributor to increase the LST.

The development of GOS in top priority can be done by planting crops in house yards and offices. Increased of GOS could be done with a greening roof or vertical garden. The major priority of GOS development in Medan City is determined to dominated settlement areas such as sub district of Medan Denai, Helvetia, Tembung, and Medan Kota.
4. Conclusions
Distribution of land surface temperature in Medan City based on Landsat 8 satellite imagery analysis ranged 20.57 - 33.83 °C with an average LST of 28.53 °C. LST has a negative correlation with NDVI. Land cover vegetation has a lower LST compared to settlement. The current study implied that GOS was important to reduce the LST. The primary priority of GOS development in Medan City is directed to areas that dominated by settlements such as sub district of Medan Denai, Helvetia, Tembung, and Medan Kota.

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