Comparison Spatial Pattern of Land Surface Temperature with Mono Window Algorithm and Split Window Algorithm: A Case Study in South Tangerang, Indonesia

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Abstract. In this paper, two methods to retrieve the Land Surface Temperature (LST) from thermal infrared data supplied by band 10 and 11 of the Thermal Infrared Sensor (TIRS) onboard the Landsat 8 is compared. The first is mono window algorithm developed by Qin et al. and the second is split window algorithm by Rozenstein et al. The purpose of this study is to perform the spatial distribution of land surface temperature, as well as to determine more accurate algorithm for retrieving land surface temperature by calculated root mean square error (RMSE). Finally, we present comparison the spatial distribution of land surface temperature by both of algorithm, and more accurate algorithm is split window algorithm refers to the root mean square error (RMSE) is 7.69° C.

1. Introduction
The land surface temperature is an essential parameter in the physical process and the interaction between the land and the atmosphere [1]. Land surface temperature data can provide information on spatial and temporal variations of the Earth's surface in various applications on a global scale [2]. It has been widely used in many studies such as estimation of energy inventories, moisture monitoring and evapotranspiration [3-14], climate change, urban heat island [15-27], and environmental studies requiring land surface temperature as the basic input.

Increasing the number of land surface temperature used in various fields of study has implications in developing of remote sensing technique to retrieving the land surface temperature value [28]. In recent decades, satellite sensors such as the Moderate-resolution Imaging Spectroradiometer (MODIS) [29] and the National Oceanic and Atmospheric Administration - Advanced Very High-Resolution Radiometer (NOAA-AVHRR) provide twice thermal data in a day using two Long Wave Infra Red (LWIR). Landsat 5 Thematic Mapper (TM) [30] and Landsat 7 Enhanced Thematic Mapper Plus (ETM +) have 16-day repeat cycle and provide thermal data with higher image resolution using infrared band. Then Landsat 8 Thermal Infrared Sensor (TIRS) is the latest generation of landsat series that has two infrared bands with the same spatial and temporal resolution as the previous Landsat [31]. Since remote sensing satellites can provide thermal data with short time intervals, it makes remote sensing an important tool in monitoring land surface temperature [32].

Along with development of remote sensing techniques for retrieving land surface temperature, algorithm, which is used to obtain land surface temperature values, is also developed. Radiative
transfer equation (RTE) was the first algorithm used [33]. The next mono-window algorithm was developed by Qin et al. (2001) [34] and single channel by Jimenez-Munoz and Sobrino (2003) [35]. Furthermore, split windows [36], and multi-angle algorithms [37] are the advanced methods used. The method which is mostly used by many researchers is the NASA methodology contained in the Landsat science data users handbook in each series of landsat [38–40]. In this book, the value of land surface temperature starts from the conversion of the digital number (DN) to spectral radian and then obtained the brightness temperature (K) [41]. The advantage of NASA methodology is easy and quick to implement but, it can not describe actual field conditions because, it only refers to the theory of blackbody [42].

Meanwhile, to obtain the land surface temperature values from satellite data well there are three main variables that must be considered and corrected: atmosphere, angular and emissivity [43]. Therefore, the author used the mono window and split window algorithm in the derivation of land surface temperature in South Tangerang City because, they used two of the three variables (atmosphere and emissivity). The purpose of this paper is to perform the spatial distribution of land surface temperature using two algorithms, as well as to determine more accurate algorithm for retrieving land surface temperature value.

2. Material and Method

2.1. Study Area
South Tangerang (106°38’00”E/06°13’30”S to 106°47’00”E/06°22’30”S) is used as a study area, it is located in the eastern of Banten Province with an area of 147.19 km² or 1.63% of the total area of Banten Province. While administratively, South Tangerang consists of seven districts.

![Figure 1. Map of South Tangerang City in Banten Province, Indonesia.](image)

2.2. Data
The land surface temperature data obtained from Landsat 8 OLI-TIRS path 122 row 64, recording date March 29 2017 at 09.20 for South Tangerang Region, and land surface temperature data based on field measurement used infrared thermometer. The training sample taken as many as 30 points and is used for calculating root mean square error as fitting parameter.
2.3. Mono Window Algorithm

Mono-window algorithm developed by Qin et al. (2015) [44], the formulation of LST can be expressed as follows.

\[
T_s = [a_{10}(1 - C_{10} - D_{10}) + (b_{10}(1 - C_{10} - D_{10}) + C_{10} + D_{10})T_{10} - D_{10}T_a]/C_{10}
\]

\[
C_{10} = \tau_{10}\varepsilon_{10}
\]

\[
D_{10} = (1 - \tau_{10})(1 + (1 - \varepsilon_{10})\tau_{10})
\]

Where \(a_{10} = -62.7182\) and \(b_{10} = 0.4339\) are model constants, when the temperature varies from 0 to 50 \(^\circ\)C; \(\varepsilon_{10}\) is the emissivity for Landsat 8 OLI; \(\tau_{10}\) is the atmospheric transmittance for Landsat 8 OLI-TIRS; \(T_{10}\) is the brightness temperature of TIRS band 10.

2.4. Split Window Algorithm

Split-window algorithm was developed by Rozenstein et al. (2014) [45]. This algorithm uses atmospheric transmittance and emissivity as inputs. The land surface temperature was estimated using the following equation.

\[
T_s = A_0 + A_1 \cdot T_{10} - A_2 \cdot T_{11}
\]

Where \(T_s\) is the value of LST in celcius degree (\(^\circ\)C), \(T_{10}\) and \(T_{11}\) are the brightness temperatures obtained of band 10 and 11, respectively, and \(A_0\), \(A_1\), and \(A_2\) are coefficients determined by the emissivity and atmospheric transmittance of both TIRS bands:

\[
C_{10} = \varepsilon_{10}\tau_{10}
\]

\[
C_{11} = \varepsilon_{11}\tau_{11}
\]

\[
D_{10} = (1 - \tau_{10})(1 + (1 - \varepsilon_{10})\tau_{10})
\]

\[
D_{11} = (1 - \tau_{11})(1 + (1 - \varepsilon_{11})\tau_{11})
\]

\[
E_0 = D_{11}C_{10} - D_{10}C_{11}
\]

\[
E_1 = D_{11}(1 - C_{10} - D_{10})/E_0
\]

\[
E_2 = D_{10}(1 - C_{11} - D_{11})/E_0
\]

\[
A = D_{10}/E_0
\]

\[
A_0 = E_1\cdot a_{10}/E_2\cdot a_{11}
\]

\[
A_1 = 1 + A + E_1\cdot b_{10}
\]

\[
A_2 = A + E_2\cdot b_{11}
\]

2.5. Root Mean Square Error

Root Mean Square Error (RSME) was considered as fitting parameters between predicted and observation data. Where \(Y_{observed}\) shows the land surface temperature measured in situ and \(Y_{predicted}\) shows the of land surface temperature from Landsat image processing.

\[
RMSE = \left(\frac{1}{n} \sum_{i=1}^{n} (Y_{observed} - Y_{predicted})^2\right)^{0.5}
\]
3. Results and Discussion

The result shows, both of the land surface temperatures distribution have got similar pattern. Figure 2 shows the LST by mono window algorithm value has got range 19.0 - 31.0 °C, and Figure 3 LST value by split window algorithm has got range 29.9 - 51.8 °C. Higher land surface temperature value for both of algorithms are dominated in southern part of South Tangerang.

![Figure 2. Land surface temperature by mono window algorithm.](image1)

![Figure 3. Land surface temperature by split window algorithm.](image2)

The way to find a more accurate method of land surface temperature value using RMSE (Root Mean Squared Error) as fitting parameter. Based on RMSE calculation of land surface temperature with mono window algorithm is 11.42 °C and for Split Window is 7.69°C. This result shows that Split Window algorithm is more accurate than mono window algorithm because it has got smaller error value.

| LST Algorithm           | RMSE °C |
|-------------------------|---------|
| Mono Window Algorithm   | 11.42   |
| Split Window Algorithm  | 7.69    |

4. Conclusion

The mono window algorithm and split window algorithm were applied to map the land surface temperature distribution in South Tangerang. Based on the maps of land surface temperature distribution for both algorithms, it is clear that that they have got similar pattern. Higher land surface temperature values dominated in the southern part of South Tangerang, and best result is obtained with split window algorithm with an RMSE of 7.69°C.

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References

[1] Wang S, Ding H, Liang H, and Ma Q 2016. Resources Conservation and Recycling 128 526-534.
[2] Kerr Y H, Lagourade J P, and Imbernon J 1992 Remote Sensing of Environment 33 197-209.
[3] Allen R G, Tasumi M, and Trezza R 2007 Irrigation and Drainage Engineering 133 380-394.
[4] Zhao W, Hu Z, Li S, Guo Q, Liu Z, Zhang L, 2017 Science of The Total Environment 599-600 891-898.
[5] Elmes A, Rogan J, Williams C, Ratick A, Nowak D, Martin D, 2017 ISPRS Journal of Photogrammetry and Remote Sensing 128 338-353.
[6] Li G, Zhang F, Jing Y, Liu Y, Sun G, 2017 Science of The Total Environment 596-597 256-265.
[7] Qiu G Y, Zou Z, Li Z, Li H, Guo Q, Yan C, Tan S, 2017 Habitat International 68 30-42.
[8] Mathew A, Khandelwal S, Kaul N, 2018 Energy and Buildings 159 271-295.
[9] Ziaul S, Pal S, 2018 Urban Climate 24 34-50.
[10] Poon P K, Kinoshita A M, 2018 Journal of Hydrology 559 71-83.
[11] Mean F H, Yusop, Yusof F, 2018 Atmospheric Research 201 102-115.
[12] Jepsen S M, Harmn T C, Ficklin D L, Molotoch N P, Guan B, 2018 Journal of Hydrology 556 645-659.
[13] Romaguera M, Vaughan R G, Ettema J, Izquierdo-Verdiguier E, Hecker CA, Van Der Mer F D, 2018 Remote Sensing of Environment 204 534-552.
[14] Urqueta H, Jodar J, Herrera C, Wilke H G, Medina A, Urrutia J, Custodio E, Rodriguez J, 2018 Science of The Total Environment 612 1234-1248.
[15] Bechtel B, Hoshyaripour G, and Zaksek K 2012 Remote Sensing 4 3184-3200.
[16] Hereher M E, 2017 Journal of African Earth Science 126 75-83.
[17] Zhao Z Q, He B J, Li G L, Wang H B, Darko A, 2017 Energy Building 155 282-295.
[18] Zhang X, Estoque R C, Murayama Y, 2017 Sustainable Cities and Society 32 557-568.
[19] Chen Y, Wang X, Jiang B, Wen Z, Yang N, Li L Landscape and Urban Planning 162 68-79.
[20] Sheng L, Tang X, You H, Gu Q, Hu H, 2017 Ecological Indicators 72 738-746.
[21] Cui Y, Yang D, Hong T, Ma Jingin, 2017 Energy 130 286-297.
[22] Estoque R C, Murayama Y, 2017 ISPRS Journal of Photogrammetry and Remote Sensing 133 18-29.
[23] Bevilacqua P, mazzeo D, Bruno R, Arcuri N, 2017 Energy and Buildings 150 318-327.
[24] Hwang R L, Linn C Y, Huang K T, 2017 Energy and Buildings 152 804-812.
[25] Kotharkar R, bagade A, 2018 Landscape and Urban Planning 169 92-104.
[26] He B J, 2018 Urban Climate 24 26-33.
[27] Wang S, Ma Q, Ding H, Liang H, 2018 Resources Conservation and Recycling 128 526-534.
[28] Li Z L, Ren H, Sobrino J A, Tang B H, Trigo I F, Wan Z, . . . Yan G 2013 Remote Sensing environment 131 14-37.
[29] Duan S B, Li Z L, Cheng J, Leng P, 2017 ISPRS Journal of Photogrammetry and Remote Sensing 126 1-10.
[30] Chatterjee A S, Singh N, Thapa S, Sharma D, Kumar D, 2017 International Journal of Applied Earth Observation and Geoinformation 58 264-277.
[31] Sekertekin A, Kotuglu S H, and Kaya S 2016 Environment Monitoring Assess 188 30.
[32] Zhou J, Zhang X, Zhang W, and Zhang H 2014 Remote Sensing 6 5344-5367.
[33] Berk A, Bernstein L S, and Robertson D C 1989 MODTRAN : A Moderate Resolution Model for LOWTRAN 7. Tech. Rep. GL-TR-89-0122 Air Force Geophysics Laboratory Hanscom Air Force Base Bedford MA.
[34] Qin Z, Berliner P, and Karnieli A 2001 Remote Sensing 22 3719-3746.
[35] Jimenez-Munoz J C, and Sobrino J A 2003 Journal of Geophysical Research 108 4688.
[36] Sobrino J A, Jimenez-Munoz J C, and Paolini L 2003 Remote Sensing of Environment 90 434-440.
[37] Dash P, Gotsche F M, Olesen F S, and Fisher H 2002 International Journal of Remote Sensing...
23, 2563-2594.

[38] Chen X, Li P, Yin Z, and Zhao H 2005 Remote Sensing of Environment 104 133-146.

[39] Singh K B, Grover A, and Zhan J 2014 Energies 7 1811-1828.

[40] Wibowo A, and Rustanto A 2013 Indonesian Journal of Geography 45 101-115.

[41] Ardiansyah. (2015). Pengolahan Citra Penginderaan Jauh Menggunakan ENVI 5.1 dan ENVI LIDAR (Teori dan Praktik). Jakarta Selatan: PT. LABSIG INDERAJA ISLIM.

[42] Meneses S F 2015 Thermal Remote Sensing at Lyte Geothermal Production Field Using Mono Window Algorithm. Proceeding World Geothermal Congress. Melbourne.

[43] Franca G B, and Cracknell A P 1994 International Journal of Remote Sensing 15 1695-1712.

[44] Qin Z, Wang F, Karnieli A, Song C, Tu L, and Zhao S 2015 Remote Sensing 7 4269-4289.

[45] Roznstein O, Derimian Y, Karnieli A, and Qin Z 2014 Sensors 14 5768-5780.