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Estimation of land surface temperature using Landsat satellite data: A case study of Mueang Maha Sarakham District, Maha Sarakham Province, Thailand for the years 2006 and 2015

Key words: land surface temperature, remote sensing, thermal infrared, Maha Sarakham

Introduction

Currently, urban areas are currently developing due to economic growth. This causes the changes in land uses as well as development, improvement and changes in several areas to accommodate the development of economic areas. The former areas which are agricultural and empty are replaced with basic infrastructures such as buildings, streets, and other infrastructures (Qureshi, Breuste & Lindley, 2010; Charoentrakulpeeti, 2012; Rozenstein, Qin, Derimian & Karnieli, 2014). The original areas covering with the surface that the water can well penetrate and full of moisture, vegetation, soil, water sources has transformed to concrete and asphalt surface (Oke, 1997). Thus, such the characteristics of the surface of the city can absorb heat from the sun increasingly and absorb more effectively during daytime more than natural surface that are mostly green areas or agricultural areas. At nighttime, the surface of the city will release the heat accumulated in the daytime into the atmosphere more than the natural surface (Mirzaei & Haghighat, 2010). Therefore, the surface of the city can accelerate the evaporation of moisture more effectively than the natural surface, which has a better absorption of moisture. As a result, the temperature in urban areas will be higher than in rural areas (Liang, 2004; Zhou, Chen, Wang & Zhan, 2011; Wang, He & Hu, 2015).

Different temperatures cause the formation by urban heat island (UHI), which is the temperature of the day in the big city that may be higher than the surrounding areas of 1–3°C. During nighttime, the temperature difference may be up to 12°C, even in small towns or communities which have a small population size. The effect will occur depending on the decreasing size of population. Many studies have widely accepted the correlation between temperature and land cover (Asaeda, Ca & Wake, 1996; Svensson & Eliasson, 2002; Wong & Yu, 2005; Li et al., 2013), indicating that the temperature in green areas will be lower than construction areas (Kataoka, Matsumoto, Ichinose & Taniguchi, 2009; Vlassova et al. 2014).

The application of remote sensing technology in the study of land use and land cover with satellite data can help the study in wide area and tracking of changes in land uses rapidly (Sobrino & Raissouni, 2000; Laosuwan, Sangpradid, Gomasathit, & Rotjanakusol, 2016; Uttaruk & Laosuwan, 2017; Uttaruk, Rotjanakusol & Laosuwan, 2018). The satellites used were namely, Landsat 5, Landsat 7 and Landsat 8. Mostly, the satellite data is mainly used in visible bands and infrared bands. Those satellites mentioned have a recording cycle that is suitable for data application. Also, it can track land use and land cover for almost real time. In addition, it can analyze land surface temperature (LST) by using a thermal infrared band with the significance of the increase in temperature as mentioned previously (Schott et al., 2012; Lagouarde et al., 2013; Blackett, 2014; Reuter et al., 2015; Chen, Yang, Yin & Chan, 2017; Peebkhunthod, Chunpang & Laosuwan, 2018). The objectives of this study is to estimate LST by applying Landsat satellite data in Mueang Maha Sarakham District, Maha Sarakham Province, Thailand, by focusing on temperature changes over the 10-year period (2006 and 2015).

Study area and satellite-based data collection

Study area. Mueang Maha Sarakham District, Maha Sarakham Province (Fig. 1) with an area of about 556.70 km^2. Mueang Maha Sarakham District

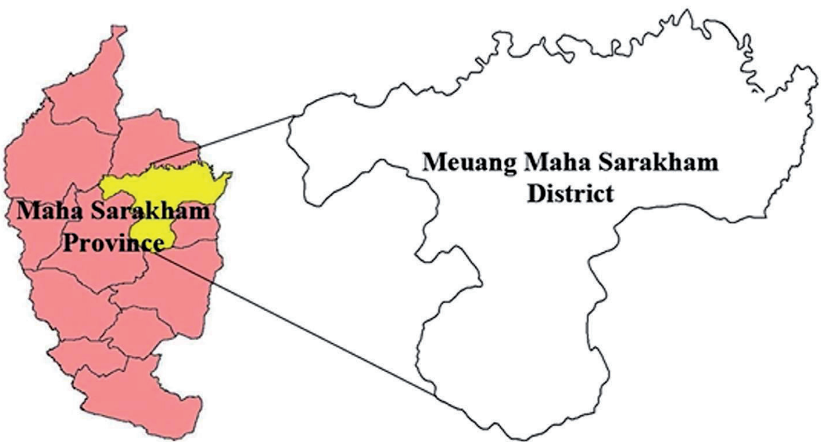

FIGURE 1. Meuang Maha Sarakham District, Maha Sarakham Province, Thailand

has the border connecting following neighboring districts such as Kae Dam, Wapi Pathum, Borabue, Kosum Phisai and Kantharawichai of Maha Sarakham Province, Khong Chai of Kalasin Province, and Changhan, Mueang Roi Et and Si Somdet of Roi Et Province.

Satellite-based data collection. The monthly data from Landsat 7 Satellite Path 127 Row 49 Band 6 (January–December) 2006 and the monthly data from Landsat 8 Satellite Path 127 Row 49 Band 10 (January–December) 2015.

Operational method

LST analysis. The LST analysis from the thermal infrared band of Landsat satellite can be calculated from Equation (1) as follows (Mallick, Kant & Bharath, 2008; Barsi et al., 2014; Rajeshwari & Mani, 2014; Laosuwan, Gomasathit & Rotjanakusol, 2017):

$$L_\lambda = M_L \cdot Q_{cal} + A_L \qquad (1)$$

where:
L_λ – TOA spectral radiance [W·m^{-2}·sr^{-1}·µm^{-1}],
M_L – radiance multiplicative band (No),
Q_{cal} – quantized and calibrated standard product pixel values (DN),
A_L – radiance Add Band (No.)

Converting the digital number. Converting the digital number to the radiation value at the recording device can be calculated from Equation 2 as follows (Chander & Markham, 2003; USGS, 2018):

$$T_B = \frac{k_2}{\ln[(k_1 / L_\lambda) + 1]} \qquad (2)$$

where:
k_1, k_2 – band specific thermal conversion from the metadata,
L_λ – TOA spectral radiance [W·m^{-2}·sr^{-1}·µm^{-1}].

Analysis of absolute temperature from band radiation. For finding the results in Celsius (°C), the absolute temperature is revised by adding the absolute zero (approximately –273.15°C) (Laosuwan et al., 2017).

Statistical correlation analysis. In this statistical correlation analysis, the analysis results of the data from Landsat 7 satellite in thermal infrared band in 2006 and Landsat 8 satellite in 2015 to find out the statistical correlation with the LST data measured from the Meteorological Station of Thai Meteorological Department (TMD).

Results and discussion

Land surface temperature analysis result. The LST analysis results from Landsat 7 satellite in 2006 and Landsat 8 satellite in 2015 through the numerical conversion of data, were radiation values at the recording device and the analysis of absolute temperature from band radiation. As a result, the LST data of Mueang Maha Sarakham District, Maha Sarakham Province can be analyzed as shown in Table 1, indicating the data obtained from monthly satellite data analysis in 2006 and 2015.

The data analysis results from Table 1 shows the monthly LST values in 2006 and 2015. This study analyzed the results of LST according to the seasons of Thailand including summer (17 February – 16 May), rainy season (17 May

TABLE 1. The analysis results of the LST in monthly of 2006 and 2015

Month	Mean temperature [°C]	
	2006	2015
Jan	27.11	22.56
Feb	27.32	25.15
March	31.17	30.21
April	26.26	30.60
May	27.19	30.53
June	28.35	28.42
July	26.56	28.01
Aug	25.21	26.06
Sept	25.75	25.26
Oct	24.77	27.11
Nov	26.82	26.21
Dec	18.90	24.55
Average	26.28	27.05

– 16 October) and winter (17 October – 16 February). The results indicated as follows.

In the summer 2006, the highest temperature in March was 31.17°C and the lowest temperature in April was 26.26°C. In the rainy season, the highest temperature in June was 28.35°C and the lowest temperature in August was 25.21°C. In the winter, the highest temperature in February was 27.32°C and the lowest temperature in December was 18.90°C. Whereas in the summer 2015, the highest temperature in April was 30.60°C and the lowest temperature in February was 25.15°C. In the rainy season, the highest temperature in June was 28.42°C and the lowest temperature in September was 25.26°C. In the winter, the highest temperature in November was 26.21°C and the lowest temperature in January was 22.56°C.

Analysis of annual average land surface temperature. The spatial analysis of annual average LST can represent the changes in surface temperature data in Mueang Maha Sarakham District, Maha Sarakham Province more distinctively than monthly data. Figure 2 and Table 2 indicate the spatial data obtained from the LST data analysis from Landsat 7 satellite in 2006 and Landsat 8 satellite in 2015. The LST was classified into six groups as 0–7, 8–14, 15–21, 22–28, 29–35, and 36–42°C.

TABLE 2. Total area classification

2006	Total area [km^2]	%
0–7°C	0.00190800	0.0003330
8–14°C	63.5924690	11.090623
15–21°C	101.092544	18.150758
22–28°C	225.801939	41.253796
29–35°C	132.496640	23.625592
36–42°C	33.7089800	5.878897
2015	**Total area [km^2]**	**%**
0–7°C	26.5188890	4.6249690
8–14°C	4.6249690	7.8006320
15–21°C	91.7658960	16.003994
22–28°C	131.470682	24.846696
29–35°C	165.989132	30.291396
36–42°C	96.2212090	16.432185

Statistical correlation analysis result. In this study, the LST data from thermal infrared band of Landsat 7 satellite in 2006 and Landsat 8 satellite in 2015 were analyzed to find out the statistical correlation with the LST data at the Meteorological Station of TMD. The chosen temperatures were in the same day, month, and year. At any rate, the

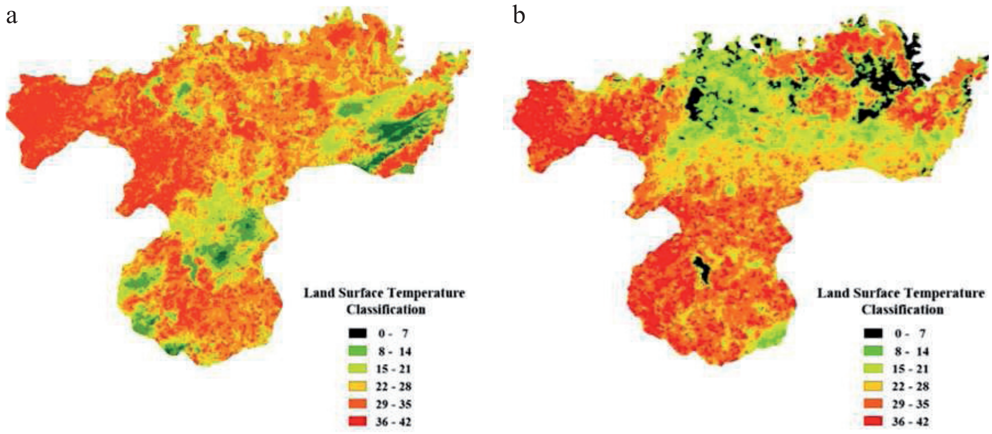

FIGURE 2. Spatial analysis of LST in 2006 (a) and 2015 (b)

TMD will monitor the meteorological data at the same time specified all over the world. In this study, the land temperature data was collected at the Maha Sarakham Meteorological Station of TMD. The results of the correlation analysis in 2006 and 2015 are shown in Figures 3 and 4 respectively.

From Figure 3, the analysis results of LST correlation in 2006 analyzed from Landsat 7 satellite and LST at the Meteorological Station of TMD resulted in the correlation equation $y = 0.7201x + 8.68$ and coefficient of determination $R^2 = 0.7527$. From Figure 4, the analysis results of LST correlation in 2015 analyzed from Landsat 8 satellite and LST at the Meteorological Station of TMD resulted in the correlation equation $y = 0.8591x + 4.8904$ and coefficient of determination $R^2 = 0.838$. It can be observed that the correlation of these two years was at a high level. If the LST analyzed from the satellite was high, the LST at the Meteorological Station of TMD would be high. On the contrary, if

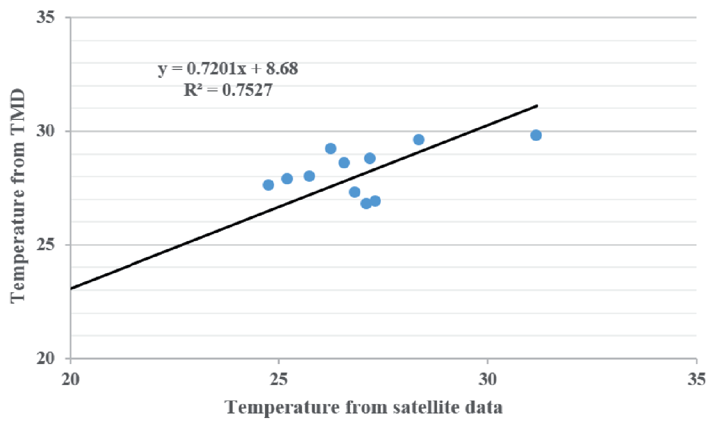

FIGURE 3. Statistical correlation analysis result in 2006

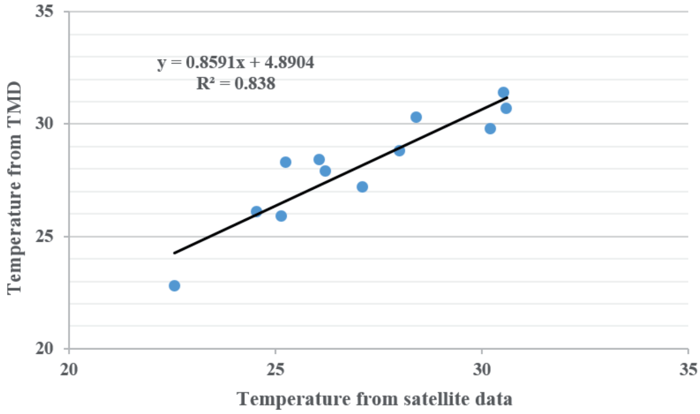

FIGURE 4. Statistical correlation analysis result in 2015

the LST analyzed from the satellite was low, the LST at the Meteorological Station of TMD would be low as well.

Conclusions

This research proposes LST estimation by applying Landsat satellite data in Mueang Maha Sarakham District, Maha Sarakham Province and fosuses on investigating temperature changes over a 10-year period (2006–2015). The LST analysis results from Landsat 7 in 2006 could be found that the annual average LST was at 26.28°C and the average LST from the Meteorological Station of TMD had an average annual surface temperature of 27.60°C with a difference in temperature at 1.32°C . The LST analysis results from Landsat 8 satellite in 2015 indicated that the annual average LST was at 27.155°C and the average LST from the Meteorological Station of TMD had an average annual surface temperature of 28.133°C with a difference in temperature at 0.98°C. For the LST analysis results from satellites over the 10-year period can be concluded that Mueang Maha Sarakham District, Maha Sarakham Province had an increase in temperature of 0.87°C. And the average LST from the Meteorological Station of TMD showed that the LST in Mueang Maha Sarakham District, Maha Sarakham Province had an increase in temperature of 0.53°C. While the two sets of data were brought to find out the statistical correlation with linear regression analysis, the correlation was found at a high level. In 2006, the coefficient of determination was R^2 = 0.7527. And in 2015, the coefficient of determination was R^2 = 0.838. In addition, this study also found that the LST from the satellite data analysis was different from the meteorological data in some months before finding out an annual average. This is because the data from the satellite in that month had clouds covering, especially when that satellite had cloud covering more than 10%. The results of this study indicated that the LST satellite data analysis method is a reliable, quick and convenient to be applied. Therefore, the researchers will conduct the LST satellite data analysis method could be applied in the analysis of Urban Heat Island (UHI) in Maha Sarakham Province in future.

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Summary

Estimation of land surface temperature using Landsat satellite data: A case study of Mueang Maha Sarakham District, Maha Sarakham Province, Thailand for the years 2006 and 2015. At present, the climate has constantly been changing, especially the increase in global average temperature that results in the risk of severe climatic conditions such as heat wave, drought and flood. The objective of this study is to estimate land surface temperature (LST) by applying Landsat satellite data in Mueang Maha Sarakham District, Maha Sarakham Province, Thailand. The study focuses on investigating the temperature changes for the years 2006 and 2015. The research was conducted by analyzing the satellite data in the thermal infrared band with a geo-informatics package software mutually with mathematical models. The operation results indicated that the average LST was at 26.28°C in 2006 and 27.15°C in 2015. In order to verify the accuracy of the data in this study, the results of the annual satellite data analysis were brought to find out a statistical correlation with the LST data from the Meteorological Station of Thai

Meteorological Department (TMD). The results indicated that there was a correlation of the data at a high level in 2006 and 2015. The results of this study indicated that the satellite data analysis method is reliable and can be used to analyze, track, and verify data to predict surface temperatures effectively.

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