ESTIMATION OF LAND SURFACE TEMPERATURE USING LANDSAT TM THERMAL INFRARED IN SELANGOR-NEGERI SEMBILAN

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Abstract

A full-scene of Landsat TM acquired on April 17, 1988 (path 127/row58) was used in this study. This scene covers the areas of Selangor and north part of Negeri Sembilan in Peninsular Malaysia. The main objective of this study is to evaluate the use of remote sensed information, especially thermal band 6 to gain land surface temperature (LST) using thermal band of Landsat images. The result will be compared with urban and non-urban surfaces by using normalised difference vegetation index (NDVI) and compare relationships between them. The initial result showed that the correlation between the LST and the NDVI over ten locations in the study area is quite significant. The derivation of LST map using remote sensing technique in this study is useful in providing information for analysing geophysical parameters over Selangor-Negeri Sembilan area, especially dealing with the urban heat island phenomenon.

Key Words

Landsat, Thermal band, LST, Emmisivity, NDVI

1 Introduction

Land-surface temperature (LST) can be defined as the thermal emission from the landscape "surface", including the top of the canopy for vegetated surfaces as well as other surfaces (such as bare soils). LST is an important parameter in the field of atmospheric sciences as it combines the result of all surface-atmosphere interaction and energy fluxes between the ground and the atmosphere and is, therefore, a good indicator of the energy balance at the Earth's surface (Wan and Snyder, 1996). LST controls the surface heat and water exchange with atmosphere. Estimation of LST from satellites infrared radiometers has been proven useful. Most studies have focused on the use of polar orbiting satellite systems because of their high spatial resolution (Sun et al., 2004).

One of the well known remote sensing satellite for natural resources and environmental applications is Landsat satellite series. Currently there are Landsat 5 TM which are operating for this puposes. In this study Landsat 5 TM was used in order to estimate LST over Selangor – Negeri Sembilan area (Figure 1).

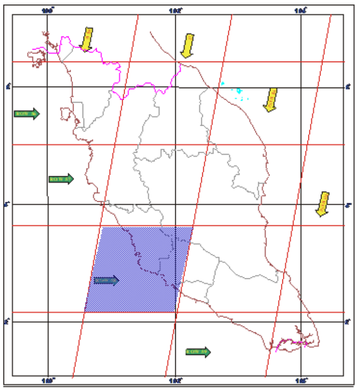

Figure 1. Area under study (shaded)

2 Data

This study used data recorded from a remote sensing satellite that was developed by NASA of USA - Landsat 5. Landsat 5 platform carries along the so called TM sensor, which is an advanced, multispectral scanning, Earth resources instrument designed to achieve higher image resolution, sharper spectral separation, improved geometric fidelity, and greater radiometric accuracy and resolution. The TM data are scanned simultaneously in seven spectral bands. Band 6 scans thermal (heat) infrared radiation. For this study, the data was recorded on April 17, 1988 for path 127/row58 (Figure 1). Spectral range of the all seven bands is shown in Table 1.

Table 1. Spectral range of bands and spatial resolution for the Landsat 5 TM sensor

Band	Spectral Range (Micrometer)	Spatial Resolution (Meters)
Band 1	0.45 - 0.52	30
Band 2	0.52 - 0.60	30
Band 3	0.63 - 0.69	30
Band 4	0.76 - 0.90	30
Band 5	1.55 - 1.75	30
Band 6	10.40 - 12.50	120
Band 7	2.08 - 2.35	30

2 Methodology

In order to estimate LST from Landsat data, the methodology in this study will be divided into four phase: (1) Data Calibration, (2) Conversion from Radiance to Brightness Temperature, (3) LST retrieval and NDVI retrieval.

2.1 Conversion from Digital Number to Radiance

All TM bands are quantized as 8 bit data thus, all information is stored in digital number (DN) with range between 0 to 255. The data was converted to radiance using a linear equation as shown below:

$$CV_R = G(CV_{DN}) + B \qquad (1)$$

Where:

CV_R is the cell value as radiance

CV_{DN} is the cell value digital number

G is the gain (0.005632156 for TM6 and 0.003705882 for ETM+6)

B is the offset (0.1238 for TM6 and 0.3200 for ETM 6)

2.2 Conversion from Radiance to Brightness Temperature

By applying the inverse of the Planck function, thermal bands radiance values was converted to brightness temperature value.

$$T = \frac{K_2}{\ln\left(\frac{K_1}{CV_R} + 1\right)} \qquad (2)$$

Where:

T is degrees Kelvin

CV_R is the cell value as radiance

K_1 is calibration constant 1 (607.76 for TM) and (666.09 for ETM+)

K_2 is calibration constant 2 (1260.56 for TM) and (1282.71 for ETM+)

2.3 LST Retrieval

LST was derived from TM6 using model developed by Qin et al. (2001) which uses the atmospheric water vapor and the near-surface air temperature on the mono-window algorithm for retrieving the LST. The surface emmissivity was fixed at 0.98 (Hadi et al., 1997). The atmospheric transmissivity was calculated using LOWTRAN 7 developed by Kneizys et al. (1989).

$$T_a = \frac{1}{C}\left[a(1 - C - D) + (b(1 - C - D) + C + D)T_{sensor} - DT_a\right] \qquad (3)$$

Where

C = es, where e is the land surface emissivity (e = 0.98 for Malaysia),

s = the total atmospheric transmissivity (s = 0.021 from LOWTRAN 7)

D=(1 _s)[1+(1 _e)s],

a = -67.355351,

b = 0.458606, and

T_{sensor} = the sensor brightness temperature,

Ta represents the mean atmospheric temperature for Tropical Climate given by

$$Ta=17.9769+0.91715\bullet T_0 \qquad (4)$$

T_0 is near surface air temperature (300.45 K for Malaysia)

2.4 NDVI Retrieval

A vegetative index is a value that is derived from sets of remotely-sensed data that is used to quantify the vegetative cover on the Earth's surface. The NDVI is calculated as a ratio between measured reflectivity in the red and near infrared portions of the electromagnetic spectrum. These two spectral bands are chosen because they are most affected by the absorption of chlorophyll in leafy green vegetation and by the density of green vegetation on the surface. Also, in red and near-infrared bands, the contrast between vegetation and soil is at a maximum.

The Thematic Mapper bands 3 and 4 provide red and near-infrared measurements respectively and therefore can be used to generate NDVI data sets with the following formula:

$$NDVI = \left(\frac{Band4 - Band3}{Band4 + Band3}\right) \qquad (4)$$

3 Result

Combination of band 3, 2 and 1 in red, green and blue channel was used to show the area in its natural colour (Figure 2). Masking of clouds and water bodies into black colour were carried out prior to any other processes. Original band used in deriving LST consist of pixels in digital number (Figure 3). The result of applying equation 1 which converts the digital number to radiance is shown in Figure 4. By applying equation 2 the radiance image was converted to brightness temperature image as in Figure 5. Finally the LST image in Kelvin was obtained by applying equation 3. NDVI image was derived using equation 4. The pixels on both the LST and the NDVI image was density sliced in order to produce colour maps based on the different ranges of the pixels value. The NDVI image will be used later in determining relationship between LST and NDVI image.

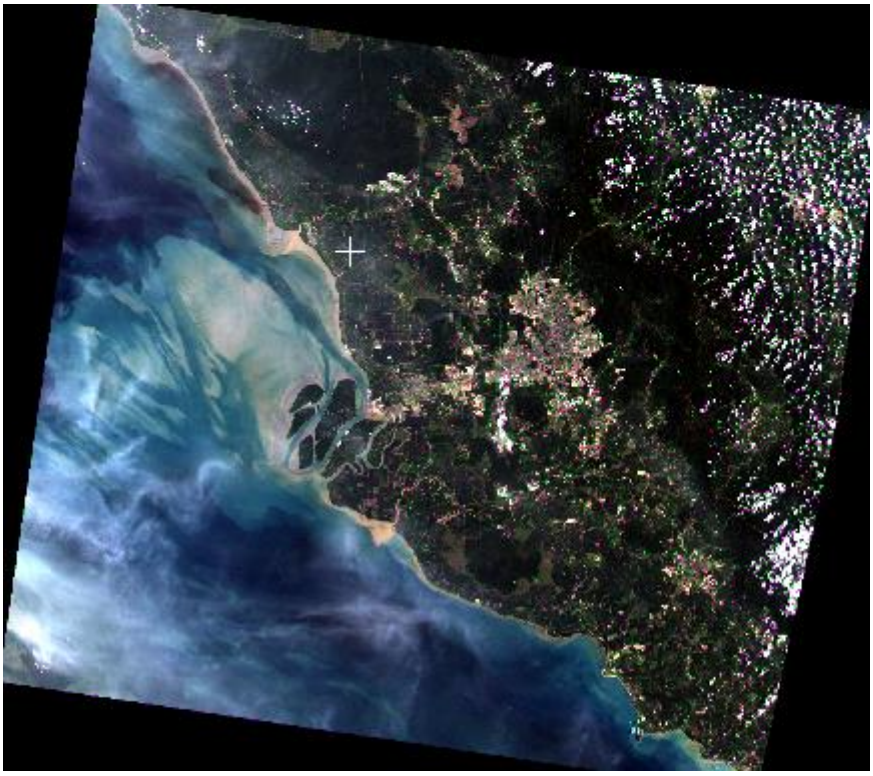

Figure 2. Combination of TM band 3,2,1 in red, green, and blue channel

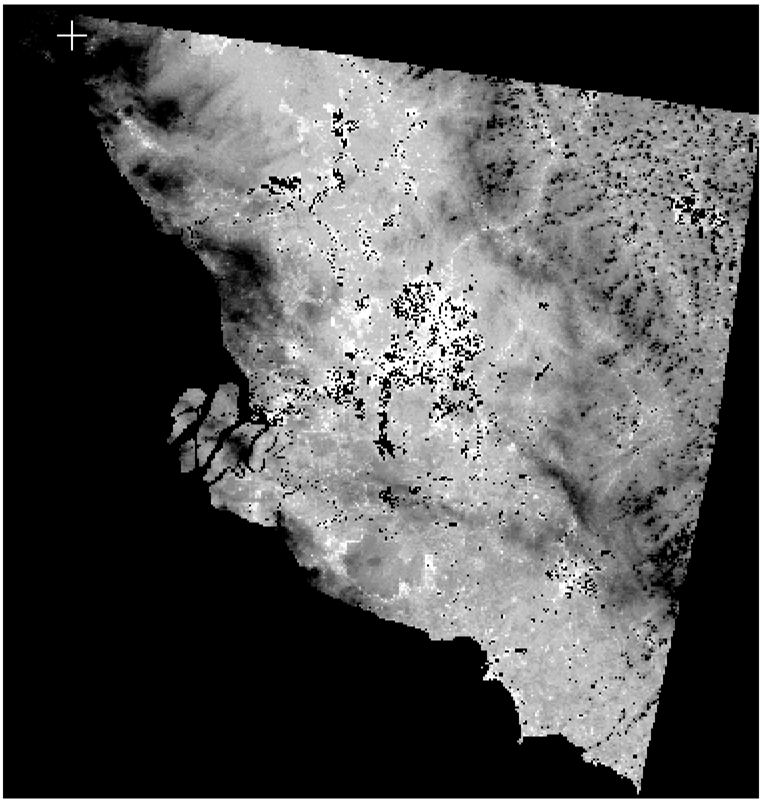

Figure 3. TM band 6 in DN

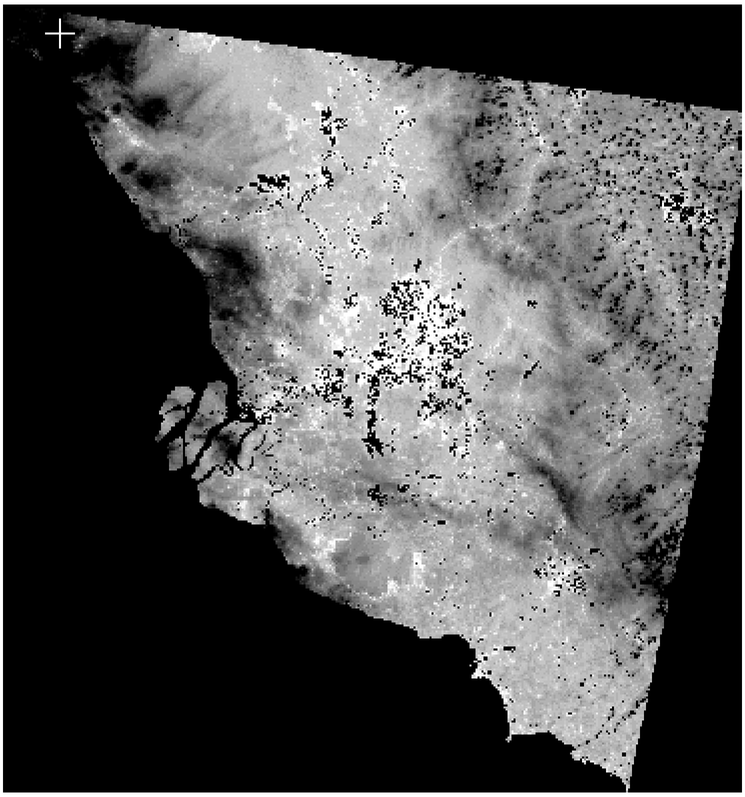

Figure 4. TM band 6 in radiance

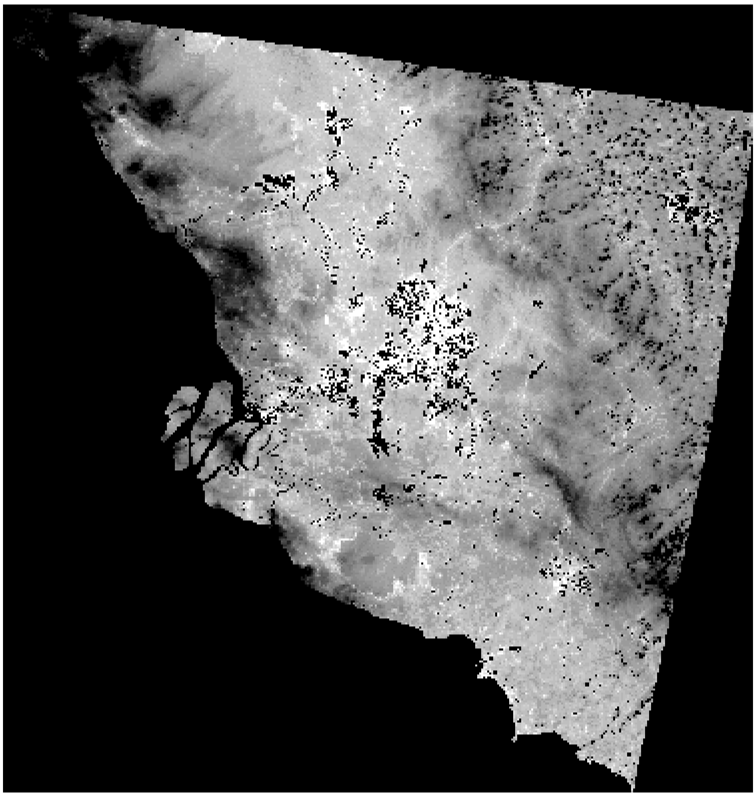

Figure 4. TM band 6 in brightness temperature

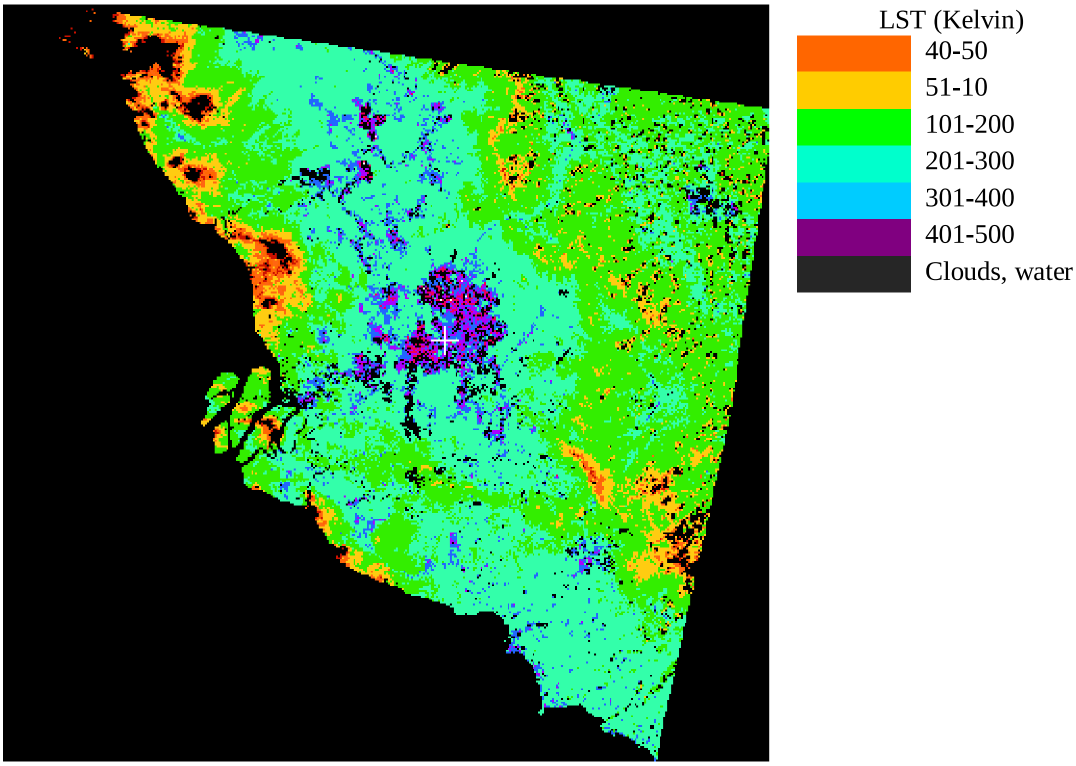

Figure 5. Map of LST

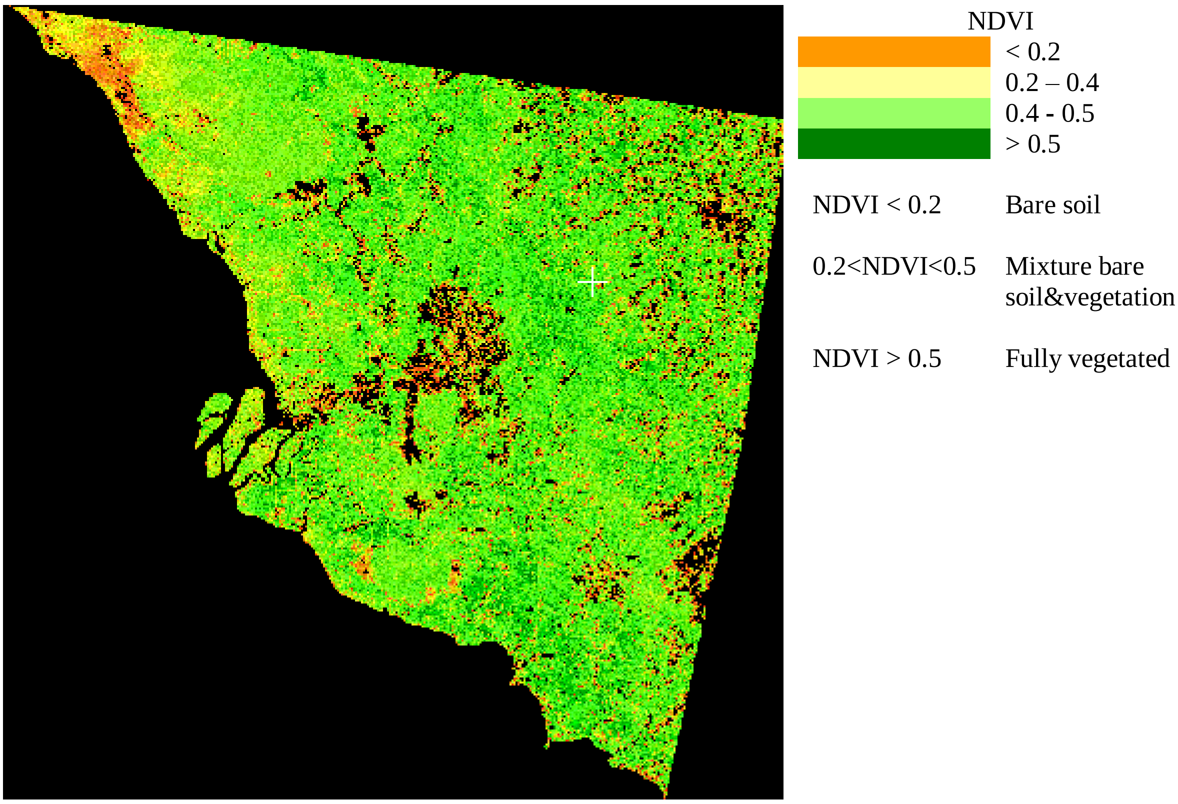

Figure 6. Map of NDVI

4 Relationship Between LST and NDVI

In order to find the relation ship between LST and NDVI, 10 locations in the in the study area were determined (Table 2). A graph of LST vs. NDVI was plotted as shown in Figure 7.

Table 2. LST and NDVI measurement at several locations

Location (Universal Traverse Mercator Projection)		LST (K)	NDVI
Eastern	Northen		
335483.776	411518.787	182.21	0.4728
372626.633	401335.662	378.83	0.3282
375891.939	370378.963	314.01	0.5804
418749.082	391559.862	248.48	0.5238
456300.102	387079.28	335.70	0.5121
394259.286	347161.438	506.44	0.4803
411810.306	350012.713	631.46	0.0270
390585.81	298689.763	159.95	0.6000
451810.306	336570.987	292.25	0.5726
437932.755	298282.438	485.36	0.2222

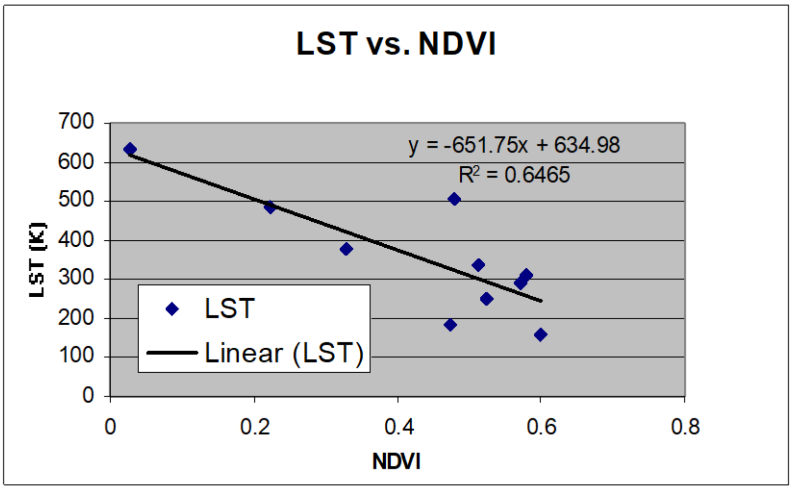

Figure 7. Relationship between LST and NDVI

5 Conclusion

The result shows that estimation of land surface temperature using thermal band 6 of Landsat 5 satellite gives a promising result. Relationship between LST and NDVI based on 10 locations can be shown as linear model y = -651.75x + 634.98 with R^2 = 0.6465. Future study will include comparison between satellite measurement and insitu readings using conventional instruments.

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