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Research Article

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Application of Remote Sensing Imagery and Model Builder in Arcgis to Determine the Change of Land Surface Temperature, Case Study in Quang Ngai Province, Vietnam

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Abstract Land surface temperature (LST) is an important variable to solve problems related to hydrology, agriculture, geochemistry, environment and, climate change. The extraction of land surface temperature from remote sensing imagery has been considered as a useful way because its advantage is that image data has been provided continuously, so the detail of the results is shown legibly on a large scale, instead of limited data at meteorological monitoring points. The study was carried out in Quang Ngai province, located in the South Central Coast of Vietnam, using thermal bands of Lands at 8 OLI/TIRS satellite and processing with Model Builder in ArcGIS software. The result showed that the distribution of different surface temperatures in each region of the province, the highest temperature in the important industrial parks, densely populated urban areas, and low temperatures in areas of dense vegetation. On the other hand, the analysis of processed images in the period from 2015 to 2020 showed that the land temperature tends to increase, and especially, regions with LST >30°C expand from 9% (2015) to 37.8% (2020). This is also an initial study to provide data for climate change research in Quang Ngai province.

Keywords Land surface temperature, LST, Quang Ngai

1. Introduction

Land surface temperature is an important variable to solve problems related to hydrology, agriculture, geochemistry, environment and, climate change. However, the installation of meteorological observation stations in large numbers and continuous operation is still a problem for developing countries, including Vietnam. Therefore, the current trend is using thermal sensing images to determine surface temperatures.

Today, the techniques of remote sensing have an important role in the detection and monitoring of meteorological and environmental phenomenons, including the estimation of land surface temperature (LST). The main reason was given as remote sensing provides an overview of a large scale, more efficient than the measurement with the meteorological monitoring points. Globally, many studies have been conducted for the determination of this index with free satellite imagery such as Modis [1] or Landsat [2-4]. The methodology in Jesus et al., [5] allowed to estimate LST associated with the caatinga vegetation influence in the different periods in the semi-arid area of the State of Sergipe. Besides, Silva, [6] also analyzed the space-time variation of the surface temperature in Pernambuco - a state of Brazil using remote sensing data. It is concluded that remote sensing techniques proved efficient to quantify the Spatio-temporal variability of surface temperature. Similarly, Vietnam has had many studies to use infrared thermal imaging to calculate surface temperature [7-9]. In which, Nguyen Duc Thuan et al., [7] showed that the increase in the percentage of built-up land will lead to an increase in surface temperature by proposing the correlation regression equation between surface temperature and urbanization speed. Trinh Le Hung [10] also applied Landsat multi-temporal thermal infrared images to detect coal fire by computing LST. Thus, predicting the change inland surface temperature are very useful to evaluate and forecast the rapidly changing climate.

Understanding the distribution of LST and its spatial variation will be helpful for related studies such as droughts, wildfires, etc. Therefore, the objective of the study is to estimate the surface temperature change in Quang Ngai province, Vietnam. This locality has been already suffered the effects of extremely hot weather, drought and, water shortage. Besides, the algorithm introduced in this paper has been developed using Model Builder in ArcGIS software allow to create a model that will repeat the process automatically, instead of the long process of retrieving LST, and many mistakes can be made. Model Builderis an application that connects geo-processing tools, map layers, datasets to a process and repeats this process. It helps for automating tasks and reducing execution time. The tool presented in this paper is used for calculating the LST from the red band, near-infrared, and TIR imagery obtained from Lands at 8 OLI/TIR, bands 4–5-10, respectively.

2. Materials and Methodology

2.1. Study area

The study area is the mainland of Quang Ngai province (excluding Ly Son Island). It located in the South Central Coast of Vietnam, which are geographically situated between 14°32’- 15°25’N and 108°06’ -109°04’W. Quang Ngai's topography is dominated by a large plain along the coast and in the center of the province and by mountains and hills in the west. In general, mountains account for about three-quarters of the province's natural area, narrow plains account for one-quarter of the natural area. Quang Ngai has a tropical monsoon climate, so the temperature is high and there are two distinct seasons: the rainy season and the dry season. The annual average temperature reaches 25.6 - 26.9°C, the highest temperature is up to 41°C in the hot season.

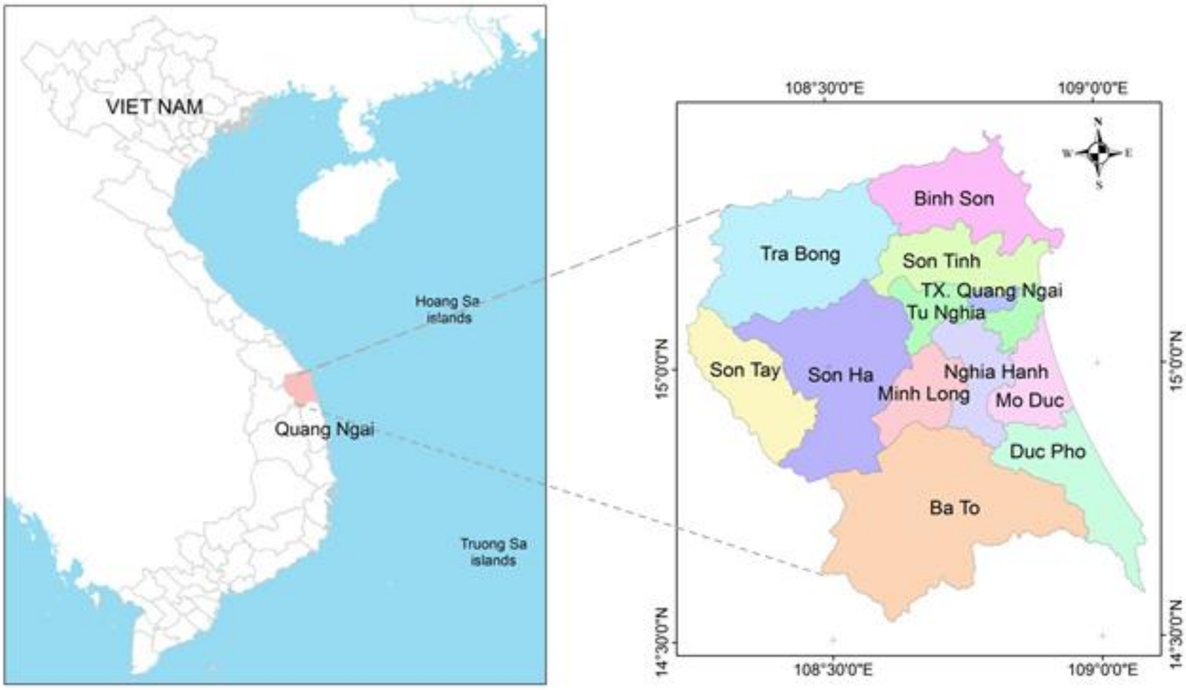


Figure 1: The location of the study area

2.2. Data input

In this study, we collected 12 Landsat 8 images in the dry season from 2015 to 2020.Landsat 8 (path 124, row 49 and path 124, row 50)entirely covering the province with less than 10% cloud cover, were downloaded from the website of United States Geological Survey - USGS (https://earthexplorer.usgs.gov/). Table 2 shows the scenes that were used in the study.

2.3. Methodology

The red and the near-infrared bands (respectively, bands 4 and band 5 of Landsat 8) are used to construct NDVI and the thermal band (band 10) is used to calculate LST. Figure 2 illustrates the image processing flowchart for generating the LST index.

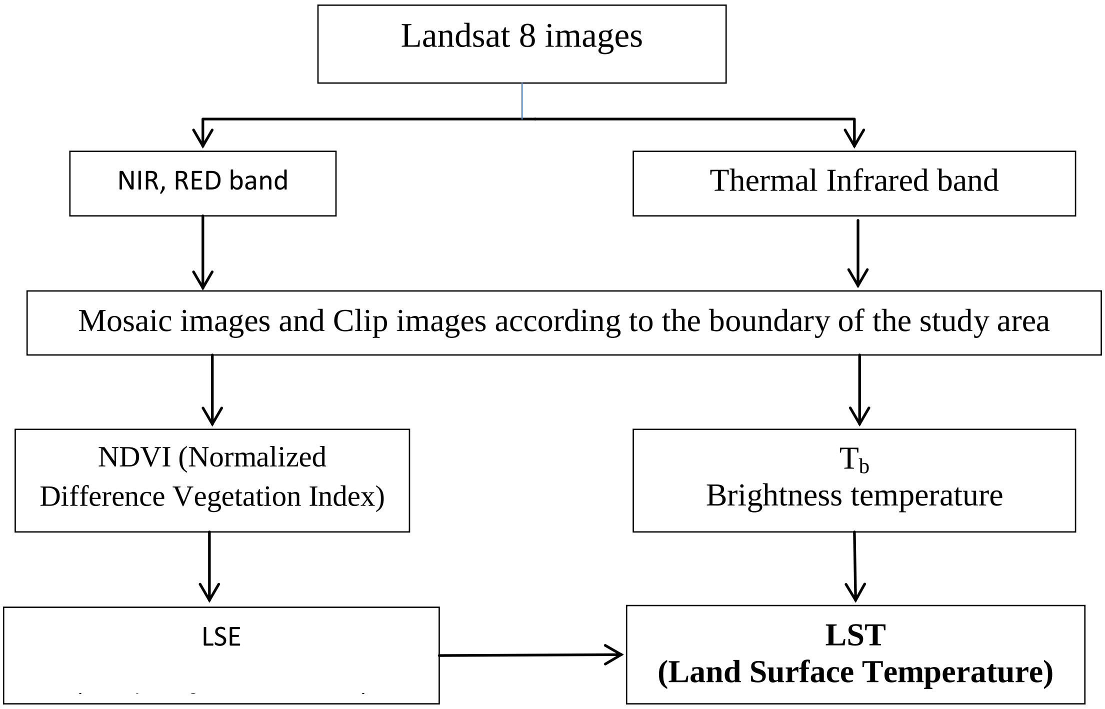


Figure 2: The flowchart of LST calculation processing

2.3.1. NDVI (Normalized Difference Vegetation Index) calculation

NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs).The range of NDVI is −1 to +1. The higher value of NDVI refers to healthy and dense vegetation. Lower NDVI values show sparse vegetation. The NDVI is calculated from these individual measurements as follows:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

where RED and NIR stand for the spectral reflectance measurements acquired in the red (visible) and near-infrared regions, respectively.

2.3.2. LSE (Land Surface Emissivity) calculation

LSE values are calculated based on the proportion of vegetation Pv [11], In this case, the pixel is composed of a mixture of bare soil and vegetation (soil and vegetation emissivities of 0.97 and 0.99, respectively), considering a total of 49 soils spectra with a standard deviation of 0.004) is obtained.

$$LSE=0.004P_v+0.986 \quad (2)$$

Where: Pv combined with NDVI are often used as parameters to assess the emissivity in the absence of actual ground emissivity data. Pv is calculated according to (3)

$$P_V = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2 \quad (3)$$

2.3.3. Brightness temperature T_B

Estimating the satellite brightness temperature T_B using equation (4)

$$T_B = \frac{K_2}{\ln\left(1 + \frac{K_1}{L_\lambda}\right)} \quad (4)$$

where K_1 and K_2 are Thermal conversion constants for Landsat 8 OLI (10.8 µm), and L_λ is spectral radiance.
L_λ – TOA spectral radiance

$$L_\lambda = M_L.Q_{cal} + A_L \quad (5)$$

M_L: Band Specific multiplicative rescaling factor from the meta (RADIANCE _MULT_BAND_X, Where X is the band number 10); A_L = Band specific additive rescaling factor from the metadata (RADIANCE _ADD_BAND_X, Where X is the band number 10); Q_{cal} = Quantized and calibrated standard product pixel values (DN).

Table 1: Value of M_L and A_L, K_1 and K_2 of Landsat 8

Band	Satellite	M_L	A_L	K_1(мВтсм $^{-2}$ стр $^{-1}$мкм$^{-1}$)	K_2(K)
10	LANDSAT8	$3.3420.10^{-4}$	0.10000	774.89	1321.08

2.3.4. LST (land surface temperature) estimation

Land Surface Temperature (LST) was derived from the Top of Atmosphere Brightness Temperature (T_B) and LSE as formula (6)

$$LST = \frac{T_B}{1 + \left(\frac{\lambda.T_B}{\rho}\right) * \ln LSE} - 273 \quad (6)$$

where

T_B= At satellite temperature;

ρ=14380, ρ=h*c/s

λ=band wavelength (µm);

h = planck's Constant ($6.626.10^{-34}$J.sec);

s = Boltzmann Constant ($1.38.10^{-23}\frac{J}{K}$);

c = Velocity of light ($2.998 * 10^8$ m/s);

3. Results and Discussion

With the Model Builder application in ArcGIS, all steps were connected including mosaic images, clip images by the areal extent of the study area (band 4,5,10), calculate NDVI, Pv, LSE, L_λ, T_B, and LST.

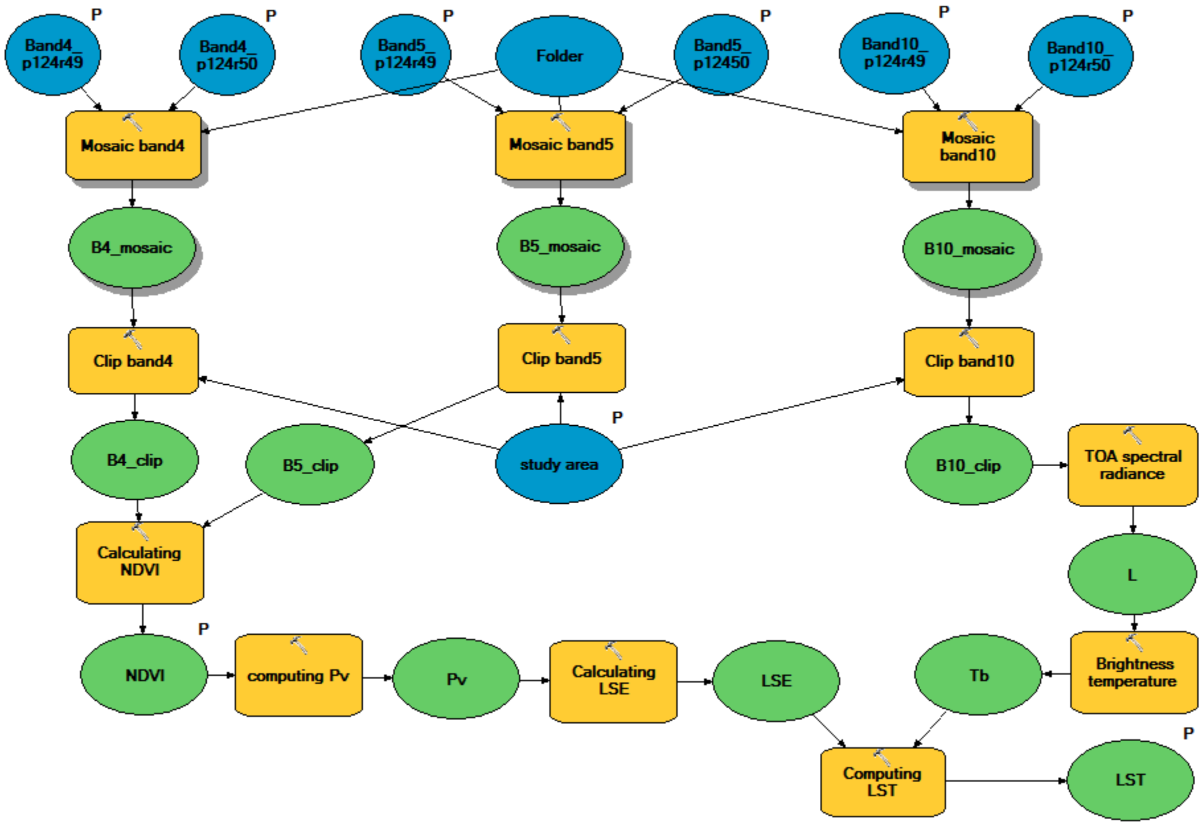


Figure 3: Model Builder in ArcGIS for estimating LST (The letter P appears beside the variable, indicating it is a model parameter)

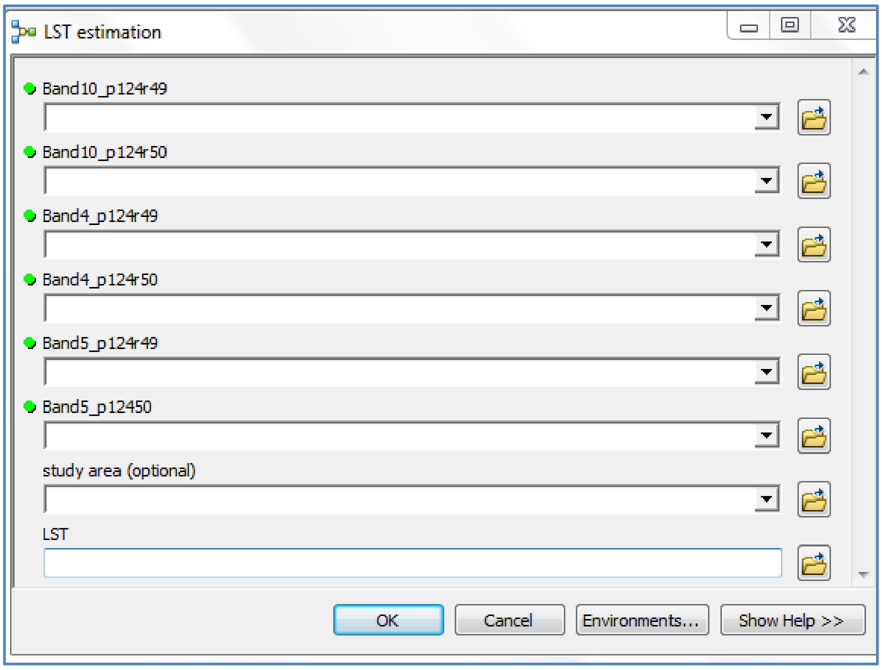


Figure 4: Open model builder and chose model parameters

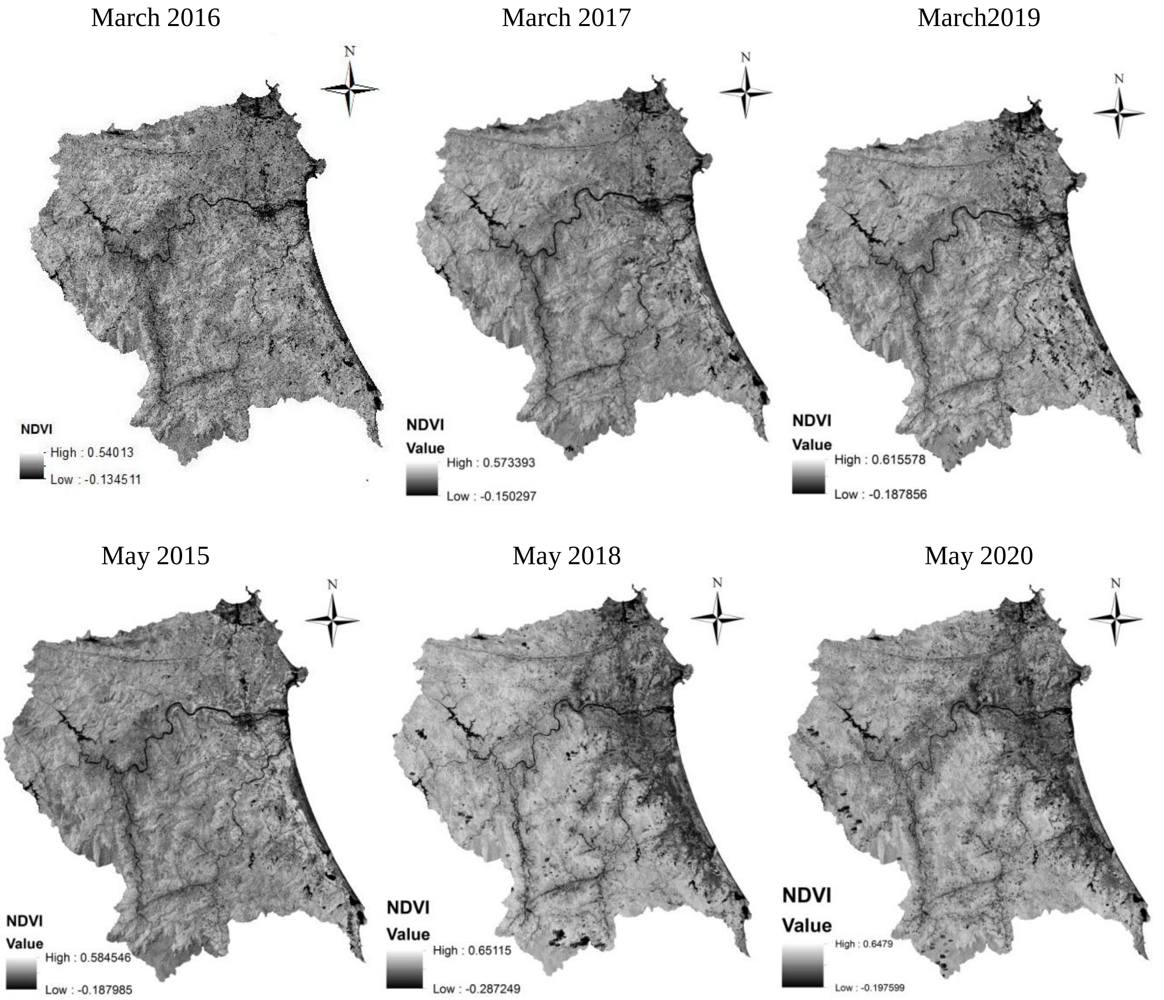
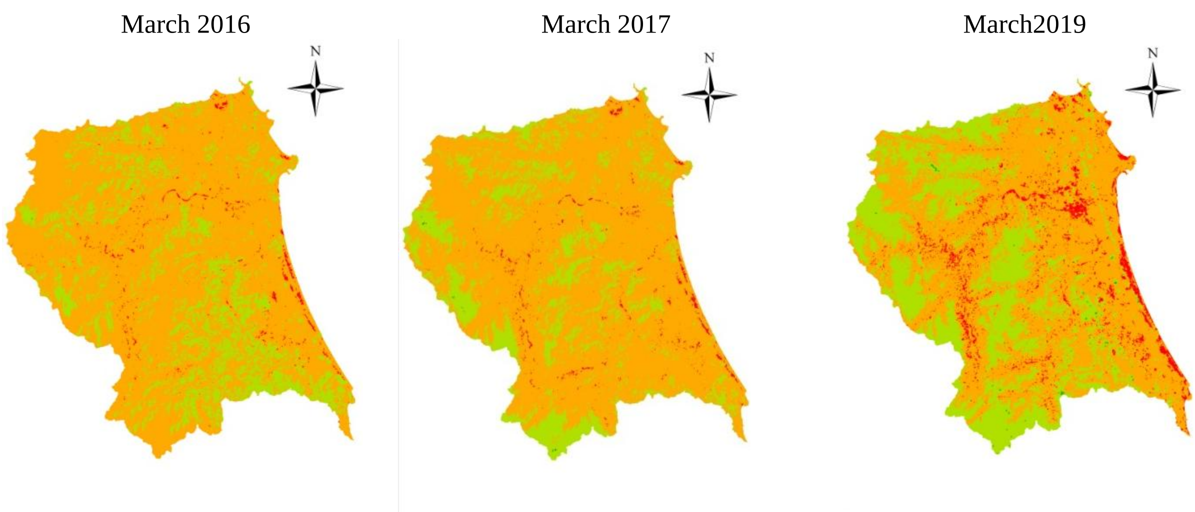


Figure 5: Spatial distribution of NDVI from 2015 to 2020

The spatial distributions of NDVI in Quang Ngai province are illustrated in figure 5. Higher values of NDVI indicate the information of health-dense vegetation in the West of the study area corresponding to the forest, while lower values represented stressed vegetation in the East, negative values correspond to areas with water surfaces.



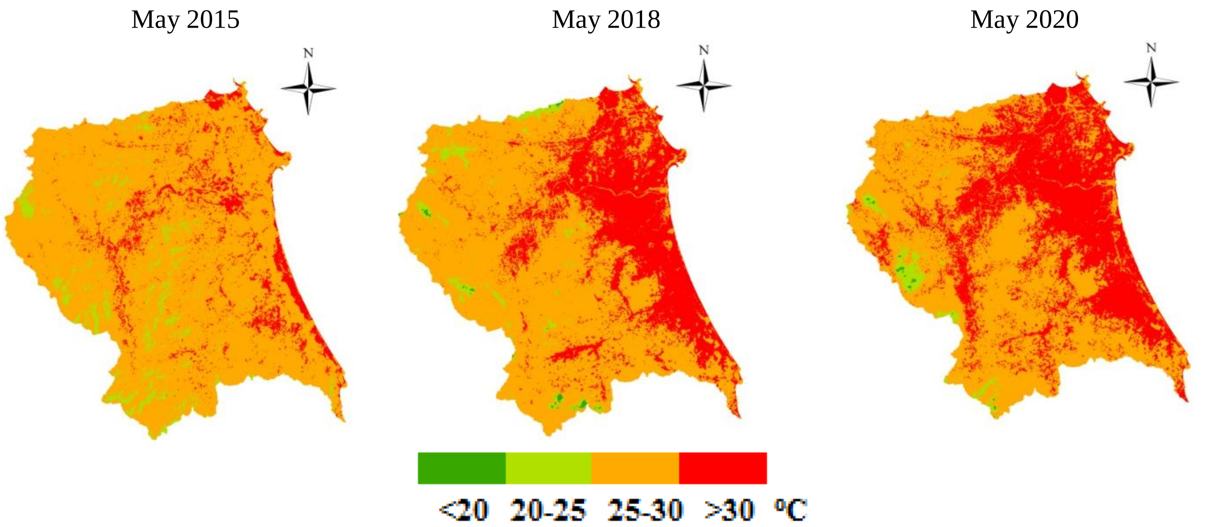


Figure 6: Spatial variation of LST from 2015 to 2020

The variation and distribution of the estimated values of the surface temperature can be visualized in Figure 6. The LST maps showed that the temperature in Quang Ngai province in the dry season from 2015 to 2020 was mostly over 25°C. Especially, the temperature in May was higher than that in March and the highest values were over 40°C in the Northern region of the study area. The process of statistical calculation of temperature in 5 consecutive dry seasons was carried out to compare the temperature variation over time. Table 2 and Table 3 illustrate the percentage of the area corresponding to different temperature ranges. In March 2016, 2017, 2019, the temperature range of 25 - 30°C occupied most of the area, about 63.6-79.6%; the temperature range of 20 - 25°C accounts for 19.2-31.3%, while the higher LST range occupied a very small area. Meanwhile, the temperature in May 2015, May 2018, May 2020, the area with the temperature above 30 degrees tended to increase, the highest percentage value in 2020 was 37.8%. Figure 5 and figure 6 show that the range of high temperatures was mainly concentrated in the East of Quang Ngai province with low NDVI values (the important industrial parks and densely populated urban areas), and low temperatures in areas of dense vegetation with high NDVI values. Besides, the research result also shows that the area with LST < 30°C and the area of vegetation and water bodies land-cover classes are similarly decreasing. At the same time, the opposite trend was seen with the relationship between the area with LST > 30°C and the area of and Built-up area and bare land. In addition, the highest temperature difference between the city area and surrounding areas with the lowest value is about 18.3°C to 24.4 °C. This is explained by the greenhouse effect and new urban areas and industrial zones increase, created the risk of absorbing heat below the ground, causing the air layer near the ground to become hotter and heating the surface. In summary, the temperature in the study area tends to increase in the dry seasons over the years. It has become one of the main reasons why Quang Ngai province will face many events related to drought, lack of water for domestic use and, agricultural cultivation.

Table 2: LST value range in March

LST (^{o}C)	**% area**		
	March 2016	**March 2017**	**March 2019**
<20	0.0	0.0	0.2
20-25	19.3	19.2	31.3
25-30	79.6	79.7	63.6
>30	1.0	1.1	4.9

Table 3: LST value range in May

LST (^{o}C)	**% area**		
	May 2015	**May 2018**	**May 2020**
<20	0.0	0.2	0.1
20-25	4.5	2.4	2.0
25-30	86.5	69.1	60.1
>30	9.0	28.3	37.8

To verify LST data derived from the Landsat image, temperature data from NASA Website were used. This dataset is accessible from the website https://power.larc.nasa.gov/. We choose temperature values in May 2020 to compare with the results of this study. From this comparison, we found that the highest temperature difference values were 5.9 ^{o}C and the lowest one was 0.3 ^{o}C (fig 7). Someother researches have been also observed that the LST measured on the ground is usually higher than that at 2m height (above the surface of the earth) [12-13]. Overall, the results also reflect the reliability of the method, especially in the absence of meteorological information in the study area.

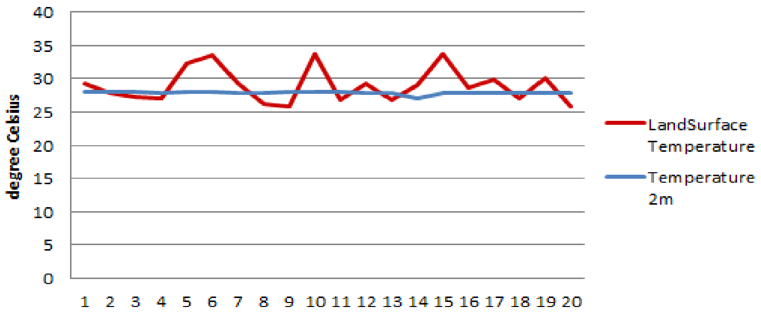


Figure 7: Comparing LST and reference data in May 2020

4. Conclusion

This paper presented the algorithm created in Model Builder in ArcGIS for calculating the LST from Landsat 8 TIRS/OLI. The tool helps many researchers to get the LST values easily and, they can apply them to other research areas. Besides, this is the first study on the change of LST for a period from 2015 to 2020 in Quang Ngai province. The area with LST > 30°C tends to increase, corresponding with the development of urban areas and industrial zones. The results also proved the suitability of monitoring LST using Landsat multi-temporal satellite images by comparing them with temperature data from the NASA Website. Although the difference can be high in some test points but also validates the results good because we are comparing two different temperatures in different places (ground temperature and 2.0m off the ground). In addition, to ensure objectivity and reliability, it is necessary to use a variety of remote sensing image materials for monitoring temperature.

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