Temperature Changes on Land Surface in the Context of Urbanization in Quy Nhon City, Viet Nam

Tho Van Phan and Rute Sousa Matos

Abstract Quy Nhon city is a grade 1 city situated in Binh Dinh province, in Viet Nam. Its population was 481.110 inhabitants and it had an urbanization rate of 60% in 2019, while Quy nhon population numbered just 260.000 in 2017. In order to evaluate the relationship between urban heat island and land cover, we used Landsat satellite imagery from 1990 to 2020 to classify the land cover by using the Support Vector Machine learning method (SVM). The classified results were evaluated with the test samples from the field survey. The accuracy is above 77%, which is reliable enough for use in research. To create the surface temperature layer, we used band 6 in the Landsat 5 ETM remote sensing imagery and bands 10, 11 in the Landsat 8 imagery. The results were calculated the surface temperature for the study area. The study carried out statistics of surface temperature value with land cover. The results show that Quy Nhon city has become warmer since 2005, which witnessed a significant increase, compared with roughly 4 degrees in 1996 and around 9 degrees in 1990. And the temperature in the urban land area is between 30 and 35 degrees. During this period, the classification results show that urban land has rapidly expanded. Especially from 2005 up to now, Quy Nhon city has witnessed a strong urban expansion, agricultural land, and water surface have been changed into urban land. To determine the area of urban heat islands we used the urban heat index (UHI). The results show that the heat island phenomenon increases with urbanization in the city and tends to increase over the years. This research result is a practical basis to propose suitable spatial and landscape planning solutions for the city, towards green and sustainable urban development.

Keywords Quy Nhon · Landsat · Surface temperature · City warming

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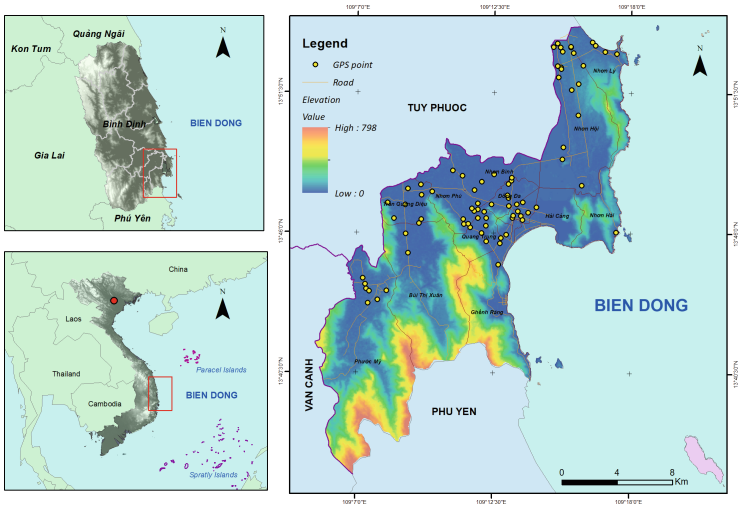

Fig. 1 Study area location

1 Introduction

In the contemporary world, the rapid process of city growth has a significant impact on the quality of life of urban residents due to a significant decrease in the quality of the urban environment and climate changes, a consequence of an increase of energy consumption. Along with the use of new materials on the surface cover, such as concrete, asphalt, bricks, etc., which has significantly changed the amount of radiation, heat, humidity, and emissions of the urban surface (Fig. 1).

In 1990, the population of Quy Nhon city was 200,000. However, by 2019, the population had reached 481 thousand with an urbanization rate of 60% [1]. With this amazing growth, observing land surface fluctuations of temperature becomes urgent to justify and find solutions for the city, towards a green and sustainable urban development.

2 Materials and Methods

2.1 Materials

To do this research, we collected all kinds of data such as the city administrative boundary layer map, traffic maps, hydrology systems, and Landsat remote sensing images from 1990 to 2020, which is available on Earth Explore website. In addition, we collected the information of the coordinates of representative points to the objects to be studied such as vegetation, roads, and rivers (Table 1).

Table 1 The quality image obtained from Landsat for six years in 1990–2020

Years	Name	Acquisition date	Quality (%)	Cloud coverage (%)
1990	LT0512305119900716	16/07/1990	99	2
1996	LT0512305119960630	30/06/1996	90	1
2005	LT0512305120050506	06/05/2005	70	1
2011	LT0512305120110608	08/06/2011	70	2
2015	LC0812305120150705	05/07/2015	90	6.7
2020	LC0812305120200515	15/05/2020	90	2.6

2.2 Research Methods

2.2.1 Method of Field Survey

As a traditional method of geography, field research results are an important basis in determining land use types. The method of field survey is collecting 80 survey points for image classification and assessing the accuracy.

2.2.2 Remote Sensing Image Processing Method

We use remote sensing image processing software—QGIS to perform layer stacking, color combination, and perform image interpretation by support vector machine (SVM) [2].

2.2.3 The Method of Calculating the Surface Temperature Value

Conversion of the Digital Number to Spectral Radiance

Landsat data was collected as grayscale images of 1C level products. Therefore, it is necessary to convert the satellite image to satellite spectral radiance using a given Formula 1 [3].

$$L_\lambda = \frac{LMAX_\lambda - LMIN_\lambda}{Q_{cal\,\max} - Q_{cal\,\min}}(Q_{cal} - Q_{cal\,\min}) + L_{\min} \tag{1}$$

L = At sensor spectral radiance in [W/(m^{2}srμm)]; Q_{cal} = Landsat image (digital number DN); Q_{calmin} = Minimum quantized calibrated pixel value corresponding to $LMIN_\lambda$; Q_{calmax} = Maximum quantized calibrated pixel value corresponding to $LMAX_\lambda$; LMIN = Spectral at sensor radiance that is scaled to Q_{calmin}; LMAX = Spectral at sensor radiance that is scaled to Q_{calmax}.

Converting the Spectral Radiation Value to Temperature

Images are converted from spectral radiation values to physical variables will be more useful. This is the effective satellite temperature. Landsat infrared thermal band images can be converted from spectral radiation values to more useful physical variables. This is the effective satellite temperature of the system viewed from the earth the lower atmosphere assumes an emission of 1 ($\varepsilon = 1$) and is converted according to the Planck physical Formula 2 [3].

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)} \tag{2}$$

With TB: At satellite brightness temperature (Unit Kelvin—K); K1: Adjustment coefficient 1 (W/m^2.Ster.um); K2: correction factor 2 (K); L: Spectral radiation value (W/m^2.Ster.um) and converted by Planck's physical formula.

The Way of Calculating the Value of Surface Temperature

Temperature is closely related to the surface emissivity (ε). Emission is the ratio of energy emitted from the natural surface and energy emitted from a black body at the same wavelength and temperature. The method of calibrating temperature based on surface emissivity is as follows [3]:

$$LST = \frac{T_B}{1 + \left(\frac{\lambda T}{\alpha}\right) * \ln \varepsilon} \tag{3}$$

where λ: is the wavelength of the emitted radiation; a = hc/K (1438×10^{-2} mK); h: Planck's constant (6.26×10^{-34} J s); c: speed of light (2998×10^8 m/s); K: Stefan Boltzmann's constant (1.38×10^{-23} J/K). For obtaining the results in Celsius the research was converted Kelvin temperatures to Celsius temperatures according to the following Formula 4 [3].

$$T = LST - 273.5 \tag{4}$$

2.2.4 Method of Calculating the Urban Heat Island Intensity Index (UHI Index)

The UHI intensity index is a method for determining the spatial distribution of the UHI intensity, estimated by Eq. 5. The output is always scaled into three categories from strong heat island to low heat island. This will be illustrated in the results section [4].

Table 2 The way of assessing the degree of urban heat island in Quy Nhon city

Level	Limitation	Significance
None	<−0.1	It is mainly vegetation and water
Weak	−0.1–0.0	This level is considered as weak
Moderate	0.0–0.5	This level is considered as moderation
Strong	0.5–1.5	The area is urban heat exploitation
Very strong	1.5–2.0	The area is in a state of high urban heat exploitation
Extremely strong	>2.0	The area is in a state of very high urban heat exploitation

$$T_r = \frac{T_i - T_a}{T_a} \tag{5}$$

With T_r is relative LST; T_i is LST at one location; T_a is the average LST.

In order to assess the urban heat exploitation level, we use the urban heat island assessment scale to divide urban heat island levels into the following levels (Table 2).

3 Results and Discussion

3.1 Establishing a Map of Urban Heat Islands in Quy Nhon City

We used the above theoretical formulas and built a series of surface temperature maps for Quy Nhon city from 1990 to 2020, with the following map results:

Through Fig. 2, we can see that the surface temperature of the regions with the temperature from 30 to 35 °C is tending to increase gradually over time. Also, the area with the temperature of 17–23 °C is in danger of being clearly narrowed. The reason is the need of urban soil for housing the population that comes from the suburban area and countryside to the city.

This requires planners to carefully study the issue of territorial planning both following current trends while ensuring social, economic and environmental sustainability. To understand the change of land use cover in the period of 1990–2020, we combined remote sensing images with infrared complexes. Then we interpreted remote sensing images according to the object-oriented classification algorithm.

To show the urban fluctuations in the city, we used a land cover map with five land cover types identified to classify specifically urban land, unused land, agricultural land, forest land, and water surface land. The study used the SVM tool in QGIS software to classify remote sensing images with 60 samples out of 80 field survey interpretation keys. After that, the results were assessed with the remaining 20 test samples through the Kappa index. The accuracy results shown in the Kappa index

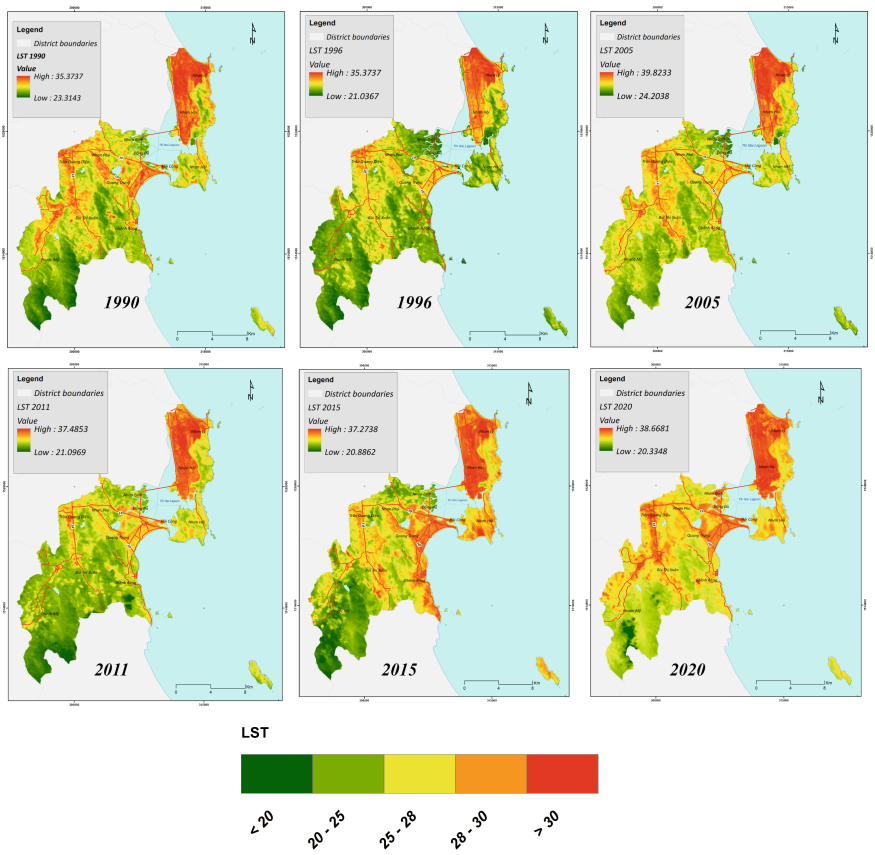

Fig. 2 Surface temperature map of Quy Nhon city from 1990 to 2020

were all bigger than 0.77. This result allowed us to calculate the next steps in evaluating the relationship between ground temperature and land cover in Quy Nhon city (Fig. 3).

Through the result of the classification of the land cover in Quy Nhon city from 1990 to 2020, it illustrates that the area of wetlands in the estuarine area of the Ha Thanh river is being narrowed gradually along the process of urban growth. Besides, the urban land area has also been expanding overtime on routes 1A, 1D, Highway 19.

To determine the urban heat island arising in the study area, we have based on the results of calculation of surface temperature of Quy Nhon city from 1990 to 2020 and used formula 5 to calculate the urban heat island in Quy Nhon city. It is graded into 6 intensity levels.

Through Fig. 4, the UHI status in Quy Nhon city is as follows: The area of the UHI phenomenon is mainly concentrated in urban areas of Quy Nhon city and residential areas gathered around 1A, 1D, national highways 19, and residential areas.

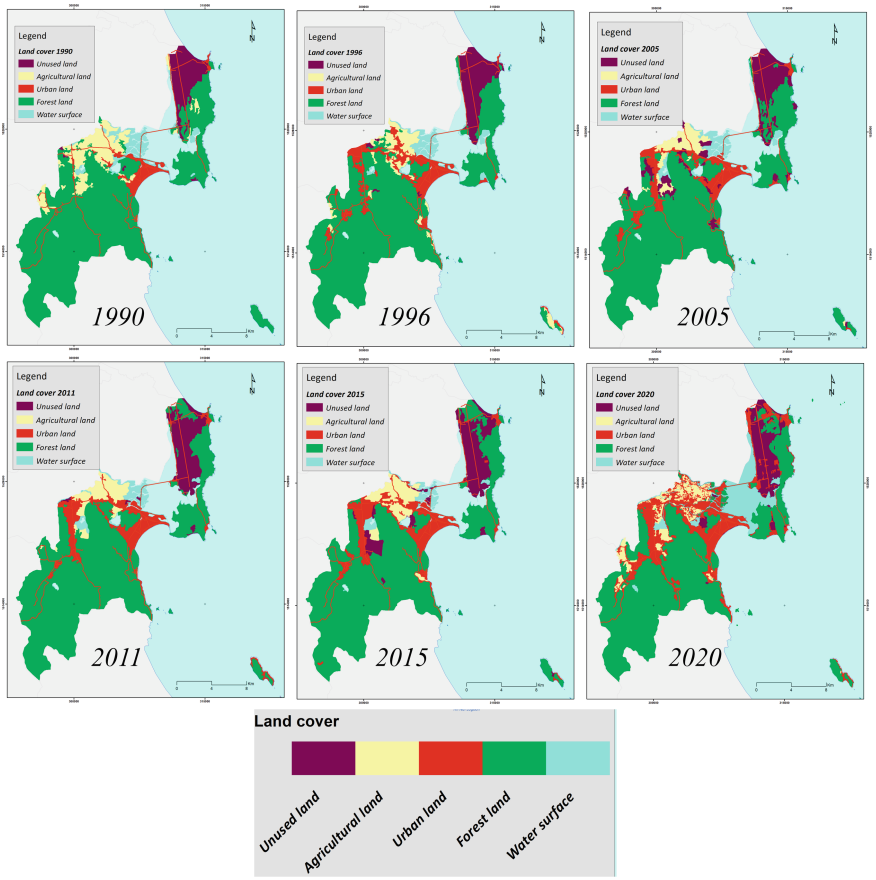

Fig. 3 Map of Quy Nhon city land cover from 1990 to 2020

Especially, in recent years, the urban expansion in the northern area of Nhon Hoi and the area of Thi Nai lagoon has led to all mangroves and shrubs destruction changing to residential and infrastructure purposes, leading to very high urban heat islands.

3.2 Assessing the Urbanization Relationship and the Heat Island Effect

Through Fig. 5, it shows that the trend of LST increases when there is urban land and bare land. This proves that LST is directly proportional to urban surface and vacant land when it is not used. On the other hand, LST tends to decrease when the soil is covered with water and plants. From this, we can recognize the importance of natural factors such as vegetation and water for urban development, especially during

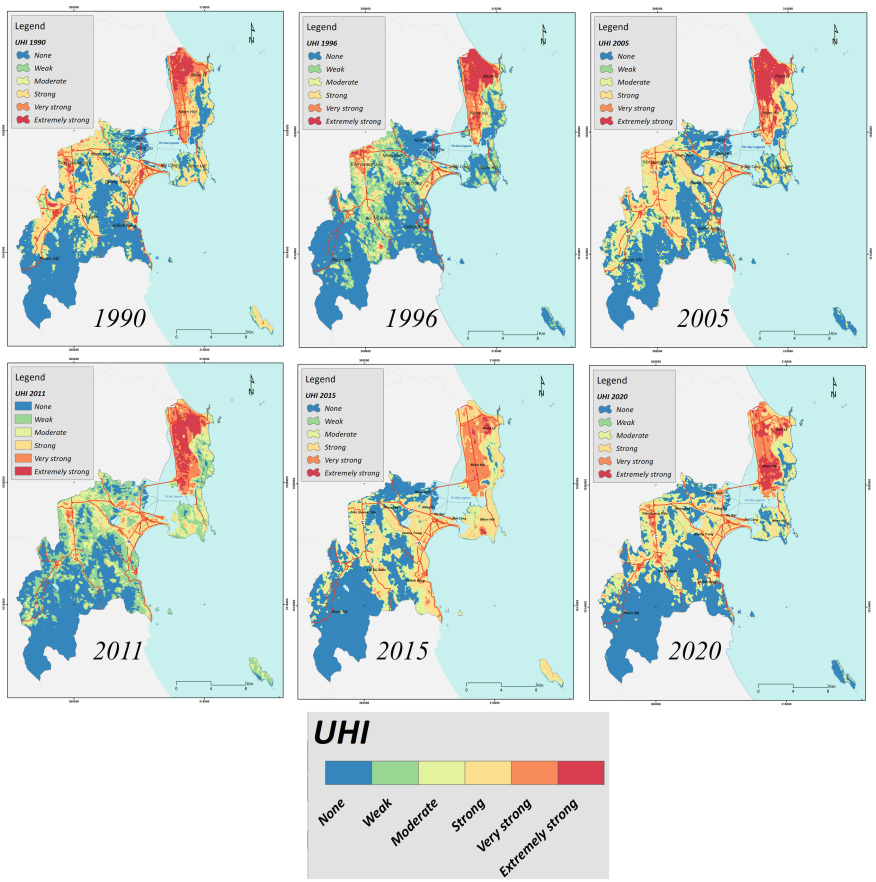

Fig. 4 Map of Quy Nhon city urban heat island from 1990 to 2020

the hot season. We can say that the impact of the urbanization process has changed the land cover, causing heat in urban areas caused specially by the development of infrastructure, which has made an LST increase.

4 Conclusions

In this study, the research provides temperature maps and land cover maps in Quy Nhon city in a 30-year period from 1990 to 2020 under the support of GIS tools. The results of the study show that urban land is expanding every year and the warming phenomenon is also rising with city development over the period in question. Temperature changes on land surface in the context of urbanization in Quy Nhon City, Viet Nam will help planners to have a more intuitive view of current affairs in the city

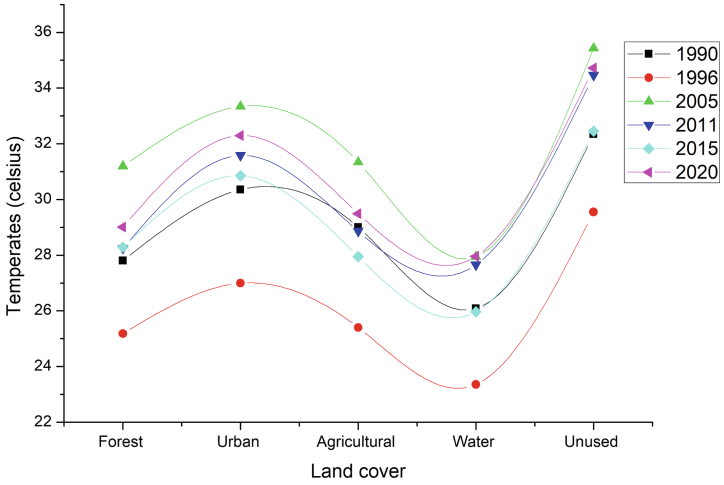

Fig. 5 The surface temperature of ground cover from 1990 to 2020

so that they can make policies for sustainable urban development and mitigation of climate change, especially the current warming phenomenon in urban areas.

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