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An approach to analyze process of urbanization in Dong Nai – Sai Gon River Basin

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Abstract

Urbanization is occurring rapidly in the developing countries in the coming decades. The urbanization changed Land Use/Land Cover (LULC) and increased urban population uncontrollably. The objective of this paper is to analyze the characteristics of urbanization in Dong Nai - Sai Gon River Basin. Four Landsat images from 1988, 1999, 2010 and 2016 were used to extract urban land employing a maximum likelihood classifier approach. Land surface temperature (LST) was obtained from thermal infrared band of remote sensing data. In addition, population statistics were also collected as indicators of the urbanization in the study area. Resulting analysis showed the urban spatial is rapidly expanded over times. Development of export processing zones and industrial parks has overshadowed the boundary between satellite towns and Ho Chi Minh City.

Keywords: Urbanization; population; Land Use/Land Cover; Land surface temperature; Landsat

1. Introduction

Nowadays, the urbanization is occurring rapidly in the developing countries (Cohen, 2004; Cui & Shi, 2012). From 1950 to 2014, the urban population of the world reached 3.2 billion people and is expected to add 2.5 billion urban residents in 2050, with 90 percent of the mainly rise in Asia and Africa (Un, 2015). Urbanization has become a major cause of urban environmental issues (Mohapi, 2009), which can affect the safety and quality of urban residents (Bhatta, 2010; Chen, Zhao, Li, & Yin, 2006).

The Dong Nai – Sai Gon River Basin is located in the most development commercial area in Vietnam and is a very important role in the development of the national economy. The population of this region has increased considerably in recent years because of the strong development of the urbanization and industrialization (Huyen & Tuan, 2004). The elements occur in urban development such as employment, environment, infrastructure... which often beyond the determined administrative boundaries. Through the model developed in the form of the multi-center/multi-polar, the urban space of Ho Chi Minh City and neighboring areas are gradually merging into one another (Việt, 2015). The approaches to the study of urbanization issues are diverse, because the

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developments have different characteristics for each urban (Rob & Talukder, 2013). The application of remote sensing data for monitoring the urbanization is commonly used for clarifying situation and solving problems of the urban environment (Cui & Shi, 2012; Xian & Crane, 2005; Xu & Li, 2005). The objective of this study is to evaluate the process and the characteristics of urbanization in Dong Nai – Sai Gon River Basin based on collected data and remote sensing images.

2. Study Area and Data Set

2.1. Study Area

The study area includes the districts of Dong Nai, Binh Duong and Ho Chi Minh City where is basin of Dong Nai - Sai Gon River. Located in the Southeast Region of Vietnam, its geographical coordinate has the range of the longitude (105°48'33"E - 107°35'58"E) and latitude (10°19'13"N - 12°17'54"). This region has a total area of 1887 square kilometers. Bien Hoa City, Thu Dau Mot City and Ho Chi Minh City are the large cities in the study area.

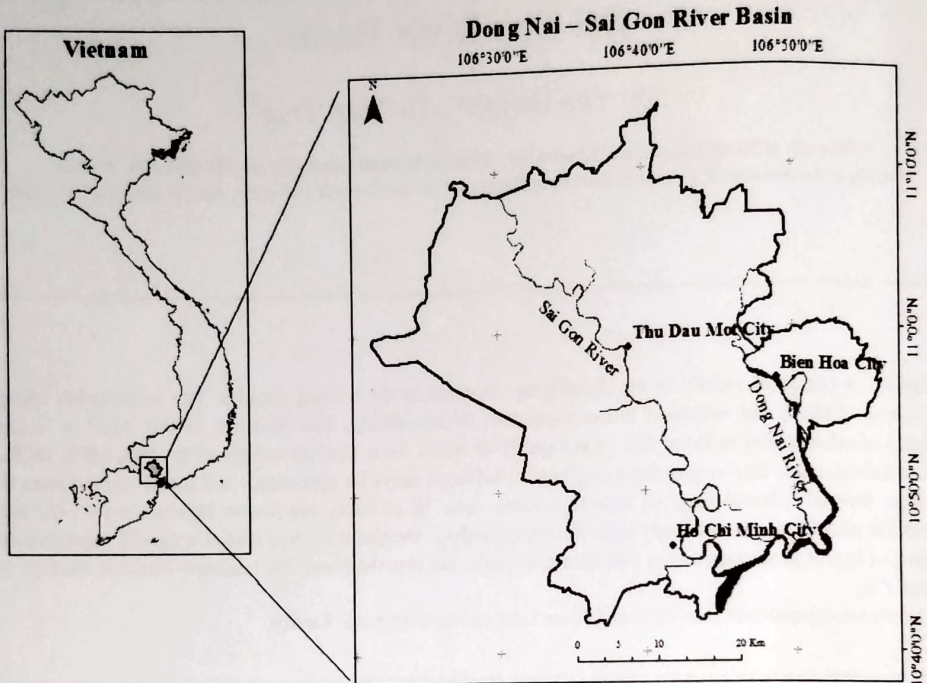


Fig. 1. Location of the study area

2.2. Data Sets

Social statistical data of the study area was collected to characterize the population changes over the years.

In order to obtain the information of built-up land and land surface temperature, multi-period remote sensing data is collected from the website USGS. Based on the historical development in Dong Nai – Sai Gon River Basin, 4 cloud-free scenes are collected for 4 dates and in the same season include Period 1 (01-30-1988, Landsat 5 TM), Period 2 (01-25-1998, Landsat 5 TM), Period 3 (02-11-2010, Landsat 5 TM) and Period 4 (01-11-2016, Landsat 8 OLI/TIRS).

3. Methods

3.1. Pre-processing of remote sensing image

3.1.1. Radiometric corrections

A) Conversion of DN values to spectral radiance

Coefficient and equation are different, which depends on the type of satellite. The results of this step are bands with value unit of $W m^{-2} sr^{-1} \mu m^{-1}$.

For Landsat 5 TM (Chander, Markham, & Barsi, 2007):

$$L_{\lambda} = ((LMAX_{\lambda} - LMIN_{\lambda}) / (QCALMAX - QCALMIN)) * (QCAL - QCALMIN) + LMIN_{\lambda}$$

Where L_{λ} , the cell value as radiance; QCAL, the cell value digital number; QCALMAX, QCALMIN, the maximum and minimum quantized calibrated pixel value; LMAX $_{\lambda}$, LMIN $_{\lambda}$, spectral radiance scales to QCALMIN and QCALMAX (LMIN, LMAX, QCALMIN, and QCALMAX values can be found in the Metadata file)

For Landsat 8 OLI/TIRS (USGS, 2013):

$$L_{\lambda} = MLQCAL + AL$$

Where L_{λ} , the cell value as radiance; QCAL, the cell value digital number; ML, Band-specific multiplicative rescaling factor; AL, Band-specific additive rescaling factor (ML and AL values can be found in the Metadata file)

B) Conversion of spectral radiance to TOA Reflectance

The equation used in this process is as follows (USGS, 2013):

$$\rho_{\lambda} = \frac{\pi \cdot L_{\lambda} \cdot d^2}{ESUN_{\lambda} \cdot \cos \theta_s}$$

Where ρ_{λ} , the Unitless planetary reflectance; L_{λ} , spectral radiance; d, the distance between Sun and Earth; $ESUN_{\lambda}$, mean solar exoatmospheric irradiances; θ_s , solar zenith angle.

3.1.2. Geometric corrections

All the images were reprojected into the projection of Vietnam (VN-2000) with a root mean squared error (RMSE) of less than 0.5 pixels.

3.2. Extraction Method of Built-up Land Information

Built-up land is extracted remote sensing image by supervised classification method. In particular, Maximum Likelihood Classifier - MLC is the most popular classification method used for remotely sensed data (Jensen & Lulla, 1987). The division of the number of object classes for the classification is based on the following factors: 1) Land Law, 1993 và Decree No.88/CP, 1994 on urban land management; 2) the purpose of the research and 3) spectral characteristics of objects. Four types of land surface are determined in research including: built-up land, vegetation, bare land, and water bodies. The result of this process is shown with three main subjects: built-up land, non-built-up land and water body.

3.3. Extraction Method of Land surface temperatures Information

The Landsat satellite images after being transferred from DN values to spectral radiance (brightness temperature), the Land surface temperature is derived on thermal bands by using Planck curve equation (Markham & Barker, 1986).

$$T = K2 / \ln(K1 / L_{\lambda} + 1)$$

Where T, At-satellite brightness temperature (Kelvin); K2, Calibration constant 2 (K2 = 1282.71 Kelvin); K1 = Calibration constant 1 (K1 = 666.09 $W/m^2 \cdot sr \cdot \mu m$); L_{λ} = Spectral radiance ($W/m^2 \cdot sr \cdot \mu m$)

The transfer value of Land surface temperature from Kelvin (oK) to Celcius (oC) is calculated according to the formula:

$$T^{\circ}C = T \text{ (Kelvin)} - 273.16$$

4. Results

4.1. Change of population and population density

Since the economic reforms initiated in Vietnam (1986), the urbanization rapidly developed in the country. So it is necessary to establish new urban, extend urban or upgrade urban.

According to the collected population statistics of Dong Nai, Binh Duong and Ho Chi Minh City over the years as follows:

Table 1. Population statistics¹ of Dong Nai, Binh Duong and Ho Chi Minh City that are represented both Table 1.A and Table 1.B

Table 1.A				Table 1.B			
Year	Population (people)			Year	Population (people)		
	Dong Nai	Binh Duong	Ho Chi Minh City		Dong Nai	Binh Duong	Ho Chi Minh City
1979	1,035,937	-	3,419,977	2004	2,220,500	1,037,100	6,044,962
1989	1,542,927	-	3,988,124	2005	2,263,800	1,109,300	6,291,055
1990	1,624,600	-	-	2006	2,314,900	1,203,700	6,541,508
1996	1,882,200	-	4,747,900	2007	2,372,600	1,307,000	6,778,867
1997	1,920,000	679,044	4,852,300	2008	2,432,700	1,402,700	7,000,746
1998	1,959,300	700,100	4,957,300	2009	2,483,211	1,482,636	7,201,550
1999	1,989,541	721,933	5,037,155	2010	2,559,673	1,619,930	7,396,446
2000	2,054,100	742,790	5,274,900	2011	2,640,200	1,659,100	7,521,138
2001	2,093,700	769,946	5,489,122	2012	2,707,800	1,731,000	7,660,300
2002	2,132,100	810,190	5,655,798	2013	2,772,700	1,802,500	7,820,000
2003	2,176,100	853,807	5,846,086	2014	2,838,600	1,873,600	7,981,900

Population increased continuously over the years in the study area. Bien Hoa City is the industrial city of Dong Nai province with a population of 1,104,495 people (2015) and is currently a provincial city with the largest population in the country². After being separated from the Song Be province (1997), from 1999 to 2009 the population of Binh Duong province has doubled where is the highest population growth rate in the country (7.3% per year). Ho Chi Minh City is the most populous province of Vietnam and is expected to become a megacity with a population of more than 10 million people in 2025³.

Population is unevenly distributed in each province. In Dong Nai, population density of delta region is six times as high as hilly region's one, including Bien Hoa City is the most concentrated population of the province with 41.6% of the provincial population and population density of 4,182 people/km². In Binh Duong, the population is concentrated in the districts in South and Southwest (adjacent to Ho Chi Minh City and Dong Nai) with a density of 3,000 people/km², where there are rapidly growing industry and convenient transportation, where only about 8.62% of the area but account for 55.34% of the provincial population (Hiên, 2012). In Ho Chi Minh City, a large population is concentrated in the urban districts with a density of 40,000 people/km², while the suburban districts have less population (100 people/km²)⁴.

4.2. Change of built-up land

The result of the built-up land maps is shown in Fig.2. The result show that a total built-up area was 71.91 km² in 1989, this increased to 184.78 km² by 1998, after that the built-up area was 691.08 km² in 2010 and now is 833.85 km² in 2016. From 1989 to 2016, the total built-up area of Dong Nai – Sai Gon River Basin has increased approximately 12 times.

¹ Statistical data is referenced from the following sources: Population Vietnam 1-10-1979 (1983); Vietnam - Population and Housing Census 1989 (1992); Vietnam - Population and Housing Census 1999 (2001); The 2009 Vietnam Population and Housing census: Completed results (2010); Statistical Yearbook of Binh Duong 2007 (2007); Population and population density of Ho Chi Minh City in 2010 by district (2010); Geography of the province and the city of Vietnam (2006); Portal Dong Nai; Portal Binh Duong; Portal Ho Chi Minh City

² Resolution No. 05/NQ-CP dated May 05th, 2010 by the Government: V/v Điều chỉnh địa giới hành chính huyện Long Thành để mở rộng địa giới hành chính thành phố Biên Hòa thuộc tỉnh Đồng Nai

³ Ho Chi Minh City's overall Socio-Economic Development Plan (2014)

⁴ Population and population density of Ho Chi Minh City in 2010 by district (2010)

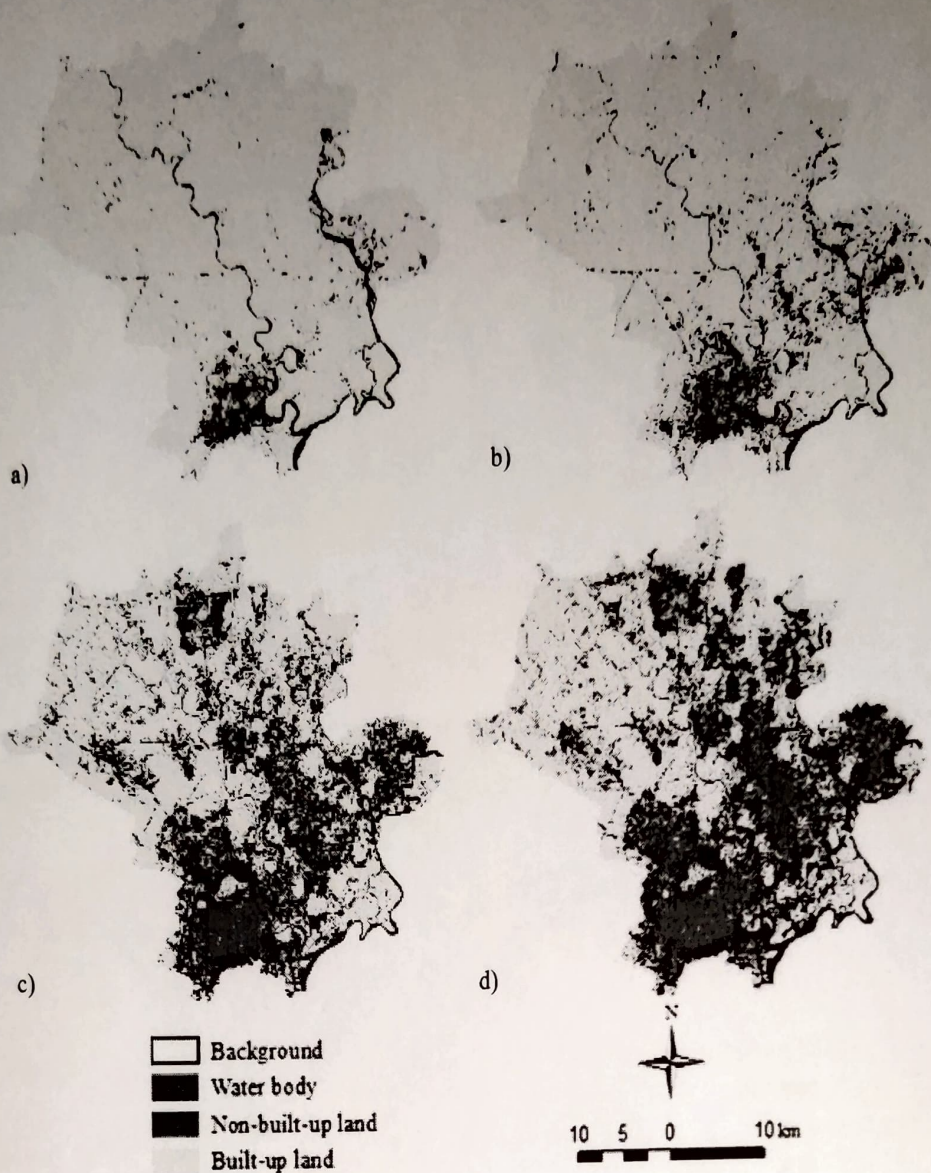


Fig. 2. The map of built-up land; (a) in 1989, (b) in 1998, (c) in 2010, (d) in 2016

In 1989, built-up land mainly concentrated in the central area of the Ho Chi Minh City and Bien Hoa City. In 1998, the urban space of Ho Chi Minh City was extended to the North in the direction of National Highway 1A to the provinces of the South-eastern region in Vietnam. From 1998 to 2010, the Southeast of Ho Chi Minh City appeared many urban areas with dense population density, population in the Southwest also developed rapidly due to the development of transport, especially the continued expansion of urban areas and industrial zones in the North and Northeast of the city. In addition to, a large amount of cultivated land is converted into building land with large industrial zones in the region of Di An, Thuan An and Bien Hoa City, which has attracted a large number of people from other localities. By 2016, because of urban expansion policy so the Northeast region of Ho Chi Minh City continues to build residential areas. In Dong Nai and Binh Duong, the industrial districts have been invested in the construction and expansion of the plants. Tan Uyen District of Binh Duong was established to become an industrial districts for economic development in this region. Urban boundaries are eliminated between districts of Dong Nai, Binh Duong and Ho Chi Minh City by the process of industrial development. From that, the population of the study area can rotate together on accommodation and job.

4.3. Change of Land surface temperature

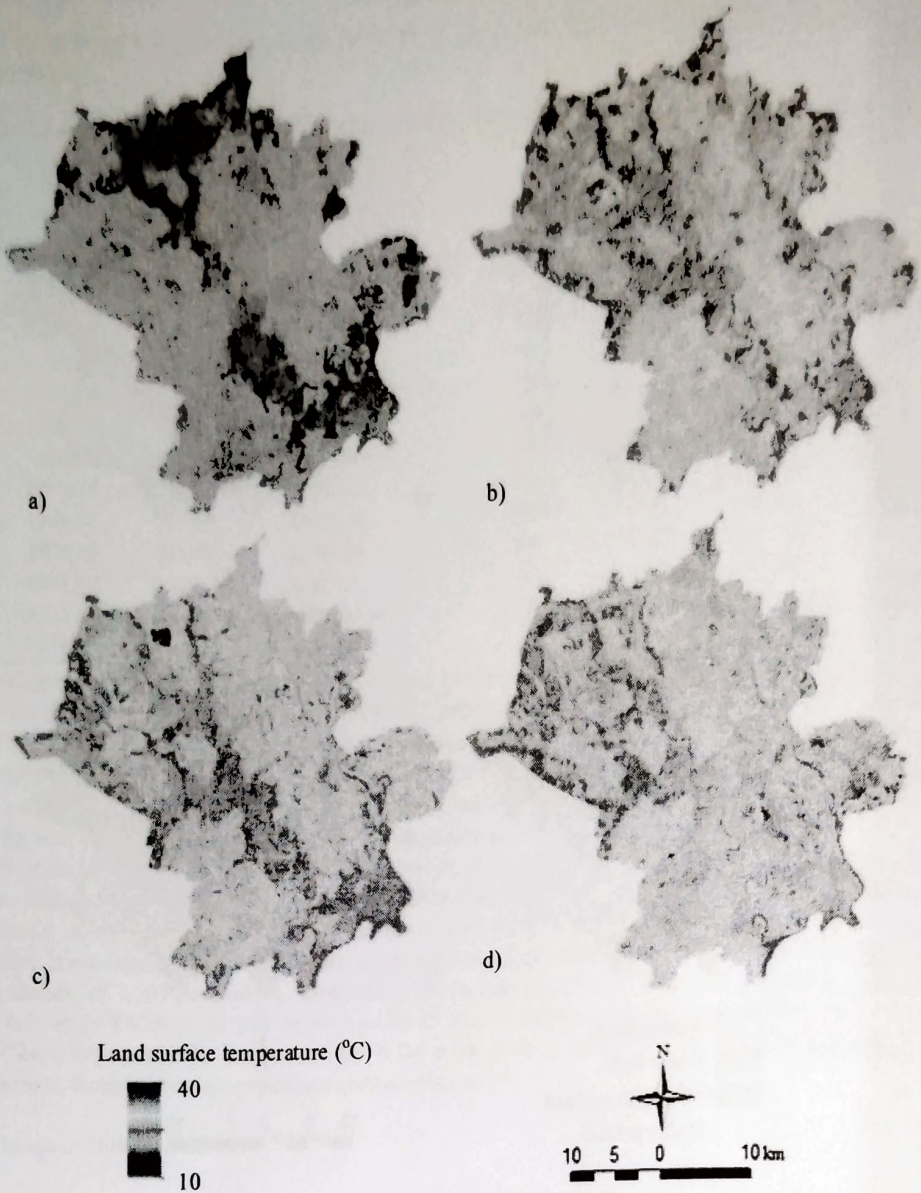


Fig. 3. The map of land surface temperature; (a) in 1989, (b) in 1998, (c) in 2010, (d) in 2016

Table of minimum, maximum and mean land surface temperature values of the study area for the 4 dates are shown below:

Table 2. Statistical data of land surface temperature for 4 dates (Unit: oC)

Date	Min	Max	Mean
01-30-1988	8	28	20.4
01-25-1998	22	36	27.1
02-11-2010	23	37	27.9
01-11-2016	23	40	29

Land surface temperature maps and statistical data results show that land surface temperature increases over the years. Mean land surface temperature of the study area have increased 6.7oC from 1988 to 1998 and this increased to 8.6°C by 2016.

Based on the result of the extraction of built-up and and the result of the extraction of land surface temperatur, mean land surface temperature for built-up land and non-built-up land are drawn as follows:

Table 3. Statistical data of mean land surface temperature for built-up land and non-built-up land

Date	Mean LST for built-up land	Mean LST for non-built-up land
01-30-1988	23.3	20.2
01-25-1998	30.2	26.8
02-11-2010	30.8	27.3
01-11-2016	33.2	28.1

The results show that high temperature concentrates in areas of built-up land or vacant land for construction. Land surface temperature of the urban areas is 3 - 5°C higher than land surface temperature of non-urban areas. The change of land-use has increased temperature in the study area. In addition, building density in urban area is increases over the years, which raises the temperature in this area.

5. Conclusion

The results of the data analysis showed that migration trends are continuing in Dong Nai, Binh Duong and Ho Chi Minh City by the process of industrialization and urbanization in the region. This is the main cause for significantly population increase with the number of migrants from other areas. However, the migration is unevenly occurring across Dong Nai, Binh Duong and Ho Chi Minh City. Geographical distribution of the urban population are constantly expanding in the district in Dong Nai – Sai Gon River Basin, where the focus of economic activity, education, industrial parks, export processing zones in the Southeast Region of Vietnam. A large amount of agricultural land is converted to industrial and residential land. This increases impervious surface area and significantly increases air temperature. Dong Nai – Sai Gon River function as a place to reduce the temperature to this urban area.

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