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The use of Built-Up Index and supervised classification in monitoring the built-up land area change of Binh Duong Province with Landsat image

Nguyen Thanh Ngan[a]*, Nguyen Quang Long[b]

[a]*Faculty of Environment, Ho Chi Minh City University of Natural Resources and Environment, 236B Le Van Sy Street, Ward 1, Tan Binh District, Ho Chi Minh City 705000, Vietnam*

[b]*Faculty of Environmental Sciences, Ho Chi Minh City University of Science, 227 Nguyen Van Cu Street, Ward 4, District 5, Ho Chi Minh City 703000, Vietnam*

Abstract

Binh Duong Province is one of the six administrative divisions of the Southeast Region. In recent years, the built-up land area in this province tends to change quickly. This paper presents the obtained results on the use of Built-Up Index (BUI) and supervised classification in monitoring the built-up land area change in Binh Duong Province from 1988 to 2015 with Landsat image. The accuracy of the classification process is shown through two coefficients: Kappa coefficient and overall accuracy. The Kappa coefficients of the classification results in 2010 and 2015 greater than 0.8 (respectively 0.8149 and 0.8432) has indicated that this solution is suitable for monitoring the built-up land area change. This research has shown the area value and the changing trend of built-up land in Binh Duong Province from 1988 to 2015, created the basis for the effective built-up land management in this region.

Keywords: built-up land; Binh Duong Province; Built-Up Index; supervised classification; Landsat image.

1. Introduction

Binh Duong Province is an administrative division in the Southeast Region of Vietnam, adjacent with Ho Chi Minh City in the south. This province is also located in the Key Economic Zone in the South, a dynamic developed region of Southern Vietnam. In recent years, because of the economic development, the urbanization process in Binh Duong Province occurs with a rapid rate. This makes the built-up land area in this province tends to change quickly. This causes a lot of difficulties and challenges for the managers in Binh Duong Province. With this reason, the managers must have effective solutions for monitoring built-up land area change, provide the basis for building appropriate strategies for managing the built-up land in this province. Using Landsat image - a type of medium-resolution satellite - to monitor built-up land area change is a possible solution to resolve that issue. This solution has been used in many parts of the world and Vietnam [1-11]. To address the research goals, the authors use Built-Up Index (BUI) and supervised classification in monitoring the

* Corresponding author. Tel.: +84-090-2382-799.
E-mail address: ntngan_hcmunre@yahoo.com.

built-up land area change in this province from 1988 to 2015. The study area is the entire of Binh Duong Province.

The BUI is a new index proposed by J. A. Lee, S. S. Lee and K. H. Chi in 2010 to distinguish non-built-up and built-up areas in Landsat image [12]. The non-built-up areas (forest land, farmland, parks) have low BUI values, while the built-up areas (commercial fields, public fields, resident areas) have high BUI values [12]. The BUI is calculated by taking Normalized Difference Built-up Index (NDBI) minus Normalized Difference Vegetation Index (NDVI) [12]. The NDBI is proposed by Y. Zha, J. Gao and S. Ni in 2003, while the NDVI is proposed by J. W. Rouse, R. H. Haas, J. A. Schell and D. W. Deering in 1973 [13, 14]. The BUI equation can be represented as following [12]:

$$BUI = NDBI - NDVI = \frac{(SWIR - NIR)}{(SWIR + NIR)} - \frac{(NIR - Red)}{(NIR + Red)}$$

Where NIR is near infrared band (0.76-0.96 µm), Red is red band (0.60-0.70 µm) and SWIR is shortwave infrared band (1.55-1.75 µm) in Landsat image. With this research, this is the first time that the BUI is used for monitoring the built-up land area change in Vietnam.

2. Methods and data

2.1 Methods

The research process is divided into six phases: (1) collecting related data, (2) correcting Landsat images, (3) enhancing and transforming Landsat images, (4) classifying Landsat images and assessing the accuracy, (5) building built-up land distribution maps and estimating built-up land area, (6) evaluating results and drawing conclusions. In order to do this research, the authors use mainly three types of software: ArcGIS Desktop 10.1, ENVI 5.3 and Microsoft Excel 2016. ArcGIS Desktop 10.1 is a GIS software of ESRI Corporation used to create built-up land distribution maps, while ENVI 5.3 is a RS software of Harris Corporation used to calculate BUI and interpret Landsat images. The Figure 1 shows the detailed research process diagram. Phase (3) and (4) are most important because they decide the accuracy of the results obtained.

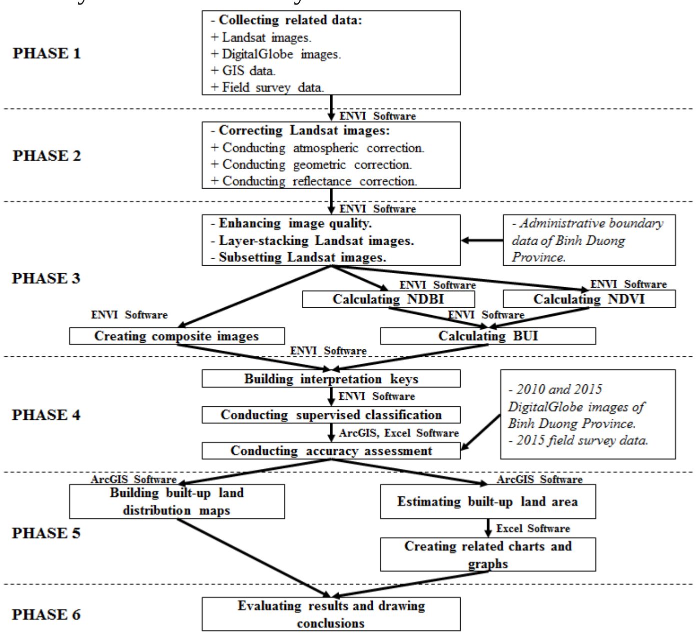


Figure 1. Detailed research process diagram

2.2 Data

In this research, the authors use three types of data: (1) remote sensing data, (2) GIS data, (3) field survey data. The remote sensing data are the Landsat images of seven years 1988, 1990, 1993, 1997, 2007, 2010 and 2015 of the study area. Besides that, the authors also use the DigitalGlobe images (a type of high-resolution satellite image that collected from Google Earth software) in 2010 and 2015 of the study area to build the base error matrices, create the basis for assessing the classification accuracy. The GIS data are the administrative boundaries of the study area. The field survey data are collected in 2015 with Garmin GPSMAP 60CSx handheld GPS navigator.

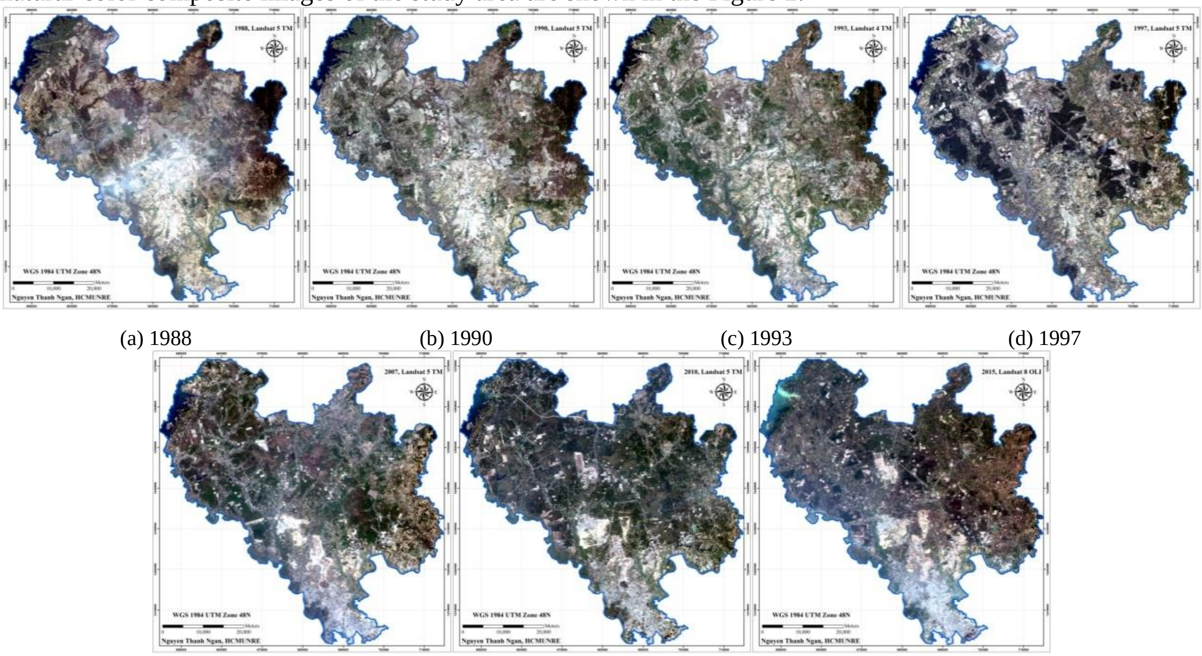
Table 1. Summary information of Landsat images used in this research

ID	Date Acquired	Satellite	Sensor	Path Row - Coordinate System
1	30/01/1988	Landsat 5	TM	125052 - WGS 1984 UTM Zone 48N
2	03/01/1990	Landsat 5	TM	125052 - WGS 1984 UTM Zone 48N
3	04/02/1993	Landsat 4	TM	125052 - WGS 1984 UTM Zone 48N
4	06/01/1997	Landsat 5	TM	125052 - WGS 1984 UTM Zone 48N
5	03/02/2007	Landsat 5	TM	125052 - WGS 1984 UTM Zone 48N
6	11/02/2010	Landsat 5	TM	125052 - WGS 1984 UTM Zone 48N
7	24/01/2015	Landsat 8	OLI&TIRS	125052 - WGS 1984 UTM Zone 48N

3. Results and discussion

3.1 Results of creating color composite images and calculating BUI

After collecting Landsat images from the GloVis website of USGS, the authors conduct to correct and enhance quality of these images. The enhanced images are subsetted with the administrative boundaries of Binh Duong Province. The subsetted images are used to create the color composite images of the study area. In the color composite images, each land cover type is represented by a different specific color. These specific colors help the interpreter easy to discriminate land cover types, provide the basis to determine interpretation keys. The natural-color composite images of the study area are shown in the Figure 2.

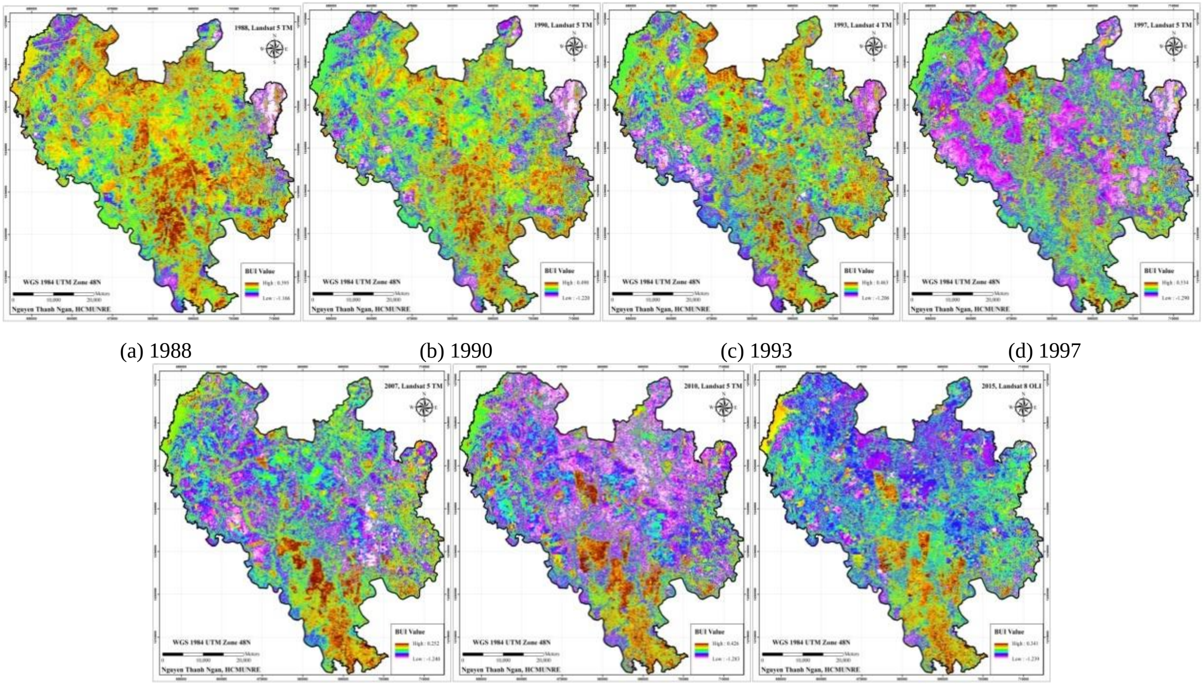


(a) 1988 (b) 1990 (c) 1993 (d) 1997

(e) 2007 (f) 2010 (g) 2015

Figure 2. Natural-color composite images of the study area

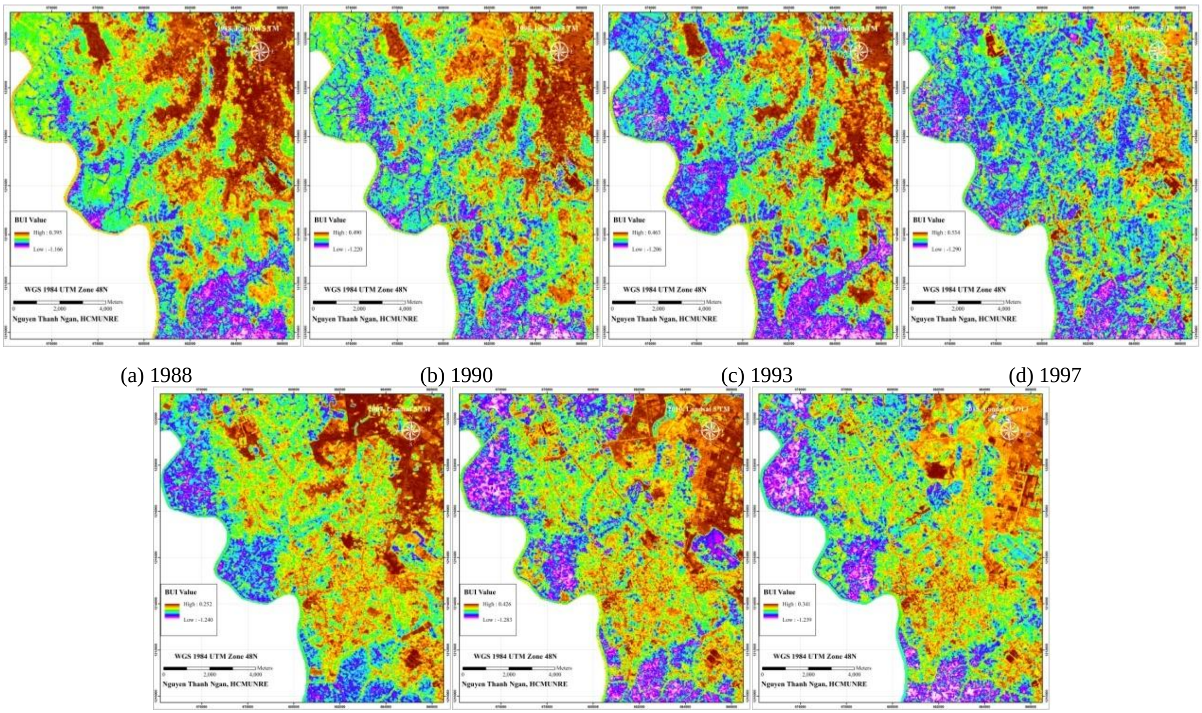
Besides creating color composite images, the authors also calculate BUI for the subsetted images. This is an important index to support for the determination of interpretation keys for built-up areas. The Figure 3 shows the BUI images of the study area and the Figure 4 illustrates Thu Dau Mot City in BUI images.



(a) 1988 (b) 1990 (c) 1993 (d) 1997

(e) 2007 (f) 2010 (g) 2015

Figure 3. The results of the BUI calculation



(a) 1988 (b) 1990 (c) 1993 (d) 1997

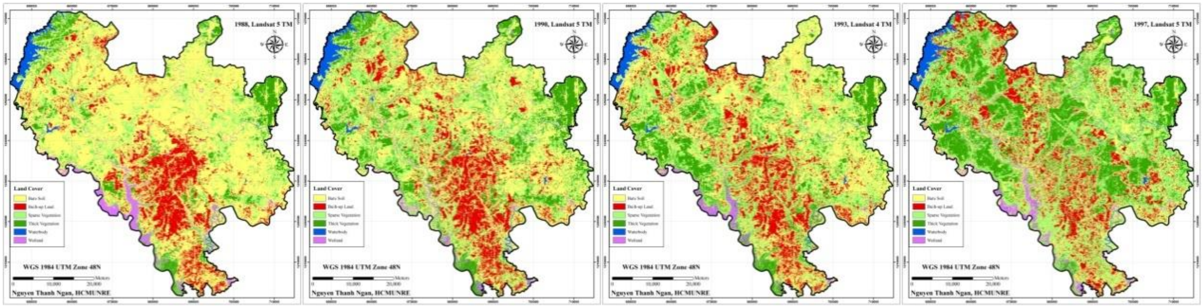
(e) 2007 (f) 2010 (g) 2015

Figure 4. Thu Dau Mot City in BUI images

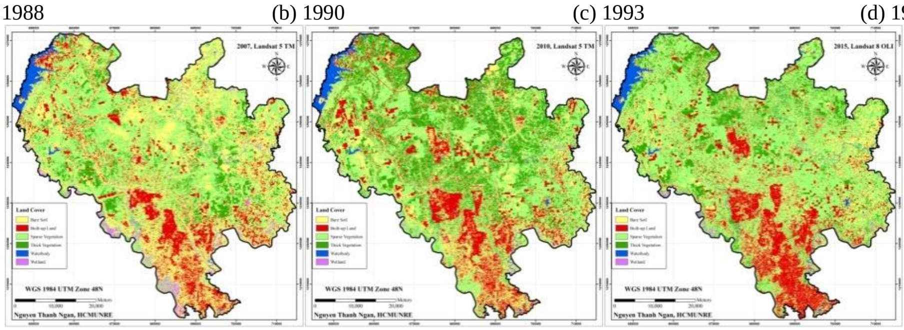
3.2 Results of classifying images and assessing the classification accuracy

The color composite images and the BUI images are combined to determine interpretation keys. Determining interpretation keys is an important process in classifying Landsat images because it affects the accuracy of the classification process. After determining interpretation keys, the supervised classification is conducted on the subsetted images with the Maximum Likelihood algorithm. This process separates the study area into six main classes: (1) bare soil, (2) built-up land, (3) sparse vegetation, (4) thick vegetation, (5) waterbody, (6) wetland. The supervised classification results of the study area are shown in the Figure 5.

The base error matrices are built from the classification results in order to assess the accuracy of the classification process. These matrices help to estimate the Kappa coefficient and the overall accuracy of the classification process. Because of the lack of reference data, the authors can only assess the accuracy for the classification results from 2010 and 2015 images (Google Earth only provides the DigitalGlobe images of the study area from 2010 to 2015). With the classification results from 2010 image, the Kappa coefficient value is 0.8149 and the overall accuracy value is 82.16%. With the classification results from 2015 image, the Kappa coefficient value is 0.8432 and the overall accuracy value is 84.95%.



(a) 1988 (b) 1990 (c) 1993 (d) 1997



(e) 2007 (f) 2010 (g) 2015

Figure 5. Supervised classification results of the study area

The classification results are also used to estimate the percentage of land cover types over the years in the study area. The Figure 6 shows the chart of percentage of land cover types from 1988 to 2015 in the study area.

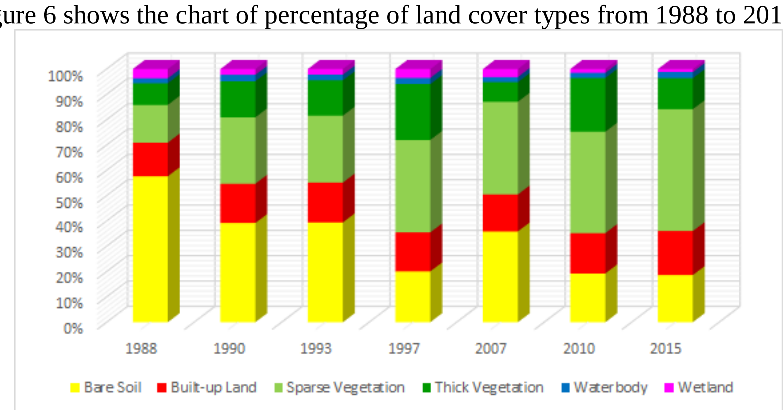
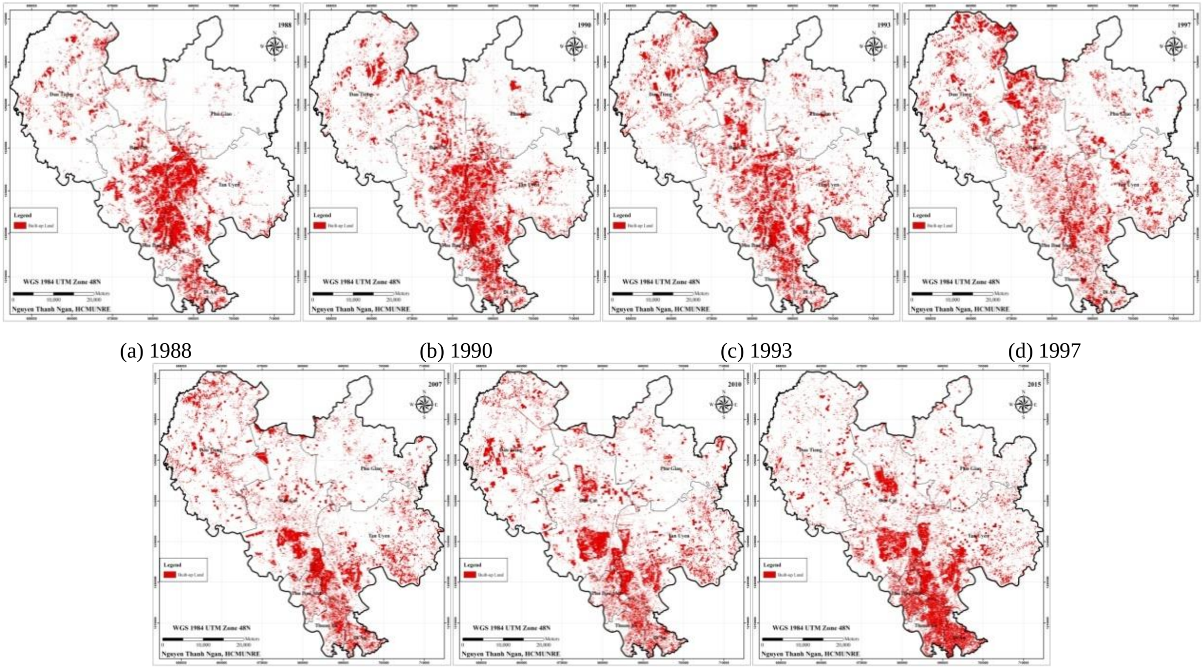


Figure 6. Chart of percentage of land cover types in the study area from 1988 to 2015

3.3 Results of building built-up land distribution maps and estimating built-up land area

In order to determine densities and spatial distributions of built-up land, the authors conduct to build the built-up land distribution maps of the study area. The built-up land data are extracted from classification results and combined with the administrative boundaries data of the study area to make built-up land distribution maps. These maps are represented in the Figure 7.



(a) 1988 (b) 1990 (c) 1993 (d) 1997

(e) 2007 (f) 2010 (g) 2015

Figure 7. Built-up land distribution maps of the study area

Besides building built-up land distribution maps, the built-up land data extracted from classification results are also used to estimate the area value, the percentage change and the annual percentage change over the years in the study area. The results of this process are shown in the Table 2. The area values of built-up land from estimating process are used to create the graph of the built-up land area in the study area from 1988 to 2015. This graph is shown in the Figure 8.

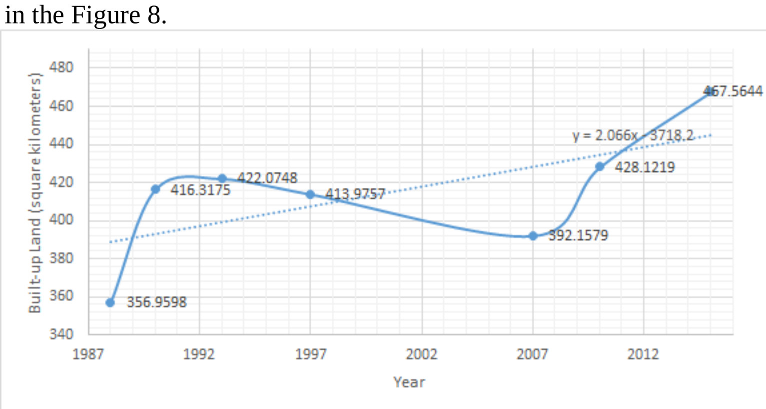


Figure 8. Graph of the built-up land area in the study area from 1988 to 2015

Based on the results in the Table 2 and the graph in the Figure 8, the authors identify the changing trend of built-up land in the study area from 1988 to 2015. From 1988 to 1990, the built-up land area in the study area tends to increase at a rate of 8.31% per year. This is the period which the built-up land area grows fastest. From 1990 to 1993, the built-up land area in the study area tends to increase at a rate of 0.46% per year. From 1993 to 1997, the built-up land area in the study area tends to decrease at a rate of 0.48% per year. From 1997 to 2007, the built-up land area in the study area tends to decrease at a rate of 0.53% per year. The decline of built-up land area in these two periods is mainly due to the relatively strong expansion of sparse vegetation areas. From 2007 to 2010, the built-up land area in the study area tends to increase at a rate of 3.06% per year. From 2010 to 2015, the built-up land area in the study area tends to increase at a rate of 1.84% per year. In general, the built-up land area tends to increase during the entire study period (minimum value 356.96 km^2 in 1988 and maximum value 467.56 km^2 in 2015). Besides, based on the maps in the Figure 7, the authors also identify the spatial distribution of built-up land in the study area. The built-up land is mainly distributed in Ben Cat Town, Di An Town, Tan Uyen Town, Thuan An Town and Thu Dau Mot City.

Table 2. Area value and percent change of built-up land from 1988 to 2015.

Year	Pixels	Area (km^2)	Percent Change (%)	Annual Percent Change (%)
1988	396,622	**356.96**	**-**	**-**
1990	462,575	**416.32**	**16.63**	**8.31**
1993	468,972	**422.07**	**1.38**	**0.46**
1997	459,973	**413.98**	**-1.92**	**-0.48**
2007	435,731	**392.16**	**-5.27**	**-0.53**
2010	475,691	**428.12**	**9.17**	**3.06**
2015	519,516	**467.56**	**9.21**	**1.84**

4. Conclusions

From the results obtained, the authors find that this research has solved the research goal which is mentioned in the introduction. This research has determined the area value, the percentage, the changing trend, and the changing rate of built-up land in the study area from 1988 to 2015. Moreover, this research has also pointed out the characteristics of the spatial distribution of built-up land in the study area. These will be valuable data for the managers of Binh Duong Province, provide a basis for them to set out the right policies on managing built-up land sustainably. Both the Kappa coefficients of the classification results in 2010 and 2015 greater than 0.8 has indicated that the solution proposed in this paper (the combination of BUI and supervised classification) is suitable for identifying the built-up land in Landsat image. In addition, through this research, the authors have built a process to create built-up land distribution map and estimate built-up land area from Landsat image. This will be a useful reference for the studies in environmental management field.

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