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Mapping Changes of Surface Topography under Urbanization Process in Ho Chi Minh City, Vietnam, Using Satellite Imagery

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Abstract: Urbanization is indispensable for the development of humanity. The changes from the urbanization process have a significant impact on other components of natural systems in Ho Chi Minh City. The problem of filling low-lying swamps, ponds, lakes as well as canal encroachment has made significant changes to the shape of the surface topography of the city and particularly affected the current flood situation around the city. The objective of the study was to map changes in surface topography in relation to urbanization process in central part of Ho Chi Minh city during the period 1989- 2011. Band ratio method and Maximum Likelihood classification were implemented to separate the objects of urban and low-lying swamp from 3 satellite images in 1989, 2003 and 2011. The change detection has been done by post-classification method combined with GIS and field data to detect changes in the disappearance of low-lying swamps as well as the existence of urban areas on it. Classification process has resulted in an overall accuracy greater than 89% with urban area increased to a half of the entire area within 22 years. Meanwhile the area of low-lying swamps reduced almost 5 times compared to the existing area in the early stage. Research has built spatial maps of the current status and changing as well as carried out the analysis and evaluation to affect flooding in the city. This is a proof of the lack of scientific methods in the urban management and the positive transformation to reduce flooding today is needed.

Keywords: flood; low-lying swamps; remote sensing; surface topography; urbanization

1. Introduction

Urbanization is a process that has many different impact on hydrological conditions of a region. The development of cities in the delta makes groundwater resources depleted. As a direct consequence, the land surface will subside and be floodded. Urbanization also means that a lot of natural surface area is concreted. Consequently, rainwater penetrates the ground less, cannot complement depleting groundwater and surface runoff more, thus causing flooding. Fast urbanization leads to demand filling low-lying areas to raise ground levels in order to balance the local terrain, but in general, it makes imbalance because it broke the conditions themselves and made the water will flow in the direction uncontrollably, causing localized flooding more.

The low-lying areas, wetlands including ponds, lakes, ditches, flooded depressions ("low-lying swamp area" for short) represent the natural shape of a terrain area which is position to the ecological balance and water flow regulation. Human activities in the process of urbanization as constucting houses, entertainment areas, industrial zones... by filling up the low-lying swamps and encroaching canals significantly altered topographical shape of urban surfaces. They are very diverse. It will not be easy to reach them and map from the in-situ survey. Remote sensing objectively provides the current status information of land surface and supports human in accessing site remotely. People do not need to take place, also can recognize all of the surface change over space and time. It reduces the load of effort for the work of photogrammmetry in the field. Since 1996, there have been studies to track movements of terrain surface with application of remote sensing [1,2,3]. These researches have proved the potential of remote sensing applications in various domains for social life. In the present context when there are many events such as increasingly complex weather development, high sea level rise, rain frequency descent, greater rain intensity, flooding and uncontrol problems..., it requires to build the appropriate reservoirs, and finds solutions to prevent flooding problem. So the application of remote sensing in the study of assessing the human impact on surface topography is extremely essential.

The objective of the study was to map changes in surface topography in relation to urbanization process in central part of Ho Chi Minh city during the period 1989-2011 by using satellite imagery. Results of the research will be a good support for urban management, administration and management of flood mitigation for Ho Chi Minh City.

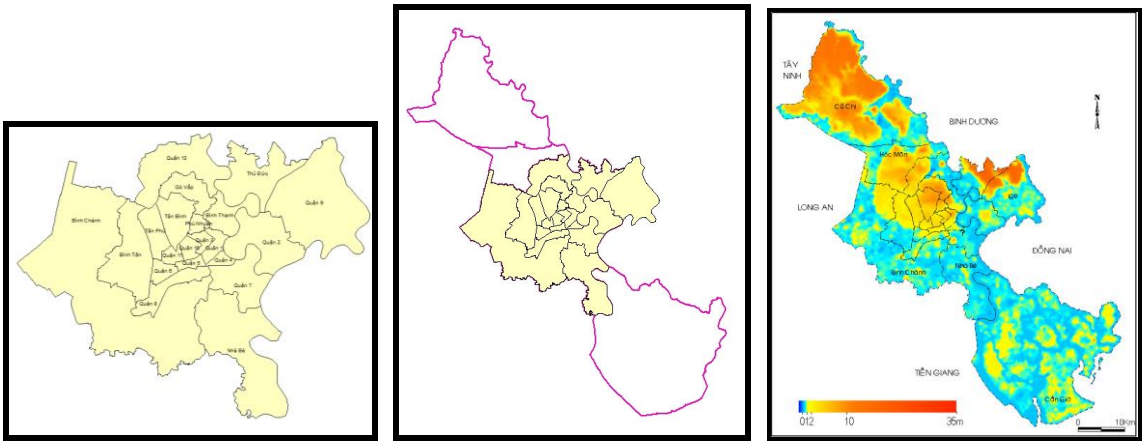
2. Experimental Section

2.1. Study area

Ho Chi Minh City is located in the southeastern region of Vietnam. Topography has lowered from north to south and from east to west. Area with an elevation of less than 2 meters accounts for 60 % of the city (Figure 1). Its dense network of canals is influenced by the ocean tide regime, so it often causes flooding to low-lying areas. However, flood water is draining quickly thanks to the dense

network of canals and low-lying swamps. Previously, the low-lying swamps as natural topography has an important role in water regulation of the whole city, especially for the urban area. In recent years, urban development spontaneously, unplanned and uncontrolly leads to increase impervious surface areas, reduce natural pervious surface areas. Besides, people fill up the low-lying swamp resulting the increasing surface runoff causing flooding more seriously.

Figure 1. Location of study area in Ho Chi Minh City



2.2. Data and Methods

Time survey was conducted in the period 1989-2011. Basic data used in this study were Landsat TM and Spot satellite images taken on 16-01-1989, 23-03-2003 and 24-02-2011. GIS data layers including maps of land use status in 1995 and 2010 were used in order to make training sample and compare the results of classification. Besides, topographic base map at scale of 1:25,000, consisting of layers of hydrological systems, transportation and elevation were also collected.

Based on remote sensing image, the color composite analysis, band ratios and image classification (supervised and unsupervised) are carried out to separate the water and urban for determining the current state of the surface terrain. Image processing results are exported to vector transferred into ArcGIS to perform spatial analysis. Change detection after post-classification was done on 3 data to find the differences and changes in the surface topography of the study area and evaluate the situation of urban development. Large river was separated not consider fluctuations.

From the analysis using the test method, we found that the band ratio of B5/B2 can be applied to separate the water from the other components, while the ratio B7/B2 can be applied to separate urban area out others. The result of classification has high accuracy and over 89% for the case of overall errors and Kappa coefficient.

3. Results and Discussion

3.1. Urban development in urbanization process in Ho Chi Minh City

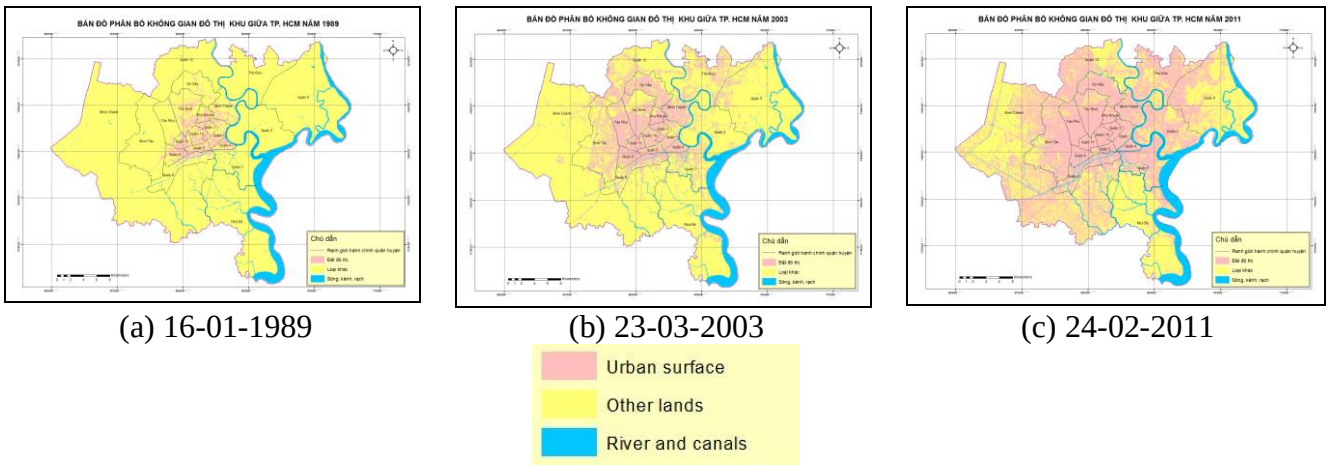
Map of urban space from remote sensing image processing is expressed in binary form, which means that only objects "urban" and "non urban" are included in the legend. The maps which show urban areas in 1989, 2003 and 2011 (Figure 2) are overlaid to assess changes in periods of 1989-2003,

2003-2011 and 1989-2011 (Figure 3). The results showed that in 22 years from 1989 to 2011, the central part of Ho Chi Minh City was thriving towards spreading from the central area and focus on expanding in northern city, especially along the main road in the suburban area. In 2011, urban areas accounted for 50.80% of the central part of city (Table 1). In terms of the spatial allocation, from years 1989 to 2011, the urban developed from the old inner city districts, expanding gradually to the new districts to the suburban districts. In the surrounding suburbs, new urban areas have been sprouting of and trends fill up over time.

Table 1. Urban land areas over the years

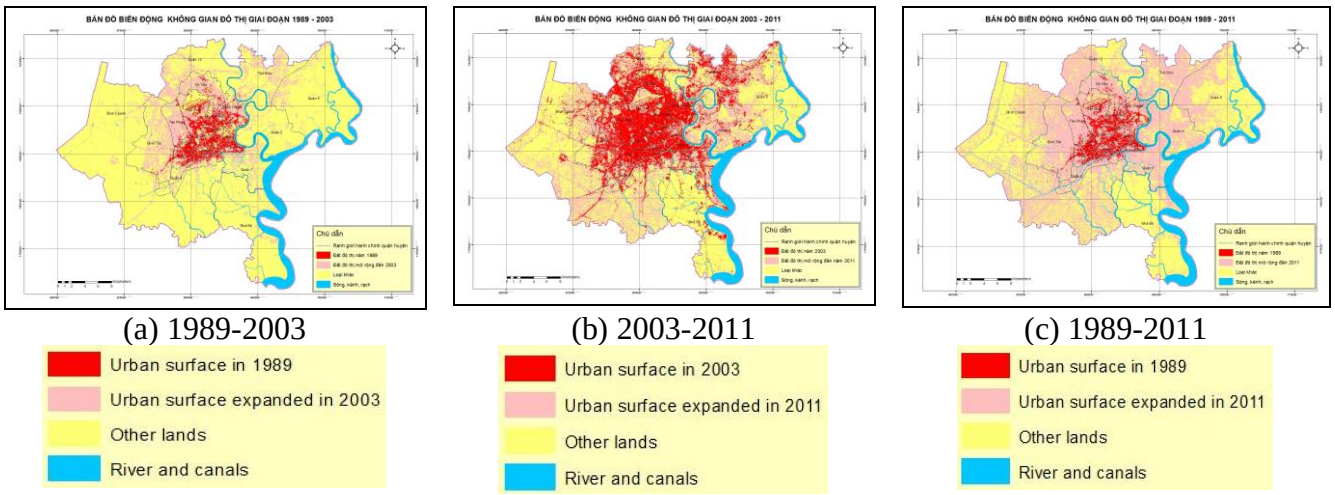
Year	Area (ha)	Percentage (%)
2011	43.035	50,80
2003	18.221	21,51
1989	6.010	7,09

Figure 2. Urban space over the years



(a) 16-01-1989 (b) 23-03-2003 (c) 24-02-2011

Figure 3. Change of urban space over the periods



(a) 1989-2003 (b) 2003-2011 (c) 1989-2011

3.2. Change of low-lying swamps

Maps in Figure 4 are results from the processing image to show the land cover changes of the central part of HCM city. The allocation of low-lying swamps in studied area in 1989 mainly concentrated in districts around inner city including Nha Be District, Binh Chanh District and District 9. In 2003 there were weakening area, particularly sharply in 2011 (Table 2).

Quantitative evaluation of surface area and comparing the ratio % of the total natural area among the whole central city (Table 3) shows clearly the inverse correspondence between urban growth and lowland swamp decline. Urban areas increased from 1989 to 2011, the area of low-lying swamp also decreased over this period. This showed that urban development in the city outside of territories primarily with crop plants; also had the development of urban areas in the region even as the water before. This is the result of leveling process for raising ground levels built urban areas. Especially the disappearance of in low-lying swamps only after 8 years in the period 2003-2011 was almost equivalent to the decline in the area within 14 years of the previous period from 1989 to 2003, approximately 4,000 hectares.

The map in Figure 5 and 6 show diminishing image of low-lying wetlands , instead of a thick covering urban. This is a fairly large fluctuation of the surface topography. According topographic allocation (Figure 1) Southern Saigon region (including District 7, Nha Be, District 8 and southern of Binh Chanh Dist) is a natural drainage for the central districts by low topography. However, urban development along with development of roads system here has become breakwater which keeps water in the inner city from escaping.

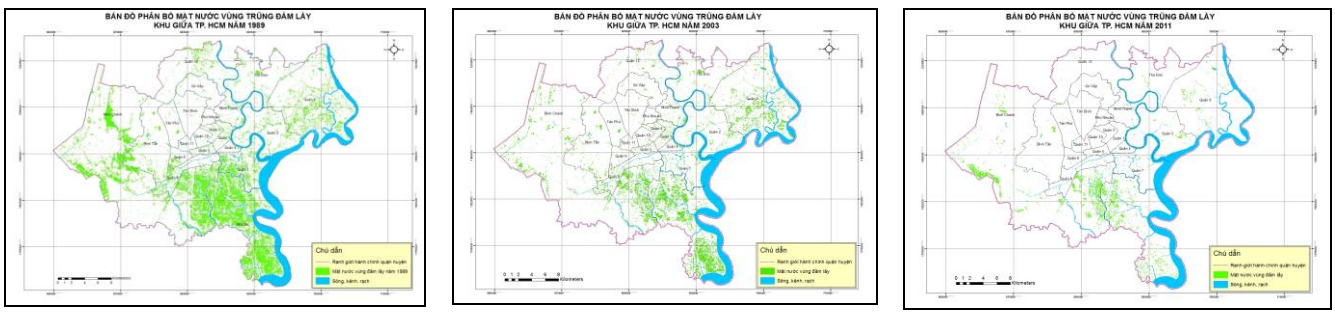
Table 2. The area of low-lying swamp over the years

Year	Area (ha)	Percentage (%)
2011	2.157	2,55
2003	6.187	7,30
1989	10.135	11,96

Table 3. The speed of the low-lying area reduction at each period

Period	Years	Reduced area (ha)
1989-2003	14	-3.948
2003-2011	8	-4.030
1989-2011	22	-7.978

Figure 4. Low-lying swamp over the years



(a) 16-01-1989 (b) 23-03-2003 (c) 24-02-2011

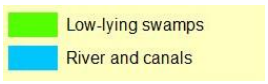
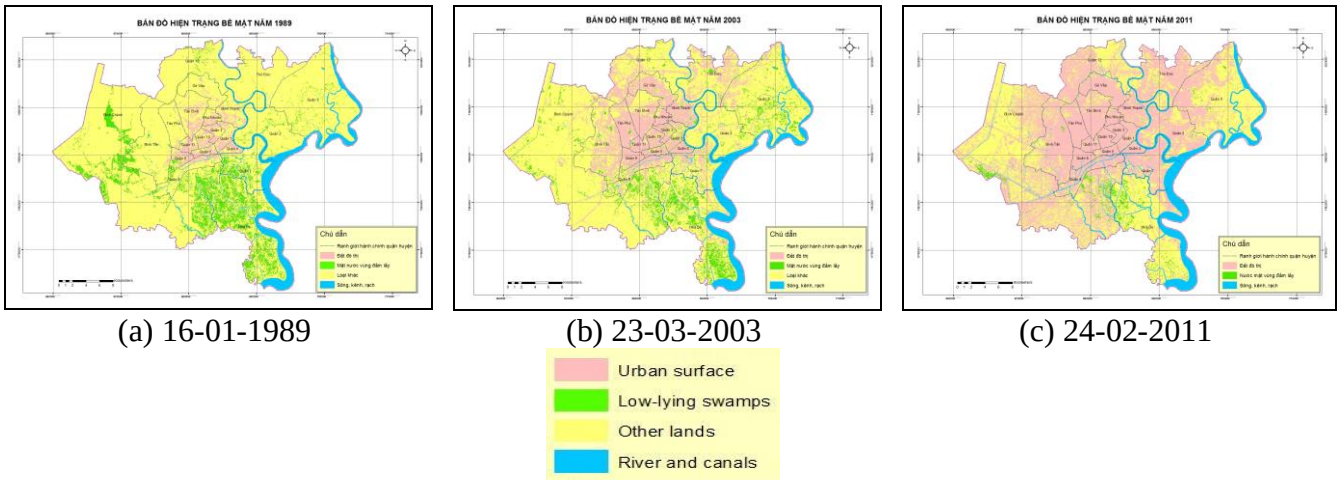
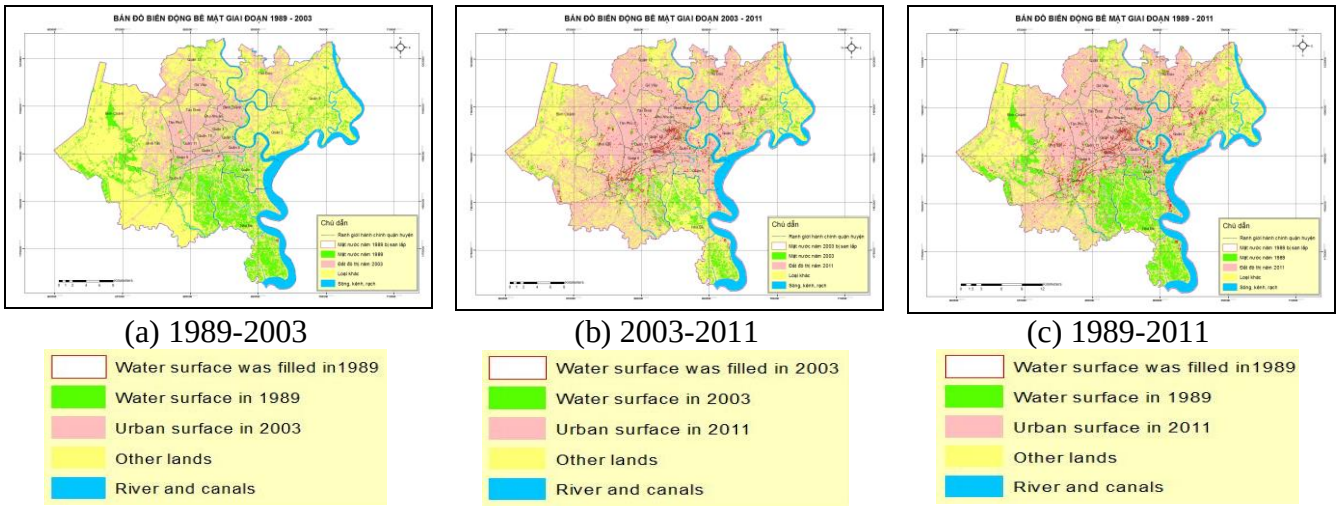


Figure 5. Surface state over the years



(a) 16-01-1989 (b) 23-03-2003 (c) 24-02-2011

Figure 6. Surface change over the periods



(a) 1989-2003 (b) 2003-2011 (c) 1989-2011

3.3. Impact of urban development after filling low-lying swamps

Ho Chi Minh City is one of 10 cities affected heavily by climate change. Therefore, in recent years, inundation in districts took place regularly each year when tide rose. In particular, the situation of urbanization is taking place quickly, many construction activities carried out in the lowlands and wetlands has contributed to the loss of natural water storage capacity of the city basin. Currently, the HCM city has 58 flooding sites in rainy season and 26 flooding sites when tides appeare [5]. Meanwhile, the planning of drainage did not keep up with the pace of development of the city, so the problem of water logging is urgent and intractable of the city. In fact, 75% of all points in the city inundated with higher than 2.5 m and 70% of the points were flooded when rainfall were measured 40mm [4]. The rapid urbanization processes accelerates concreted area rainfall caused surface increases runoffs, the shortage of water drainage from ponds that caused flooding problems. Typically, the urbanization of the southern city occurs on low and weak ground and led to thousands of area

water disappears. District 7 and Nha Be area are located in this sensitive areas, the location is at the bottom of slopping topography in the city, in the lowlands, many lakes and rapid urbanization in these areas have water storaged areas that make the central city become more serious flooding [4].

4. Conclusions

With the advantage of monitoring changes over space and time, remote sensing technology has demonstrated the ability to monitor applications in environmental issues and resources, to support and to reduce the load for people in the work of fieldwork, fast analysis and evaluation. Results of the study was to determine the current status of the allocation of low-lying areas and ponds and their changes cause in surface topography area variability of Ho Chi Minh City, to assist policy makers have a better overview and to detect areas where ponds are being filled, and the vegetation disappeared due to urban growth in order to have management measures in time, limiting the current flooding problems and prevention for the future, given the proper development

Conflicts of Interest

The authors declare no conflict of interest.

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