Applied Geography 92 (2018) 168–181

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Multiscale remote sensing of urbanization in Ho Chi Minh city, Vietnam - A focused study of the south

Tuong-Thuy Vu[a,b,*], Pham Thi Mai Thy[c], Lam Đao Nguyen[c]

[a] Faculty of Science and Engineering, Hoa Sen University, Ho Chi Minh City, Viet Nam
[b] School of Environmental and Geographical Sciences, University of Nottingham, Malaysia Campus, Malaysia
[c] Ho Chi Minh City Space Technology Application Center (STAC), Vietnam National Space Center (VNSC), Viet Nam

ARTICLE INFO

Keywords:
Remote sensing
Multi-scale
Urbanization

ABSTRACT

This study focuses on monitoring and mapping the urbanization process in the south of Ho Chi Minh City, Vietnam. Among the most vulnerable cities worldwide due to climate change, Ho Chi Minh city is experiencing the fast urbanization in last decades, especially in the south, a wetland area. The severe environmental impact such as flood has occurred more frequently implying the critical infrastructures development is far behind the expansion of newly built-up residences and hence, growing population. To what extent, the newly built-up areas have contributed to accelerating the environmental impacts in the context of climate change? The aim of this study is twofold. Firstly, we experiment three different levels of spatial resolution, sub-meter, 2.5 m and 10–15 m in mapping the landcover changes of a selected typical fast urbanization area in 2000–2010. With all about 80% classification accuracy achievement, we found that sub-meter resolution is the best for a reliable identification of land cover changes in such complex and fast-growing built-up areas whereas 2.5 m resolution is sufficient to identify the extent of built-up areas and 10–15 m is unsuitable. We also confirmed a consistent expansion, over 25%, of built-up area in our study area, using three different resolutions in spite of small differences in other landcover types. Secondly, in comparison of ground data, we revealed that most of the newly built-up areas in 2000–2010 were built on the higher land and no flood incident was recorded obviously. However, the nearby lowland experienced more floods due to the changes. A slight increase of sea level and the sinking of the city due to the groundwater extraction may also contribute to more flood incidents. Remote sensing proved to be effective in revealing the temporal urbanization and its possible consequences. However, a holistic approach to investigation needs to be developed to better understand the contribution of anthropogenic activities to environmental impacts in the climate change context.

1. Introduction

For decades, the world has experienced the acceleration of urbanization processes (UN, 2014). In the Southeast Asian region, urban land increased by 22% between 2000 and 2010 while urban populations grew over 31% (Schneider et al., 2015). Consequently, land resources are heavily exploited for growing settlements and transportation infrastructures. The development of urban areas can dramatically change the landscape along with substantial destruction to the environmental integrity (Grimm et al., 2008). Sealing the natural soil with impermeable materials such as concrete causes a strong negative impact on the urban environment and human life quality like loss of plant production and natural habitats pollution, health risks and higher social costs (Scalenghe & Marsan, 2009). In particular, the sealed soil causes more frequent flooding due to the impedance of percolation into the aquifer. The impact is obvious in Vietnam, a tropical country with the fast-growing population and emerging economy, and accelerated as the climate is changing.

The biggest city in Vietnam, Ho Chi Minh city (HCMC), is 1 of 10 most severely impacted cities worldwide due to climate change (ADB, 2010). Being the economic hub of the country, it produces 23% of GDP, attracts 20% of foreign investment and has a population of 7 million, (over 3000 people/km2). Spreading on a lowland terrain, about 40–50% of the city area is below 1 m above sea level and another 15–20% is between 1 and 2 m. According to Asian Development Bank report (ADB, 2010), the below 1-m area will be underwater, and the 1–3 m area will be flooded by the normal tide in 2050. Land conversion due to urbanization would be the major factor in increasing urban flooding events from 356 in 2003 to 478 in 2006 (Webster, McElwee, & Worldbank, 2009).

The on-going expansion of the city to the southeast direction is sealing more wetland areas for settlements, reducing the land capacity to handle excess water. The current city drainage system is incapable of handling current water volume (Hanh, 2006) and the renovation or

* Corresponding author. Faculty of Science and Engineering, Hoa Sen University, Ho Chi Minh City, Viet Nam.
E-mail addresses: tuongthuy.vu@nottingham.edu.my, thuy.vutuong@hoasen.edu.vn (T.-T. Vu).

https://doi.org/10.1016/j.apgeog.2017.12.026
Received 30 June 2016; Received in revised form 26 December 2017; Accepted 26 December 2017
Available online 21 February 2018

development of infrastructure is far behind the growth of residential areas. It seems no obvious issue in newly developed areas but the pressure bounced back to old developed areas. To bring the city planning back to a sustainable development track, there is a strong need to monitor the current urban growth process and reveal its impact in relation to climate change impacts such as frequent heavy rain, increasing temperature, etc.

Remote sensing has been extensively used in monitoring urban growth via impervious surface mapping (Weng, 2007). Medium resolution satellite images such as Landsat, which has been archived since the 70s, or SAR family is commonly used (Gómez, White, & Wulder, 2016; Lu & Weng, 2004; Van de Voorde, Jacquet, & Canters, 2011; Wieland & Pittore, 2016; Zhang, Zhang, & Lin, 2012; Zhu, 2017). Its wide extent is suitable for mapping the growth of a city as a whole but its coarse spatial resolutions (around 30-m) do not provide enough detailed information to precisely delineate the sealing of soil in a complex urban landscape with mixed pixels (Lu & Weng, 2004). To overcome this limitation, many researchers have incorporated additional information like geospatial vector data, aerial images to reach the sub-pixel details (Esch et al., 2009; Hu & Weng, 2009; Mountrakis & Luo, 2011). Alternatively, sub-meter resolution satellite images such as QuickBird, IKONOS, WorldView are used to improve the sub-pixel mapping from medium resolution images (Lu, Moran, & Hetrick, 2011; Van de Voorde et al., 2011). Moreover, these high-resolution images are suitable for deriving a detailed landuse map or mapping the details in cities such as trees, buildings (Lu, Li, & Moran, 2014; Pu & Landry, 2012; Zhang & Kerekes, 2011). Overall, data fusion is necessary to deal with complex urban landscape (Gamba, Dellâ™Acqua, & Dasarathy, 2005; Weng, 2012; Zhang, Zhang, & Lin, 2014).

In terms of methodology development, pixel-based classification is the common approach for medium resolution images but it hardly deals with complex urban areas. Spectral mixture analysis (SMA) has been proved to be effective and improve the classification accuracy (Lu & Weng, 2004). However, SMA has its own issue, the impervious surface is overestimated in the small impervious surface areas or underestimated in the large impervious surface areas (Weng, 2012). With the introduction of very high-resolution satellite images, the complexity of urban areas is better revealed by applying object-based image analysis method (OBIA) approach (Blaschke, 2010). Based upon the multi-scale observation which actually mimics the human interpretation and perception, OBIA is able to represent the complexity to a multi-scale link space and hence, eventually put pixels into the context and expand the capability of multi-source data fusion. A plethora of OBIA development in last 2 decades proved that OBIA is not just simply another classification approach but a new paradigm (Blaschke et al., 2014; Ma et al., 2017). The suitability of these methods, however, should be placed in the context of the study area and the data availability towards a cost-effective mapping solution (Gamba et al., 2005; Vu, Matsuoka, & Yamazaki, 2007).

Complex growing Asian cities provide a great challenge to further improve object-based image analysis methods. Huang, Zhang, and Zhu (2014) developed a method based on morphological building index, which achieved over 80% accuracy when testing with Wuhan city (China) images. To deal with multi-sensors, Leichtle, Geiß, Wurm, Lakes, and Taubenböck (2017) proposed an object-based clustering method that successfully detected building changes in Dongying, China. In addition to new development for object-based change detection, at the level of landcover classification, there was the introduction of object-based backdating (Yu, Zhou, Qian, & Yan, 2016) and object-based semantic classification (Gu et al., 2017). Both were proved effective in

Fig. 1. The study area.