Habitat International 48 (2015) 131–139

Contents lists available at ScienceDirect

Habitat International

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

Urban land expansion in Quanzhou City, China, 1995–2010

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ARTICLE INFO

Article history:
Received 3 January 2015
Received in revised form
28 February 2015
Accepted 26 March 2015
Available online 7 April 2015

Keywords:
Quanzhou
Urban land expansion
Land use change
Population growth
In situ urbanization

ABSTRACT

With its phenomenal development in recent decades, urbanization in China has been covered in a large number of studies. These studies have focused on large cities, with smaller and lesser known cities largely overlooked. This study analyzed the spatiotemporal changes of land use in Quanzhou, a historical city in Fujian Province, using GIS and remote sensing tools. Based on the land use change indices and spatial metrics, our results showed that built-up (urban) land in Quanzhou increased more than twofold in 1995–2010, at the expense of cultivated land, woodland, and grassland. During the same period, urban land patches increased in both number and size, while becoming more irregular and complex in shape. Most urban land expansion took place in the coastal areas, including the city districts and development and industrial zones. Although urbanization in Quanzhou has been remarkable since 1995, its average rate of urban land expansion has fallen behind Shenzhen and Dongguan in the Pearl River Delta. Geographic location and population growth are two important factors for the difference. Quanzhou is located in a less developed region of China, and its population growth has been slow due to its heavy reliance on labor-intensive, low-technology industries, which do not offer sufficient rural—urban wage differential to attract large inflows of migrant workers. Urbanization in China follows different paths in different cities and regions, as shown in this study by comparing Quanzhou with cities in the Pearl River Delta.

1. Introduction

In a recent study of global urban land expansion of 67 countries from 1970 to 2000, China was ranked with the highest rate of increase, from 13.3% for the coastal areas to 3.9% for the western regions annually (Seto, Fragkias, Güneralp, & Reilly, 2011). China's urban population increased from 170 million in 1978 to 670 million in 2010, and the urban proportion rose from 18% to 50% during the same period (Chen, Liu, & Tao, 2013). Although China accounts for less than 20% of the global urban population at present, close to one third of the global urban population growth between 2000 and 2010 was realized in China (http://data.worldbank.org/). China is the engine of not only global economic growth but also global urban population growth (Chen, Chang, Karacsonyi, & Zhang, 2014).

A variety of resource and environmental problems have been linked to urbanization globally, such as habitat loss, species extinction, land-cover change, and alteration of hydrological systems (Seto et al., 2011). With the rapid urbanization rarely seen in other parts of the world, China faces additional challenges. Because large amounts of agricultural lands have been converted to urban land and rural settlements, protection of cultivated land is an urgent issue (Liu, Liu, & Qi, 2015) and food security may become an issue in the future (Angel, Parent, Civco, Blei, & Potere, 2011; Wang & Fang, 2011). Questions have also been raised on sustainable urban development (Chen, Jia, & Lau, 2008; Yu, 2014; Zhao, Song, Tang, Shi, & Shao, 2011) and social segregation and inequality of migrant rural workers (Chen et al., 2013).

A large number of studies have analyzed the pattern and process of urban land expansion. They have focused primarily on major cities of China, including cities in the Pearl River Delta (Seto & Fragkias, 2005; Seto, Fragkias, & Schneider, 2007; Yeh & Li, 1999), Guangzhou (Ma & Xu, 2010; Sun, Zhou, Lin, & Wei, 2013), Hong Kong-Shenzhen (Luo & Shen, 2012), Wuhan (Zeng, Zhang, Cui, &

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http://dx.doi.org/10.1016/j.habitatint.2015.03.021

He, 2015), Beijing (Deng & Huang, 2004), Chengdu (Schneider, Seto, & Webster, 2005; Seto et al., 2007), Shijiazhuang (Xiao et al., 2006), Shanghai (Zhang, Zhou, Chen, & Ma, 2011), Nanjing (Luo & Wei, 2009), Hangzhou (Yue, Liu, & Fan, 2013), and the urban agglomeration around Hangzhou Bay (Zhang, Su, Xiao, Jiang, & Wu, 2013). However, few studies have reported on urban land expansion in smaller and lesser known cities.

To analyze the spatial characteristics of urban land expansion in China, many studies have used multi-temporal land cover data derived from satellite images, landscape metrics (McGarigal, Cushman, Neel, & Ene, 2002), and the physical patterns of urban sprawl (Harvey & Clark, 1965). For examples, Seto et al. (2007) and Schneider and Woodcock (2008) described the two-step process of diffusion and coalescence in Chengdu and cities in the Pearl River Delta. Likewise, Sun et al. (2013) categorized the urbanization processes of Guangzhou into infill, edge expansion, and outlying growth. To characterize the temporal changes of urban land expansion, many studies have used the indices of the average expansion rate and the average expansion intensity (Chen et al., 2014; Ma & Xu, 2010; Schneider & Woodcock, 2008; Seto et al., 2011; Xiao et al., 2006; Xu & Min, 2013) Thus, the literature has been dominated by analysis of the spatiotemporal characteristics of urban land expansion in China, but few studies have attempted to explain the driving factors for urban land expansion and the difference between cities in urban land expansion.

This study analyzes urban land expansion from 1995 to 2010 in Quanzhou, Fujian Province, a historical city reported to be the largest seaport in China at the time Marco Polo visited (Leaf, 2002). Throughout the period of centralized economy, Quanzhou received disproportionately low attention and investment from the Chinese Central Government due to its location directly across the strait from Taiwan (Leaf, 2002). In 1980, four special economic zones were set up along the southeast coast of China for its new open door policy. Quanzhou was overlooked; instead, Xiamen, a city to the south of Quanzhou, was selected. However, because of the kinship factor (70% of the Taiwanese people have ancestral connections to southern Fujian) and the geographic distance, Taiwanese investment, primarily in labor-intensive industries and working with township and village enterprises (TVEs), poured into the Quanzhou area following the open door policy. In 2009, the Chinese Central Government announced plans to accelerate the development of the Western Taiwan Straits Economic Zone and to upgrade the economy of Fujian Province, including Quanzhou (Tang, 2010).

So far as we know, urban land expansion of Quanzhou has only been covered in regional journals in Chinese. Specifically, this study asks: what were the spatiotemporal characteristics of Quanzhou's urban land expansion in 1995–2010? Then based on these characteristics, this study discusses two related issues. First, how has Quanzhou differed from cities in the Pearl River Delta (i.e., Shenzhen and Dongguan), one of the most populated and developed regions in China, in terms of urban land expansion? Second, given the prevalence of *in situ* urbanization in Fujian Province (Zhu, 2000; Zhu, Lin, Lin, & Chen, 2013), how has it affected urban land expansion in Quanzhou? As urbanization is taking place rapidly in all regions of China, we must study the topic in not only large cities but also lesser known cities such as Quanzhou to gain a better understanding of this remarkable development.

2. Study area

Measuring 11,221 km^2 in size, Quanzhou borders the provincial capital Fuzhou in the north, Xiamen in the south, and Taiwan in the east across the Taiwan Strait (Fig. 1). Quanzhou (24°22′–25°56′N; 117°25′–119°05′E) has a subtropical marine monsoon climate with an average annual temperature of 19.5–21.5 °C and an annual precipitation of 1682–1800 mm. The city has higher elevations in the northwest and lower elevations in the southeast, with landforms varying from mountains, to hills, to plains. Mountains and hills account for 79% of the land area, and plains and tablelands for 21%. Quanzhou City has complex and diverse soil types; red soil is the most dominant soil type, followed by paddy and lateritic soils. Vegetation on slopes consists of evergreen broad-leaf and coniferous forest, brush, crops, tea plantations, fruit trees, and grasses.

Quanzhou is a prefecture-level city, which administers four city districts (Licheng, Fengze, Luojiang and Quangang), three county-level cities (Shishi, Jinjiang and Nan'an), four counties (Hui'an, Anxi, Yongchun and Dehua), and two special economic districts (Quanzhou Economic Development District and Quanzhou District for Taiwanese Investment). According to the *Quanzhou Statistical Yearbook* (http://www.qztj.gov.cn/outweb/index.asp), Quanzhou had a year-end population of 8.4 million in 2013, of which 6.9 million were registered residents and the rest were temporary residents. The urban population was 5.2 million or 62% of the year-end population. The GDP of Quanzhou has ranked first in Fujian Province since 1991, with a GDP of 522 billion RMB (~US$83.5 billion) and a GDP per capita of 62,700 RMB (~US$10,032) in 2013.

3. Land use data processing

3.1. Data

In China land use change has been tracked mainly by remote sensing data (Deng, Huang, Rozelle, & Uchida, 2008; Ma & Xu, 2010). This study used Landsat TM images of 1995, 2000, 2005 and 2010 for delineation of built-up land and other land uses in Quanzhou. These images were acquired on April 2, 1995; March 25, 2000; April 18, 2000; October 5, 2004; November 5, 2005; December 6, 2009; and May 24, 2010. They covered line numbers P119R42, P119R43, P120R42 and P120R43, in the WGS1984 coordinate system with a transverse Mercator projection. Landsat TM includes near-infrared visible light (1–5 bands), thermal infrared (6th band), and mid-infrared (7th band).

3.2. Image pre-processing

Image pre-processing covered band combinations, atmospheric correction, georeferencing, and image clip. This study used Basic Tools-Layer Stacking Parameters in ENVI 4.8 to combine the TM image bands for better expressions of surface information and more accurate extractions. The FLASH module of ENVI 4.8 was used for the atmospheric correction of images. For georeferencing, topographic maps of the study area with a spatial resolution of 30 m were selected as a reference. The Auto Sync module of ERDAS IMAGINE 9.2 was used for georeferencing, and nearest neighbor was selected for the re-sampling method. Also, the method for automatic acquisition of control points was used. At the end of the data extraction procedure, the error in the control points was checked for the process of TM image orthorectification. In this study, the control points were within 0.5 pixels. After the images were orthorectified, they were divided into various sub-areas by clipping so that the interpretation could be done in sub-areas. In the end, the vector boundary of the study area was used to mask the clip of TM images in ArcGIS 9.3 and ENVI 4.8.

3.3. Image processing

This study adopted eCognition Developer 8, the object-based image analysis software, to interpret and classify the TM images. The processing involved segmentation and classification. Segmentation partitioned the image into objects, and classification