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Studies on the temporal and spatial variations of urban expansion in Chengdu, western China, from 1978 to 2010

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ABSTRACT

Analysis of the urban expansion and its driving forces is critically important for sustainable urban development. The majority of studies on Chinese urbanization have been focused on coastal areas, while with less attention given to urban centers in the west. Chengdu, western China, however is undergoing significant urban growth due to rapid economic development and demographic growth. This research examines urban expansion in Chengdu based on remotely sensed data, urban expansion model, buffer analysis of geographic information system (GIS) and quadrant orientation analysis. Driving forces of urban expansion are also examined based on principle component analysis (PCA). Results indicate that the urbanized area increased by more than 17 times, up to 1910.2 km^2 from 1978 to 2010, the urban expansion rate and intensity increased significantly and exhibited the spatiotemporal heterogeneity. We found that urban expansion patterns changed from patch infilling to patch margin expansion, and the expansion direction is primarily toward the northwest, west and southwest. The results suggest an obvious trend of urban expansion in Chengdu witnessed in coastal cities of China. The information provided by this research ultimately helped impact on future policies and plans for better land management and urban sustainability.

1. Introduction

China has experienced rapid economic development and demographic growth over the last three decades (Xu & Min, 2013). China began its far-reaching economic reform and open-door policy in 1978, starting with rural reforms that released a substantial amount of labors from farming industry; the policies that ranged from anti-urban to ambivalence with cities over the last decades, the government appears to have recently recognized that large cities can make major contributions to the country's economic development and to sustaining China's long term growth (Kamal-Chaoui, Leman, & Rufei, 2009). Up to now, China has entered into the rapid urbanization stage with the high rates of economic growth, exhibiting remarkable urban expansions.

With the high rates of physical urban expansion, great changes have taken place in the pattern and structure of urban land use has been improved significantly. The urbanization process is unprecedented in history and unparalleled anywhere else in the world (Pannell, 2002). The urbanization process has inevitably caused a series of resources and environmental issues throughout China (Fang, 2009), such as soil erosion and environmental desertification, the obvious contradiction between demographic growth and land requirement, the shortage and inequality of distribution of available water resources, and etc. (Wang & Fang, 2011). Urbanization is a major threat on biodiversity due to the direct destruction of natural and semi-natural habitats and to the indirect impacts caused by urban areas beyond their limits (Ruppert, Ghislain, Pascal, Claude, & Jacques, 2012). The environmental impacts of the land use changes resulting from urbanization process are significant (Carlson & Traci Arthur, 2000; Xiao et al., 2006). Therefore, studying the spatiotemporal characteristics of urban expansion in China has important significance to promoting urban sustainable development and maintaining ecological safety (Xu & Min, 2013).

China's rapid urbanization process has generated much attention in recent decades (Ma, 2002; Schneider, Seto, & Webster, 2005). Since the 1990s, the scholars in China and globally have increasingly studied the process and characteristics of urban expansion (Ji, Ma, Twibell, & Underhill, 2006; Yang, Jiangnan, Su, & Zheng, 2005), such as Centre County, Pennsylvania (Batisani & Yarnal, 2009), Yazd, Iran (Zanganeh Shahraki et al., 2011), Beijing (Liu, Wu, & Shen, 2000),

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Shanghai (Xu, Min, & Tian, 2010), Shenzhen (Shi, Chen, & Pan, 2000), Hangzhou (Deng, Li, Yu, & Wang, 2008), Zhengzhou (Wang, Zhang, & Geng, 2010), Changchun (Kung, Zheng, Zhang, & Sheng, 2005), and Guangzhou (Mu, 2007), and in special regions in such as in the Zhujiang Delta (Weng, 2002), the Yangtze River Delta (Che, Duan, Guo, Wang, & Cao, 2011), Pearl River Delta (Zhang, Wang, & Xue, 2003), and the Nile Delta (Yin, Stewart, Bullard, & MacLachlan, 2005).

One of the central goals of the Go West program is to industrialize and modernize the region making use of cities as engines of growth (Schneider et al., 2005). Chengdu has benefited from China's reform policies, which has been a major factor in the economic success of the municipality (Schneider et al., 2005). Since the late 1980s, the land use pattern and scale in Chengdu have undergone significant changes, with striking urban land expansions. Although Chengdu serves as a good case study of ongoing land use changes in mid-sized cities in China, the majority of studies on Chinese urbanization have been focused on coastal areas (Liu, Zhang, & Hu, 2012), with little attention given to urban centers in the west (Schneider et al., 2005). So, as in most rapidly developing cities in Southeast Asia, there are no current maps or statistics on land use are available in Chengdu (Schneider et al., 2005).

The importance of studying urban dynamics in western China is prompted by not only national but also international trends (Schneider et al., 2005). Increased urbanization in Chengdu, western China will have profound impacts on natural and agricultural ecosystems. If a city is more urban expansion has important implications for the management of natural resources, energy demands, infrastructure support, and local and regional climate change (Alberti, 2002; Anderson, Kanarogulu, & Miller, 1996; Douglas, 1994). It is critically important to properly characterize urban expansion before developing a comprehensive understanding of urbanization processes (Ji et al., 2006; Xu & Min, 2013). By monitoring the urban development information timely and accurately, we can explore the patterns and rules of spatial developments, and then assess the urban expansion and the related driving forces more objectively. All of these are of great significance to making and improving the urban plan in a more reasonable manner, contributing to the realization of sustainable developments in urban economy and ecological environment (Peng and Zhou, 2011; Zhang et al., 2003).

The objectives of this study were to: (1) to provide a quantitative analysis of the spatiotemporal patterns of urban growth in Chengdu, a large or mid-sized city typical of those targeted for development in central and western China. We use remotely sensed data to map and examine the spatial patterns of urban expansion by using model, buffer analysis of geographic information system (GIS) and quadrant orientation analysis. (2) To analyze in detail driving forces by observed patterns of urban growth spurring land conversion based on principle component analysis (PCA). This research is one of the few that documents the recent changes in urban expansion in western China. The information provided by this research ultimately impacts on future policies and plans, which were adjust to foster better land management and to reduce fragmentation of new development in the greater Chengdu region for urban sustainability.

2. Study area and data source

2.1. Study area

Chengdu is the state capital of Sichuan Province and is an important political, economic and cultural center in the southwest. Chengdu is located in the transition zone from the northwestern Tibetan Plateau to the Sichuan basin, at 102°54′–104°53′ E, 30°05′–31°26′ N (Fig. 1). Chengdu borders on the city of Deyang to the northwest while it borders on the city of Ziyang to the southwest. In the south, it is adjacent to the city of Meishan. The city is also connected to Ya'an and Aba Tibetan and Qiang Autonomous prefecture southwestward and northwest, respectively. This area is an important ecological buffer region for upstream areas within the Yangtze River watershed. The environmental situation in Chengdu is related to the ecological balance in the Yangtze River basin and the ecological security of the Three Gorges Reservoir area.

With a length of 192 km and a width of 166 km, Chengdu covers 12,390 km^2 and has total ten districts, four cities and six counties under the jurisdiction. The Chengdu area has a subtropical humid climate with mild weather and ample rainfall year-round, favorable for agricultural production. Irrigated by the water reservation project built in 256 BC, the western Sichuan Plain provides ample water supply for the local residents. The soil types and ecological environment are diverse while the topography is complicated.

In 2007, Chengdu was approved as the first national experimental zone for overall urban–rural reform. Chengdu is undergoing strong economic development, with the fifth highest GDP among the 15 sub-provincial cities in China and a wide variety of industries. The GDP reached 5551.3×10^8 RMB in 2010, with a restructuring of the economy away from the primary sector to the secondary and tertiary sectors. The composition of the three sectors was 5.1%, 44.7%, and 50.2% in 2010, respectively (Chengdu Statistical Bureau, 2011). Chengdu has played a strong supporting role in economic development in China. It has also experienced rapid urbanization, reaching 56.65% in 2010 (Chengdu Statistics Bureau, 2011).

2.2. Data sources

The adopted data in the present study are the remotely sensed data and the related auxiliary data. MSS/TM/ETM+ remote sensing data were provided by the USGS EROS Data Center, the Institute of Remote Sensing and Digital Earth, and Data Center for Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC; http://www.resdc.cn). The remotely sensed data includes the Landsat MSS data on 3rd and 21st, August 1978, at a resolution of 78 m; the Landsat ETM+ image data on 29th, March 2002 and 5th April 2002, at a resolution of 30 m and the Landsat TM image data on 18th and 27th, March 2010, at a resolution of 30 m. The related auxiliary data, such as 1:50,000 topographic maps and vector boundary data for Chengdu were obtained from the Sichuan Bureau of Surveying, Mapping, and Geoinformation. The corresponding data on general land use plan in Chengdu (2006–2020) was provided by the Chengdu Bureau of Land and Resources (outline of general land use plan in Chengdu).

3. Method

3.1. Classification system of land use

According to the land use classification system by Second National land survey results, the land use classification system has been adjusted based on the present work, the interpretation capability of remote sensing (RS) image data. The classification system in this paper includes five types of land: farmland, grassland, forest land, water area, built-up land.

3.2. RS data processing

The remote sensing were geometrically rectified independently using the 2002 ETM+ image and 1:5000 topographic maps by the polynomial function method and the Albers projection method based on ERDAS IMAGING 8.5 and ARGIS 9.3, the error was $\leq$0.5 pixels. The TM image for 2010 and MSS image for 1978 were