Habitat International 60 (2017) 81–90

Contents lists available at ScienceDirect

Habitat International

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

Spatial-temporal dynamics and associated driving forces of urban ecological land: A case study in Shenzhen City, China

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ARTICLE INFO

Article history:
Received 22 March 2016
Received in revised form
24 November 2016
Accepted 14 December 2016
Available online 28 December 2016

Keywords:
Urban ecological land
Ecological land quality
Driving forces
Multiple logistic regression
Shenzhen city, China

ABSTRACT

Ecological land is an important component of urban ecosystems. Detecting the change of urban ecological land and its driving forces will offer scientific basis for the optimization of urban landscape patterns. The rapid urbanization in Shenzhen City has brought the serious conflicts between socio-economic development and ecological protection. In this study, we characterized ecological land dynamics in Shenzhen City and quantified the driving forces using multivariate logistic regression, and subsequently mapped the transition probability of ecological land. The results showed that in Shenzhen City, urban ecological land had changed dramatically during 1990–2010 in terms of its quantity, quality, and spatial distribution. Land use change matrix between ecological and non-ecological land showed that the area of ecological land decreased more fast during 1990–2000, compared with that during 2000–2010. There was a decrease in area equivalents calculated by the adjustment coefficient of ecosystem services, although the quality per unit was improved. Furthermore, the gravity center of ecological land gradually moved to the southeast. The driving force analysis suggested that the slope, the minimum distance to construction land, and the growth rate of construction land were the vital factors determining the change of urban ecological land. Finally, the transition probability mapping showed that the water body, wetland and grassland near the city center had a higher transition probability to construction land. This study illustrated the change characteristics of urban ecological land, as a result of rapid urbanization. The transition probability can serve as the basis for decision making on constructing urban landscape ecological security pattern.

1. Introduction

Global environment and related earth surface processes have changed dramatically due to climate change and urbanization (Antrop, 2004; Rounsevell et al., 2012). These changes often manifests as the significant alterations in the spatial patterns of land use, both in terms of amount and spatial layout (Peng et al., 2008; Shahraki et al., 2011). Since cities are the primary habitat of humans, the expansion of these cities, i.e., urbanization has become one of the crucial characteristics of human development in the 20th century (Cui & Wang, 2015; Li, Li, Zhu, Song, & Wu, 2013; Zheng, Shen, Wang, & Hong, 2015). Urban development leads to the transition from the original natural ecosystem to a coupled human and nature system. Within this system, the quantity and quality of the ecosystem services change, such as carbon storage (He, Zhang, Huang, & Zhao, 2016), climate regulation (Zhou et al., 2004), and soil and water conservation (Li, Li, Qureshi, Kappas, & Hubacek, 2015; Li, Li, & Wu, 2016). This consequently affects regional landscape patterns and ecological security. For example, in the conversion from forestland or farmland to construction land, the ecological function of the former land use type is lost completely. Moreover, the ecological function is also partly degraded for the adjacent land use types, due to the influence of enhanced human activities (He, Liu, Tian, & Ma, 2014; Zhou, Qian, Li, Li, & Han, 2014). This has given rise to the concept of urban ecological land, which is also influenced by the increasing awareness of sustainable urban development (Pickett, Cadenasso, Childers, McDonnell, & Zhou, 2016).

Although urban ecological land has not yet been proposed as an

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http://dx.doi.org/10.1016/j.habitatint.2016.12.005
0197-3975/

explicit concept, it has already been considered in the land use classification system. The functions of urban ecological land are not only maintaining ecological circulation and biological diversity, and balancing the regional or global ecosystem, but also meeting reasonable human needs, improving the quality of citizens' lives, and providing ecosystem services (Bergsten, Galafassi, & Bodin, 2014; McPhearson, Kremer, & Hamstead, 2013). Urban ecological land has both natural and social attributes to maintain the stability of the energy flow, material flow, and information flow in its own ecosystem, and to provide multiple ecosystem services. These ecosystem services include all the four categories of supporting, provisioning, regulating and cultural services. We can therefore define urban ecological land as the natural basis for survival of the city, which maintains urban ecological security, and provides the necessary ecosystem services for the citizens. Generally speaking, urban ecological land usually includes orchard, forestland, water body, wetland, and grassland, because their functionalities include the maintenance of ecosystem stability, and providing ecosystem services. In other words, they have a far-reaching influence on the ecological sustainability.

Currently geographic information system (GIS) technologies have been widely used in land change science (Peng, Liu, Shen, Han, & Pan, 2012). Spatial and temporal series of environmental data can be easily obtained through remote sensing, and GIS provides the approach to spatial analyzing, modelling, and mapping. Furthermore, land use change matrix is commonly used to characterize the quantity change of ecological land, and landscape metrics are generally applied to quantify spatial pattern dynamics (Gao et al., 2012; Sharma, Chakraborty, & Joshi, 2015; Vaz, 2016). However, shortcomings and limitations are still existed, including low spatial and temporal resolutions, and obscure ecological meanings of landscape metrics (Peng et al., 2010). The recent rise and development of geographical statistical analysis (Wu & Li, 2013), such as spatial autocorrelations (Zheng, Myint, & Fan, 2014), spectrum analysis (Meyer & Okin, 2015), trend surface analysis (Fu & Weng, 2016), blocked quadrat variance analysis (Perry et al., 2002), fractal geometry (Song, Zhang, Liu, Qu, & Xue, 2015), wavelet analysis (Shekede, Murwira, & Masocha, 2015), and cellular automata (Bozkaya, Balcik, Goksel, & Esbah, 2015), are helping to solve the above problems in analyzing ecological land dynamics. Among these, the multivariate logistic regression model has been widely used for investigating the mechanisms and driving factors of ecological land dynamics. The regression coefficients of each independent variable are derived from sampled data, and can be interpreted as the specific weighting rules calculated for land use change probability. This model can effectively overcome the shortcomings of traditional linear regression models when the variables are categorical instead of continuous (Hu et al., 2014; Liu, Dai, & Xiong, 2015; Lopez-Barrera, Manson, & Landgrave, 2014). However, there are little studies with a special focus on the transition mechanism of urban ecological land pattern.

Fragile ecosystems in China have been experiencing the degradation along with the process of intensified land use change (Chen, 2007; Wu, Xiang, & Zhao, 2014) that accompanied the rapid economic growth and urbanization since the Chinese economic reform (Chen, Liu, & Tao, 2013; Normile, 2008; Wu, Zhang, & Shen, 2011). Shenzhen City is a typical region in China with rapid urbanization since the establishment of the Special Economic Zone in 1980. In recent decades, Shenzhen City has been undergoing rapid changes in land use patterns. The environment has deteriorated dramatically, with ecological land highly occupied by construction land. Overall, the demanding conflict between construction land development and ecological land protection has become a serious dilemma for urban land management, which is seeking spatial solutions for sustainable development (Shi & Yu, 2014). In order to solve the ecological problems mentioned above, the government of Shenzhen City issued “Management stipulation of the basic ecological line in Shenzhen City”. It prescribed a strict control of land use development within the basic ecological line. With the increasing demand of construction land in the past decades, revisions to the basic ecological line have come into the sight of general public.

Therefore, it is necessary to investigate the driving mechanism of ecological land dynamics, and to map the transition probability of ecological land, in order to provide a scientific basis for the optimization of ecological land in Shenzhen City. More specifically, the aims of this study are: (1) to use GIS-based land use change matrix, landscape metrics, and gravity center calculations to investigate ecological land dynamics in Shenzhen City from 1990 to 2010, in terms of its quantity, quality, and spatial distribution; and (2) to apply the logistic multivariate regression model to quantify the human-natural driving forces of urban ecological land change, and thus to map the transition probability of ecological land in Shenzhen City.

2. Methodology

2.1. Study area

Shenzhen City, located in the southeast coastal area of Guangdong Province, China. It occupies an area of 1952.84 km^2, ranging geographically between 113°46′E–114°37′E, and 22°27′N-22°52′N. It faces the Daya Bay, and is adjacent to Huizhou City in the east. To the west, its neighbors are Zhongshan City and Zhuhai City, across the Zhujiang River Estuary. Furthermore, it borders Dongguan City and Huizhou City to the north, and ranges southward to the Shenzhen River, adjacent to Hong Kong (Fig. 1). In 1980, Shenzhen City had a population of about 330 thousand people, with GDP of approximately 270 million Yuan. From the mid-1980s to the mid-1990s, Shenzhen City made a rapid transition from a traditional agricultural region to a high-speed urbanized area. Because of its unique geographical advantage and favorable foreign policy, Shenzhen City has been promoting rapid industrialization and urbanization. At the end of 2010, its population was over 10 million permanent residents, and the GDP was 958.1 billion Yuan. This growth was established by an industrial system with four pillar industries, i.e. the new technology industry, the financial services industry, the modern logistics industry, and a cultural industry. Shenzhen City has been the first ‘international garden city’ in China. Currently, nearly half of the total land is designated within the basic ecological line, which forbids any construction projects in the control zone. Until December 31, 2010, Shenzhen City consisted of eight districts, including Futian District, Luohu District, Yantian District, Nanshan District, Bao'an District, Longgang District, Guangming district, and Pingshan District, together with 57 street offices, and 790 resident committees. To ensure comparability, the data in this study was analyzed according to the six administrative regions, being Futian District, Luohu District, Yantian District, Nanshan District, Bao'an District, and Longgang District.

2.2. Data source

Landsat TM and ETM + images of 1990, 2000, and 2010 were selected as data sources. They were mainly obtained from the Geospatial Data Cloud Platform (http://www.gscloud.cn/). It needs two images to cover the territory of Shenzhen City with bands number 122/44 and 121/44. These images were obtained on November 23 and December 23, 1990 with a resolution of 30 m obtained from Landsat TM, on December 23, 1999 and January 2, 2000 with a resolution of 15 m from ETM+, and November 30 and