Landscape and Urban Planning 125 (2014) 290–297

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research Paper

# Assessing urban environmental resources and services of Shenzhen, China: A landscape-based approach for urban planning and sustainability

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## HIGHLIGHTS

- We put forward a methodology to establish environmental resource value account.
- Ecological core areas were identified.
- We planned the ecological infrastructure for Shenzhen City.

## ARTICLE INFO

*Article history:*
Available online 29 March 2014

*Keywords:*
Landscape ecology
Urban ecology
Ecological network
Environmental resource
Ecosystem services
Urban sustainability
Shenzhen

## ABSTRACT

More than half of the planet's residents now live in urban areas. In the foreseeable future, global urbanization will continue. China is one of the most rapidly urbanizing countries in the world, and during the past three decades its urban expansion has encroached on productive lands and caused myriad environmental problems. To achieve urban sustainability, Chinese cities need to be better designed, planned, and managed in a more ecological and sustainable way. In this study, we focused on Shenzhen City in southern China, which has experienced extremely rapid urbanization and socioeconomic transformations since China's economic reform and open-door policy enacted in 1978. We have proposed a methodology for environmental resource accounting, which consists of ecosystem services, atmospheric environment capacity, water environment resource, and land value. Our methodology recognizes the strategic significance for conserving biodiversity and maintaining high environmental quality. In particular, protecting the remaining natural and semi-natural areas in and around the city – ecological core areas – is of paramount importance. In addition to valuating urban environmental resources and services, we have also proposed an ecological network-based urban landscape design in order to improve urban sustainability for the city. Our proposed urban design plan has been taken seriously by the city government. Overall, this study provides a quantitative approach for research and practice in urban sustainability, and should be of value to other rapidly urbanizing regions around the world.



## 1. Introduction

In 2008, for the first time in human history, more than half of the world's population (3.3 billion) lived in cities, and the world's urban population is expected to increase to 5 billion by 2030 (UNFPA, 2007). As a socio-economic process, urbanization along with the geospatial form and structural changes (Antrop, 2004; Friedmann, 2006) has great impacts on the global environment (Grimm et al., 2008).

Different disciplines have defined urbanization from their respective perspectives. The economists believe that urbanization is a process when the natural economy in rural areas becomes socialized mass production in urban areas; the demographers think that the rural population becomes urban population during urbanization process; the geographers think that urbanization is a process for rural areas to be converted into urban areas; and the sociologists regard urbanization as a process when the

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http://dx.doi.org/10.1016/j.landurbplan.2014.01.025
0169-2046/

rural lifestyles convert into urban lifestyles. Urbanization has many dimensions, but the population component of urbanization includes the increase in number and density of people, and the landscape component involves the growth of built-up space with accompanying infrastructures.

Internationally, population urbanization is a process when the urban population increases its proportion in the total population (UNFPA, 2007). According to the study of Redman and Jones (2005), urban population grows mainly through four processes: (1) rural-to-urban migration attributable to economic benefits, urban lifestyle, and better medical and educational services; (2) the natural growth of the urban population; (3) cross-border immigration due to the same reasons as in the first process, or reduced domestic employment opportunities, environmental degradation, political instability, and civil war; (4) classification system and institutional changes, accounting for changes in both the rural-to-urban land conversion and demographic transition.

Many researchers have studied the pattern, process, and impacts of the land use change during urbanization (e.g. Dai & Wu, 2004; Gu et al., 2008; Lambin & Geist, 2006; Nagendra, Munroe, & Southworth, 2004; Zhao et al., 2006). Land use/cover change may have important impacts on biodiversity and ecological processes (Sala, Chapin, & Armesto, 2000; Shi, Song, & Jing, 2002). As one of the driving forces of regional climate change and even global warming (Chase, Pielke, Kittel, Nemani, & Running, 1999; Houghton, Hackler, & Lawrence, 1999; Pielke, 2005), land use/cover change may impair ecosystem functions, lead to soil degradation (Tolba & El-kholy, 1992), affect the ability of the earth system to meet the needs of the mankind (Vitousek, Mooney, Lubchenco, & Melillo, 1997), and influence the degree of vulnerability of a region and its population to various climatic, economic and socio-political changes (Kasperson, Kasperson, & Turner, 1995). Although cities cover about 2% of the earth's land surface, they account for 78% of carbon emissions, 60% of residential water use, and 76% of the wood used for industrial purposes (Brown, 2001).

Land use intensity has become an important indicator of the relationship between the economic system and the ecosystem (Hubacek & van den Bergh, 2006). Two major international scientific programs, namely the "International Geosphere-Biosphere Program" (IGBP) organized by the International Council for Science and the "International Human Dimension Program on Global Environmental Change" (IHDP) organized by the International Social Science Alliance, have adopted land use/land cover change (LUCC) as a co-conducted comprehensive interdisciplinary scientific research program, to improve the understanding of the dynamics of land use and land cover change, as well as the understanding of the relationship between such changes and global environmental changes. IHDP & IGBP-GLP (Global Land Project) and IHDP-UGEC (Urbanization and Global Environmental Change) has considered the land system, global change, and sustainable development as a research focus for quite a long period of time, and land-use change and its environmental effects have been one of the key research areas.

The importance of land use to sustainable development was evident in several reports published by the Ecological Society of America (ESA) during the past few decades. In that report, Lubchenco et al. (1991) proposed the Sustainable Biosphere Initiative and "the research of sustainable ecosystem" as one of its three priority areas of research. Five years later, the report by Christensen et al. (1996) emphasized to focus on "the scientific basis for ecosystem management". The report by Dale et al. (2000) focused specifically on the principles and guidelines for land use management. Similar efforts were also made in China to optimize land use pattern so as to achieve sustainable development (Shi, Yuan, & Chen, 2001). Therefore, landscape urbanization, which means the process of a natural or rural landscape changing to an urban landscape, not only expresses the urbanization process, is a concept that links urbanization with ecological processes and environmental consequences in a spatially explicit land use and land cover framework (e.g. Alberti, 2008; Grimm et al., 2008; Turner, Lambin, & Reenberg, 2007; Wu, 2008).

China has been rapidly urbanizing in the recent decades at the expense of arable land. In 2006, the per capita arable land was only 0.09 ha, less than 40% of the world average. In addition, the continuing urbanization in China is faced with increased population, shortage of water resources and energy, land degradation, and a series of negative impacts on the environment of many cities (Yu, Shao, Shi, Pan, & Zhu, 2009; Yu, Shi, Liu, & Xun, 2013; Yu, Xun, Shi, Shao, & Liu, 2012; Zhang et al., 2008). The expansion of urban land has become one of the most prominent features of land use change in China (Liu, Liu, Zhuang, Zhang, & Deng, 2003), and is also considered a major threat to the food security of the most populous country in the world (Chen, 2007). Thus, the main objectives of our study were: (1) to propose a quantitative methodology for assessing urban environmental resources and services in Shenzhen – one of the most recognized, rapidly developing cities in China, and (2) to propose an ecological network-based urban landscape design in order to improve urban sustainability for the city.

## 2. Study area

Shenzhen is located in the central coastal area of Guangdong Province, bordering with Dongguan and Huizhou in the north, Hong Kong across the Shenzhen River in the south, Daya Bay and Dapeng Bay in the east, and Lingdingyang Bay at the mouth of the Pear River in the west (Fig. 1). The jurisdictional area of Shenzhen is long and narrow, covering 90 km from east to west, and 44 km from south to north. According to the detailed survey results of land resources in Shenzhen completed by the end of 1995, the total area of the municipality was 1948.69 $km^2$, and increased to 1991.64 $km^2$ by the end of 2009 after reclamation of some costal wetlands (SSY, 2009). The administrative boundary of Shenzhen starts from 22°26′59″ to 22°51′49″ N and from 113°45′44″ to 114°37′21″ E (Fig. 1).

Shenzhen has three geomorphologic belts in the south, middle and north, with the peninsula gulf landform in the south, the coastal mountain range in the central part, and hills-and-tableland topography in the north. The orientation of the three geomorphologic belts is from southeast to northwest, resulting in the topographic pattern of high in southwest and low in northwest. Characterized by a subtropical marine monsoon climate, Shenzhen is warm and humid throughout the year. The multi-year average annual temperature is 22.0 °C, with the lowest average monthly temperature of 14.1 °C in January and the highest average monthly temperature of 28.2 °C in July. The multi-year average rainfall is 1882.8 mm, with 1591.0 mm falling in the rainy season (April–September), accounting for 84.5% of the annual rainfall. The average number of rainy days is 139.3 per year, with 96.3 days during the flood season, accounting for 69.1% of the year's total. The soil types in Shenzhen include latosolic red soil, paddy soil, coastal sand and coastal saline marsh soil. The zonal vegetation types in Shenzhen include tropical evergreen monsoon forests in the south and subtropical seasonal evergreen broad-leaved forest in the north.

Before China's economic reform and the open-door policy in 1978, Shenzhen's economic development was quite slow for years. Its population in 1979 was only 314,100, with gross domestic product (GDP) of 196 million RMB. However, since the establishment of the Shenzhen Special Economic Zone (SSEZ) in 1980, Shenzhen has developed into a modern metropolis with well developed secondary and tertiary industries. By the end of 2010, the municipality's population of residents was 10.37 million, with GDP of 958.15 billion RMB. While having achieved economic development