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Understanding the dynamic of greenspace in the urbanized area of Beijing based on high resolution satellite images

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ABSTRACT

Urban greenspace plays an essential role in urban ecosystem and highly contributes to the welfare of urban residents. Understanding the dynamics of greenspace is crucial for its planning and management. Previous studies have largely focused on changes in greenspace in urbanizing regions, using medium resolution remotely sensed data. However, the changes of greenspace in urbanized areas need to be accurately quantified based on high spatial resolution images because they are directly related to human health and well-being. This paper aims to enhance the understanding on dynamics of greenspace within well-developed areas of the city, using Beijing City, China as a case study. Using high spatial resolution remotely sensed imagery, we analyzed the spatial pattern of greenspace and its change on two scales: (1) the entire area within the 5th ring road, and (2) in 4 belts from urban center to fringe. We found urban greenspace was very dynamic. The proportion of urban greenspace increased by 5.45%, or 36.3 km^2 in size from 2005 to 2009. The amounts of gain and loss of greenspace were 69 km^2 and 32.7 km^2, respectively, or 10.36% and 4.91% of the entire study area. Because of the very limited lands for greening in urbanized areas, the new patches of greenspace were generally small, with the mean patch size of 676.31 m^2. However, those small patches enhanced the connectivity and continuity of urban greenspace. In addition, we found the differences in configuration of greenspace patches across the 4 belts were greater than the differences in total percent cover, indicating that compared to percent coverage, greenspace configuration may be more influenced by the development age.

Introduction

Rapid urbanization has greatly changed urban greenspace (Zhou and Wang, 2011), and consequently affected its functions. Understanding the dynamics of urban greenspace is crucial for urban greenspace planning and management. Greenspace in urban area is closely connected with human health, well-being, and social safety (Groenewegen et al., 2006). The presence of greenspace can purify polluted air (Yang et al., 2005; Nowak et al., 2006), alleviate urban heat island (Zhou et al., 2011a; Li et al., 2013), protect water from non-point source pollution (Conine et al., 2004), and maintain biodiversity (Attwell, 2000; Dwivedi et al., 2009). It also provides considerable socioeconomic benefits (Geoghegan et al., 1997; Gobster and Westphal, 2004).

Numerous studies have investigated the changes in urban greenspace. Most of the studies have used remotely sensed data with medium spatial resolution such as Landsat Thematic Mapper (TM) images to quantify the spatial pattern of urban greenspace and its changes (Hurd et al., 2001; Seto et al., 2002; Yuan et al., 2005; Kong and Nakagoshi, 2006; Zhou and Wang, 2011; Miller, 2012; Portillo-Quintero et al., 2012). These studies have shown that greenspace was very dynamic on the urban fringe. In particular, urban expansion has led to great loss of urban greenspace (Seto et al., 2002; Yuan et al., 2005; Portillo-Quintero et al., 2012), as well as greenspace fragmentation (Hurd et al., 2001; Miller, 2012). In contrast, changes in urban greenspace tended to be ignored in more intensively urbanized locations (Zhou et al., 2011b).

With the importance of urban greenspace increasingly recognized, more and more efforts have been dedicated to increase urban greenspace (Li et al., 2004; Beijing Landscape Bureau, 2007; Van Den Hoek et al., 2014). This is particularly true in many Chinese cities such as Beijing, which now face serious environmental issues, in spite of the desire of the general public for high quality environment with the increased welfare (Yang et al., 2005; Yu et al., 2005). Meanwhile, cities are still facing great pressure from development due to economic and population growth. Therefore, we hypothesize urban

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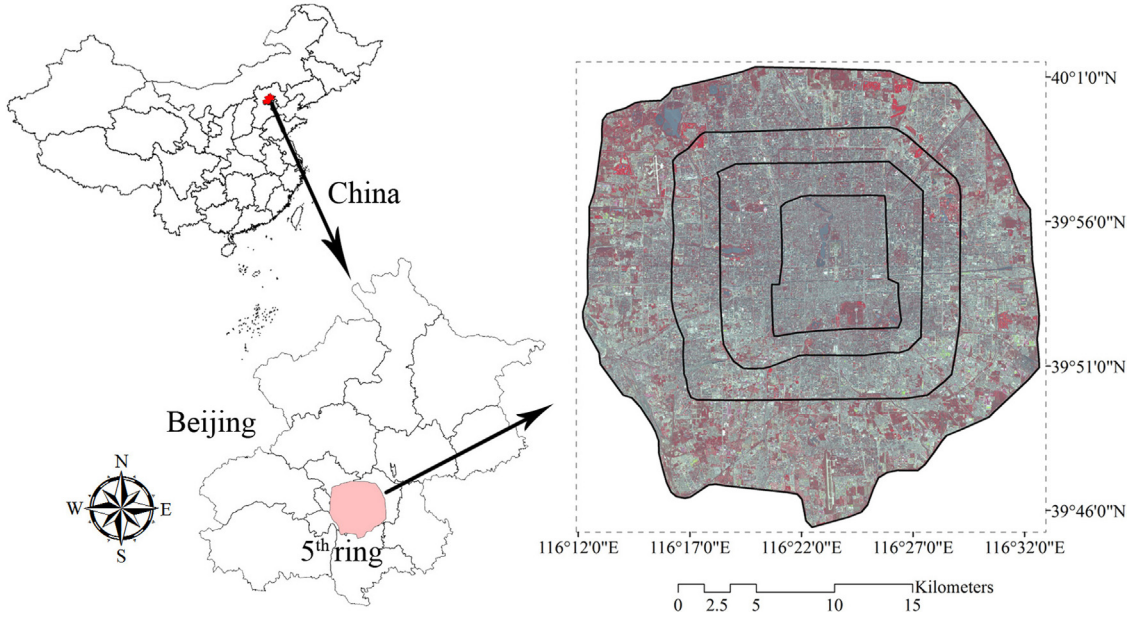

Fig. 1. The study area: the region within the 5th ring road of Beijing, China.

greenspace in well-developed city regions may be experiencing great changes, even over a very short time period because of the combination of pressure in development and increasing efforts being taken to increase urban greenspace in many cities.

Using Beijing as a case study, we aim to test this hypothesis by quantifying the spatial-temporal dynamics of urban greenspace in the most developed area of Beijing City, that is, the area within the 5th ring road. We used high spatial resolution image data to map urban greenspace. This is because urban greenspace is highly fragmented, and many of the patches are quite small (Zhou et al., 2011b). Images with medium resolution are inadequate to depict the dynamics of greenspace at the fine scale within urbanized areas. Greenspaces were mapped for 2005 and 2009, using an object-based approach. The spatial pattern of greenspace and its change were analyzed at two scales: (1) the entire area within the 5th ring road, and (2) in 4 belts from the urban center to the fringe, namely the areas within the 2nd ring road, and between the 2nd and 3rd ring road, 3rd–4th ring road and 4th–5th ring road, respectively. In addition, the spatial patterns of greenspace gained and of greenspace lost were analyzed separately.

Study area

Beijing, the capital of China, is located in the northeast of the North China Plain (longitude: 115°25′–117°30′ E, latitude 39°28′–41°25′ N; Fig. 1). It has a total area of approximately 16,410 km^2; roughly 38% is flat and 62% is mountainous. The city has a history of more than 3000 years, and has been as the capital for more than 800 years. Since the implementation of the Reform and Open Policy in 1978, Beijing has undergone dramatic economic and population growth. The total population increased by 137% from 8.72 million in 1978 to 20.69 million in 2012, and the percentage of the urban population increased from 55% to 86% (Beijing Municipal Statistical Bureau, 2013). The gross domestic product (GDP) also increased rapidly from 10.88 billion RMB in 1978 to 1787.94 billion RMB in 2012 (Beijing Municipal Statistical Bureau, 2013). Along with this rapid socioeconomic development was the fast expansion of Beijing city, and the increasing efforts being taken to increase the urban greenspace in the city (Beijing Landscape Bureau, 2007).

We chose the study area within the 5th ring road of Beijing City, a well-developed area (Fig. 1). Inside the study area, there

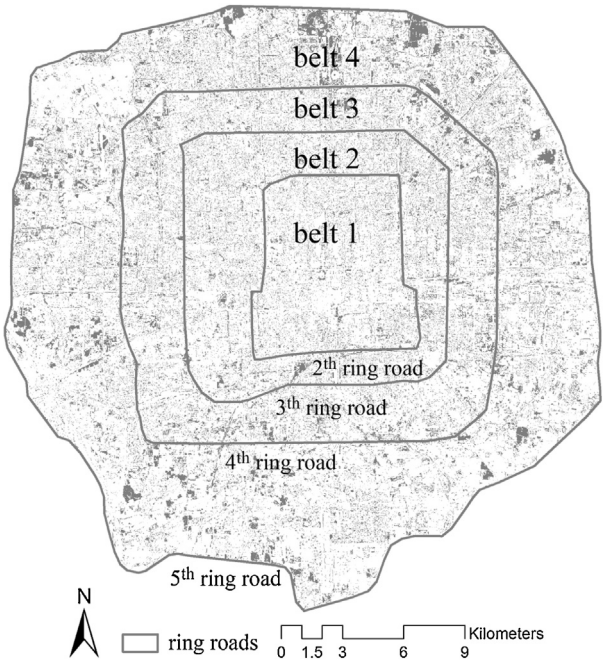

Fig. 2. The layout of four belts inside the 5th ring road.

are 4 ring roads concentrically arranged from the urban center to the fringe, namely the 2nd, the 3rd, the 4th and the 5th ring road which were built in 1992, 1999, 2001 and 2003, respectively (Fig. 2). The areas within each of the ring roads were 62.1 km^2, 158.2 km^2, 301.9 km^2 and 666 km^2, respectively, from the 2nd to the 5th ring road. Land cover in the study area was dominated by impervious surfaces and vegetation. Most of the agricultural land occurred in the urban fringe.

Materials and methods

Image data preprocessing

We used SPOT-5 (Systeme Probatoire d'Observation dela Tarre) image acquired on October 8, 2005 and ALOS (Advanced Land