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Original article

Assessing the impacts of urbanization-associated green space on urban land surface temperature: A case study of Dalian, China

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ABSTRACT

Taking Dalian City as the study area, the spatial distribution of urban green space and land surface temperature (LST), as well as their evolution in 1999, 2007 and 2013, were obtained through remote sensing (RS) interpretation and inversion. Landsat ETM and SPOT data were used for this purpose. By combining the temperature and vegetation index models (TVX), the effects of urban green space reduction on the thermal environment during city development were evaluated. The results show the following. (1) During 1999–2013, 88.1 km^2 of urban green space was converted to other land uses, accounting for a 29.4% reduction in urban green space in the study area. (2) During the study period, the LST in this area increased by +8.455 K. The evolution of the regional thermal landscape can be characterized by increases in the LST, greater complexity of the thermal landscape structure, increase and aggregation of high-temperature areas, and reduction and fragmentation of low-temperature areas. (3) During the process of urbanization, urban green space with low land-surface temperature was converted to other land use types with high land-surface temperature. When development occurred at the price of urban green space, negative effects on the regional thermal environment were observed.

1. Introduction

As one of the basic elements of the urban environment, urban green space is the only type of land use with natural or semi-natural conditions inside a city, and plays a significant role in protection of the ecological environment of cities (Ngom et al., 2016). Urban green space is gradually capturing the attention of researchers in the fields of urban ecology and urban geography. As a result, urban space is becoming a popular research topic in relation to the concepts of urban economic space and urban social space (Yang et al., 2015; Morris et al., 2016). On the basis of achievements in other fields, geographical studies mainly analyze the distribution characteristics of urban green space, as well as its social, economic and ecological functions from the perspective of spatial distribution (Tao et al., 2013; Sun and Xu, 2008). In recent years, rapid urbanization has greatly changed city surfaces, resulting in the reduction of urban green space and problems in the natural environment, some of which are reflected in negative effects on regional climates (Salazar et al., 2015). One of the most obvious urban environmental problems is the effects of urbanization on the urban thermal environment (Feizizadeh and Blaschke, 2013; Su et al., 2011).

Such effects have been monitored for over two centuries in some countries. In the initial stage, most of these were empirical studies describing and investigating effects on the urban thermal environment. In addition, they mostly concentrated on the atmospheric heat island phenomenon of urban areas. With the development of satellite RS technology, the radiation temperature obtained from inversion of RS data could involve most land surfaces with high spatial resolution and spatial continuity. Rao (1972) first applied satellite RS to the observation and analysis of the LST of coastal cities in the central Pacific Ocean, and investigated characteristics of the urban thermal environment. Gallo et al. (1995) first reported the negative correlation between vegetation index and urban thermal environment. Rotem-Mindali et al. (2015) verified the remediation function of urban green space on the urban heat island effect, and revealed that the temperature reduction effect of green space depended on a number of factors, such as species, canopy density, and distribution area and pattern. The thermal environment adjustment effect of urban green space has become a hot topic, and the relationship between green space evolution and urban thermal environment has not been documented in a systematic fashion.

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From the above studies, it can be concluded that the mainstream method of investigating the urban thermal environment is to invert LSTs based on satellite RS data, using the single-channel method (Demirli et al., 2015), split-window method or multi-channel method. The research perspective has gradually evolved from descriptive studies of urban thermal environment to causes and development research in this area, with most studies focusing on the cooling effect of urban parks (Declet-Barreto et al., 2013; Feyisa et al., 2014).

Studies on the urban thermal environment effect in China started slightly later than in western countries, mostly focusing on regions that had experienced rapid urbanization (Cui and Shi, 2015). In one study, the daily, yearly, and multi-year variations in thermal effects in Shanghai were reported based on meteorological data between the 1950s and 1980s (Zhou and Zhang, 1982). This work laid the foundation for studies on the effects of urbanization on urban thermal environment in China. Zhou et al. (2008) used RS dynamic monitoring and GIS multi-element spatial analysis technology to investigate urban expansion in Shanghai, and heat island distribution and its pattern of evolution. They showed that expansion of the urban area was spatially consistent with the tendency for expansion of the heat island effect. From the perspective of land use, Kuang et al. (2015) discovered the mechanism of influence. They pointed out that urban construction, green space, and human activities jointly, but differently, impacted the occurrence and development of urban thermal effects. Moreover, the effect of urban vegetation on the thermal environment was emphasized in this study. Chen et al. (2002) integrated landscape ecology theory into studies of urban thermal environmental effect in order to explore the spatial structure and pattern of urban thermal environments. In China, studies integrating urbanization and thermal effects are increasingly capturing more attention (Xiong et al., 2012; Qian et al., 2006). Research has mainly concentrated on synchronization of increases in urban areas and urban heat island effects, as well as the relationship between land use and urban LST. However, the relationship between urban green space and developmental mechanisms of the thermal environment (Zhang et al., 2009), model quantization and simulation (Wang et al., 2015), risk evaluation (Morabito et al., 2015), and related strategies (Touchaei et al., 2016) have also been studied. In addition, new perspectives provided by RS and GIS technology, landscape theory (Huang and Chen, 2015) and ecological theory (Chen et al., 2012a,b) have recently been applied in the studies of the urban thermal environment effect.

In the past, most research focused on the relationship between urban expansion and LST driven by urbanization. Our study emphasizes the relationship between urban green space decline and LST. In our study, urban green space is divided into three categories, with the aim of identifying the type of green space that is the main cause of the urban thermal effect. Spatial transposition, mono-window algorithm, landscape analysis and TVX model and so on are applied to the study using GIS and RS technology. We used traditional landscape pattern indices to explain the evolution of the surface temperature pattern. This study expands the research perspective of urban green space, provides a typical case study, and points out the insufficiency of policy implementation, the intensity of the urban thermal effect, and the fact that this is a typical problem in China.

2. Study area, data and methods

2.1. Study area

Dalian is located in the warm temperate zone of the Northern Hemisphere on the southern tip of the Liaodong Peninsula in China (38°43′–40°10′N; 120°58′–123°31′E). The main city of Dalian represents the study area, and consists of four districts: Ganjingzi Shahekou, Xigang and Zhongshan (from left to right are displayed in Fig. 1), with a total area of 620.8 km^2. In the last two decades, Dalian has experienced profound economic development, with significant urbanization effects. It is the biggest port city in northeast China.

2.2. Data sources

The data used in this study are from RS images from Landsat 7 ETM and SPOT5 (Table 1), as well as from regional planning data sets

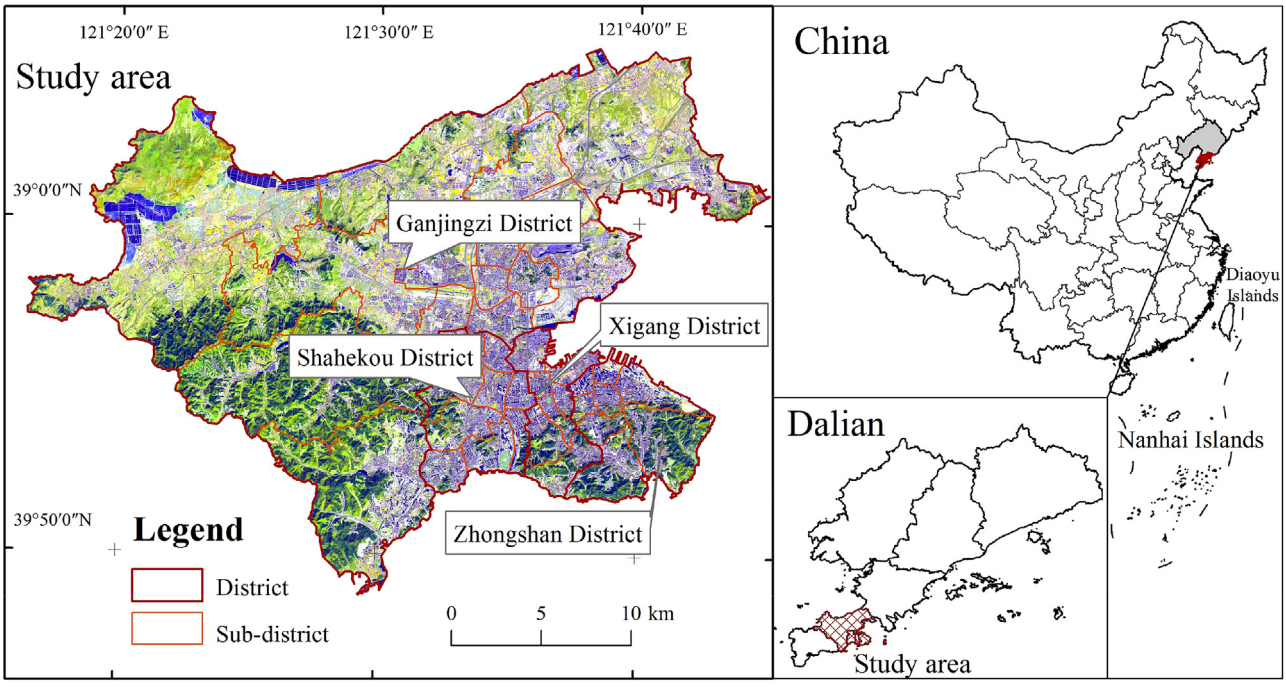

Fig. 1. Location of the study area.