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Research Note

Urban stormwater management based on an analysis of climate change: A case study of the Hebei and Guangdong provinces

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ABSTRACT

Analysis of the urban climate changing is the basis for the implementation of stormwater management measures. This study analyzed the climate conditions of 230 cities in the Hebei and Guangdong provinces from 1958 to 2016, and then discussed stormwater management of these cities. The results demonstrated the following: (1) The climatic indicators differed significantly between the two provinces. These indicators include the aridity index, annual average potential evapotranspiration, precipitation, temperature, extreme precipitation frequency, precipitation intensity, drought frequency, and drought intensity of 146 cities in Hebei and 84 cities in Guangdong. (2) With the exception of temperature and potential evapotranspiration, most of the above indicators showed a non-significant trend (at the significance level of 5%) in the past 59 years. Temperature of most cities in the two provinces had a significant upward trend, and the potential evapotranspiration of most cities had a significant downward trend. (3) According to the above analysis, we constructed a system to evaluate the flooding and drought risk for these cities, and the evaluation indicated that all cities of Guangdong had a high flooding risk and approximately one-fifth cities of Hebei had a high drought risk. Finally, we divided 230 cities into five types based on the above risk analysis, and proposed stormwater management strategies for each type of city based on Low Impact Development (LID).

1. Introduction

Rapid progress of urbanization often causes environmental deterioration and ecological destruction in urban areas (Chen, Samuelson, & Tong, 2016; Cohen, 2006). In a number of cities, the urban impervious surface leads to water shortages and water pollution in drainage areas (DeLaria, 2008). Many cities are facing serious hydrological and ecological problems with the rapid urbanization in China, leading to nationwide property damage, heavy casualties, traffic paralysis, water pollution and economic losses (Li, 2012). The cities of Wuhan, Guangzhou and Beijing are typical cases, with frequent flooding and drought events occurring in recent years (Sheng & Nawari, 2016; Zhang, Yang, Voinov, & Gao, 2016). Hydrological and ecological protection have been bottlenecked for urban sustainable development in many developing countries (Han et al., 2016; Hubacek, Guan, Barrett, & Wiedmann, 2009; Li et al., 2016). In recent years, due to the severe global climate change, the economic losses caused by natural disasters, especially the flooding and drought events are gradually increasing. At the same time, more and more population and economy are gradually exposed to natural hazard because of the acceleration of urbanization (Güneralp, İnci, & Liu, 2015). Therefore, the assessment of urban flooding and drought risk is particularly important in urban reconstruction.

The conventional approaches to urban stormwater management overemphasize the drainage efficiency. However, these measures changed the natural hydrologic processes and led to further increases of storm frequency, magnitude, volume and decay time, and a decrease of base flow (Burns, Fletcher, Walsh, Ladson, & Hatt, 2012). Since the 1970s, in an attempt to control the negative influence of urbanization on hydrology and improve the ecological environment around the city, many stormwater management measures have been proposed. These measures include the Best Management Practices (BMPs, proposed by United States in 1972); Low Impact Development (LID, termed by United States in 1990); Sustainable Urban Drainage Systems (SUDS, a British drainage strategy launched in 1999); Water Sensitive Urban Design (WSUD, an urban water recycle system in Australia); and the Active Beautiful Clean Waters Program (ABC Waters Program, launched in 2006 by Singapore government). These measures have matured after decades of exploration and practice, and have been applied in many countries (Ahiablame, Engel, & Chaubey, 2012; Selvakumar,

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Muthukrishnan, Madge, Field, & Tafuri 2005; Andoh & Iwugo, 2002; Roy et al., 2008; Lim & Lu, 2016). Throughout the urbanization process, the Chinese government has made a great effort to solve urban droughts and floods. In 2012, based on the LID method and the stormwater management experiences of other countries, China proposed the idea of a “sponge city”. Sponge city means that the city can absorb, impound, leak, and purify rainwater with good “elastic” in adaptation to environmental change and disaster response like a sponge, and the stored water can be released and utilized when necessary (Yang, Scheffran, Qin, & You, 2015). Presently, sponge cities have risen to the national strategic level, and there were 30 cities received the government's financial support to pilot their own sponge cities by the end of 2016.

So far, there has been considerable research on urban stormwater management in China (Jia, Yao, & Yu, 2013; Liao, Zhang, Wu, He, & Chen, 2015; Yu, Huang, & Wu, 2014). However, few studies have taken into account the background of climate change. The global climate is changing significantly, and the warming of the climate is bringing more energy into the atmospheric system, resulting in a more vigorous hydrological cycle (Güneralp et al., 2015). On the other hand, the change of land use and land cover make the regional hydrologic process more complex and varied (Zhang et al., 2004; Zhang, Lu, Jing, Rustomji, & Hairsine, 2008). The extreme weather events have become more frequent in many regions, including northwest China, northern Europe, the southern US, southeast Asia and others (Cheng et al., 2015; Khoi & Trang, 2016; Rajczak, Pall, & Schär, 2013; Wang & Zhang, 2008). The extreme changes in climate will force many cities to face the serious risks involved with flooding and drought, which will result in a significant economic burden (Lo, Xu, Chan, & Su, 2015; Xie, Lo, Zheng, Pan, & Luo, 2014).

Hebei and Guangdong Provinces were selected as examples of a typical arid and semi-arid and a humid and semi-humid region, respectively. What is the interaction of urban climate change and stormwater management? What are the differences of urban climate change and stormwater management in Hebei and Guangdong? The above two problems deserve further study, therefore, the main goals of this study were (1) to analyze the climate characteristics and changes in the cities of Hebei and Guangdong over the past 59 years (1958–2016), (2) to construct a system to evaluate the flooding and drought risks based on meteorological factors, and (3) to discuss the stormwater management for these cities based on the above analysis. The results from this study will provide critical references for the development of sponge cities worldwide.

2. Materials and methods

2.1. Study area

The Hebei Province (36°05′N- 42° 40′N, 113°27′E- 119° 50′E, Fig. 1b) is divided into 11 prefecture-level cities (including 22 county-level cities and 113 counties and autonomous counties), and has an area of 199,000 km^2 and a population of 74.7 million (2016). The climate of Hebei is a temperate, continental, and monsoonal, with a mean annual precipitation of approximately 500 mm, and a mean annual temperature of 10 °C. Hebei has begun to build its own “sponge city”, where all the new and developing projects must meet the requirements of sponge city. Qian'an County has been selected as a national sponge city pilot in 2015.

The Guangdong Province (20°13′N-25°31′N, 109°39′E-117°19′E, Fig. 1c) is located in southern China, has a population of 108 million and an area of 179,800 km^2, and is divided into 21 prefecture-level cities (including 23 county-level cities and 40 counties and autonomous counties). The climate of Guangdong is subtropical and monsoonal with a mean annual precipitation of approximately 1777 mm and a mean annual temperature of 22 °C. Zhuhai and Shenzhen have been selected as national sponge city pilots in 2016.

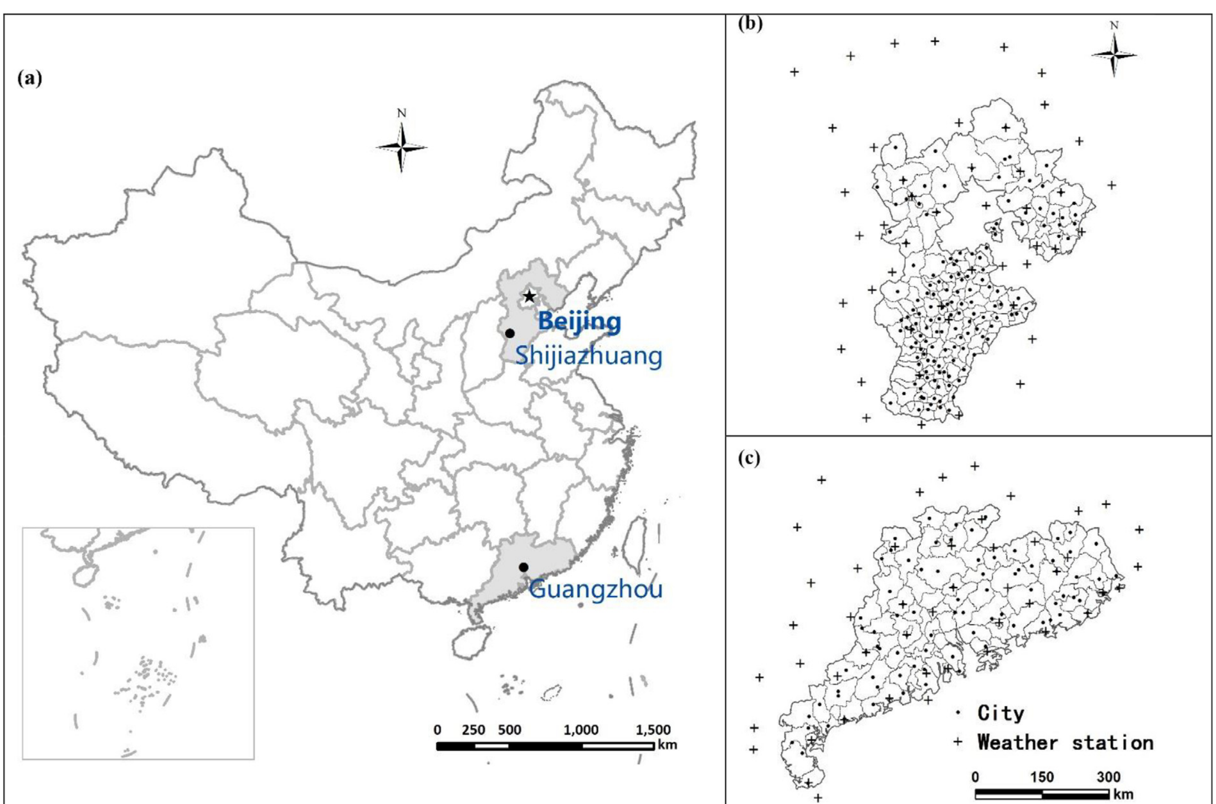

Fig. 1. Geographical locations of Hebei and Guangdong in China (a), the locations of weather stations and cities in Hebei (b), and in Guangdong (c).