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Urban waterlogging risk assessment based on internet open data: A case study in China

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ABSTRACT

Urban waterlogging caused by rainstorm occurred frequently in many cities of China these years and seriously influenced city safety and residents' daily life. Meanwhile, many remarkable achievements with open data and big data have been applied in urban research, but rare to urban waterlogging research. Taking Xiamen city in China as a case, this study aims to analyze spatial-temporal distribution of waterlogging and assess waterlogging risk of each district in the city. Risk assessment model was built by considering both population and urban public facilities, which acquired from coupling urban internet open data and field investigation. Then we analyzed the government management efficiency through comparison of urban government management plan and waterlogging information from internet. The result indicates that internet open data can be utilized as an effective tool to identify urban waterlogging risk in China, to verify urban waterlogging management efficiency, and to support for urban waterlogging risk prevention and management combining with field investigation.

1. Introduction

Recently, urban waterlogging caused by rainstorm occurred frequently in many cities of China, resulting in traffic paralysis and flooding in the residential and public buildings, which influenced city safety and residents' daily life badly (Han, Xie, Li, Li, & Sun, 2006; Li, 2012; Yin, Ye, Yin, & Xu, 2015). Existing studies on urban waterlogging problems include waterlogging causes, prevention and control strategy, waterlogging model and risk assessment, etc., among which urban waterlogging risk assessment is one of the major research contents.

Previous researches on urban waterlogging risk assessment mainly focus on waterlogging risk assessment and hazard vulnerability based on GIS, simulation model and scenario simulation. Submerged area and depth of different rainstorm return period are calculated and simulated by constructing model to estimate or predict waterlogging risk and spatial distribution characteristics. Hydrological-geo-morphological, photogrammetric/photointerpretation and socioeconomic data were often used in the studies (Pistrika & Tsakiris, 2007). Spatial analysis technique is used in GIS-based waterlogging risk assessment research through constructing terrain, rainfall, drainage and other models (Hu, Zhou, Wang, Xu, & Meng, 2012; Quan, 2014; Sun, Shi, & Shi, 2010; Wang et al., 2004; Yin, Bao, & Yin, 2011; Yin, Yin, Wang, Xu, & Chen, 2009; Zhao, Chen, & Xiong, 2004). GIS-based method of urban storm-inundation simulation is useful when only some usual data can be obtained (Zhang & Pan, 2014). Hydrodynamic-equation-based mathematical simulation model is also one of the main methods to evaluate urban waterlogging risk (Duan, Xie, Chen, Zhao, & Ren, 2014; Shi, 2013; Shi, Xu, Shi, Sun, & Zhao, 2011; Xie, Han, You, Wang, & Yan, 2004). Urban waterlogging prevention strategies include improving city drainage system and planning (Che, Yang, Zhao, & Li, 2013; Xie, 2013), rainwater utilization (Li et al., 2013) and perfecting management system. Low impact development (LID) techniques has been increasingly recognized and applied to urban stormwater management (Joksimovic & Alam, 2014; Martin-Mikle, Beurs, Julian, & Mayer, 2015; Sin, Jun, Zhu, & Yoo, 2014; Yazdi & Salehi Neyshabouri, 2014). Some progress has been made in current researches, but little concerned the information from open urban data which are increasingly growing and of great potential for waterlogging risk assessment.

As a vital complement to traditional investigation data, open urban data and big data can contribute to urban management and solving city

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problems (Long, 2015). Open urban data was adopted to understand Chinese cities and proved the availability of it (Liu et al., 2015). Long explored big/open data of road/street to redefine Chinese city system (Long, 2016). Smartcard big data was employed in the analysis of the commuting efficiency of Beijing (Zhou, Murphy, & Long, 2014).

Open data can be defined as the various types of data generating or existing in the web, which can be developed, processed, stored, organized according to the specific needs of users and the corresponding internet protocol, rule and frame (Tan, 2011; Wu, 2012). Open data can strengthen and promote scientific development (Reichman, Jones, & Schildhauer, 2011). Although it is prone to loopholes and lack of intuitive information, open urban data has the advantages of easy access and high degree of quantification. Field investigation data, generally difficult to obtain and highly qualitative, can make up for the inadequacy of open/big data on account of its direct and thorough survey on the field. Field investigation was combined with a numerical model to study the storm surge and propose evacuation suggestions (Takagi et al., 2016). More and more researches have made remarkable achievements in the application of open data and big data to urban research, and it has been recognized necessary to integrate open/big data and field investigation in urban research. But up to the present open/big data used in urban waterlogging research is rare. In our study, the big data application on urban storm management is demonstrated in a Chinese city and our research hypotheses are: (1) Is open/big data available for identifying urban waterlogging risk in China? (2) If it is available, how open/big data and field survey can be utilized for urban waterlogging management?

Taking Xiamen city in China as a case, this paper adopted a comprehensive research method combining urban internet open data and field investigation to systematically analyze spatial-temporal distribution of waterlogging occurred in 2013–2015 and assess waterlogging risk of each district of Xiamen city using assessment model based on population and urban public facilities suffering from waterlogging, and further study government management efficiency through comparison of urban government management plan and waterlogging state.

2. Study area and methods

2.1. Study area

Xiamen city, located on the southeast coast of China, was selected as the study area. Xiamen is a port city facing the Taiwan Strait. The city consists of six administrative districts: Siming, Huli, Haicang, Jimei, Tong'an and Xiang'an (Fig. 1). Xiamen Island includes Siming District and Huli District, and the mainland is comprised of four districts involving Haicang, Jimei, Tong'an and Xiang'an.

Flooding is one of the biggest challenges facing coastal cities due to storm polytropy, sea-level rise and coastal change (Woodruff, Irish, & Camargo, 2013; Xu, He, Huang, & Cui, 2016). Exposure of coastal developing countries to future sea-level rise and storm surges will significantly increase (Dasgupta, Laplante, Murray, & Wheeler, 2011). Coastal areas in developing countries are more vulnerable to floods disasters (Webster, 2013). Xiamen is a typical coastal city in southeastern China. Dominated by a subtropical maritime monsoon climate, Xiamen is warm and humid with abundant rainfall, especially from May to August with maximum. Xiamen city often suffers from thunderstorm and typhoon disasters due to its low-lying topography and the climate factor. Many rainstorms caused waterlogging of different severity in recent years, with serious consequences for residents' lives and assets. According to the research that studied the global ranking of 136 large port cities exposed to coastal flooding risk, Xiamen ranked seventh in the ranking of the highest rate of increase in exposed assets by the 2070s compared with the current situation, and within the top 20 cities with the greatest rate of increase in exposed population respectively (Hanson et al., 2011).

2.2. Data collection

We searched the urban waterlogging news reports in the internet by exploring key words including Xiamen, waterlogging, rainstorm, typhoon and disaster using Baidu search engine (http://baidu.com) in March 2016. We selected the useful reports through rapid reading, and eliminate duplicate reports. About 122 reports of 2010–2015 were found (Fig. 2). And then we extracted the news reports which mentioned the specific location of waterlogging spots. We did not utilize news report data of 2010–2012, because the majority of them only reported general situation of waterlogging and did not mention the location of waterlogging spots. 99 news reports data of 2013–2015 were adopted for the analysis. The remote sensing image of Xiamen city in 2015 was from GF-1 satellite and Google Earth. The population data at the end of 2014 was provided by Xiamen Civil Affairs Bureau. The POI (point of interest) data was obtained by grabbing from Baidu map in 2015 (http://map.baidu.com). Municipal supervision waterlogging spots distribution of hidden danger data was from NetEase network (http://www.163.com/) in June 2014.

2.3. Methods

Rainstorm waterlogging information extracted from the internet news reports was digitalized using ArcGIS software to construct the spatial distribution of waterlogging spot. The spatial-temporal distribution and variation characteristics of waterlogging spots were analyzed combined with GF-1 and Google Earth remote sensing images. The waterlogging spot was regarded as the risk resource and the area distant from the risk source boundary 0.5 km which was influenced the most significantly was regarded as the risk area, because 0.5 km is generally considered to be the daily life radius of residents. Some urban public services in China, such as primary schools, have a service radius

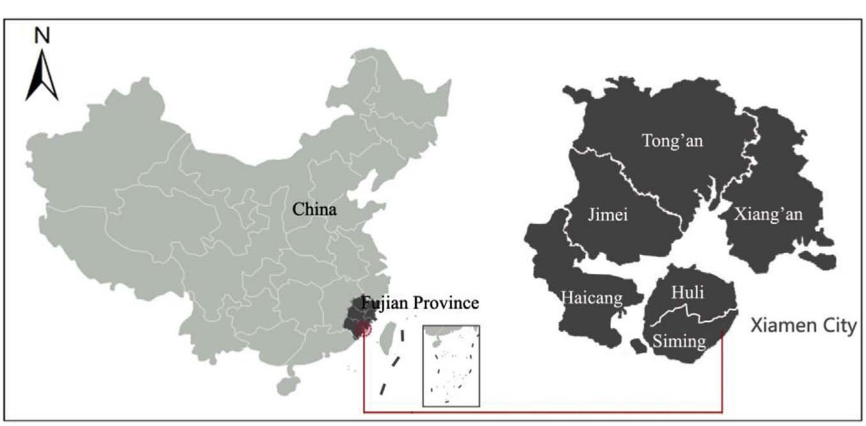

Fig. 1. Study area.