



## Review

# Urban pluvial flooding and stormwater management: A contemporary review of China's challenges and “sponge cities” strategy

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## ABSTRACT

In recent years, urban pluvial flooding caused by extreme rainfall has increasingly occurred across China. This paper reviews the challenges faced by China in addressing urban pluvial flooding and managing urban stormwater, with a particular focus on a policy initiative termed *sponge cities*. The paper first synthetically presents pluvial flood disasters in urbanized areas, and analyses their causes and formation mechanisms. It then introduces China's sponge cities initiative and discusses policy implementation in relation to contemporary understanding of sustainable urban stormwater management and international experience with innovative practices. The initiative, while theoretically well grounded and appropriate by its design principles, is shown subject to diverse implementation challenges, ranging from technological complexity to limited or lack of governance capacity as reflected in management ideology, knowledge and capacity of learning, participatory and integrated governance, investment financing, implementation pathway, planning and organization, and project evaluation. The paper offers some strategies for addressing those challenges, which include: 1) continuous experiment-based deep learning through pilot and institutionalization of knowledge and information management with city-to-city peering learning mechanisms, 2) establishment of institutional mechanisms dedicated to participatory, coordinated and integrated governance of the policy initiative, 3) increased government role in creating favorable conditions for investments, and 4) appropriate planning and an adaptive approach to policy implementation. The paper concludes that the sponge cities initiative can be an effective approach only if China commits to appropriate technical, governance, financial, and organizational measures to effectively address the challenges for policy implementation.

## 1. Introduction

In recent years, urban pluvial flooding caused by extreme rainfall events has increasingly occurred across China. A classic example frequently cited is the devastating flash flood brought by a cloudburst that hit Beijing – the capital city of this country – on 21 July 2012 (Qiu, 2012). Similar flood events have also been reported in megacities such as Shanghai (Du et al., 2015), Wuhan (Liu and Hou, 2016), Shenzhen (Shi et al., 2007), Tianjin (Liu and Wang, 2016), and Ningbo (Shen, 2016). More recently, in 2016, weeks of torrential rainfall during the monsoon season led to severe flooding, which submerged 28 provinces, thousands of counties, and hundreds of cities in both the north and south of this country (Shepard, 2016). Urban pluvial flooding seems to become a regular hydrometeorological phenomenon associated consequently and inevitably with heavy rainfalls, and is of increasing concern due to its potential diverse damages and societal impacts (e.g., Zevenbergen et al., 2013).

In response to rising pluvial flooding events in urban areas, the Chinese government has adopted a series of policies and programs to expedite and strengthen the development of drainage systems across cities (e.g., SC, 2013). Most significantly, in 2014, the government formally announced a national initiative termed *sponge cities* as a holistic strategy to tackle urban pluvial flooding while improving ecosystems and the environment (MHURD, 2014a,b). By this initiative, the government hopes to reshape and improve its ongoing urbanization and development process in a way that explicitly takes into account urban water cycle.

Currently, the Chinese government has been undertaking preparatory actions for implementing the policy initiative of sponge cities, including publishing a preliminary technical guideline, setting targets, and establishing a regulatory framework. Two batches of cities were selected, 16 in 2015 and 14 in 2016 including Beijing and Shanghai (Fig. 1), as pilots for carrying out the initiative. Given its large scale and foreseeable impact, the sponge cities initiative (SCI) is of strong

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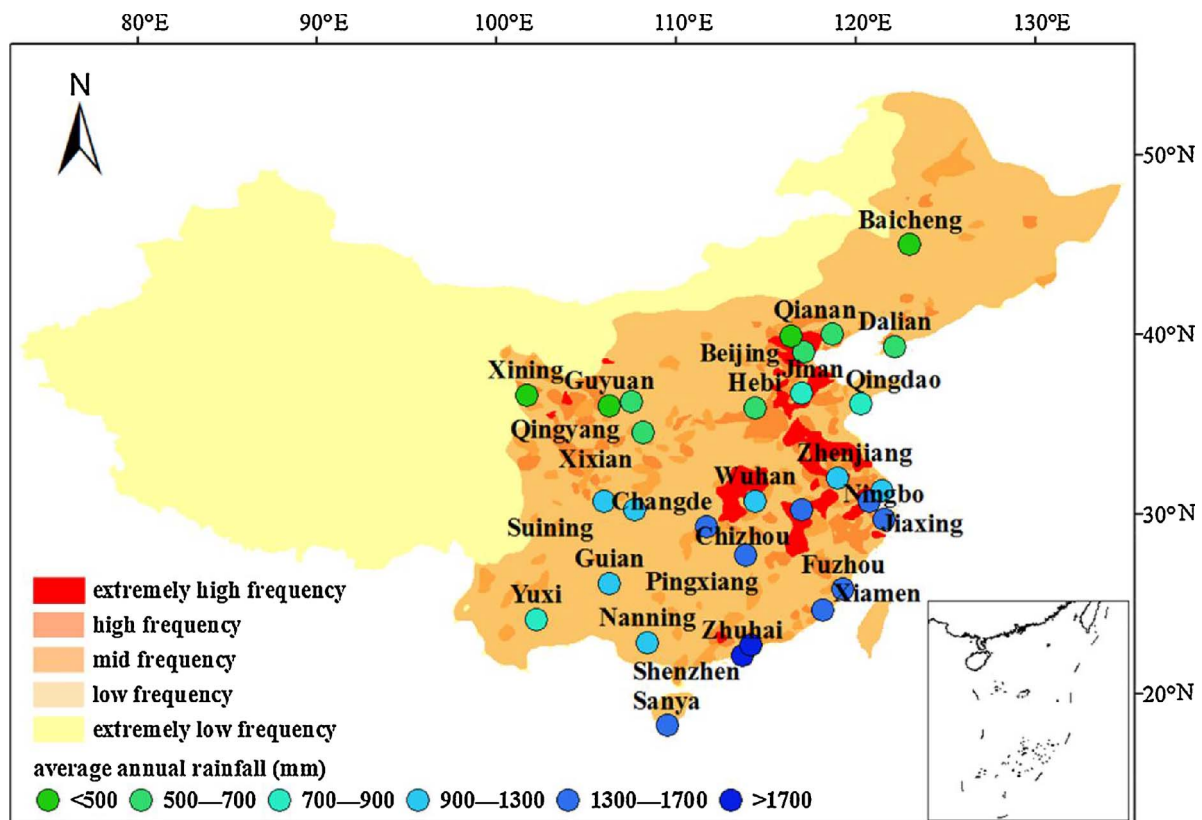


Fig. 1. Spatial distribution of selected pilot cities for sponge city development as compared to annual rainfall and water disaster frequency in China (adopted from Sang and Yang, 2016).

interest. To what extent does this initiative represent a reliable solution for alleviating increasingly severe urban pluvial flooding faced by Chinese cities? What are the practical challenges ahead for policy implementation that require serious attention by the government? Yet, there is a lack of literature deliberating on the initiative from a practical, management perspective despite its policy relevance and importance.

[Fig. 1]

This paper aims to review from a practical perspective the challenges faced by China in managing urban stormwater and pluvial flooding, particularly in promoting and implementing the SCI. For this purpose, the paper adopts an approach examining the policy initiative right through the lens of recent developments in innovative urban stormwater management and international practices and experiences. This particular focus of and method for developing the review are mainly due to the practical nature of the initiative, the current policy need, and the aim of the paper. As the initiative is shaped around the modern understanding of innovative stormwater management and as there is much experience accumulated already across western developed countries in experimenting with and implementing relevant management concepts, this paper is motivated to develop insights into the practical aspect of China's initiative and to identify areas and potential for further improvement and upscaling based on synthesis of current knowledge and experience.

This paper is justified by: 1) the close relevance of the policy on a pervasive global water issue in the biggest developing country under climate change, 2) the potential huge societal, economic and environmental impact of the policy initiative, 3) the fundamental, transformative change of China's water management from the traditional sector based, engineering oriented paradigm to a nature-based, holistic approach marked by the initiative, and 4) the relevance and the practical and theoretical value of China's experience to global sustainable urban development. A clear understanding of the SCI to address urban pluvial flooding and implementation challenges has strong potential to feed

into and influence China's current urban development toward water resilience and security under climate change. It also offers experience and implications on practice in a development setting allowing learning and knowledge co-production in global experimentation and effort to pursue sustainable and climate-proof urban development (e.g., Ahem, 2011; Farrelly and Brown, 2011; Bulkeley and Broto, 2013; McCormick et al., 2013; Valkering et al., 2013; Anguelovski et al., 2014).

This paper is organized as follows. The next section elaborates on China's urban pluvial flood disasters and the strategy of SCI. Specifically, in this section, the paper first characterizes urban pluvial flood disasters by significance and socio-economic impact, and analyses their cause. The paper then describes China's initiative, including its policy context, guiding principles and development, and the current status of policy implementation. Section 3 discusses the implementation challenges of the policy identified based on a review of the state of the art of innovative stormwater management, shedding some light on areas for further improvement. Section 4 offers strategies and measures for addressing those policy implementation challenges. Section 5 concludes the paper.

## 2. China's urban pluvial flood disaster and sponge cities initiative

### 2.1. Urban pluvial flood disaster

China is a country with severe water problems, including water scarcity (Jiang, 2009), flooding (Du et al., 2016; Duan et al., 2016), and water pollution (Jiang, 2009, 2015), which all have been intensifying in urban areas threatening socio-economic development (Shi et al., 2005; Jiang, 2015). In recent years, urban pluvial flooding has become even more frequent, pervasive and severe (Liu and Xia, 2016). It was found that 641 out of 654 Chinese cities are exposed to frequent floods (TFUFPSI, 2014). A survey conducted by the Ministry of Housing and Urban Rural Development (MHURD) showed that over the period 2008–2010, 62% of 351 cities surveyed suffered urban pluvial flooding,

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