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Review

China's water security: Current status, emerging challenges and future prospects

Yong Jiang [a,b,*]

[a] Department of Integrated Water Systems and Governance, UNESCO-IHE Institute for Water Education, Westvest 7, 2611AX Delft, The Netherlands
[b] Institute for Environmental Studies, VU University Amsterdam, De Boelelaan 1085, 1081HV Amsterdam, The Netherlands

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ABSTRACT

China has been facing increasingly severe water scarcity that seriously threatens the socio-economic development and its sustainability of this country. This paper is intended to analyze and assess the water security of China. It first attempts to characterize the current status of water security within a risk-based, integrated framework that encompasses five key aspects critical to water sustainability, including water availability, water use patterns, wastewater generation and pollution control, water institutions and management, and health of aquatic systems and societal vulnerability. Based on the above assessment, the paper then analyzes emerging challenges for water security brought by climate change, population growth and rapid urbanization, and the water-food-energy nexus. In the end, the paper discusses China's future prospects on water security, including current achievements, government actions and policy initiatives, and recommendations for management improvement aimed at increasing water security.

1. Introduction

With rapid socio-economic development, China has been facing increasingly severe water scarcity (Jiang, 2009). On one hand, China's per capita water availability is low and unevenly distributed, both spatially and temporally, which are inconsistent with the rising socio-economic need for water; on the other hand, inefficient use, wastage, and pollution are common that have been negatively affecting the capacity of water systems to sustain China's socio-economic development. The constraint of water resources on China's future development is of great concern, both domestically and internationally, and is considered a grand challenge that the Chinese government has to address in years to come (NYT, 2007; Jiang, 2009; Schneider et al., 2011; Moore, 2013a).

This paper is intended to examine China's water security. It is motivated by the grand challenge imposed by water resources on China's socio-economic development. What is the current status of China's water security? What are the emerging challenges for achieving water security be China's development path? How will the future prospect for water security in China? These are important questions critical to China's sustainable development requiring policy attention but have not been systematically addressed in the literature.

Assessing water security is largely an empirical matter, with distinct conceptualizations, analytical methods and focuses having emerged from different disciplines over the past decade (Cook and Bakker, 2012). This paper attempts to frame and characterize the water security of China by examining based on literature review two questions: (1) to what extent China is exposed to water-related issues, and (2) at what level the capacity of China's institutional system stands in addressing water related issues and effectively managing water resources. These two questions help shape an integrated framework for assessing water security that is fundamentally rooted in the concepts of risk management, social resilience surrounding sustainable water use, and integrated water resource management.

In this paper, a framework was developed to examine water security from five aspects, including socio-economic assessment of water availability, water use patterns, wastewater generation and pollution control, water institutions and management, and health

* Correspondence to: Department of Integrated Water Systems and Governance, UNESCO-IHE Institute for Water Education, Westvest 7, 2611AX Delft, The Netherlands.
E-mail address: y.jiang@unesco-ihe.org

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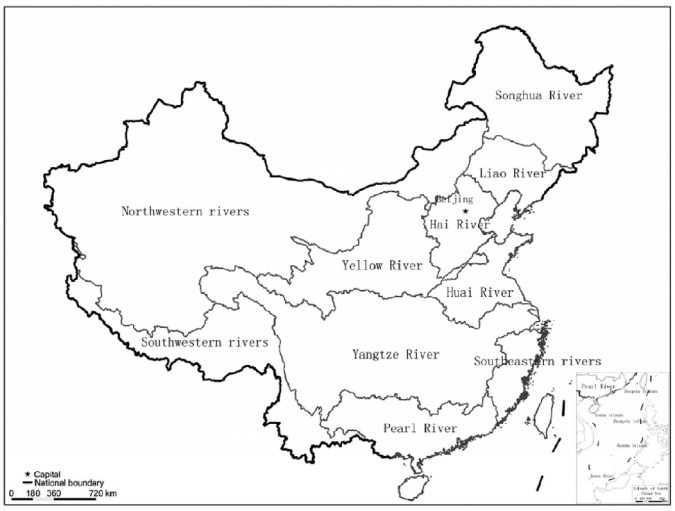

Fig. 1. Spatial distribution of level-I water resource zones in China.
Source: Adopted from Li et al. (2014).

of aquatic systems and societal vulnerability. The socio-economic assessment of water availability considers the biophysical condition of water resources within the social, demographic context, depicting the water-related risk while laying out the foundation and boundary for managing water resources for sustainable use. Within the water availability context, water use patterns and wastewater generation and pollution control look further into how water resources have been used and managed and to what extent the current water use increases China's exposure to difference water risks. Water institutions and management synthesize China's governance and administration of water and existing issues, providing an institutional perspective on China's capacity to address water issues. The dynamic evolution of the health of aquatic systems and societal vulnerability across the country presents an indirect measure partially reflecting the capacity and resilience of China's water institutions to address water-related risks.

Based on the status assessment laid out above, the paper elaborates on emerging challenges for achieving water security in China, including climate change, continuous socio-economic development, population growth and urbanization in particular, and the water-food-energy nexus. How do these three challenges play out affecting China's water security? To what extent do these challenges differentially or uniformly influence water security? The paper is motivated to develop a clear understanding addressing the above questions so as to inform water-related decision-making in China. In the end, the paper concludes with some discussion of current, ongoing government actions and policy initiatives aimed at tackling water issues, shedding some light on the future prospect for the water security of China.

2. Characterizing China's Water Security: the Current Status

2.1. Water availability: mapping water resource capital in the socio-economic context

The total volume of China's internal renewable freshwater resources on average is about 2813 billion m^3 per year (FAO, 2015). Although ranked the fifth in the world behind Brazil, Russia, Canada, and Indonesia (Jiang, 2009), China's water resources endowment is low on a per capita basis. As of 2012, with a total population of approximately 1.36 billion (NBSC, 2014), China's annual water availability on a per capita basis was about 2068 m^3, an amount that was 34% of the world average at 6016 m^3 per capita per year.[1]

China's water resources are spatially distributed, and this distribution unfortunately is inconsistent with local socio-economic needs for water, implying the risk of water shortages and crises in local areas. Geographically, water resources in China can be divided into 10 water resource zones of level I (Fig. 1). The Yangtze River by tradition is the dividing line between North China (or the North) and South China (or the South), with the river itself belonging to the South. Table 1 provides further details by catchment on water availability as compared to local population and the acreage of arable land. It shows that North China accounts for 45% of the country's total population and 65% of the total arable land but has only 19% of the total water resources. Consequently, water availability in North China is about 904 m^3 per capita per year, which is in sharp contrast to the level of 3280 m^3 per capita per year in South China. The situation is even worse at the catchment level. In the Hai River basin, for instance, water availability is only 314 m^3 per capita per year, which is even below the threshold level of 500 m^3 per capita per year that is commonly considered signaling absolute water scarcity (UN, 2014a).

China's spatially distributed water resources are subject to precipitation and its seasonal cycle, which further exacerbate the scarcity issue. In China, precipitation is the main driver for water resource availability and reliability (Lu et al., 2013). Dominated by strong monsoon climate, precipitation is characteristic of both intra- and inter-year variations. In most areas, four consecutive months can account for up to 70% of annual rainfall (MWR, 2007). The spatial-temporal feature of water resources represents a serious challenge for water management to maintain a reliable, sufficient supply to meet an increasing demand from socio-economic development, particularly in North China where water availability is already low across catchments.

2.2. Water use patterns

With limited water availability across space and time, how to effectively and efficiently use water at minimum risk of shortages becomes critically important. China's water use pattern, however, intensifies water scarcity, with increased exposure to the risk of severe water shortages, particularly in North China. At the national level, China's total water consumption has been steadily increasing, of which agriculture remains the biggest water user among sectors. As demonstrated by Fig. 2, China's total water consumption increased from 550 billion m^3 in 2000 to 614 billion m^3 in 2012, an average growth rate of 0.97% per year. Of the total water use, agriculture accounted for 61–69%, with industry 21–24%, domestic use 10–13%, and environment 1–2%. Moreover, agricultural water use steadily increased to 388 billion m^3 in 2012, despite its decrease from 378 billion m^3 in 2000 to 343 billion m^3 in 2003.

To examine water use within its socio-economic context, Table 2 compares the growth rates of total water consumption, gross domestic product (GDP), and population over the period 2000–2012 in China. While total water consumption seemed not to grow as fast as GDP, it outpaced population that increased by about 0.6% per year. As a result, per capita water consumption also increased from 435.4 m^3 in 2000 to 454.7 m^3 in 2012.[2] This is certainly of concern, given China's existing water scarcity and

[1] The world per capita freshwater resources was calculated based on the global total population of 7.04 billion in year 2012 and the world total freshwater resources of 42,370 billion m^3 in 2011, both of which were from the database of the World Bank (http://data.worldbank.org/indicator).

[2] Per capita water uses in different years were calculated based on national total water use and population.