Zhang, Jianyun; Jin, Junlian; Zhou, T. David

China's water security: Problems, pathways and practices

Hydrolink

China's water security: Problems, pathways and practices

By Jianyun Zhang, Junliang Jin and T David Zhou

With a vast territory and almost one fifth of the world's population, China's water security is not only an important issue for the country, but also a topic worth discussing in the context of global water security. Under a monsoon climate, China receives ample vapour from both the Pacific Ocean to its east and the Indian Ocean to its southwest, which would subsequently turn into rainfall over the country. However, the vast amount of rainfall isn't taking place regularly over seasons year-round, nor is it evenly distributed over the territory because of various blockages out of huge variations in land elevation and topography, which marvelled the 18th century European travellers as much as they do to the Chinese themselves today. Moreover, China's booming economy and growing population are both making the country increasingly thirsty for water, while bringing about more pollution to the precious resource. Similar to many other places in the world, the country's plight of water security includes, as distilled by some researchers, too little water, too much water, and too dirty water. While water managers endeavour for water security of the country, many of the problems they have come across, pathways they are choosing, and practices they have taken are interesting to share and discuss.

Too little water: droughts and water scarcity

China is not well endowed with water in general. The per capita water availability of China is around 2000 m^3/year, which is less than one quarter of the world's average. Though its monsoon climate brings plenty of rainfall, the annual precipitation, if averaged over the whole country, is around 640mm, which is about 35% less than the global average according to the Global Precipitation Climatology Project (GPCP). Moreover, the majority of China s precipitation takes place during its rainy season between July and September (see **Figure 1**), which allows rapid rotations between droughts and floods. Apart from the temporal heterogeneity, much of the rain (~80%) falls on its southern part. While annual rainfall in the south could reach as high as 2,000 or even 3,000 mm, the vast northern China could only see 20 to 30 mm of precipitation. Rapid changes taking place in the country means more disturbance to its water system. While China's Meteorological Administration estimates that the country is very sensitive to global warming and expects significant impact from climate change, the country has become the world's biggest Greenhouse Gas emitter and its energy portfolio is still heavily reliant on fossil fuel. The warming climate brings noticeable changes to water. For instance, river flows have been dwindling in the last decades, and the decrease could be up to 70% at some gauge stations on the Haihe River[1]. Meanwhile, as China's urbanisation keeps ramping up, more people are dependent on centralised water supply. The Second National Water Resources Assessment Programme of China in 2012 estimated that China is in shortage of 50 billion m^3 of water even in a year of normal conditions. Of a total of 661 cities, around 400 are in shortage of water and 110 among them are in severe shortage.

Water stress leads to an array of problems related to it. A direct one is drought, the frequency and impact of which have been increasing since the 1990s[2]. Insufficient water means less water for the environment, which degrades ecological systems

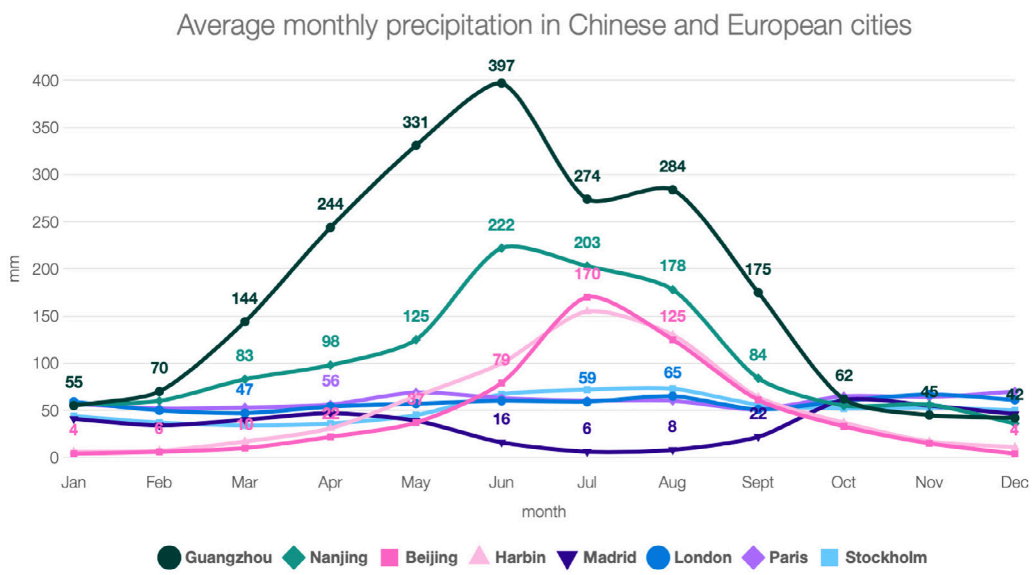

Figure 1 | Average monthly precipitation in Chinese and European Cities. Unlike European ones, cities in China receive the majority of their rain in the rainy season between July and September, and see much higher variation over the year. Data source: climate-data.org. Interactive figure available at: https://s.yicode.org.cn/kzuwxhy

and the invaluable services they provide. In the Haihe River basin where Beijing is located, it is estimated that about 18% of its annual runoff should be reserved for healthy ecosystems, but the region is consuming up to 108% of the basin's available water[3]. Meanwhile, limited water availability also becomes a constraint on socio-economic development. Northern China is home to 46% of its population and has 64% of its arable land, but has to support 45% of the country's GDP with 19% of its water.

The country's response to droughts and water scarcity has been on both the demand and the supply side. To bring water demand under control, in 2012, China s State Council put into force the Most Stringent Water Management policy, which is known as the "Three Red Lines". The policy package caps the quantity and efficiency of water consumption, and raises the bar for water quality. Tiered water pricing is another measure that aims at the demand side. To incentivise water saving, water is priced differently by purposes of consumption, and prices grow as the quantity of consumption grows. On the supply side, the massive inter-basin water transfer project, the South-to-North Water Diversion, now has two routes in operation. By January 2022, the two routes have delivered more than 50 billion m^3 of water to northern China[4]. Non-traditional sources of water, such as flood, recycled or desalinated water, are also being explored.

Too much water: flooding and sea level rise

Flooding is a prominent and recurring disaster in China. Despite the overall water stress, too much water is another problem for the country in some parts, some times. According to China's National Flood Defence Plans, about two thirds of the country is under significant risk of fluvial or flash flooding, and over two thirds of its cities face problems of urban pluvial flooding. Seasonality of precipitation in China makes the country prone to flooding in the rainy season. 2020 saw abundant precipitation and therefore extensive flooding along the Yangtze River, Huai River and in the Taihu Lake Basin. As urbanisation accelerates in China and climate change impacts kick in, cities are becoming more vulnerable to pluvial flooding, especially under extreme precipitation events such as the one in Zhengzhou in July 2021. Other factors that raise the risk of flooding in coastal areas are storm surge and sea level rise. Sea level close to China, although fluctuating, is on a rising trend with an annual average of 3.4 mm, which is higher than the global average[5].

The flood defence system of China consists of both engineering and non-engineering measures. The water engineering system in China consists of around 98,000 reservoirs, 340,000 kms of river dikes, 145,000 kms of sea walls, and 98 retention areas. The National Commanding System for Flood Control, on the non-engineering side, is a decision support system that combines data collection, communication, real-time forecasting, and coordinating emergency responses.

In addition, initiated in 2013, the Sponge City programme aims at streamlining the infiltration, retention, storage, purification, reuse and discharge of rainwater in cities, so as to better manage urban pluvial flooding. The programme prioritises local retention of rainwater, but also engineers artificial infrastructure, such as large-scale underground storage and treatment facilities, for managing excessive rainwater. However, these measures have to be informed by multi-dimensional monitoring, real-time simulation and forecasting, and risk assessment.

Year	Cities
2007	Jinan
2010	Guangzhou, Chongqing
2012	Beijing
2013	Ningbo, Yuyao, Shanghai
2015	Shanghai, Changzhou, Zhengjiang, Nanjing
2016	Wuhan, Nanjing, Zhengzhou
2017	Guangzhou, Changsha, Chongqing, Nanjing
2018	Beijing
2019	Guangzhou, Shenzhen
2020	Guangzhou
2021	Zhengzhou

Table 1 | Pluvial flooding events in Chinese cities according to various news sources.

Too dirty water: pollution

Water pollution is another challenge for China's water security. 2018 data shows that (see **Figure 2**), though the country has invested a lot in improving surface water quality, water quality in 5 of its 10 major river basins is still not desirable. Less than half of the water bodies in the Haihe (northern China) and Liaohe (northeastern China) rivers are suitable for direct human contact. Water quality in estuaries could be even worse. Around 80% of the water in the Yangtze (east China) and Pearl (south China) estuaries is not recommended for direct human contact. About half of the lakes in China are in eutrophic state, and almost half (46.9%) of its shallow groundwater reserves could not be used for water supply even after treatment.

To control water pollution, China's present strategy incorporates [1] controlling sources, which targets diffusive pollution by reducing the use of fertilisers & pesticides, and point sources by regulating industrial effluence; [2] improving wastewater treatment by centralising wastewater treatment, adopting higher standards and improving treatment efficiency; [3] improving river connectivity to replenish clean water and raise loading capacity; [4] adopting nature based solutions through the rehabilitation of wetlands and other ecosystem services; and [5] reforming institutions to put river/lake management under the explicit responsibility of local government heads (the 'River Chiefs').

Conclusion

China's water security is a challenging issue for the country because of its unique meteorological, geological, and hydrological features. Therefore, the country is highly susceptible to droughts,

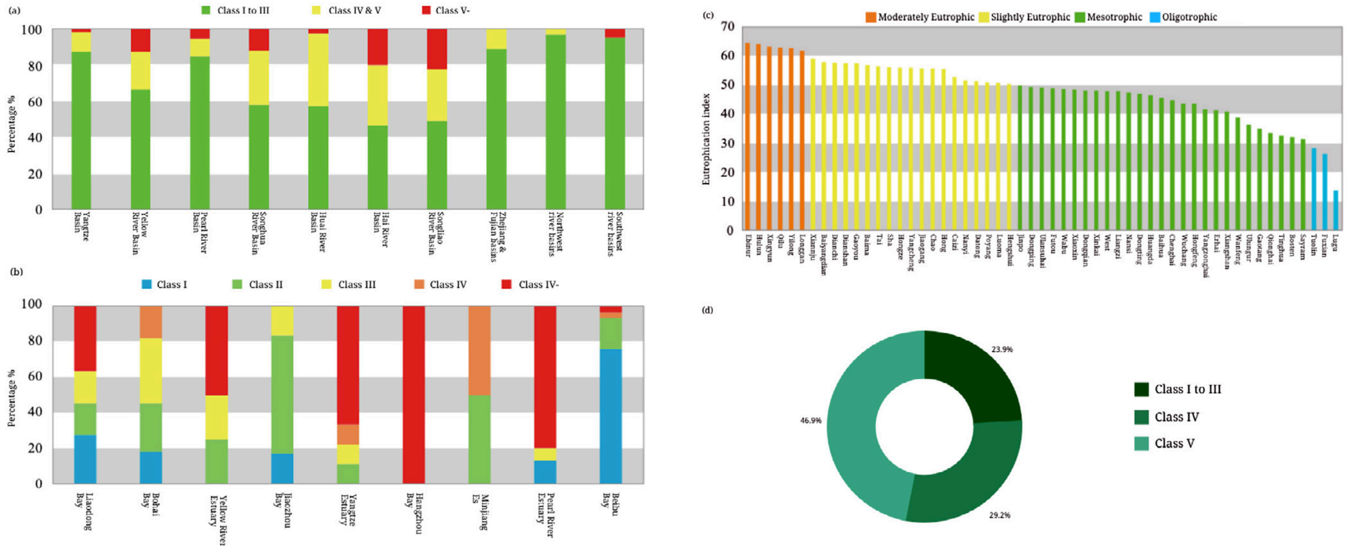

Figure 2 | 2018 water quality data of China, (a) water quality by basin, (b) water quality at major estuaries, (c) eutrophication of major lakes, and (d) shallow groundwater quality. China classes surface water quality into six classes (from good to poor, Class I, II, III, IV, V and V-). Water quality below Class III is not recommended for direct human contact. Groundwater quality below Class IV is not recommended for water supply even after treatment. Source: State of the Environment Bulletin of China 2018

flooding, water pollution and ecological degradation. The impact of climate change and rapid urbanisation further challenges the country by bringing higher risks and more uncertainties. To build a water-secure future, it is necessary to combine both engineering and non-engineering measures, the former of which enhances the robustness of the overall system of water management, and the latter develops its capacity for better resilience.

The 'too much', 'too little' and 'too dirty' water problems may not be unique to China only, and therefore China's experience and practices could be valuable for other countries challenged by similar issues. However, this does not mean that China's strategies are universally applicable, nor that they are flawless. First, the approach to water security taken by China relies heavily on massive engineering. Though nature-based solutions are gaining popularity and influence, there is still a need for more attention in the country on how to make best of them to build a **resilient infrastructure system** under growing uncertainties. Second, it is not difficult to see that China's current strategies are mostly top-down and government-centric. For a **resilient institutional framework,** it would be better for the country to diversify the current framework by introducing more contributions from other institutions including the market and local communities. Third, as the most vulnerable communities are often hit the hardest by global warming and natural disasters, tipping the policy scale towards their water security would be a necessity for the country to mould a **resilient society** and realise, to quote its leadership, common prosperity.

Jianyun Zhang
Dr and Prof. Zhang is a leading scientist of China in the field of hydrology and water resources. He contributed extensively to China's water resource planning, flood control and drought relief, and climate change adaptation through his career both as a prominent scientist and government advisor. He is member of the Chinese Academy of Engineering and fellow of the British Royal Academy of Engineering.

Junliang Jin
Dr and Prof. Jin currently co-leads the team on climate change impacts on hydrology with NHRI/RCCC, MWR. Junliang has developed a career as a well-known expert on climate change, flood risk and water resources management. He leads or has led over 40 major research projects under important initiatives funded by MOST, NSFC, and so forth, and has published extensively on flood risk and water resources management.

T David Zhou
Mr Zhou studied water science, policy and management at the University of Oxford and is interested in water policies and the interface between water science and social institutions. He currently manages outreaches and science communication at the Yangtze Institute of Conservation and Development.

References

1 | Zhang, J., Wang, G., Jin, J., He, R., & Liu, C. (2020). Evolution and variation characteristics of the recorded runoff for the major rivers in China during 1956-2018. Advances in Water Science, 153 161.

2 | Wu, Z., Yu, L., Du, Z., Zhang, H., Fan, X., & Lei, T. (2020). Recent changes in the drought of China from 1960 to 2014. International Journal of Climatology: A Journal of the Royal Meteorological Society, 40(7), 3281 3296. https://doi.org/10.1002/joc.6397

3 | Yang, T., Liu, J., Chen, Q., Zhang, J., & Yang, Y. (2013). Estimation of environmental flow requirements for the river ecosystem in the Haihe River Basin, China. Water Science and Technology, 67(4), 699 707. https://doi.org/10.2166/wst.2012.571

4 | State Council. (2022, January 8). More than 50 billion cubic meters of water delivered by the South-to-North Diversion Project. http://www.gov.cn/shuju/2022-01/08/content_5667224.htm

5 | NMDIS. (2020). China Sea Level Bulletin 2019. National Marine Data and Information Service (NMDIS). http://www.nmdis.org.cn/hygb/zghpmgb/2019nzghpmgb/