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Title: Ensuring water resource security in China; the need for advances in evidence based policy to support sustainable management.

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Abstract:
China currently faces a water resource sustainability problem which is likely to worsen into the future. The Chinese government is attempting to address this problem through legislative action, but faces severe challenges in delivering its high ambitions. The key challenges revolve around the need to balance water availability with the need to feed a growing population under a changing climate and its ambitions for increased economic development. This is further complicated by the complex and multi-layered government departments, often with overlapping jurisdictions, which are not always aligned in their policy implementation and delivery mechanisms. There remain opportunities for China to make further progress and this paper reports on the outcomes of a science-to-policy roundtable meeting involving scientists and policy-makers in China. It identifies, in an holistic manner, new opportunities for additional considerations for policy implementation, continued and new research requirements to ensure evidence-based policies are designed and implemented and identifies the needs and opportunities to effectively monitor their effectiveness. Other countries around the world can benefit from assessing this case study in China.

Keywords

China, water resources, water security, policy, sustainable management, research requirements.

Introduction

Globally, the issue of insufficient future water resource availability (here defined as the difference between rainfall and water use with no assumption included for environmental allocation) has been highlighted as being critical in several regions (Gleick, 2003) and this has been linked to potential fears around global food security (Hanjra and Quereshi, 2010). In China, the concerns over future sustainability of current water use continue to grow (Fant et al. 2016; Zuo & Liu, 2015) as a result of increased pressure from population growth, which is becoming increasingly urbanised (Gong et al. 2012), and climate change (Piao et al. 2010). In addition to the potential lack of an adequate quantity of water, there is evidence of growing problems related to water quality, largely resulting from sewage treatment discharges, industrial outfalls and agricultural sources (Tao and Xin 2014, Lu et al. 2015a). This is despite the ambition in the most recent, 13th Plan for Science and Innovation, which states, as one of 5 targets, the aim that 'Ecological environment be improved with green, low carbon production and life style, cutting pollution and carbon emissions as well as use of energy, water, land and mineral resources' (People's Republic of China, 2016).

To achieve the challenging ambition set by this target, there are many opportunities that need to be considered, including: the potential management options for dealing with this looming water crisis, the potential policy solutions that are available and can be implemented, potential changes to policy implementation and opportunities for China to take advantage of the issues and solutions that have been implemented elsewhere. At a unique roundtable meeting held in Beijing in March 2016, the possibilities for enhancing science/evidence-based policy-making and implementation with respect to water resource protection and water use in China were examined by senior Chinese policy makers from a wide range of Ministries and scientists from China and the UK. Here we summarise the current and ongoing issues around water resources policy development in China and present the conclusions of the roundtable as a series of recommendations for further policy development to help deliver sustainable water resource availability and ensure water security in China. The issue of current and future water security and its 'solution' in China has clear relevance to countries around the world.

The Current water situation in China.

China is a rapidly changing country with the largest population in the world and prestigious industrial and economic growth. Water resources are abundant, but the per capita water resources equate to only 2100m^3 compared to a global average of 7342m^3, leading to a ranking of 125th in the world (Global Water Partnership, 2015;' The World Bank, 2016). Nationally, the total water use has risen by almost 150 billion m^3 since 1980 and this possibly reflects the sharp and dramatic increase in GDP over the same period (Figure 1). An expanding population, increasing urbanisation and changing lifestyles all contribute to the increase in water resource use (Lu et al., 2015).

There also exists a significant difference in the hydrological regime regionally from south to north across China. This uneven distribution of water resources in China presents a major challenge because spatial patterns of water availability do not match those of water resources demand and economic and social development. Currently, 47% of the total national population are located in northern areas (Figure 2) where agriculture use accounts for 65% of land area and GDP is 45% of national total, but only 19% of national water resources are available. In the south, population is 53% of the total national population, agriculture accounts for 35% of the land area GDP is 55% of the national figure and water resources are 81% of the national available. As a result, significant engineering schemes have been instigated to transfer water from the south to the north, but their ultimate success remains a question (Barnett et al., 2015).

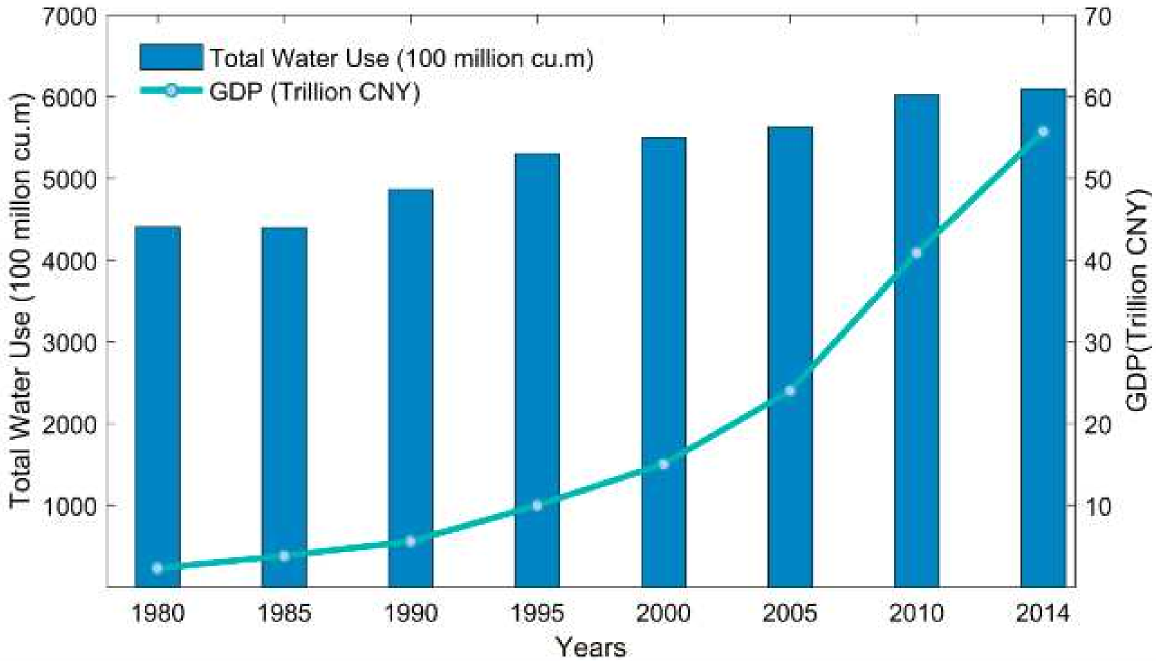

Figure 1. Total water use and GDP (price base year of 2010) in China since 1980 (data source: General Institute of Water Resources and Hydropower Planning and Design, Ministry of Water resources, unpublished)

Figure 2. China map showing north and south regions.

Current water policy In China

By 2030, it has been estimated that China's total available water resource availability will be 619 billion m^3, which falls significantly short of the projected aggregate demand of 818 billion m^3 – a deficit of 25 percent (2030 Water Resources Group, 2009). At this time, 8 of 10 major water basins will experience water shortages. Agriculture is the largest water use sector in China, currently consuming an estimated 65% of total water resources and although this is likely to reduce to c. 50% by 2030, the overall water resources deficit will increase if action to improve the situation is not taken and food production is to be increased (2030 Water Resources Group, 2009). To address these issues, there is a wide range of water policy from high-level national policy to administrative laws and regulations and regulatory documents and rules targeted at many different issues and aimed at provincial or local levels. Additionally, irrigation water use efficiency is generally low (30 – 40%) compared to EU countries (60 – 70%) and efforts are being made to improve this. Poor water quality presents a further problem for exploiting available water resources.

Because the quality of some water is so low, it cannot be considered as available as a water resource, and the "quality-adjusted" water resource is significantly lower than the quantity-only available resource, exacerbating the overall water resource availability deficit. In this respect, some 21% of surface water nationwide is unsuitable in quality even for agricultural use. This is highly variable between catchments and, for example, the Hai River Basin has 50 percent of its available water resource below the required quality standard (Liu and Speed, 2009)

With regard to wastewater reclamation and reuse, there are no special regulations although as part of the People's Republic of China Water Law (2002) the use of recycled water and improved wastewater reclamation and utilization was encouraged. The urban drainage and sewage regulations, promulgated by Decree No. 641 on January 1, 2014 (State Council of People's Republic of China, 2013) encourage urban sewage treatment recycling and requires industrial production, urban greening, road cleaning, vehicle washing, construction and landscape, to give priority to the use of reclaimed water. Furthermore, in recent years, local Government has introduced a number of investment incentives, tax support, recycled water prices and preferential policies to further encourage wastewater reclamation and reuse (Yi et al. 2011).

China is not unique in identifying a looming water crisis if current practices are left to continue, but it has responded by implementing various ambitious policies to achieve water security. In 2011, the State Council's *No.1 Document and Central Work Conference on Water Conservancy* introduced the concept of the "Three Red Lines" principle for water management, which was further detailed in the State Council's *Opinions on the Practice of the Strictest System for Management of Water Resources* in early 2012 (State Council of the People's Republic of China, 2012; Siyi, 2012). The Three Red Lines provide for controls on:

1. Development and utilization of water resources, with the target of reducing national water consumption below 700 billion m^3 by 2030;
2. Improvement of water use efficiency, with the targets of reducing water consumption per RMB10,000 industrial value added to below 40 m^3 and raising effective water use efficiency of agricultural irrigation to above 0.6 by 2030;
3. Restriction of pollutants in water source areas, with the targets of controlling total quantity of major pollutants discharged into rivers and lakes and raising water quality compliance rate to higher than 95%.

This was followed in 2015 by the release of an *Action plan for the prevention and control of water pollution (State Council of People's Republic of China, 2015a)* from the State Council that strives to achieve clean water (ie. clean for humans as well as ecosystems) as well as the effective management of water as a resource. The 10-point plan specifically requires the government and the market to collaborate to achieve these ambitions through not just legal mechanisms, but also through reform and innovation in the market. The key objectives of the plan are that by 2020, water quality nationwide will be improved, with heavily-polluted water bodies dramatically reduced in number, drinking water safety improved, groundwater overexploitation reduced through strict control, groundwater pollution curbed, environmental quality in offshore areas improved and the ecological quality of the water environment in Beijing-Tianjin-Hebei Region, Yangtze River Delta, Pearl River Delta and other areas ameliorated (Figure 2). By 2030, it is expected that the overall water environment quality will continue to improve and that water ecosystem functions and services will have started to recover. By the middle of this century, overall ecological environment quality will be enhanced and 'virtuous' cycling of the ecosystem will be achieved.

There remains much speculation and uncertainty over whether these ambitious goals can realistically be achieved. There are significant questions to be addressed as to whether; the stated timescales in policy are realistic and commensurate with previous findings relating to the timescales to recovery? Whether the policy that has been established can be translated into action on the ground and appropriately implemented, monitored and reviewed? Whether further policy requirement might be needed and what tools the scientific community might provide to help address these issues? The Roundtable event brought together scientists, policy engineers, policy makers and practitioners to attempt to address these questions.

Conclusions

A number of opportunities to improve water management and policy development, implementation and review were identified at the Roundtable. Many of these opportunities would require major investment but would support the required progress towards establishing 'water security' in China.

<u>What more is needed for policy development, implementation, and review?</u>

1. The implementation of national legislation, such as the 3 Red Lines, must be delivered at a local level to account for the variation in physical, social and agricultural conditions across the country. With the responsibility for water 'security' being currently held by at least four ministries (Ministry of Water Resources, Ministry of Agriculture, Ministry of Housing and Urban and Regional Development, NDRC) the tracking and monitoring of policy implementation would best be achieved by a neutral third-party organisation or committee to ensure full advantage of best practice is taken and adopted. This would alleviate the potential for fragmentation of policy responsibility between the different Ministries and Departments of Government with a stake in 'water security'. This is exemplified by the current lack of overall responsibility for the implementation of the 3 Red Lines policy. An integrated policy and assessment methodology based around natural capital or natural resource assets could provide an effective solution.

2. It is apparent that policy conflicts can be an issue for the successful implementation of water resources legislation, particularly at local government level, and a mechanism needs to be developed to enable policy integration with a common metric. For example, industrial policy conflicts with water quality policy and, water resources policy around dam building conflicts with environmental policy. The approach of 'natural and built capital' (the capital concept) provides an opportunity to address these conflicts and enable integrated management of natural resources.

3. The opportunity to make 'water security' the basis for integrated water policy is now under consideration in many countries around the world. This includes an emphasis on the need for long-term ecological protection to support sustainable development but also encompasses the requirement of ensuring and developing economic growth. The development of such an integrated policy would be beneficial in ensuring future water resource security in China.

4. There is clear potential for the use of agricultural subsidies and investment incentives to encourage and ensure improved water use efficiency and good practice with respect to chemical and nutrient additions to farmland. In the EU, subsidies are made available to farmers based on them following good practice with respect to environmental protection (Nazzaro and Marotta 2016).

5. Research on water saving technologies in agriculture has shown the potential to achieve the necessary water savings required to deliver planned increases in food production (Peng, 2011, Kang et al. 2017). There should, therefore, be a policy of zero increase in irrigation volume similar to the policy of zero increase in fertilizer use by 2020, recently released by Chinese Ministry of Agriculture (Liu et al., 2016).

6. For water quality, China is currently designing a comprehensive and practical risk assessment system (Han et al. 2016). Currently, China's surface waters in many provinces are below the desired quality (Lu et al., 2015b) and much effort and investment will be required to achieve the necessary remediation to improve their status, it would be appropriate to establish the priority pollutants causing environmental impacts in different water basins.. To this end, China has started to make an in-depth study aimed at different water basins, establish the monitoring system for early warnings and enable risk management to be implemented (Wu et al. 2010). In this respect, Environmental Quality Targets and standards need to be reviewed with the focus on developing well defined environmental standards and biomonitoring techniques in China rather than employing standards in

place in the US or EU (i.e. based on percentiles or means rather than maximums) (Pignata et al. 2013). These overseas Standards are very strict and difficult to achieve in China and may not be appropriate for the physical, social and economic circumstances in China.

7. The opportunity to specifically incorporate ecological/environmental protection into water policy remains an option for China, by introducing a system mirroring the EU Water Framework Directive (Yang and Griffiths 2010), but the over-arching requirements of food production and industrial and potable supply, make this an optimistic scenario in the short term. Clearly, such an environmental standard based system could be achieved through the concept of natural capital or natural resource assets, ideas that have much in common. This must, however, build a methodology for assessing ecological status; for example, the river health report cards, established in the EU under the WFD, and trialled recently on the Gui River provide a potentially useful approach for application in China (International Water Centre 2012).

8. A further problem in the development of national level policy is that the implementation of pollution discharge policy is variable at regional government level (Shen 2012). The Ministry of Environmental Protection's (MEP) standards are regionally flexible in that they can be tougher locally but are not permitted to be more relaxed (World Bank 2006). The recent change in pollutant discharge policy from the basis of allowing the total amount of pollutant to be discharged to defining an environmental quality standard as the goal, akin to the approach outlined in the EU Water Framework Directive, is a step in the right direction (*State Council of People's Republic of China, 2015b*). In this case, determining appropriate Environmental Quality targets is paramount.

9. The potential for re-use and recycling of waste water in both rural and urban environments needs to be considered as this represents a potentially important contribution to the water resource management system (Lu et al. 2015b).. This must be considered in light of the potential pollutant contribution from the use of poorly treated water (Zhang et al. 2010). The opportunity remains to adopt new policy on the use of re-cycled water in agriculture as at present there are no clear objectives around the potential to increase the waste water utilization rate.

10. There is a clear need for scientists and policy makers to consider carefully the time-scale between policy implementation and environmental response. In this respect, the expectations of politicians are often short-term (of the order of 1 – 5 years) compared to longer term interests of businesses and environmental needs (of the order of 10+ years). In addition, experience in the EU shows that environmental benefits can take several decades (greater than 20years) to occur (Spears and May 2015, Jarvie and Jenkins 2014).

11. At both regional and national levels, the development, implementation and assessment of water related policies would benefit from the establishment of a formal and recognised network of policy makers, policy engineers and scientists (Yang et al. 2013). Such a network should be directly supported by a unified national scientific committee, comprising water, soil, agriculture, ecology and socio-economic experts. This science forum could provide solution-oriented advice on practical policy construction, implementation and review. Furthermore, given the aim of 'water security' a special 'committee' for water, with representatives from all Departments, may well be beneficial to ensure that policy design, implementation and review is both appropriate and fit-for-purpose. Such a committee would undoubtedly benefit the implementation of policies by providing the framework for discussion of the existing political, economic, legislative and scientific constraints that often prevent effective and efficient policy implementation (Kiem and Austin 2013, Kiem, Verdon-Kidd and Austin 2014).

12. There is also an urgent need for a national monitoring network (similar to that implemented for air quality and/or the compliance monitoring requirement of WFD in the EU) to enable assessment

of environmental protection and water resources policy. For example, there is now a national network detection system to detect the quality of the atmosphere which can provide hourly data updates (Rohde and Muller 2015). A similar detection network could be established for the country's water quality testing. If such a system were implemented, the improvements resulting from new policies would become clear to both central and local governments.

Identification of key research requirements

Whilst currently available research can provide much evidence to support the policy recommendations above, there remain gaps in understanding that require further research effort. The most significant of these that should be addressed as a matter of urgency are:

- How to deal with future climate change impacts on water resources availability and flood and drought frequency and magnitude? This research can be undertaken by Universities and Government Research Institutes and could be started immediately as models and data are currently available. This research would greatly benefit from China/UK collaboration and could be supported from current bilateral funding initiatives such as the Newton Fund. Policy relevant results can be achieved within 1- 2 years although model refinements and improved data availability through time will enable reduced uncertainties.
- The need to incorporate the ecological requirement for water into resource allocation for example through the assessment of environmental flows. Water resources models are commonly used at Provincial and watershed scale in China but more research is needed to ensure that the environmental water requirements are encapsulated. This could be achieved within a short time scale given appropriate collaboration between scientists and stakeholders.
- A need to understand groundwater dynamics to ensure that irrigation associated with increased future grain yield does not de-stabilise aquifers. This research could be initiated immediately but requires significant investment in improving groundwater observation well networks at a regional scale. The research can be undertaken by Universities and Government Research Institutes and will require Chinese funding beyond the scope of current China/UK bilateral initiatives. Policy relevant results may be achieved within 5 years.
- An understanding of the eco-toxicological impacts of current and emerging pollutants and, crucially, of mixtures of pollutants to enable development of appropriate standards for policy development. Additionally, at the catchment scale, soil and water pollution are intrinsically linked and the appropriate Ministries in China need to employ a synergistic approach to policy development and implementation. Much research in this area has already been completed but the many isolated studies need to be brought together through appropriate literature review and analysis. This activity should be undertaken within the appropriate Government laboratories and Institutes.
- The need to define natural capital metrics that quantify how environmental assets combine to deliver services and human well-being. This area is in its infancy and much needs to be done to define the concepts and enable the natural capital approach to be utilised as a tool in integrated catchment management.
- The development of models to enable assessment of long-term impact of policy. This requires monitoring data at national scale and needs a centralised body to compile, QA/QC and ensure that data are openly and freely available. Until data is more openly available, this research requirement remains unachievable.

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