Mainstreaming adaptation in integrated water resources management in China: from challenge to change

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Abstract

China is facing many challenges in the water sector while implementing integrated water resources management (IWRM). Another daunting task – adapting to water-related impacts of climate change, is also challenging China’s water managers. These challenges have been posing threats to China’s economic, social and environmental development. While separate efforts in promoting IWRM and climate change adaptation have been made, the approach of mainstreaming climate change adaptation strategy within IWRM is seldom studied. Attempting to fill the gap, this paper argues that there is great potential in synergizing them after analysing their distinctions and common points. By developing climate-proofing strategies within IWRM, mainstreaming is able to minimize adverse water-related climate change risks and maximize the benefits of policies and plans. In this study, entry points of mainstreaming climate change adaptation in the sustaining environment of IWRM and its process will be identified and analysed.

Keywords: Adaptation; Climate change; Integration; IWRM; Mainstreaming; Water management regime

1. Introduction

China is facing severe water crises in spite of its substantial water resources. Widely recognized challenges include flooding and water logging, water scarcity and subsequent drought, ecological and environmental deterioration caused by pollution, declining water levels in lakes, wetlands and rivers, erosion of land and subsequent sedimentation of the river channel and salt water intrusion. Among all the problems, water scarcity, water pollution, floods and droughts are the most severe ones (Sun et al., 2002; Lee, 2006). Water problems will ultimately affect land use, food security, industrial and energy development and other sectors highly dependent on water as the raw material. For example, although China ranks sixth in the world with its 2.8 trillion m³ total water volume, it still struggles with water shortages. Water scarcity in Northern China will reduce the irrigation water and consequently change the agricultural structure. These interrelated problems have already been diagnosed as the major

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constraints to China’s economic development and its goal to improve people’s living standards (Varis & Vakkilainen, 2001).

While the current water crises are inevitably the result of the unchangeable natural condition of the water resources, such as uneven distribution, they are mainly due to the poor management of water resources. Much of the literature has revealed that inadequate legal framework, weak enforcement and the unsatisfactory implementation of integrated water resources management (IWRM) are the root causes of current water crises in China (Zhang et al., 2011). Nowadays, the ongoing rapid economic development, urbanization and improvement of living standards require a higher standard on water quantity and quality. As the natural condition of water resources is hard to change and represents the physical limit to which China needs to adapt, improving water resources management is a far-sighted and promising approach to address current water crises. More often, it is a country’s ability to manage water resources sustainably that could affect the economic and social development rather than the quantity of water resources (Lenton & Muller, 2009). A constantly improving water resources management regime not only contributes to achieving sustainable development but also enables itself to respond effectively to emerging new challenges, such as climate change. Given the fact that water management is not merely a technical issue, the perspective of policy, law and management will be employed to analyse how to improve the existing water resource management regime.

External challenge from climate change has posed incremental pressure on the water system due to the intrinsic uncertainty and complexity of climate change. According to the Intergovernmental Panel on Climate Change (IPCC), ‘water and its availability and quality will be the main pressure on, and issue for, societies and the environment under climate change’ (Bates et al., 2008). Water-related problems induced by climate change, especially extreme weather events, have been one of the most urgent issues restricting China’s development and planning progress. When appropriate adaptation measures are absent, these emerging stressors in conjunction with old water problems will drive China’s water system to its threshold. The salient feature of current study is to reveal the approach of integrating climate change adaptation with the improvement of water resource management in China.

2. Current water resource management paradigm of China

In the first 20 years of the Reform and Opening up Policy, China had gone through an intensive exploration of its water resources without giving adequate consideration to the water use efficiency and aquatic environment, due to the immense pressure to reduce poverty and develop the economy. The adoption of ‘treatment after pollution’ pattern had dominated the overall management paradigm in the water sector for decades (Varis & Vakkilainen, 2001). Nowadays, water managers are aware of the importance of managing water in a holistic and preventative way. Significant progress has been made in water-related policies and legislation. For example, some water legislation has been amended to reflect the development in water management, such as the 2002 ‘Water Law’ (WL) and the 2008 ‘Water Pollution Prevention and Control Law’ (WPPCL). Unfortunately, increasing water-related incidents show that problems like water over-exploitation, severe pollution and ecosystem deteriorating are still severe, restraining the effective management of water resources (Economic Daily, 2011). It also reveals that current policies and legislation on water management do not effectively deliver sustainable water management outcomes.
2.1. Related water laws and water resources management – a review

With a centralized and unified administrative and political system, the Chinese government has developed an approach having policies and laws set centrally but implemented locally (Cosier & Shen, 2010). Local legislatures are delegated some certain powers in making local legislation. In the water sector, River Basin Commissions (RBCs) are also entrusted with limited power in formulating regulations on specific issues within the basin area. Under such legislative structure, China has built up a comparatively comprehensive legal framework on water resources at both national and local level, which almost covers all the aspects of water resources: water resources development, utilization and protection, water and soil conservation, flood and drought prevention and control, engineering project management and protection, etc.

Water laws and regulations in China are classified into four categories: (1) laws enacted by the Standing Committee of the National People’s Congress, (2) State Council decrees, (3) ministerial regulations of the Ministry of Water Resources, and (4) laws and regulations formulated by the local legislature and implemented by local governments. There is a hierarchical order from (1) to (4), in which the laws and regulations of the higher level have higher legal force than those of lower level. With regard to the content, national and local laws are more general while decrees and ministerial regulations tend to be more specific and technical (Zhang et al., 2012). At the national level, ‘Water Law’, ‘Water and Soil Conservation Law’, ‘Water Pollution Prevention and Control Law’ and ‘Flood Control Law’ are the ‘Four Basic Laws’ governing national water resources management. These laws play a great role in managing water quantity and distribution, protecting water quality, preventing soil erosion and controlling floods respectively. In addition, more than 25 State Council decrees, 100 ministerial regulations and 800 local laws and regulations have been in place to provide regulatory framework for various levels of water management activities. Having outlined China’s legal framework, this section is going to take the 2002 WL as an example to investigate to what extent the legislation could contribute to effective water management.

With the purpose to establish a water-saving society, prevent water pollution, achieve the sustainable use of water resources and facilitate economic and social development (Water Law, 2002a), the 2002 WL, evolved from the 1988 Water Law, signals a significant step in China’s water management history. First of all, it emphasizes the conservation, protection and rational allocation of water resources, trying to balance water’s economic, social and environmental value (Water Law, 2002b). Furthermore, it encourages the adoption and implementation of IWRM, of which integrated river basin management (IRBM) in conjunction with jurisdictional management is stipulated as a dominant water management regime on seven major rivers (Water Law, 2002c). According to this law, RBCs have been established on significant rivers and lakes, in order to implement IWRM (Water Law, 2002c). It is the first time that RBCs have been given formal legal status. This law requires that national strategic water resources planning and river basin (regional) planning (comprehensive planning and specific planning), water supply and demand planning, etc. should be conducted, providing water resources planning a clear legal position and a good start for IWRM implementation (Water Law, 2002d). It also sets up a water rights licensing system along with a compensation system, signifying the transition from exclusively focusing on infrastructure development to paying considerable attention to the management and protection of water resources (Zhou, 2008). Other important mechanisms, such as water-function-zone system, total pollutant discharge and combined total-quantity control and quota-based control are also established to promote water quality and sustainable water use. After 10 years’ application, mechanisms...
like water planning, water rights licensing, total water volume control and water function zone have been generally established in China. Attempting to establish a water trading market, this law has promoted the development of water trading practices. For example, a few water transfers have taken place between municipalities (Moore, 2012), helping to alleviate pressing water shortages in some cities.

However, the 2002 WL is criticized for its low ability in delivering good water governance. The deteriorating water shortage and water pollution has not been seriously curbed. The deficient WL has been regarded as one of the root causes. First of all, it only provides general principles and framework for water management, lacking clear definitions, mechanisms and procedures for implementation. For example, the vague language frequently employed in this law has led to various conflicted explanations and difficulties in implementation. The unclear responsibilities and duties of the local governments, water authorities and RBCs also create lots of vacuums and conflicts. Second, although with the aim of facilitating an integrated water management regime, this law does not resolve the conflicts between central and local governments, between basin management and administrative management and between water authorities and other related authorities (Wouters et al., 2004). Third, it is very sector-based, representing sectoral interests and lacking coordination with other relevant water laws. In some cases, there are even contradicted provisions among different sectoral laws. For example, provisions on water utilization and development in WL sometimes are not compatible with those on water protection in the WPPCL. In addition, numerous regulations and rules formulated under the old 1988 WL have not been updated or amended accordingly, resulting in vacuums and conflicts (Wouters et al., 2004).

In practice, certain incidents (especially water pollution incidents) could speed up the legislative process, with a special intention to resolve related water problems. For example, the enforcement of ‘Temporary Regulation on Public Participation in Environmental Impact Assessment’ is largely due to the Songhuajiang Pollution Incident and Nujiang Dam Construction Dispute (China Water Net, 2005), while the formulation of ‘The Taihu Basin Management Regulation’ is catalysed by Wuxi Water Incident. This sometimes inevitably results in inconsistency with other laws (Yang & Griffiths, 2010).

Comparing the progress with the deficiencies of the WL, it is revealed that current Chinese water resources management practice is mixed with a traditional fragmented management regime and an advanced IWRM regime. Similar conclusions could be got from reviewing other related water legislation. China has developed its IWRM mainly by integrating the concept of IWRM into the existing legal and institutional framework. Although prudent steps have been taken to support the adoption and implementation of IWRM, they do not entail a complete advocacy of IWRM. This, as a result makes IWRM struggle to survive within the current fragmented and sectoral legal framework. In many cases, the inconsistencies between IWRM requirements and the current legal and institutional framework create most of the problems.

2.2. The implementation of IRBM

The IRBM is the adoption and implementation of IWRM at basin level due to the recognition that the river basin is a basic unit suitable for integrated water and land resources management. It is by no means a simple combination of the water resources, land and forest management. Rather, based on the ecological system theory and the extensive participation of stakeholders (CWRC, 2007), IRBM intends to break departmental, sectoral and administrative barriers in the management of river basins to build a systematic and comprehensive management regime to rejuvenate the rivers. It also implies and requires a
transformation in mentality, legislation, institutional arrangements and management approaches. IRBM has been recognized as the fundamental platform for pursuing the harmonization between people and nature, urban and rural areas, and economic and social development. Nonetheless, the full understanding and implementation of IRBM may take some time and encounter some difficulties due to the entrenched fragment mentality.

China’s 2002 WL introduced and denoted IRBM as the main water management regime. By implementing IRBM in conjunction with jurisdictional management (Water Law, 2002b), this law signifies that China is starting to transit from a fragment management regime to an IRBM regime. Nevertheless, current institutional arrangements on water management are still characterized as ‘nine dragons administering water resources’: the departments of water resource management, environment protection, transportation, agriculture, forestry and construction, etc. conduct their responsibilities within their own jurisdictions on the different facets of water resources (Li & Yao, 2002; Feng et al., 2006). While it is important to differentiate multiple water uses among various agencies, this fragmented administrative structure too often leads to overlaps and conflicts while conducting their respective responsibilities. If there is lack of a coordination mechanism, these overlaps or vacuums not only result in controversial plans and actions but also contribute to ineffective water management. For instance, basing on their own interests on water resources, most local governments do not take account of the health condition of the whole river basin while exploiting and managing water resources within their own jurisdictions (Jiang & Fan, 2006).

To implement an IRBM regime, seven RBCs, with the responsibility to conduct water management in seven river basins of national significance, have been dispatched by the Ministry of Water Resources (MWR). They have been the principal scientifically-administrative, advisory and consulting agencies within river basins (He & Chen, 2001). Establishing comprehensive RBCs is an important step towards IWRM. According to related legislation, RBCs have been delegated with substantive powers such as water distribution among provinces, certain legislative powers and the operation of water projects, and procedural powers such as providing guidance, coordination and supervision on legislation implementation, flood control and river sand extraction. From a substantive perspective, RBCs have a very limited power in allocating water resources, coordinating water resources exploration and conservation, and enforcing water resource planning at the basin level (Jiang, 2009). For example, in the WPPCL, the responsibilities of RBCs are limited to monitoring water pollution and reporting the monitoring results to the MWR and Ministry of Environmental Protection (MEP). RBCs do not have authority over pollution control at the source. From a procedural perspective, supervising the implementation of laws and plans, coordinating conflicted interests and providing scientific guidance have been the main responsibilities of RBCs. Being entrusted with procedural power is essential and crucial for RBCs to mediate conflicted interests, but without appropriate substantive power, they are not able to function as real RBCs for the interests of the whole basin.

Furthermore, the affiliated position to the MWR also restrains RBCs from being real basin commissions. First of all, they are merely the extension of the MWR and take a very narrow top-down approach to manage water resources within the responsibility of the MWR (e.g. they have authority for water

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quantity management issues, but not for water quality) (Turner, 2004). Due to their status under the MWR, there is no procedure for other related departments (e.g. environmental protection departments) and local governments to participate, which inevitably impair the RBCs’ ability in managing water resources comprehensively and in coordinating and mediating the conflicts among them (Li & Zhao, 2012). Secondly, labelled as institutions affiliated with MWR, they are intended to provide technical support, which consequently results in an overemphasis on technology and engineering approaches. In addition, although using the term ‘commission’, RBCs do not have wide representatives of various levels of governments, related governmental agencies, water users and the interested public. In a nutshell, RBCs in China have not been empowered to be fully fledged basin commissions (Yang & Muller, 2009). Having been aware of these problems, some RBCs are undergoing a step-by-step reform of their management system to enable themselves to be proper basin commissions (CWRC, 2005). Nonetheless, their fully fledged status cannot be established just through self-reform. They need the empowerment from relevant laws to clearly stipulate their substantive responsibilities. More importantly, it requires a paradigm shift to include the public participation as an integral part of RBCs and the decision-making process.

2.3. Water resources management approach

Owing to the identification of water resources management as a technical issue in China, water infrastructure construction (such as dams, dikes and reservoirs) to resolve problems like floods, droughts and uneven distribution plays a dominant role among various water management approaches. The social and legal dimension of the traditional ‘harmony thought’ has long been ignored. Wherever there is a water crisis, water managers prefer to resort to water project construction, which as a result, subjects most of China’s rivers to intensive project constructions (Wang et al., 2010). Unfortunately, the excessive adoption of this infrastructure construction measure has resulted in an inappropriate expensive approach which requires evaluation and public acceptance (Gourbesville, 2008; Wang et al., 2012). Many researchers, both domestic and international, have revealed that the overreliance on projects has caused a number of environmental and ecological problems due to the interruption of water integrity, the alteration of physical habitats and the disruption of longitudinal connections (Qian et al., 2009). Examples of such problems include the deterioration of aquatic environments and land habitats, the loss of biodiversity and the drying up of river systems.

This approach is further challenged by the following drawbacks: foremost, it is highly dependent on science and technology, by which water managers try to control the ‘wicked’ water problems. On the one hand, these engineering solutions exaggerate the role of water facilities in managing water resources while despising the function of institutional arrangements, law and other ‘soft’ measures (such as floodplain area reclamation and wetland protection) (Lee, 2006). On the other hand, they result in overconfidence in future water status predictions and ignorance of the potential change in the past hydrologic variability (Cheng et al., 2009). In many cases, the high reliance on technical experts has been the ‘sound’ excuse to exclude the stakeholders and public from the relevant decision-making process (Jiao, 2010). Although there is provision, in principle, for ‘public participation’ in the 1989 Environmental Protection Law, lack of mandatory legal requirement and institutionalized procedure makes this principle inoperative. All of these challenges have demonstrated that the identification of water management as a merely technical issue and the excessive adoption of a project construction approach are unable to ensure sustainable water management.
2.4. The adoption of new water policy

The 11th Five-Year Plan (FYP) (2006–10) set out a number of policies and priorities for water resources management, including: (1) adopting a more unified management system, (2) shifting from supply-side to demand-side management, (3) integrating river basin management with regional management, and (4) establishing a preliminary system of water rights trading. These first three descriptions of water resources management at a national level provide a strong policy support for, and a clear recognition of, IWRM in China (Jiao, 2010). Triggered by the pressure of water scarcity and water pollution, the importance of integrating water quantity and quality management to the management of water resources has been recognized by some highly industrialized cities, including Shenzhen, Beijing and Shanghai (Lee, 2006). These cities have attempted to implement IWRM by setting up overarching water authorities. Although these authorities are not strictly fledged as integrated institutions, their experiences could provide valuable insights for larger-scale IWRM.

In 2009, at a central-level government conference about water reform, an administrative approach ‘implementing the strictest water resource management system’ (SWRM) was brought out to address current water problems and promote sustainable water use (Jiang, 2011). Three approaches (the so-called ‘three red lines’) – water volume control approach which requires considering the availability of total water volume; water efficiency improvement approach which needs to improve water-use efficiency to save water; and water-functional-zone pollution control approach which sets aquatic environment as a high priority, are identified as the keys to apply SWRM. The requirement to implement SWRM has been written in the 12th FYP as an approach to realize a water-saving society. In January 2012, the State Council released the ‘Proposal on How to Implement SWRM’ (MWR, 2012). It not only sets the general principles and goals of water utilization, but also puts forward corresponding measures of managing those ‘three red lines’. Safeguarding measures are also brought out as a significant part of this proposal, mainly including responsibility and assessment mechanism, water monitoring, water legislation and institutional arrangements as well as the financial support. In January 2013, the ‘Assessment Methods of Implementing SWRM’ was promulgated to allocate different goals among provinces (MWR, 2013). According to this method, the completion of the allocated goals and the implementation of SWRM have been regarded as an important index of assessing local economic and social development performance.

All of these policies and methods imply that water security has been attached high importance to national security like food security (Xu, 2012). While it is important to implement stricter management on water resources, this approach should combine with a sound market mechanism and well-designed regulatory framework (Xu, 2012). Furthermore, SWRM must be implemented on an improvement of the current water management regime: otherwise, it will be only another political slogan or movement without achieving the desired results and contributing to effective water management.

3. IWRM – an effective water resources management regime

3.1. Theoretical understanding of IWRM

Along with the evolution of the concept of sustainable development which has gradually become a national priority in China, IWRM is being adopted with a view to sustainable water resources
management (Chinese Academy of Science, 2007). The adoption and implementation of IWRM is particularly facilitated by the amendment of the WL in 2002, which has stipulated some of the key elements of IWRM, such as integrated river basin planning and river basin organization (Song et al., 2010). Its status was further reinforced in the 11th national FYP by setting policies such as a more unified management system and integrating river basin management with jurisdictional management. However, while China is moving towards an IWRM regime and taking the entire river basin into account, in most of the Chinese literature, the use of the IWRM concept is presented more widely than it seems to be in reality (Campbell, 2005). The understanding and implementation of IWRM are still in their infancy and far from reality (Campbell, 2005). Thus, in this part, a brief analysis of IWRM is introduced and its challenges confronted in the context of climate change are then explored.

In many developed and developing countries IWRM has evolved over the last century and then eventually became the dominant regime for water management. The USA, Australia and Thailand are some of the countries that introduced IWRM (Rahaman & Varis, 2005). Compared to current fragmented, messy and single-objective water management paradigm, IWRM is expected to achieve sustainable water management through an integrated, coherent, collaborative and participatory framework. Within this framework, strategic operational planning and implementation is processed, stakeholders are properly involved, and economic efficiency, social equity and environmental sustainability are fairly balanced (Zhang et al., 2010). A widely adopted definition of IWRM is given by the Global Water Partnership (GWP) (GWP and International Network of Basin Organizations, 2009), which describes IWRM as

’a process that enables the co-ordinated management of water, land and related resources within the limits of a basin so as to optimise and equitably share the resulting socio-economic well-being in an equitable manner without compromising the long-term health of vital ecosystems’.

Although there are various definitions, most of them are based on the Dublin Principles: (1) water has an economic value and should be recognized as an economic good; (2) water is an integral part of the ecosystem and is a finite resource; (3) human activities affect the productivity of water resources: water management requires a coordination of policy-making at all levels; (4) integration of land and water and of institutional integration; (5) water has to be managed at a basin, watershed, lake or aquifer level through active participation of the stakeholders at all levels through a decentralized approach; (6) women should play a central part in the water provision and management (Pangare et al., 2006). These definitions and principles reflect a paradigm shift in water management, both from a substantive perspective and a procedural perspective. Developing from the Dublin Principles, IWRM has formed its own principles, such as basin-level management, public participation, good governance and information sharing. Most of them have been widely recognized and implemented by both developed and developing countries in order to achieve sustainable water management.

Theoretically, for IWRM per se, firstly, it should not be seen as a single approach but as a wide range of approaches involving institutional, legal, economic and environmental measures to manage water and related resources (Lenton, 2011). Secondly, it prefers to be regarded as a holistic or systemic approach.
process – changes or transformations in policies, laws, institutional structures rather than a once-for-all project or investment which focuses more on the ultimate outcome and impact (Lenton & Muller, 2009). Thirdly, it is a dynamic process. IWRM plans and strategies need to take future scenarios into account and they are subject to changes as per the changing situation. The perspective of progress implies that IWRM should be developed as a circular rather than a linear course. In a cyclic process, the previous step is able to shape the next. This explanation about process enables IWRM to respond to new challenges and opportunities rather than seeking an end point (Lenton & Muller, 2009).

Even if there have been some concerns that IWRM is an unrealistic and impractical approach, difficult to be put into practice and with a lack of operational definition and measurable criteria (Biswas, 2004), the majority of scholars and practitioners applaud its application. IWRM has been widely acknowledged as a pragmatic, incremental and promising approach offering practical framework for various countries and communities to address water problems within their own context (Lenton & Muller, 2009). Just as some scholars have argued, if IWRM is deemed to be more like a practice around which it has been very difficult to build a good theory, rather than a theory difficult to practise (GWP-TAC, 2009), then we can go beyond its criticism to a better practical management.

3.2. Rethinking the ability of IWRM in adapting to climate change

Water resource management has traditionally been about understanding and assessing the risks and uncertainties the hydrological cycle brings and then designing robust responses to them (Lenton & Muller, 2009). The constant change in economic circumstances and social priorities also catalyse water resources management to evolve to meet these challenges (GWP-TAC, 2009). Derived from these requirements, IWRM has been developed on the concepts of flexibility and adaptability, which fit with adaptation to some extent. Nevertheless, due to the larger-scale uncertainty and complexity brought by climate change, questions have been raised about the ability of IWRM to deal with these new challenges.

Firstly, the emphasis of most work on IWRM is to manage water and interrelated resources in an integrated way to maximize economic and social welfare (Aerts & Droogers, 2009), without considering external pressures like climate change. The adaptability (coping range) of a current water system may be unable to adapt to future uncertain climatic projections because it is set up and designed according to historical information and current climate conditions (Aerts & Droogers, 2009). While uncertainty is prevalent in the context of climate change, IWRM does not explain explicitly how to manage water resources under uncertainty (Medema & Jeffrey, 2005). Adopted and developed before climate change became an internationally hot issue and a domestic policy driver, IWRM is not explicitly required to integrate adaptation considerations. The vulnerability assessment of water resources is mainly confined to the ecosystem, underground water resources and natural disasters, without giving much consideration to climate change vulnerability. Adaptive capacity enhancement is also not set as a goal in IWRM.

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3 According to IPCC, 2001, vulnerability has been defined as ‘the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.’
Moreover, originally advocated as a politically feasible approach to manage water resources, IWRM does not invite much science in its concept and practice (Pahl-Wostl & Sendzimir, 2005). The scientific basis of IWRM concept and practice has not been well established (Pahl-Wostl & Sendzimir, 2005). For example, monitoring is often limited and passive, making periodically scientific assessment and review very difficult. However, adapting to water-related climate change impacts needs to be based on the scientific understanding of future projections and dynamic assessment. These new challenges come up with a significant question for water resources management: to what extent could IWRM facilitate adapting to water-related climate change impacts?

4. Adaptation to water-related climate change impacts

4.1. Climate change impacts on water resources

The water system is identified as one of the most vulnerable ecosystems by the IPCC and China’s National Climate Change Programme (CNCCP) (CNCCP, 2007; Bates et al., 2008). Over the past two decades, the gross amount of water resources in the Yellow, Huaihe, Haihe and Liaohe rivers in Northern China has been significantly reduced, while the amount of water in Southern China has slightly increased. This will most likely exaggerate the already existing ‘dry North and wet South’ water problem, making the management of water resources ever more challenging. For example, climate warming would possibly reinforce the drought trend in Northern China by intensifying the water scarcity (CPAACC, 2008), significantly challenging current water demand and supply management approaches.

On the contrary, water managers have to improve their water quantity management in order to deal with the increasing precipitation in Southern China. It is also projected that future climate change would have great impacts on the temporal and spatial distribution of water resources by augmenting annual changes, increasing the frequency of floods, droughts and other extreme disasters. This requires some reflection and improvement in current water disaster management, such as the early warning and emergency management system. In particular, climate change is expected to accelerate the melting of glaciers in Western China, further reducing the area of glaciers and glacier ice reserves. This will have significant impacts on the rivers and run-offs which get water from them. Along with changes in water resources, related natural and socio-economic ecosystems depending on water resources are affected as well.

4.1.1. Water security. Water security is usually defined by three aspects: water quantity, water quality and the security of water infrastructures. While climate change models are riddled with great uncertainty, their conclusions are overwhelmingly consistent: climate change will impact temperatures, precipitation rates, and the consistency of precipitation (Eckstein, 2010), resulting in a change in water quantity, availability and distribution. A warmer climate could drastically alter glaciers melt and stream flow regimes. For instance, in the Tibetan Plateau of the Himalayas, where the Yangtze River and Yellow River originate, the glaciated area has shrunken 5.5% over the past 45 years, with glacial recession rates averaging between 4 and 65 metres annually (UNESCO, 2009). By 2050, climatic changes are expected to reduce the glaciated area of the Plateau by 100,000 km² (IPCC, 2007a). The change in water quantity will largely determine the water distribution among agriculture, industry and domestic use. Due to different topography, geography and meteorological circumstances in a
broad territory, it will be wetter in some places and drier in other places. This uneven precipitation increases the possibility of extreme weather events, such as floods and droughts, which are already creating serious problems in the Yangtze River and the Yellow River.

Water quality can be affected by climate change and the changes in water quantity. The IPCC predicts that regions enduring higher water temperatures and increased precipitation will likely see an increase in water pollution from sedimentation, nutrients, agricultural chemicals, and dissolved organic substances (Bates et al., 2008). In such circumstance, the goal of improved access to adequate safe drinking water will be hard to achieve. The changes in water quantity and quality may significantly influence the balance of the water ecosystem, increasing the vulnerability to climate change. Furthermore, most existing water infrastructures are designed and operated on the assumption that future water status and climate will be similar to the past (stationary climatic conditions), or at least will perform the same hydrological variability (Mattews & Wickel, 2009). Such historical infrastructures will be placed under greater pressure as a result of hydraulic changes and warmer temperatures, as well as the increased demand linked to population growth, development and associated demographic and other changes (UNESCO, 2011). These infrastructures will be damaged or out of function if unexpected events happen.

4.1.2. Other interrelated ecosystems. While the water ecosystem is recognized as one of the most important ones for providing vital services, for other, related ecosystems, it is also the primary media through which climate change influences the planet’s ecosystem and the systems of human existence. Other ecosystems and sectors that interact with water resources mainly include land, agricultural and coastal systems. They are subjected to changes due to the changes in the water system. For example, declining glaciers compounded with earlier spring snowmelt are likely to reduce water availability for irrigated agriculture in Western China (Bates et al., 2008). Rising sea levels in low-lying areas on the eastern coast of China would cause the loss of coastal wetlands and river estuaries, and the contamination of underground water due to salt-water intrusion (Teclaff, 1991). The damage to watershed forests due to climatic stress could have impacts throughout the entire river basin, causing soil erosion and altering the amount, timing, and succession of downstream flows (Teclaff, 1991). Changes in these ecosystems will also alter the distribution and quantity of living creatures depending on them, resulting in biodiversity reduction.

4.1.3. Socio-economic system. The changes in water quantity and distribution will inevitably affect electricity generation in the river. For example, during the drought in south-west China in 2010, the power generating ability of the hydropower station in The Three Gorges, which is the main electricity supplier for the Yangtze River Basin and middle China, was affected severely. The shortage was ultimately met by around 300,000 tons of coal, which changed the distribution of electricity among different districts. It also changed the energy structure, influenced environmental quality and economic development, which in turn affected climate change. Extreme weather events and natural disasters

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4 IPCC suggests that a global temperature rise of only 2 °C will flood as much as 23–29% more land area than is currently inundated by seasonal deluges.
increase the risk of humanitarian emergencies, and thus the risk of instability and dislocation in vulnerable basins (Ban, 2007). The effects of climate change will also reduce the output of agriculture, change the farming structure and influence the municipal water supply and sanitation systems. Another crisis is emerging, that of people displaced by climate change (Asian Development Bank, 2005). Climate change-induced displacement could deepen existing tensions and conflicts, affecting China’s economy, society, environment and culture in a broader way. Water managers must learn how water management practices will be able to manage all these inevitable climate change impacts.

4.2. Adaptation to water-related climate change impacts

Mitigation and adaptation are widely recognized as two related but distinct methods designed to address climate change (Burton et al., 2002). However, until recently, the focus of debate about global climate change has been on the mitigation of greenhouse gases (GHGs) emissions (Bonyhady et al., 2010), while adaptation was put aside. China has put a lot of effort into mitigation: working to reduce GHGs emissions by a variety of approaches, such as improving energy utilization efficiency, exploiting renewable energy and developing a low-carbon economy. While mitigation is very important to slow down climate change and reduce the urgency of adaptation, this article argues that adapting to the climate change impacts that are already ‘locked in’ is also crucial. Climate change adaptation has been brought to the fore as a result of the international community’s failure to resolve a number of critical issues at the United Nation’s Framework Convention on Climate Change (UNFCCC) COP 15 (Lean, 2009), COP 16 and COP 17. Given the physical attributes of GHGs, which will remain in the atmosphere long after they were emitted, the warming phenomenon will not be reversed for at least one century even if we stop emitting GHGs immediately. The frequent extreme weather events, such as floods and droughts, have forced China to manage climate-related water crises urgently. Therefore, the critical issue here is how to adapt to this unstoppable changing situation in the water sector.

Adaptation has various definitions focusing on various perspectives. This article will not focus on analysing different definitions but will adopt the definition in the IPCC 2007 (IPCC, 2007b), where

‘adaptation to climate change is the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities’.

Adaptation can be divided to different categories according to various criteria: planned or autonomous (by purposefulness), anticipatory or reactive (by timing), public or private (by adapting agent). Autonomous adaptation results from meeting altered changes; reactive adaptation is triggered by current events; and private adaptation is taken by individuals or private groups. They are very common in China’s water management practices. For instance, the farmers in Shandong Province usually dig wells to supplement the insufficient irrigation water in dry seasons. These autonomous, reactive and private actions help farmers cope with the dry situation that was not forecast. Although these types of adaptation will continue to play a great role in China’s forthcoming adaptation practices, they have great risk of maladaptation. In the example of farmers in Shandong Province, autonomous unplanned well-digging could result in potential damage to land use or sea water intrusion. Thus, planned, anticipatory and public adaptation should be adopted to facilitate more effective adaptation. According to Adger et al. (2005), adaptation can involve both improving adaptive capacity (the ability of individuals, groups or organizations to adapt to changes, such as managerial ability, access to
resources and information, robust decision-making process) and implementing adaptation decisions (i.e. transforming that capacity into action). The Copenhagen Climate Change Conference in 2009 suggests that the most effective adaptation strategies are likely to be building resilience, managing risks, and employing adaptive management (Richardson et al., 2009). Unfortunately, much of the literature does not illustrate how these adaptation strategies could be integrated with other development activities. Thus, this paper is going to explore the potential to synergize climate change adaptation with water resources management in China.

5. The synergies and trade-offs between IWRM and climate change adaptation

While there has been vigorous comparison of the IWRM approach and the adaptive management approach to the management of natural resources, there have been few studies comparing IWRM and climate change adaptation in the water sector. Theoretically, IWRM is widely regarded as an approach to manage water and related resources among different users with a holistic perspective, while adaptation to water-related climate change impacts is required to enable related water management regimes to adapt to expected or unexpected climate change impacts. However, if IWRM is regarded as an ongoing development approach due to the internal challenge of fragmented management, climate change adaptation in the water sector can be deemed as a response to an emerging external challenge – climate change. The internal and external challenges have been recognized and addressed separately due to their different concerns. Not enough study has been done in terms of integrating these two challenges. This section will conduct a comparative study of IWRM and adaptation in the water sector from various perspectives to find out the distinctions, overlaps and the likelihood to integrate them (Figure 1).

5.1. The comparison of IWRM and adaptation to water-related climate change impacts

5.1.1. Integrated approach vs. specific context. IWRM is characterized by its integrated approach, which integrates different sectors, water users, regions and different aspects. In China, in order to implement IWRM, seven basin-level commissions have been established to manage water resources in a basin-wide context. Fragmented management among the RBCs and local governments has long been criticized for impeding the integration of management of water resources. Conversely, adapting to water-related climate change impacts is characterized by specific context due to different climate change impacts, vulnerability and adaptive capacity (McDonald, 2010). There is no panacea or one-size-fits-all approach for climate change adaptation. Adaptation strategies are effective only in a specific temporal, spatial, institutional, social and economic context. There is a growing awareness that it is better to leave relevant power and resources to local governments, allowing them to design and implement their own adaptation strategies according to their local specific impacts and adaptation capacity. Given the various climate change impacts and adaptive capacity of different reaches, regarding the river basin as a unit (an approach which is effective for IWRM) may be not applicable for climate change adaptation.

5.1.2. Stationarity vs. uncertainty. The premise of most natural resources management is an equilibrium-based understanding of ecosystems (Tarlock, 1994; Profeta, 1997), which assumes the stability of the ecosystem. It relies on the predictability of future changes and resorts to a return to equilibrium.
following disturbance (Godden & Peel, 2010). Based on this ecological theory, stationarity, which implies that ‘natural systems (water system) fluctuate within an unchanging envelope of variability’, prevails in current water resources management practice (Milly et al., 2008). Stationarity depends on our ability to forecast and implies that the basis of water resource management is captured through the

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Fig. 1. Distinctions and common points between IWRM and climate change adaptation in the water sector.
historical record of that basin’s hydrological variability (Matthews & Wickel, 2009). On the basis of stationarity, the hydraulic rules and the adaptability (coping range) of a water system are set up and designed according to current climate conditions and historical information (Aerts & Droogers, 2009). Most of the water management strategies and practices in China also have been based on this ‘stationarity’ assumption, which could be justified by the high reliance on historical records and the preference of hydraulic projects. Recently, a series of intensive droughts in southern and southwest China where water resources are regarded as abundant, have made the challenge to ‘stationarity’ self-evident. Historical records should not be fully trusted and relied on to make water-related decisions. Nevertheless, it needs time for water managers to understand and adjust their assumption and approaches in managing water resources.

After the 1970s the equilibrium theory was questioned and the so-called non-equilibrium theory was introduced to understand and explain how ecosystems function (Godden & Peel, 2010). The impacts of climate change speed up the reflection of current management paradigms. By altering the patterns and extremes of precipitation and evapotranspiration, climate change has posed a major conceptual challenge to water managers (Allen et al., 2012). In much of the literature on adaptation, stationarity has been declared ‘dead’ and ‘should no longer serve as a central, default assumption in water resources management’ due to human-induced climate change (Milly et al., 2008). On the contrary, almost all of the researchers agree that uncertainty pervades the whole process of adaptation – from decision-making to implementation and that we will live and embrace uncertainty for a long time (O’Brien & Sculpher, 2000; Reilly & Schimmelpfennig, 2000; Matthews & Wickel, 2009).

Climate change uncertainty implies that our human system cannot predict and make thorough preparation for future climate change impacts due to the imperfect knowledge of an event’s probability, magnitude, timing and location. Generally, while scientific approaches such as General Circulation Models, GHGs emission scenarios and the downscaling of models are indispensable, they are the main sources of scientific uncertainty (Allen & Ingram, 2002). Not only do these scientific uncertainties exist, but also epistemological uncertainty (who should be involved in decision-making and whose values count) and ethical uncertainty (who is responsible and accountable) are challenging when taking adaptation measures (Leitch et al., 2010). The uncertainty of the cost, implementability and effectiveness of any anticipatory adaptation response should also be counted (Barnett, 2001). As a consequence, the pervasive uncertainties in the whole adaptation process determine that decisions have to be made in the face of uncertainties and actions have to be implemented along with uncertainties. It is not surprising that adaptation strategies are closely related to (described as forms of) risk management (Smit & Pilifosov, 2001). ‘No-regret’ or ‘low-regret’ principles must be employed to reduce the risk of invalid investment and policy failure.

5.1.3. Core and urgent issues vs. non-core and long-term issues. Due to the pressure of population growth, economic development and urbanization, water problems such as water shortage, water pollution and uneven water distribution have been some of the core and urgent issues given high priority by the Chinese government. They also have been well-recognized by various levels of governments due to their potential to impact China’s food security and economic development. Although slow in taking innovative water management approaches, Chinese water managers never stop facilitating sustainable and efficient water development. IWRM has been adopted and implemented, combining with China’s specific political, legal and institutional environment.
On the other hand, water-related climate change adaptation is not regarded as a security issue in the short-term and the Chinese government has not accorded it a high priority (Moore, 2011). Even though some policies and plans (such as CNCCP) on climate change adaptation have been carried out in the past 5 years, adaptation is still in its infancy, both theoretically and practically. Most of the development in adaptation is partly due to the requirements of, and pressure from, the international community. For example, the CNCCP describes how the responsibility, stipulated in the UNFCCC (which requires all parties to formulate, implement, publish and regularly update national programmes to mitigate climate change and facilitate adaptation), will be met. The Adaptation Fund, established at COP-7, aims to finance concrete adaptation projects and programmes in developing countries stimulates China’s further adaptation action. The commitment the Asian Development Bank (ADB) makes in helping China adapt to unavoidable climate change impacts also contributes to its development. Nevertheless, all of them are external stimulations. The various levels of government lack internal incentives to make innovative adaptation strategies. While both the national and local governments are engaged with reducing the GHGs and developing the economy, climate change adaptation obviously has not attracted enough attention from them.

5.2. The possibilities of synergizing IWRM and climate change adaptation in the water sector

As shown in Figure 1, although IWRM and climate change adaptation differ from each other in various dimensions, they share much in common: (1) IWRM and adaptation share the same goal of reducing ecosystem vulnerability and achieving sustainable water management; (2) both water management and climate change adaptation are cross-cutting issues, which determines that IWRM and adaptation need a comprehensive, coordinative and collaborative framework; (3) both of them are best regarded as a process which provides an ability to integrate new information and knowledge into future practices; (4) some identical key elements are required for their successful implementation, such as public participation, information disclosure and concern for social justice. Overlapping in areas such as objective, institutional framework and key elements, these common elements provide great potential for synergizing IWRM and adaptation to water-related climate change impacts. With regard to the distinctions previously analysed, it is not impossible to find a way to synergize them.

Firstly, although an integrated approach is preferred by IWRM, it is not a universal concept or strategy that can be applied as a fixed model in all situations (Pangare et al., 2006). The effectiveness of IWRM relies on recognizing water realities in different regions: hydro-geological reality, demographic reality, socio-economic-cultural reality, and the institutional arrangements (Shah et al., 2000). Therefore, the successful application of IWRM must tailor measures or initiatives to fit with local situations and priorities with a view to the basin interests. For instance, the implementation of the Yangtze River Basin (YRB) plan has been conducted by taking local conditions into consideration, as provinces along Yangtze River vary enormously in natural, economic and social circumstances.

Vice-versa, water-related decisions made at local levels should ultimately be in line with national frameworks and plans to achieve the broader river basin objectives (Slootweg, 2009). Furthermore, based on the ecological system theory, an integrated regime requires shifting from existing fragmented water management to a systematic and integrated management regime. With this regime, a coordinative and cooperative mechanism should be put in place to build a common water vision among different water users. Just as has been analysed before, the localized nature of adaptation determines that adaptation is best managed at the local level. Meanwhile, it also requires that adaptation strategy or planning should be conducted in a holistic way to avoid mal-adaptations and conflicts (Ranger & Garbett-Shiels, 2011). For example, in order to manage floods and droughts, a dam built on the upper reach may enhance the adaptive capacity of one region, but it may also be a mal-adaptation activity for another region relying on fishery. More importantly, as neither central nor local government could handle the challenges of climate change alone, a cooperative mechanism between central and local governments is essential to formulate compatible goals and deliver effective adaptation strategies. In a nutshell, proceeding from basin interests, IWRM needs to be implemented according to local realities and interests, while being based on local conditions, adequate consideration must be given to the impacts of adaptation at basin level. In fact, in order to minimize conflicts and trade-offs, the integrated approach needs to be combined with the localized approach, and a coordinative and cooperative mechanism should be in place.

Secondly, given the climate change challenges of water resources management, learning how to manage these uncertain climate-related risks has been on water managers’ agenda. Whether they admit ‘stationarity is dead’ or not, most IWRM practices have to engage with uncertainty management in the water sector, such as the disaster risk reduction programmes in many river basins (Wilby et al., 2006). While uncertainty has not been fully recognized and integrated in China’s water management practices, it is essential to provide some approaches to bridge the gap between the assumptions of IWRM and adaptation. Although it is naïve to call for a significant reduction in the scientific uncertainty, more can be done to explore legal principles and instruments and establish legal institutions and mechanisms to reduce the epistemological and ethnic uncertainties. At the least, the following principles and approaches could be employed to implement IWRM in a climate change context: (1) a precautionary principle which implies that decisions cannot be made until all the uncertainties about climate change impacts have been resolved; (2) a public participation principle which argues that the affected people should be identified and integrated in the decision-making process to supplement the inadequate knowledge of decision-makers; (3) an adaptive management approach which could provide an iterative and experimental process to monitor and evaluate, learn from experience and respond to emerging information or knowledge (Pahl-Wostl et al., 2007); (4) a risk management approach which is able to reduce risks, provide alternatives and prepare for negative risks (Aerts & Droogers, 2009); (5) a vulnerability-based approach which focuses on reducing climate exposure and human sensitivity as well as increasing adaptive capacity (Ford, 2008); (6) a ‘no-regret’ or ‘low-regret’ strategy which requires that adaptation measures should have the ability to deliver and resolve other economic, social or environmental concerns rather than depending primarily on climate change projections, thus reducing the impacts of uncertainty (Abramovitz et al., 2001).

Thirdly, although climate change is not regarded as a core or security issue, it has great potential to directly threaten China’s water security through affecting water quantity, the aquatic environment and water projects. Furthermore, through the impacts on water resources, climate change may have the potential to pose severe challenges on food supply, ecosystem security and even social stability (Moore, 2009). Therefore, all these potential challenges to the economic and social stability and
development require water managers to take climate change very seriously through embracing uncertainty, thinking ahead and acting ahead in a no-regrets way. IWRM has been advocated by Chinese water managers as a promising regime to enhance the resilience of the water system, and contributing to adapting to climate change challenges. In addition, the vulnerability reduction and adaptive capacity enhancement in the water sector are usually realized by the conduct of core and urgent tasks such as water pollution prevention and aquatic environment protection (ISDR, 2009). In a nutshell, adapting to water-related climate change impacts should be taken seriously in order to ensure water security. It could be integrated with IWRM which is the priority of Chinese governments.

After the previous detailed analysis, it is safe to conclude that the likelihood of integrating the two is very high. As climate change is an emerging external challenge while the water management issue has already been a challenge for quite a long time, the best solution would be to integrate climate change adaptation in the water sector within IWRM. On the one hand, climate change is mainly the result of human-induced GHGs emissions driven by social-economic development, and thus is better addressed in the development process by transforming development patterns or approaches (Klein et al., 2005). It is particularly important that climate change adaptation in the water sector should not be isolated with other water development policies or activities such as water pollution prevention, water conservation and other water management activities (Tan, 2010). This idea is supported by the GWP, which suggests that IWRM provides the best approach to manage the impacts of climate change on the water system (GWP, 2007). On the other hand, although climate change is a source of significant stresses for societies, it has always been only one factor among many (Smit & Pilifosov, 2001). Climate change should never be overemphasized and should be better considered equally with other issues in the development process, such as natural resource management—IWRM in this study.

This process is usually named after mainstreaming adaptation by many scholars (Smit & Wandel, 2006; Huq & Reid, 2004). Mainstreaming adaptation refers to integration or incorporation of climate change adaptation in the development process, mainly national (local) and sectoral policies, plans and activities, especially in developing countries (Huq et al., 2004). Mainstreaming is highly praised for its aims to inter-link climate change adaptation with other development issues to minimize contradictory trade-offs, to maximize the benefits of policies and activities and to develop a climate-proofing development pathway (Kok & Coninck, 2007). Just as the ADB finds, it is possible to avoid most of the damage costs attributable to climate change if climate-proofing measures are undertaken at the design stage of the policy, plan or project (ADB, 2005). Climate-proofing strategies in the water sector are achieved if climate change impacts and adaptation are mainstreamed in IWRM. Mainstreaming is also recognized as an effective approach in putting adaptation into practice (Patwardhan et al., 2009). Some entry points for mainstreaming climate change adaptation will be analysed in section 6.

6. Mainstreaming climate change adaptation in IWRM

As a holistic approach for managing water and related resources, IWRM could provide an integrated and practical framework to manage water resources by taking emerging climate change impacts into account. It has immense potential to contribute to the delivery of sustainable water management, reducing vulnerability and building resilience to enable water managers and communities to manage adverse climate change impacts (Phukan & Tomar, 2012). Thus it is necessary to retain many of the elements that have been developed as part of IWRM. Nonetheless, the incremental challenges from adaptation indicate
it is also very necessary to develop or extend IWRM’s focus to include adaptation. IWRM will ‘need to evolve in ways that place a much greater emphasis on risk, uncertainty and the ability to respond to change and inevitable surprises’ (Aerts & Droogers, 2009). Mainstreaming climate change adaptation considerations could provide this opportunity to develop IWRM through identifying key entry points.

To identify the entry points of mainstreaming strategies, the key elements and processes of IWRM should be outlined primarily. According to the GWP, three pillars of IWRM, described in the GWP-TAC, are as follows:

(A) Moving towards an enabling environment of appropriate policies, strategies and legislation for sustainable water resources development and management.
(B) Putting in place the institutional framework through which the policies, strategies and legislation can be implemented.
(C) Setting up the management instruments required by these institutions to do their job (GWP-TAC, 2004).

An enabling environment mainly represents the political will in adopting IWRM, the institutional framework for IWRM implementation and the management instruments to conduct specific IWRM measures. They provide basic environmental, institutional conditions and practical tools for the process of IWRM. The process of IWRM mainly comprises of establishing water status, setting overall goals, analysing gaps, preparing and deciding on strategy and the action plan, implementing decisions, monitoring, evaluating process (see Figure 2) (GWP-TAC, 2000). According to the IPCC, successful IWRM strategies in a climate change arena at least include: capturing society’s views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface and underground water, protecting and restoring natural systems, and including consideration of climate change (Bates et al., 2008). Given China’s understanding and implementation of the IWRM regime, significant transformations in various aspects should be made in order to achieve the criteria listed above. As the sustaining system of IWRM, these three pillars should be ‘strengthened’ to prepare for climate change impacts. Entry points identified in the process of IWRM will serve as the crucial catalysts in integrating climate change impacts.

6.1. Improving the enabling environment, institutional framework and management instruments

China’s 12th National FYP has required development plans and projects considering climate change impacts in their design stage. In light of that, the first step for mainstreaming adaptation in IWRM would be integrating adaptation factors in water-related policies, legislation and plans. For example, the goal should be extended to climate change vulnerability reduction. The criteria to assess effectiveness should also include adaptation parameters.

In addition to these mainstreaming-related policies and legislation, institutional arrangements should be improved to provide enforcement capacity for mainstreaming process. The current fragmented institutional arrangements must be shifted to integrated and cooperative institutional settings, either through institutional reform or through establishing a cooperative mechanism. Given the difficulty, and slow progress, in making institutional reform, it is feasible to facilitate mainstreaming by promoting cooperation and coordination among related institutions. To facilitate mainstreaming the central, regional and local water authorities should work closely with those taking charge of climate change adaptation
(e.g. National Reform and Development Commission and its sub-level commissions). The RBCs could play a greater role in the mainstreaming process as a coordinator between various governments. The overlaps and conflicts between the RBCs and local governments and those in between the different levels of governments should be settled; and the institutional responsibilities on adaptation should also be clarified (Liu & Speed, 2009).

A platform is necessary to facilitate information and knowledge exchange and communication among different adaptation-related authorities. For instance, Yangtze Forum, formed in 2005, has operated to bring key government departments and stakeholders to work on disputes and conflicts, share knowledge and visions and to promote sustainable management of the YRB (Yu et al., 2009). In the future, this forum could play a greater role in promoting information exchange and cooperation on climate change adaptation by inviting authorities, such as development and reform commissions and meteorological authorities, to work together.

Moreover, water managers should develop the ability to make, and implement, flexible (not locked in) climate-proofing policies (Neuman, 2001). For example, water managers in the YRB should advocate and advance floodplain restoration to restore the freshwater system, which could reduce the river basin’s vulnerability to climate change (Yu et al., 2009). Another ability water managers should build is the ability of ‘learning by doing’, which refers to the ability to learn and make progress in future decisions through the outcomes of implemented actions (Doremus, 2010).
During the decision-making process, the active involvement of the stakeholders and the public, and transparent information sharing and disclosure (which constitutes the foundation of effective IWRM and climate change adaptation) should be facilitated and developed to make legitimate, scientific and democratic decisions. Water management instruments, such as water planning and (strategic) Environmental Impact Assessment (SEA/EIA) are also important entry points for mainstreaming by considering adaptation in their processes.

6.2. Revisiting the IWRM process

The point has been made clear that both IWRM and adaptation are better to be regarded as an ongoing process which can respond to changing conditions. It implies that every step of the IWRM process could provide an opportunity for integrating adaptation considerations, from the first step of water status investigation to the last step of monitoring and evaluation. This section is going to illustrate how climate change adaptation could be considered in some of the key IWRM steps.

Water status investigation should be based on the climate change–water–(land)–human system analysis rather than water–human interaction. Current water status investigation is mainly conducted by the MWR, focusing on water quantity (include floods and droughts) and water quality. To mainstream climate change adaptation, potential climate change impacts on water resources and other interrelated resources, along with uncertainty, should be scientifically studied and investigated. Furthermore, the vulnerability of the water ecosystem to climate change, as determined by the physical attributes of the water ecosystem and the relevant socio-economic circumstances, should be reasonably assessed as well. To date, the assessment reports about the climate change impacts on the YRB, Poyang Lake, Huai, Hai, Songhuajiang and Tarim Basins and their vulnerability have been published, providing a scientific foundation for basin and local level adaptation decision-making. Unfortunately, these assessments do not really investigate and assess the river basin’s social and economic vulnerability in detail, which consequently may affect the ability of IWRM in managing water-related climate change impacts.

Based on an understanding of the current water status, the objectives of mainstreaming should be identified correspondingly. In addition to the recognized IWRM objectives, reducing the vulnerability to climate change and enhancing the adaptive capacity of ecological and socio-economic system to better respond to water-related climate change impacts should be another important goal. In a mainstreaming process, this goal could be subject to change, due to the uncertainties around adaptation and the new information coming from implementation.

The step of preparing and deciding on strategies and actions is one of the crucial steps to integrate adaptation considerations. One of the significant strategies to apply to IWRM is water planning, which provides a vision and a roadmap for managing water resources over a relatively long period. If adaptation is mainstreamed in the water planning process, it could lead to systematic consideration of climate change and adaptation in the subsequent planning stage, such as water infrastructure planning and delta development planning. Generally, three aspects should be given appropriate attention by water managers when mainstreaming adaptation. Firstly, mainstreaming strategies or plans should be coherent or coordinate with existing policies in related areas, such as hydropower development and

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agriculture development. If certain trade-offs are unavoidable, a cost–benefit analysis is needed to make sure the optimal choice is made. Secondly, owing to the uncertainty inherent in climate change, alternatives based on different scenarios to achieve the same objective should be prepared and provided for decision-makers. Not only can alternatives provide a comparison and evaluation among different methods achieving the same goal, but they also shift the attention of communities away from a narrow focus on water and climatic risks to a much wider range of strategic pathways responding to climate change (Aerts & Droogers, 2009). Unfortunately, alternatives are currently absent in various mechanisms, like water planning and EIA, which narrows the choices and often leads to locked-in actions. Thirdly, unlike traditional water resources management, adaptation measures are highly dependent on the perception, knowledge and experience of certain affected groups and communities. Considering that, a mechanism to collect their perceptions of risks and their experiences of managing risks will be very necessary (Aerts & Droogers, 2009).

Both IWRM and adaptation insist they are ongoing processes rather than one-off actions, thus the monitoring of the dynamic water ecosystem should be conducted continuously to enable decision-makers and more widely, water users, to make timely assessments and adjustments. Based on various scenarios, the scientific foundation and hypothesis of decision-making should be tested and the

Fig. 3. Revised process of mainstreaming adaptation within IWRM.
effectiveness of decisions should be evaluated. What needs to improve in China’s practice is to inform water users of the monitoring and evaluation outcomes with transparency.

While most IWRM processes stop at evaluation, mainstreaming asks for a further step – adjustment to close the loop. The traditional method that attempts to predict all the consequences of an action before deciding to go forward and then never looks back again has been obsolete under climate change because of its inherent uncertainty (Ruhl, 2009). If decision-makers could develop the ability of ‘learning by doing’, they will be able to adjust current actions to the changing condition through the outcomes of implemented actions. Furthermore, feedback from the outcomes of monitoring and evaluation should be put into the decision-making process to shape the next round of the mainstreaming process. The revised process of mainstreaming adaptation within IWRM will look like Figure 3.

7. Conclusion

Due to the uncertainty of climate change and the limited resources in China, it would be better if climate change adaptation was mainstreamed in routine development issues like water resources management. This article reveals that there are high possibilities to synergize IWRM and climate change adaptation. Given the IWRM implementation in China, a successful mainstreaming process is highly dependent on a significant improvement in IWRM and the advancement of the ability to respond to external climate change challenges. By integrating adaptation considerations in the enabling environment, institutional framework and management instruments as well as the IWRM process, mainstreaming adaptation with IWRM could greatly contribute to vulnerability reduction and adaptive capacity enhancement in the water sector. If the mainstreaming process is successful in the water sector, these pioneer ‘trial and error’ experiences can be used for reference in other vulnerable areas, such as agriculture and coastal management. These adaptation strategies are expected to help China adapt to climate change without compromising routine development goals.

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