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Comparison of water resources management between China and the United States

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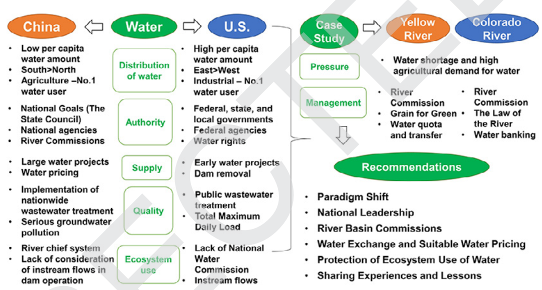
HIGHLIGHTS

- People-water harmony and water-saving society should become the new paradigms.
- Empowerment of river basin commissions with comprehensive authority.
- Expansion of water exchange through market and pricing mechanisms.
- Ecosystem service approach should be an integral part of water resources management.
- China and the U.S. can cooperate and assist other countries to achieve the UN sustainable development goals.

GRAPHICAL ABSTRACT



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ABSTRACT

As the world's top two economies, the United States (U.S.) and China face a number of similar water resource problems. Yet, few studies have been done to systematically compare policies and approaches on water resources management between China and the U.S. This study compares water resource policies of China and the U.S. in the areas of national authority, water supply, water quality, and ecosystem use of the water to draw lessons learned and shed light on water resources management in China, the U.S., and the rest of the world. The lessons learned from the comparison include six aspects. 1) New paradigms of people-water harmony and a water-saving society are urgently needed to address the pressing water crisis and achieve the United Nations Sustainable Development Goals (UN SDGs). 2) A comprehensive, consistent, forward-looking national policy is necessary to achieve sustainable use of water resources. 3) Empowerment of river basin commissions with comprehensive authority over the integrative management of air, land, water, and biological resources in the river basin could significantly enhance the benefits and effectiveness of economic development and environmental protection. 4) Expansion of water exchange through market mechanisms among water users promotes efficient and beneficial water uses. 5) Use of water for ecosystem services should be an integral part of water resources management. China has set up a national blueprint for achieving ecological civilization; maintaining appropriate amounts of flow in rivers and lakes for maintenance of wildlife and fisheries and ecosystems should be institutionalized as part of this national strategy as well. 6) By sharing their rich experiences and lessons in water resources management, economic development, and ecological protection with other countries, China and the U.S. can help the world to achieve global human-water harmony and the UN SDGs.

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1. Introduction

Water sustains life, economic prosperity, ecological security, and human civilization. However, rapid population growth, fast urbanization, increasing economic development, unprecedented technological innovations, drastic land-cover alterations, and climate change have led to a global water supply crisis (Johnson et al., 2001; The World Economic Forum, 2013). Worldwide, over two billion people have no access to safe drinking water and another over four billion lack access to safely managed sanitation services. Water-borne diseases lead to 250 million illnesses (Gleick, 2016; WWAP, 2019). More than 80% of industrial and municipal wastewater is discharged into rivers or oceans without any treatment, leading to 800,000 deaths in 2012 alone and negatively impacting fisheries, livelihoods, and food chains (WWAP, 2017). As a result, the World Economic Forum has declared the water supply crisis as one of the top five crises facing the globe over the next 10 years (The World Economic Forum, 2013). In the face of this crisis, water resource and its management play key roles in achieving the Sustainable Development Goals of the United Nations (UN, 2019).

As the world's top two economies, the United States (U.S.) and China also face a number of similar water resource management problems. For example, from 2012 to 2016, California encountered a record-breaking, five-year consecutive drought (Fahrenkamp-Uppenbrink, 2015; Udall and Overpeck, 2017). Over the past few years, high concentrations of contaminants, such as polychlorinated biphenyls (PCBs) and per- and polyfluoroalkyl substances (PFAS) from industrial manufacturers, have contaminated drinking water supplies and endangered thousands of human lives across the U.S. (Wigginton, 2016; Talpos, 2019). Upgrading deteriorating water infrastructure in the U.S. is estimated to cost over one trillion dollars over the next 25 years (American Water Works Association, 2012). In China, about 60% of the 669 largest cities are facing water shortages at a rate of about six billion m^3 per year, affecting over 40 million urban residents' daily lives. In the water-scarce North China Plain, the annual water deficit is up to 36 billion m^3, and may reach 56 billion m^3 by 2050 (He et al., 2005; 2010; Liu and Yang, 2012). In Beijing, even with the additional water transferred from the South-to-North Water Transfer Project (SNWTP), water availability per person still amounts to roughly 10% of the water requirement defined by the WHO for living a normal, healthy lifestyle. Despite its huge investment in pollution prevention and management, China still faces serious soil, water, and air pollution problems (Liu and Yang, 2012; Liu et al., 2013a, 2013b; Famiglietti, 2014; MEE, 2019).

To address the global water crisis, a number of water resource management approaches have been developed during the past decades, such as supply management, demand management, integrated water resources management (IWRM) (He et al., 2005; 2014). Traditionally, supply management has played a major role in meeting the increasing demands for water, through constructions of water works such as dams, reservoirs, and transfer projects to deliver water to multiple users in a region. Demand management emphasizes managing demands for water by institutional approaches and water saving technology, i.e. soft paths such as water pricing, water rights and markets, conservation, and efficiency improvement, etc. (Gleick, 2016). The IWRM, defined as systematic consideration of water supplies and water demands, natural and human systems, and upstream and downstream linkages in development and implementation of water resources policies and decisions, as well as stakeholder participation in water resource management processes, has been accepted globally (Home, 2004; He, 2012; Hering and Ingold, 2012). Since 1990s, IWRM framework has been implemented to address a range of water problems across the world, for example, degradation of ecosystems and water-related diseases and public health problems in sub-Saharan Africa, flood protection and pollution management in southern China, and protection of the nation's drinking water and wastewater infrastructure from terrorist attack in the U.S. (Bakker, 2012; He et al., 2014). Despite these programs, we are still facing multiple problems and challenges in achieving the United Nations Sustainable Development Goals (UN SDGs) (He et al., 2005; 2010; He, 2012; WWAP, 2019).

Water resources management aims to develop and implement policies, processes, technologies, leadership, and organizations for understanding, distributing, and improving the movement and characteristics of water resources to meet the multiple needs of human societies and ecosystems in a socially responsible, economically viable, and environmentally sustainable way (He et al., 2005). Globally, water supply, water quality, and approaches to water resource management are integral to successfully achieving all UN SDGs (UN, 2019). Two of the goals (goal #6: Clean water and sanitation and goal #14: Life below water) specifically target water resources. In addition, effective water resource management is essential for agriculture and a dependable food supply (goal #2: Zero hunger), affordable and clean energy (goal #7), and life on land (goal #15). The process of effective water resource management builds institutional relationships (goal #17: Partnerships for the goals) and supports efforts to achieve responsible consumption and production (goal #12) as well as peace, justice, and strong institutions (goal #16). Together, these efforts contribute to alleviating poverty (goal #1) and creating sustainable cities and communities (goal #11). All nations working toward these goals can benefit from knowing the experiences of others.

Studies have addressed water resource problems and made necessary recommendations in different parts of the world, such as China (Gleick, 2008; Liu et al., 2012; Xia, 2012, 2013a), the U.S. (Christian-Smith et al., 2012; Gleick, 2016; and CRS, 2019), and Europe (Hoornbeek, 2004; Pulido-Velazquez, 2017). Grafton et al. (2011) assessed the institutional foundations, economic efficiency, and environmental sustainability of water markets in Australia, the western United States, Chile, South Africa, and China. Yang et al. (2013) analyzed policies and their implementation on IWRM in France and China and reported that France's experience in the implementation of IWRM and the European Water Framework Directive can shed light on China's efforts to implement IWRM. Worster (2011) analyzed how China and the U.S. have employed different approaches to control water from a historical perspective. Both countries focused on using their rivers and waterways to power their economy, but at present China has the world's largest dam, while the U.S. has started to remove its dams (Worster, 2011). However, to the best of our knowledge, few studies have been done to systematically compare policies and approaches on water resources management between China and the U.S., the two largest economies in the world. Here, we contribute to the sharing of experience by comparing water resource management policies and approaches in the U.S. and China, presenting the cases of the Yellow River and Colorado River, and finally offering policy recommendations. It is hoped that these lessons will shed light on water resources management and help other countries achieve their UN SDGs.

2. Distribution of water resources in China and the U.S.

The total amount of renewable freshwater resources do not differ greatly between China (averaging 2700 km^3 /year; He et al., 2005) and the U.S. (averaging 2930 km^3 /year), but the amounts expressed on a per capita basis differ dramatically. China's per capita freshwater resource is only 2220 m^3, about one-fourth of the world average, whereas the U.S. has 11,500 m^3 per capita, five times China's per capita amount (Shiklomanov and Rodda, 2003; Brown et al., 2008). Thus, China is a water-scarce country and the U.S. a water-rich country in terms of per capita water resources. Despite the differences in climate, geography, and social economic systems between the two countries, China and the U.S. both face the problem of uneven distribution of water resources over time and space. As shown in Table 1, China's total withdrawal of freshwater in 2007 was greater than that of the U.S., with agriculture, the largest water user, accounting for 63% of the total freshwater use (Gleick et al., 2012). Although the U.S. withdraws less freshwater than China, U.S. per capita freshwater withdrawal tripled the Chinese per

Table 1
Freshwater withdrawal by sector in China and the United States.

Country	Total freshwater Withdrawal (10^9 m^3/yr)	Per Capita Withdrawal (m^3/person)	Domestic Use (%)	Industrial Use (%)	Agricultural Use (%)	2010 Population (10^6)
China (2007)	578.90	425	12	23	63	1361.76
U.S. (2005)	482.20	1518	13	46	41	317.64

Source: Gleick et al., 2012.

Table 2
Distribution of population and water resources in China and the United States.

Country	Region	Population (%)	Water Resource (%)	Water Resource (m^3/person)
China	North	46.4%	19.6	747
	South	53.6%	80.4	3481
	Nation-wide	100	100.0	2220
U.S.	East	64.2	69.2	6147
	West	35.8	30.8	5049
	Nation-wide	100.0	100.0	11,500

Sources: 1) Qian and Zhang, 2001; 2) Brown et al., 2008; 3) Shiklomanov and Rodda, 2003.
Notes: China's population and water resources were based on the 1997 statistics by Qian and Zhang, 2001; The U.S. population and water resources were based on the 1953–1994 information by Brown et al., 2008 and the per capita water resource computation only considered 48 contiguous states (excluded Alaska and Hawaii).

capita withdrawal, with the industrial sector, the largest water user, accounting for 46% of total water withdrawal. In the U.S., agriculture only used 41% of the total freshwater withdrawn in 2005.

Spatially, China can be divided into the north and south using the Qinling Mountain and the Huai River as the climate-geographical boundary (Table 2) (Qian and Zhang, 2001). The water-scarce north makes up 46.4% of the national population but only possesses about 20% of the nation's water resources, with a per capita water resource of 747 m^3. The water-rich south makes up 53.6% of the national population but possesses over 80% of the nation's water resources, with per capita water resource (3481 m^3) quadrupling the amount in the north.

Similarly, the 48 contiguous states in the U.S. can be divided into the east and the west along the Mississippi River. The water-rich east makes up over 64% of the population but possesses 69% of the nation's water resources (6147 m^3 per capita). Comparatively, the dry west supports 35.8% of the national population but possesses only 30.8% of the national water resources (5049 m^3 per capita, Table 2, Brown et al., 2008).

3. Water resources management in China

3.1. National authority

The central government of China regulates and manages water resources in China. Since the 1970s, a number of national regulations have been established to manage and protect China's water resources, including soil and water conservation, drinking water standards, agricultural irrigation, wastewater discharge, and environmental protection (He, 2012; MWR, 2017; MEE, 2019). In 2011, the State Council of China (the executive branch of the central government) set that the goals of China's water resources management are to develop a system that optimizes distribution and efficiency of nation's water resources, ensures the health of river and lakes, mitigates the impacts of floods, droughts, and other natural disasters, and values the advancement of water science and governance by prioritizing municipal water supply, implementing comprehensive water resources management, maintaining people-water harmony, ensuring governmental leadership, and promoting reforms and innovations (He 2012; MWR, 2017). Specifically, in 2011, the central government issued the Central Document No.1, "The Decision on Accelerating the Reform and Development of Water Conservancy," that sets Three Redlines: 1) the total annual water use Redline - the maximum amount of annual water use shall not exceed 700 billion m^3 by 2030; 2) the water use efficiency Redline - water use efficiency will approach to leading level globally, the amount of water used to generate additional 10,000 CNY industrial value will not exceed 40 m^3, and effective farmland irrigation efficiency will be greater than 60%; and 3) the total discharge Redline - total discharge of main pollutants to the nation's rivers and lakes shall be limited to the assimilation capacity of those waterbodies, meeting water quality standards 95% of the time by 2030 (Liu and Yang, 2012; Liu et al., 2013a; MWR, 2017).

In China, about 20 central governmental agencies are involved in managing the nation's water resources. The primary agencies include the Ministry of Water Resources (MWR), which oversees the construction and maintenance of major water works and allocation of water resources; the Ministry of Ecology and Environment (MEE), which is responsible for management and protection of the quality of the nation's ecosystems and water resources; and the Ministry of Agriculture and Rural Development (MARD), which administers agricultural irrigation and production and rural development (MWR, 2017). However, these agencies often have ambiguous, overlapping responsibilities and lack coordination, leading to increased transactions costs and delays in policy development and implementation (Liu and Yang, 2012; Lu et al., 2015).

Believing that a river is an integrated system of the mountain, river, forest, farmland and lake, China has a long history of taking watershed approach in managing rivers. There are seven major river and lake basin commissions, such as the Yellow River Conservancy Commission and the Yangtze River Water Resources Commission, to lead the water resources management of China's major river and lake basins (Qian and Zhang, 2001; He et al., 2010; He, 2012). Although they have played a significant role in watershed management, these commissions lack authority for resource allocation, pollution management, and enforcement of environmental regulations. Empowerment of these agencies with administrative authority over the integrative management of the air, land, water, and biological resources in the river basins would significantly enhance the benefits and effectiveness of both economic development and environmental protection. In addition, these watershed management approaches should also be extended to other river basins in the rest of the country to ensure the sustainability of China's watersheds across the country (He, 2012).

3.2. Water works and water supply

Historically, China relied on large water works and built some of the world's largest water projects to meet the increasing water demands. For example, between 456 BCE and 1239 CE, China constructed its well-known Grand Canal, a 1783-km canal linking Beijing and Hangzhou for transportation. Around 256 BCE, the State of Qin built the famous Dujiang Dam to divert water from the Mian River, a tributary of the Yangtze River to irrigate 0.2 million ha farmland in Sichuan, and after over 2200 years, the dam is still functioning well today (Shi, 1996; He et al., 2010). The Three Gorges Dam, the world's highest dam, was completed in 2006 after 12 years of construction, despite persistent socioeconomic, environmental, and ecological challenges and controversies. With even greater magnitude than the Three Gorges Dam Project, the ongoing South-to-North Water Transfer Project (SNWTP) is designed to transfer about 45 billion m^3 of water annually from the Yangtze River to the North China Plain and the Yellow River via three routes: East, Central, and West Routes. Since 2014, SNWTP has already started to deliver water to Tianjin and Beijing via the East and Central Routes (He et al., 2010; MWR, 2017). China has built over 97,988 reservoirs, with a combined storage capacity of over 858 billion m^3, accounting for 32% of China's surface water resources (Qian and Zhang, 2001; He et al., 2010; MWR, 2017).

Small-scale water projects that take local climate, geography, culture and economy into account are also widely constructed to provide water for drinking and agricultural irrigation. In the arid Turpan Basin in Northwest China, for example, over 2000 years ago, the Uyghurs started to construct kaner wells to deliver snow and glacial melt through underground tunnels to irrigate cash and cereal crops and support municipal water supply in the desert region (Wittwer et al., 1987; Shi, 1996). The kaner well system consists of vertical wells (allowing people to pull up water in buckets or to go down into the underground tunnel for repairs), underground tunnels (transferring groundwater from the Tian Mountain ranges to the low elevation farmland by gravity to eliminate evaporation), ground canal (a small canal on the ground surface for people to use the water), and a dam (a small reservoir for farmland irrigation). In the 1960s, there were more than 1000 kaner wells, with a combined total tunnel length of over 5000 km, irrigating over 30,000 ha of farmland. Unfortunately, large-scale irrigation over the past few decades has reduced the number of kaner wells to a few hundred (Wittwer et al., 1987; Shi, 1996).

Due to multiple environmental and social economic problems related to large water works (He et al., 2005, 2010; Liu and Yang, 2012; Liu et al., 2013a), since 1990, China has started to shift its paradigm to maintaining people-water harmony and promoting nationwide water saving behavior to support sustainable socio-economic development. China has developed some institutional initiatives (i.e., soft-path approach) such as water pricing, water rights, and transfers to manage the increasing water demand (He et al., 2010; He, 2012; Liu et al., 2013a). For example, water prices for both industrial and agricultural uses have increased more than five-fold. In Beijing municipal water prices increased from 1.6 CNY (roughly \$0.23) /m^3 of water in 2000 to 4.6 CNY (roughly \$0.65) /m^3 in 2010 (He et al., 2010). Urban residents pay an additional cost of 50 ~ 100% for the amount of water use exceeding their monthly quota (He et al., 2010). In 2016, China established its National Water Rights Exchange platform to facilitate water exchange through a market mechanism and promote water saving behavior in the nation (MWR, 2017). Each water user is allocated a water quota each month, users can sell the amount of the saved water to other users, and users who need more water beyond their quota must purchase additional water from other users in the same watershed (MWR, 2017). In addition, China has also launched: 1) a water resource tax experiment to manage increasing water demand; and 2) incentivize water saving practices. Varying taxes are imposed upon water users based on their designated uses, consumption amount, source of water supply (surface or groundwater), and locations. Golf courses, for example, pay a much higher amount of water resource tax as they consume a large amount of groundwater (MWR, 2017).

3.3. Water quality

China's water quality programs are governed primarily by: 1) The Ministry of Ecology and Environment (MEE), which oversees surface and groundwater monitoring and quality management and the municipal wastewater treatment and discharges; and 2) The Ministry of Agriculture and Urban-Rural Development (MAURD), which administers agricultural nonpoint source management (management of pollutants originated from a diverse area rather than from specific locations and boundaries) (MEE, 2019). In 2018, the previous National Environmental Protection Administration was replaced by the new Ministry of Ecology and Environment, showing the importance of ecological civilization in China's developmental agenda (MEE, 2019). Ecological civilization is a governmental framework that sets the maintenance of human-nature harmony, implementation of a circular economy, and comprehensive societal development. It serves as the overarching principle in the social-economic development process to achieve sustainable and beautiful China through law enforcement (e.g., Water Pollution Prevention Act of 2008) and policies, promotion of technological innovations, and practice of environmental stewardship (MWR, 2017; MEE, 2018; Hansen et al., 2018).

In 1997, 45 billion m^3 of wastes were discharged to the rivers, lakes, and coastal waters. Only 13% of them received some types of treatment (Qian and Zhang, 2001). By the end of 2018, the national urban wastewater treatment capacity reached 167 million m^3/day, treating 51.9 billion m^3 annually (MEE, 2019). While the industrial and municipal wastewater discharge treatment rate has increased significantly since 1997, not all wastewater treatment facilities operate all the time, thus affecting the effectiveness of wastewater treatment (Qian and Zhang, 2001; Lu et al., 2015; MEE, 2019). According to the China Ecology and Environment Bulletin 2018, out of the 1935 surface water monitoring stations throughout the country, 71% achieved national water quality standard levels I-III (suitable for drinking water and body contact recreation), levels IV and V making up the remaining 29% (suitable for non-body contact recreational and agricultural uses) (MEE, 2019).

China has also started nationwide agricultural nonpoint-source (NPS) pollution management programs, such as soil and water conservation, and nutrient management (application of fertilizer and manure based on soil survey and crop needs) programs. But such programs are not mandatory for all impaired rivers. Since China applies a much higher fertilizer and pesticide than the world's average, the outcome is dire to the aquatic environment (Liu and Yang, 2012; Lu et al., 2015). Out of the 10,168 national groundwater monitoring wells, only 13.8%, 70.7%, and 15.5% achieved water quality standards I-III, IV, and V, respectively, in 2018 (MEE, 2019). Approximately 8.3% of the country's 120 million hectares of arable land are contaminated by pesticides and heavy metals such as cadmium and lead (Liu et al., 2013b).

3.4. Ecosystem use of water

Since 1980s, China has established a number of environmental regulations such as The Forest Protection Act of 1984, The Soil and Water Conservation Act of 1991, and The Environmental Protection Act of 2015, and started a number of ecological restoration and protection programs to protect and rehabilitate the nation's water resources and ecosystems (MEE, 2019). In 2018, achievement of "ecological civilization" and "construction of beautiful China" were amended to China's constitution at the 13th Plenum of The People's Congress of China. The Ministry of Ecology and Environment was created to administer and enforce the nation's environmental regulations (MEE, 2019). To implement the national water resource and environmental regulations, a river chief system was established in 2016 to oversee the nation's rivers and lakes. The system consists of provincial governors, city mayors, county commissioners, and township supervisors that are responsible for managing water resources at the province, region, watershed, and tributary levels, respectively (MWR, 2017; MEE, 2019). To date there are over 300,000 river chiefs overseeing the nation's rivers and lakes (MWR, 2017). Assessment of the river chief's performance in water resources management becomes part of the evaluation for promotion in a river chief's political and administrative career (MEE, 2019).

Despite the numerous policies, maintaining appropriate amounts of water in lakes and flow in rivers for the health of wildlife and fisheries and ecosystems has yet to be institutionalized and enforced in China. As a result, nearly all of China's rivers are regulated for water supply and hydropower generation, uses that can negatively affect downstream habitat and ecosystem diversity (Liu et al., 2013a; Lu et al., 2015). River flow regimes affect the composition, structure, and dynamics of ecosystems at local to regional scales (Palmer and Ruhi, 2019). Thus, operation of dams must maintain the proper river flows to meet both human consumptions and ecosystem function preservation (Poff and Olden, 2017).

4. Water resources management in the United States

4.1. Federal and state authority

In the U.S., management of water resources is shared by the federal, state, and local governments. The federal government governs the nation's freshwater through laws and regulations. The state and local governments regulate allocation of water (Christian-Smith and Gleick,2012). Some of the primary federal laws include: 1) the Water Resources Development Act of 1965, which governs civil works activities of the U.S. Army Corps of Engineers (USACE), including navigation, flood protection, and aquatic ecosystems protection and restoration; 2) the Federal Water Pollution Control Act of 1948 (later it was amended and renamed the "Clean Water Act" in 1972), which oversees water pollution; 3) the Safe Drinking Water Act of 1974, which protects the quality of drinking water in the U.S.; and 4) the Endangered Species Act of 1973, which protects and recovers imperiled terrestrial and aquatic species and the ecosystems (Christian-Smith et al., 2012; USACE, 2012).

More than 40 federal agencies are involved in managing the U.S. water resources. Of these, the USACE is responsible for building, operating, and maintaining dams and distribution infrastructure over the navigable waters, the U.S. Environmental Protection Agency (USEPA) administers surface water quality and environmental protection regulations, the U.S. Fish and Wildlife Service enforces preservation and restoration of aquatic ecosystems, while the U.S. Geological Survey (USGS) oversees collection and sharing of water resources data (Christian-Smith et al., 2012; Gleick, 2016).

Besides the federal regulations that apply to all states, state-based water rights also govern the use of water resources. Two main types of water rights (doctrines), the riparian rights and the prior appropriation doctrine, govern the use of surface waters in the United States. Riparian rights, which entitle owners of property adjacent to a water body access to use the water without harming downstream users, are widely implemented in the eastern U.S. (Christian-Smith et al., 2012). In most western states, the prior appropriation doctrine ("first in time and first in service") enables the senior water users (those who arrived in the western United States first and had priority over the latecomers) to divert and use water for mining, agriculture, and industry regardless of their land ownership (Christian-Smith et al., 2012; USACE, 2012). In addition, some states now have implemented permit systems and allowed some forms of water marketing, especially the water-scarce states that need to manage their groundwater use to meet the changing water demands of growing urban population.

4.2. Water works and water supply

Water works, including water transfer schemes have been an essential component of supply management for hundreds of years to meet the needs of water scarce regions. Prior to the 1970s, the U.S. primarily relied on large water works to support flood control, water supply, urbanization, economic prosperity, regional development and national security (He and Fu, 1998; Kline, 2011). For example, the Reclamation Act of 1902 authorized the establishment of the Bureau of Reclamation and the construction and maintenance of large dams and irrigation works for the reclamation of arid and semiarid lands (Christian-Smith et al., 2012; Ho et al., 2017). The famous Hoover Dam on the Colorado River was authorized by the U.S. Congress in 1928 for flood control, irrigation water supply and hydropower generation for the western states. The construction began in 1931 and was completed in 1936. It was the largest concrete structure in the world at that time (He and Fu, 1998; Kline, 2011). The California State Water Project, completed in 1973, transfers 400 million m^3 of water from the northern to the southern part of the State each year (He et al., 2005). There are approximately 85,000 dams in the U.S., with a combined storage capacity of almost one year's mean natural runoff, equivalent of about 5000 m^3 per person in the U.S. (Ho et al., 2017).

4.3. Water quality

In the U.S., worsening pollution of the nation's water, soil, air, and ecosystem, and increasing public environmental awareness and movement led to the passage of the Clean Water Act (CWA) of 1972 and the establishment of the U.S. Environmental Protection Agency (USEPA). The objective of the CWA is "to restore and maintain the chemical, physical, and biological integrity of the nation's waters" (USEPA, 1999). Under the CWA, point sources that discharge pollutants to waters of the United States must apply for the National Pollutant Discharge Elimination System (NPDES) permits. Such sources include manufacturing facilities, wastewater treatment plants, and concentrated animal feeding operations where animals are confined and fed. Other agricultural stormwater discharges and return flows from irrigated farmland, however, are not considered point sources (USEPA, 1999).

Since the passage of the CWA in 1972, over $650 billion of federal grants have been provided to local governments to construct additional wastewater treatment plants, which contributed to the 12% increase in safe waters for fishing between 1972 and 2001 (Keiser and Shapiro, 2019). Today over 75% of the nation's population is served by public wastewater collection and treatment systems and the remaining population uses septic systems for wastewater treatment. However, much of the water infrastructure in the U.S. has deteriorated and is rated a grade D by the American Society of Civil Engineers (Ho et al., 2017). Despite a total investment of over $1 trillion by government and industry in water pollution control, or $100 per person/year, over half of the U.S. streams and rivers still violate water quality standards (Keiser and Shapiro, 2019).

Managing NPS pollution is more challenging and expensive than managing point source pollution due to its magnitude and complexity (He et al., 1998). The CWA establishes a Total Maximum Daily Load (TMDL) to restore water quality and meet water quality standards (USEPA, 1999). A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. It also provides an allocation of that amount to the pollutant's sources. TMDL programs must be developed between the relevant state and local governments and approved by the USEPA, with funding for prioritized impaired rivers. Implementation of the TMDL is to be carried out within 10 years to reduce pollutant loadings to achieve water quality standards in the impaired river. Since 1977, TMDLs have been implemented to rehabilitate the impaired rivers throughout the country; however, NPS pollution is still a serious challenge. Outbreaks of harmful algae blooms in the Lake Erie Basin and the Gulf of Mexico remain a persistent problem (He et al., 1998; USEPA, 1999).

4.4. Ecosystem use of water

The watershed (land draining into a stream or lake at a given location) has been widely recognized as a basic unit for hydrologic research and water resources management among researchers, resource managers and decision/policy makers (NRC, 1999; He and Croly, 2010; Pulido-Velazquez and Ward, 2017). Freshwater ecosystems include floodplains, wetlands, rivers and estuaries as well as the flora and fauna (He et al., 2000; Christian-Smith et al., 2012; Gleick, 2016; Poff and Olden, 2017). In the U.S., recognition of the use of water for ecosystem protection and maintenance led to the passage of The Wild and Scenic

River Act of 1968 and the Endangered Species Act of 1973. The former Act now designates more than 200 rivers for greater protection of instream flows. The Endangered Species Act is the primary legal instrument used to protect instream flows for ecological benefits (Christian-Smith et al., 2012). In 2001, the use of water for irrigation from the Klamath Riverin California was restricted to protect threatened fish species in the river (Christian-Smith et al., 2012). An instream flow program has also been established to maintain a minimum amount of flow in the river to meet the multiple demands for water quality management and protection of aquatic ecosystems (NRC, 2005).

Concerns about ecological consequences have changed people's attitudes about hydrological modification in the U.S. (Graf, 2003). More than 1300 dams have been removed (Duda et al., 2016; Foley et al., 2017). For example, the Elwha Dam in the State of Washington was removed in 2014 to restore the altered ecosystem and protect the habitat of the native salmon and trout species in the river (O'Connor et al., 2015). Many dam removals have not only improved aquatic ecosystem functions but also avoided catastrophic consequences to either ecosystems or human uses (O'Connor et al., 2015). Wetlands, once considered to be wastelands and drained under The 1849 Swamp Land Act, are now highly valued for their ecosystem services (e.g., flood protection, water quality management, research, education, and recreation) (Kline, 2011).

Watershed-based water resource management programs have been implemented in the U.S. since the early 20th century (NRC, 1999). Several active river basin commissions were established in 1939, and the National Water Commission (NWA) was created in 1968 to coordinate and lead the nation's water resources programs and report to the president. Unfortunately, NWA, along with a number of the river basin commissions were abolished in 1981 (Christian-Smith et al., 2012; Gleick, 2016; Pulido-Velazquez and Ward, 2017). Today's river basin governance for major U.S. rivers varies in structure and authority. They range from regional (e.g., TVA) to multi-state watershed councils (e.g., Chesapeake Bay Partnership), and from interstate basin commissions (e.g., the Council of Great Lakes Governors) to federal-state basin compact commissions (e.g., Delaware River Basin Commission) (Kauffman, 2015).

In summary, both China and the U.S. take different approaches to address similar water resources problems. Their differences are briefly discussed below:

Q4

4.4.1. Authority

The central government of China regulates and manages water resources in China. This top-down approach is consistent and more efficient but often lacks the participation of stakeholders at the local levels. In the U.S., however, management of water resources is shared by the federal, state, and local governments. The federal government governs the nation's freshwater through laws and regulations. The states and local governments regulate allocation of water. This shared approach embeds much authority in the state and local governments but leads to an inconsistent, diverse, and uncoordinated federal water responsibilities and laws (Gleick, 2016).

4.4.2. Water supply

Large water works were the main approach to provide an adequate amount of water to meet the increasing multiple demands for water in both China and the U.S. China still firmly relies on the development of large water works for regional development, flood protection, irrigation expansion, hydropower generation, and ecosystem services, although it has started to shift its water resources management paradigm to maintaining people-water harmony and promoting nationwide water saving behavior. United States, on the other hand, has entered a dam removal era since 1990s to minimize the negative ecological consequences. China can learn from the U.S. to gradually lessen its dependence on large water works, and instead, focus on demand management approaches to meeting its increasing demands for water for multiple services.

4.4.3. Water quality

Water pollution management has progressed in both China and the U.S. over the past 50 years. Point source pollution such as wastewater treatment is well-under control in the U.S.. China's urban wastewater treatment capacity has reached nearly 95% since the 1990s but not all of its wastewater treatment facilities are operating at full capacity all the time. Nonpoint source pollution, particularly from agricultural sources remain challenging for both U.S. and China.

4.4.4. Ecosystem use of water

China's water resources management policies call for optimal distribution and efficiency of the nation's water resources, maintenance of the health of river and lakes, and mitigation of the impacts of floods, droughts, and other natural disasters. But it overlooks the maintenance of flows in rivers and lakes for the health of aquatic ecosystems and services. In the U.S., the Endangered Species Act is the primary legal instrument used to protect instream flows for ecological benefits. China needs to incorporate instream flow in its water resources policies for management and protection of aquatic ecosystems.

5. Comparison of the yellow river and the Colorado river

China's Yellow River and the Colorado River in the U.S. are both located in semi-arid and arid areas and face similar water shortage problems. This section reviews these problems and compares the policies, programs, and approaches used to tackle the problems and to provide insights and lessons for managing such large rivers.

5.1. The yellow river

The Yellow River, the cradle of the Chinese civilization, originates in the Tibetan Plateau and flows about 5500 km through Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong Provinces to the sea. It has a drainage basin of 795,000 km^2 (He et al., 2005) (Fig. 1). As the second longest river in China, the Yellow River Basin is important for agricultural and industrial production, supporting over 101 million people, and supplying oil, natural gas, coal, hydroelectricity, and other mineral resources to the country (He et al., 2005; 2010).

There are more than 3382 reservoirs in the Yellow River Basin, with a total storage capacity of more than 53 billion m^3, accounting for 91% of the mean annual discharge of the river (He et al., 2005). Despite these large reservoirs, water shortages led to frequent desiccations of the Yellow River between 1972 and 1999. The longest of these (226 days) occurred in 1997, in the 700 km lower reaches of the Yellow River, creating serious economic and environmental problems, including water rationing, reduced grain production, decreased industrial output, increased sediment deposition, and worsening water pollution in the Yellow River (He et al., 2005; 2010).

5.1.1. Authority

In the Yellow River Basin, the Yellow River Conservation Commission (YRCC), an agency in the Ministry of the Water Resources, is responsible for management of water resources of the Yellow River (Table 3). Since 2016, river chiefs have the authority to manage water resources at the province, region, watershed, and tributary levels, respectively in the Yellow River Basin.

5.1.2. Water supply

Allocation of the Yellow River is governed by the Yellow River Water Allocation Plan of 1987 issued by the State Council. It allocates certain amount of water among the nine provinces and autonomous regions in the basin, and the YRCC is in charge of monitoring and enforcement of such allocations. Water shortage has been a chronic problem in the Yellow River Basin. The annual water deficit in the Yellow River Basin is anticipated to range from 11 to 19 billion m^3 between now and 2050

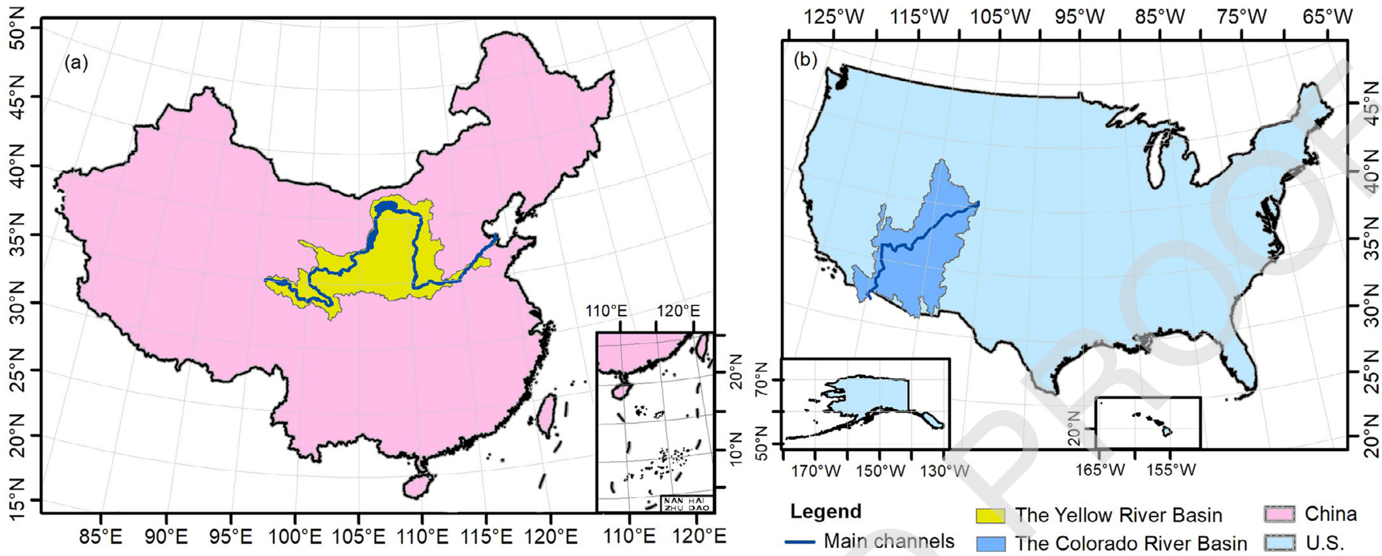

Fig.1. Boundary of the Yellow River in China and the Colorado River in the United States.

Table 3
Comparison of the Yellow River in China and the Colorado River in the United States.

	The Yellow River	The Colorado River
Drainage area (km^2)	795,000	647,000
Population in the basin (million)	101	40
Management authority	The Ministry of Water Resources The Yellow River Conservation Commission River Chief System	Federal, state and local governments
Water supply	The Yellow River Water Allocation Plan	The Law of the River
Water quality	The Water Pollution Prevention Act	The Clean Water Act
Ecosystem use of water	The Environmental Protection Act of 2015; The Soil and Water Conservation Act of 1991.	The Wild and Scenic River Act of 1968; The Endangered Species Act of 1973.
River flow to the sea	Yes, since 2000	Rarely

(Qian and Zhang, 2001; He et al., 2005). Fully realizing the critical nature of the water shortage problem, the YRCC has initiated a number of institutional programs to holistically manage the water resources in the basin in order to achieve the goal of maintaining the Yellow River as a "healthy living river" (Ding, 2004). Such programs include monitoring and enforcement of the Yellow River Water Allocation Plan of 1987 among the nine provinces and autonomous regions in the basin, establishment of water rights and market transfer mechanisms, setting appropriate water prices, and adoption of water saving technology (He et al., 2005; MWR, 2017). For example, water prices have increased more than fivefold for industrial withdrawals and agricultural irrigation since the 1990s. For municipal supply, a water use quota is allocated to each enterprise. Water use exceeding the quota amount is charged a higher price. In a water-right experimental city of Zhangye, Gansu Province, Northwest China, users are allocated a water quota each month and pay an additional 50% charge for exceeding their quota by 30%, a 100% charge for use of extra 31–50% of water, and a 200% charge for extra water use of 51% or more (Ding, 2004). In Zhangye, each county within the Heihe River Watershed is given a water allotment. Surplus water can be transferred among counties at mutually agreed prices (He et al., 2005; MWR 2017). At the same time, China is increasing investment to improve irrigation efficiency, and programs are also underway to develop water rights and water market systems throughout the country.

5.1.3. Water quality

Water shortages in the 1990s led to reduced river flow and concentrated effluent discharge, causing frequent violations of drinking water quality in municipal water supply systems such as Xinxiang and Zhengzhou Cities of Henan Province, and destruction aquatic ecosystems in several main tributaries like the Wei, Fen, and Huangshui Rivers. The increased groundwater pumping and the reduced groundwater recharge also induced sea water intrusion, expanding salinization, and alkalinization of cropland (He et al., 2005). Since 2000, with the increased waste-water treatment capacity and well-coordinated operations of reservoirs throughout the Yellow River Basin, the YRCC successfully achieved its goal of "no water pollution event". According to the China Ecology and Environment Bulletin 2018, 66.4% of the 137 surface water monitory stations on the Yellow River achieved national water quality standard levels I-III (suitable for drinking water and body contact recreation) (MEE, 2019). The report shows that the main pollutants are ammonium nitrogen and chemical oxygen demand (COD), indicating that NPS pollution remains a challenge.

5.1.4. Ecosystem use of water

Construction of field-scale engineering projects such as terracing and check dams (dams consist of an embankment and a spillway, widely used for soil conservation in erodible areas) has been practiced over a hundred years to conserve soil and support food production in the middle reach Loess Plateau of the Yellow River Basin (Fu et al., 2011; Xu et al., 2013). More recently, since 1999, large-scale ecological restoration programs such as "Grain for Green" and "Northern China's Vegetation Belt" have been widely implemented in the Yellow River Basin to comply with the Water Pollution Prevention Act (2008) and to rehabilitate ecosystem services (Table 3). These programs, together with the engineering measures, have dramatically reduced the sediment load from ~1.6 billion tons/year in the 1970s to ~0.3 billion tons/year at present (81% reduction) (Fu et al., 2011; Wang et al., 2012; He, 2016). Q5 Although the programs have led to decreasing water yields in both the lower reach and the delta of the Yellow River particularly during dry years, they have increased soil carbon storage and net primary productivity (Fu et al., 2011; Wang et al., 2012; He, 2016). Overall, the Yellow River has largely maintained a healthy ecosystem, as indicated by the absence of riverbank break, desiccation, water pollution event and elevated riverbed (Ding, 2004).

5.2. The Colorado river

The Colorado River, covering portions of seven U.S. states: Wyoming, Utah, Colorado, Nevada, New Mexico, California, and Arizona, part of Mexico, and 34 Indian reservations, has a drainage area of about 647,000 km^2 and serves over 40 million people distributed across major southwestern cities such as Los Angeles, San Diego, Las Vegas, Phoenix, and Denver (Fig. 1. Table 3). It flows 2300 km to the Gulf of California, dropping more than 3000 m in elevation along the way (Weatherford and Brown 1986; USACE, 2012; Udall and Overpeck, 2017). There are 12 major dams built along the river for flood control, water supply, and hydropower generation, with a total storage capacity of about 76 billion m^3, more than four times the average annual flow in recent decades (Weatherford and Brown 1986; Udall and Overpeck, 2017).

Agriculture is the largest water user in the Colorado River basin. About 80% of the river's supply is used for irrigating ~1.2 million ha of farmland at a heavily subsidized rate, about 1/20 of the costs the neighboring communities pay. The largest agricultural user, the Imperial Irrigation District with an area of 243,000 ha in arid southern California, uses nearly 20% of the river's average annual flow (Pontius, 1997; USACE, 2012; Maggioni, 2015).

5.2.1. Authority

The Law of the River (LOR) is a set of statures and court decisions that governs the management of the Colorado River and defines the states' and individual entitlement holders' rights and obligations (Pontius, 1997; Congressional Research Service, 2019). It includes the federal government's 1922 Colorado River Compact, which divides the river between the Upper and Lower basins; the U.S.-Mexican Water Treaty of 1944, which guarantees delivery of 1.85 billion m^3 of Colorado River water to Mexico annually under normal conditions, and numerous other statutes and legal precedents (Weatherford and Brown, 1986; NAS, 2007) (Table 3).

But unlike the Yellow River, no basin-wide institution is established to coordinate a comprehensive management of the water resources with environmental and economic programs. This lack of coordination creates competition and wasteful use of limited water resources in the basin. Development of a cooperative management structure involving the basin states and Secretary of the Interior would address and resolve major water management issues in the basin (Pontius, 1997; USACE, 2012; Grafton et al., 2013; Maggioni, 2015; Gleick, 2016).

5.2.2. Water supply

The 1922 Colorado River Compact allocates 9.25 billion m^3 of water each to the Upper Basin (Colorado, Utah, Wyoming, and New Mexico) and Lower Basin (Arizona, California and Nevada) every year, with an additional 1.23 billion m^3 allocated to the Lower Basin. However, the Lower Basin, particularly California, the largest user of Colorado River water, has exceeded its annual apportionment for many years while the Upper Basin is using about 60% of its entitlement (Pontius, 1997; Maggioni, 2015). Moreover, precipitation and runoff in the basin have become more variable in recent decades, and climate projections indicate a continuing warming trend, which will, in turn, decrease runoff (NAS, 2007; USACE, 2012; Udall and Overpeck, 2017; Milly and Dunne, 2020). The multiple, competing water uses, large storage capacities of the dams and reservoirs, and diversions in the Lower Basin stop the river from flowing to the Gulf of California in most years (Pontius, 1997; Grafton et al., 2013). A zero discharge negatively affects the bilateral relationships between the U.S. and Mexico, as well as environmental conditions of the delta region and the Sea of Cortez.

Of all states in the Lower Basin of Colorado River, only the State of California has the voluntary, mandatory, and market-based conservation strategies for effective water resource management (Fahrenkamp-Uppenbrink, 2015). The establishment of Emergency Drought Water Banks in 1990s facilitated the purchase, sale, and transfer of water (Pulido-Velazquez and Ward, 2017). With such strategies, California coped with the worst five-year drought on record during the period of 2012–2016 (Maggioni, 2015; Tarhule, 2017). Establishment of other interstate water exchange market, with appropriate pricing for storing and marketing water, could stimulate major transfers of water rights from agricultural to municipal or industrial users and promote water-saving technologies and behaviors in the Lower Basin (Weatherford and Brown, 1986; Grafton et al., 2013; Maggioni, 2015; Gleick, 2016; Tarhule, 2017).

5.2.3. Water quality

Irrigation runoff from agricultural fields carries a large amount of nutrients, pesticides and heavy metals to surface waters, worsened stream conditions, and leached chemicals into groundwater supplies (Pontius, 1997; USACE, 2012). High salinity level in the irrigation return flow is another major problem and causes about $295 million damages per year (USBR, 2013). Salinity control programs currently prevent ~1.3 million tons of salt from entering the Colorado River, but an additional 555,000 tons of salts need to be removed in order to meet the goal set by the Colorado River Basin Salinity Control Act (USBR, 2013). In recent years, water levels in the Colorado River's biggest water reservoirs – Lake Powell and Lake Mead – declined by ~50% from 1999 to 2004. During the worst 15-year drought on record (2000–2014), the average annual Colorado River flow was 19% below the 1906–1999 average, leading to increased water conflicts, deteriorated water quality and aquatic habitat, particularly during summer months (USACE, 2012; USBR, 2013; Linard and Schaffrath, 2014). These problems are likely to intensify with projected climate change and more frequent droughts (Overpeck and Udall, 2010; Grafton et al., 2013; Udall and Overpeck, 2017; Milly and Dunne, 2020).

5.2.4. Ecosystem use of water

Traditionally, water is valued for food production, municipal supply, and industrial development. Since the passing of the Endangered Species Act in 1973, maintaining flows in streams and lakes is increasingly valued for protection of aquatic ecosystems and recreational opportunities in the Colorado River Basin. Federal agencies, including the Bureau of Reclamation and the U.S. Army Corps of Engineers, Indian tribes, state and local governments, and nongovernmental organizations (NGOs) work together to pursue river ecosystem restoration. Such programs include the Upper Basin Recovery Implementation Program, the San Juan River Recovery Implementation Program, the Lower Colorado River Multi-Species Conservation Program, and the Colorado River Delta and Upper Gulf Ecosystem to rehabilitate endangered fish habitat by altering the timing and volume of flow from the reservoirs (Pontius, 1997; USACE, 2012). With their coordinated efforts, the Colorado River reached the delta for an 8-week period of time in 2014 to rehabilitate deserted riverbank vegetation and wetlands for wildlife habitat (Stokstad, 2014).

In summary, both the Yellow River and the Colorado River face chronic water shortage problems but management approaches differ between the two Rivers.

5.2.5. Authority

In the Yellow River, the Yellow River Conservancy Commission (YRCC) is responsible for the management of water resources of the Yellow River. In the Colorado River, the Law of the River (LOR) governs the management of the Colorado River, involving multiple federal, state, and local governments. However, no basin-wide institution is established to coordinate a comprehensive management of the water resources, environmental, and economic programs in the Colorado River Basin.

5.2.6. Water supply

The Yellow River Water Allocation Plan of 1987 governs the allocation of water resources of the Yellow River. Under the leadership of the YRCC, a number of soft-path approaches have been established to manage the increasing water demand, including water rights and market transfer mechanisms and adoption of water saving technology in the basin. In the Colorado River, the 1922 Colorado River Compact regulates water allocation among the water users in the Basin. Adoption of water saving technology has significantly improved the efficiency of water use. However, no basin-wide, voluntary and mandatory water saving and exchange mechanisms exist outside California in the Lower Basin of the Colorado River. Establishment of a basin-wide river commission and implementation of similar soft-path programs are urgently needed to make the Colorado River a healthy living river (Tarhule, 2017; Udall and Overpeck, 2017).

5.2.7. Water quality

Agricultural NPS control remains challenging in both rivers.

5.2.8. Ecosystem use of water

In the Yellow River, the YRCC focuses the benefits of ecosystem services, such as no riverbank break, no desiccation occurrence, no water pollution event, and no elevating riverbed by implementing both large ecological restoration programs and construction of field-scale engineering projects. But it ignores the value of maintaining flows in the streams for the protection of aquatic systems. In the Colorado River, multiple federal, tribal, state, and local governments work together to pursue river ecosystem restoration to comply with the Endangered Species Act. Maintaining instream flows should become a priority at the YRCC's agenda to protect the aquatic ecosystems and services.

6. Summary and recommendations

This study compares water resource policies of China and the U.S. in the areas of national authority, water supply, water quality, and ecosystem use of the water, with cases of the Yellow River and the Colorado River. To help other countries benefit from these lessons learned from the comparisons, specific Sustainable Development Goals are referenced for each.

6.1. Paradigm shifts

Freshwater is a scarce resource. No amount of freshwater supply is large enough to meet the rapidly increasing multiple demands for water. New paradigms of people-water harmony and water-saving society are urgently needed to address the pressing water crisis to achieve the UN SDGs. China has set the achievement of ecological civilization and construction of beautiful China as its development goals. Although having changed its paradigm on hydrologic modification, the U.S. can do better to revise its water rights and river basin management to better align with changing realities of water availability, ecosystem health, and human well-being (SDGs 1, 2, 6, 7, 9, 15, 16: Poverty, Food, Water, Energy, Infrastructure, Terrestrial ecosystem, and Safe society).

6.2. National leadership

Numerous national government agencies oversee the management of water resources in both China and the U.S., with short-term, compartmentalized regulations and overlapping, even conflicting, responsibilities leading to increased transaction costs and decreased efficiency, which, in turn, impede the effectiveness of water resource management. A more comprehensive, consistent, forward-looking central policy is necessary to achieve the sustainable use of water resources in both China and the U.S. (SDGs 1, 2, 6, and 9: Poverty, Food, Water, and Infrastructure).

6.3. Empowerment of river basin commissions

Watersheds are the most useful and logical geographic units for water resources management. China has a long history of taking a watershed approach in managing her rivers. While having played a significant role in watershed management, Chinese river and lake basin commissions lack authority for resource allocation, pollution management, and enforcement of environmental regulations. The U.S. has experimented with a variety of different forms of interstate river basin governance. Empowerment of river basin commissions with administrative authority for the integrative management of the air, land, water, biological, economic, and recreational resources in the basin could significantly improve economic, environmental, and human health (SDGs 9 and 13: Infrastructure and Climate)

6.4. Promotion of water exchange and suitable water pricing

Water exchange through market mechanisms among water users promotes efficient and beneficial water uses. It provides income and flexibility in meeting future water needs to both the sellers and buyers. Water should be appropriately priced such that the cost of supplying and distributing water and the cost of integrated watershed management are included in the price of water. Development of a water resources tax (now being experimented in China) should be based on careful experimentation and assessment before being expanded gradually to stimulate water saving and innovation in water-scarce regions. At the same time, any effort to price water or tax water use must address the needs of all members of society, following the United Nation's resolution recognizing access to safe and clean drinking water and sanitation as a human right (United Nations, 2010) (SDGs 2, 6, 7 and 12: Food, Water, Energy and Consumption and Production Patterns).

6.5. Protection of ecosystem use of the water

Use of water for ecosystem services is an integral part of water resources management. China has set up a national blueprint for achieving ecological civilization, but maintaining an appropriate amount of flow in rivers and lakes to support wildlife, fisheries, and ecosystem services should also be institutionalized as part of this strategy. The U.S. has taken some actions to promote ecosystem use of surface waters (e.g., dam removal, TMDL process), but must continue to seek new strategies for addressing the competing water needs of in-stream and off-stream water uses (SDG 15: Terrestrial Ecosystem).

6.6. Sharing china's experiences and lessons with the world

Over the last four decades, China has become the second largest economy in the world and successfully supported nearly 20% of the global population with 9% of the world's arable land and 6% of the world's total freshwater resources. By sharing its rich experiences and lessons in water resources management, economic development, and ecological protection with the U.S. and the rest of the world, it can help to achieve human-water harmony and the UN SDGs globally (SDG 17: Global Partnership).

6.7. Sharing experiences and lessons from the U.S

Like China, the U.S. has a diverse climate, water resources, water demands, and challenges to water resource management, including changes in precipitation regimes and water use priorities. The evolution of water resource management in the U.S. has demonstrated a possible co-existence between different water rights and the importance of convening stakeholders to better understand the implications of water management decisions. The variety of basin-specific organizational frameworks for water management implemented in the U.S. provides a range of examples and lessons likely to be instructive to water resources managers across the globe (SDG 17: Global Partnership).

While water resource management involves multiple disciplines and stakeholders, this study only focuses on comparison of national authority, water supply, water quality, and ecosystem use of the water between the U.S. and China. These suggestions, by no means, are comprehensive, but represent some of the pressing issues facing China, the U.S., and the world today. The comparison serves as food for thought for further discussions and suggestions for achieving the UN SDGs by 2030.

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Uncited references

AghaKouchak et al., 2015, Feng et al., 2013, Wang et al., 2016, Executive Office of the President of the United States 2004.

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