ADDRESSING WATER SECURITY IN THE PEOPLE'S REPUBLIC OF CHINA

THE 13TH FIVE-YEAR PLAN (2016–2020) AND BEYOND

ASIAN DEVELOPMENT BANK

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Foreword

The rapid economic development of the People's Republic of China (PRC) accompanied an unprecedented pace of industrialization and urbanization as well as extensive agricultural development. This resulted in substantial pressure on the country's scarce water resources—with about 20% of the global population, the PRC is only endowed with 7% of the world's water resources. For the PRC's continuing development, the country must protect and develop its freshwater resources.

In order to feed its population, expected to reach 1.4 billion by 2030, the PRC needs to improve water efficiency in agriculture to produce more food with less water. With high rates of urbanization, increasing demand for drinking water will also put additional stress on existing water sources. Energy demand will more than double in the next 20 years, and hydropower will need to be a key contributor to clean energy production. Maintaining the environmental water flows required to sustain the ecosystems is also crucial. In addition, rare and severe droughts gripped the southwest region of the PRC in 2010 and the Yangtze River Basin in 2011, proving that even one of the largest river basins in the world, known for its high rainfall, is not immune from the effects of climate change.

The PRC's ability to make more water available for domestic, agricultural, energy, industrial, and environmental uses will depend on better management of water resources and more cross-sector planning and integration. With water security declining in many parts of the country, strengthening the resilience of the water resources becomes crucial, not only to ensure future water supply but also to combat food and energy price volatility which has major global ramifications.

The partnership between the Asian Development Bank (ADB) and the PRC on water sector development goes back 30 years. Soon after the country became a member of ADB in 1986, collaboration in water management began. A study of various strategic options for the water sector contributed to amendments to the 1988 Water Law, with the amended law becoming effective in 2002. ADB has also supported a variety of water-related projects in the PRC. These projects have improved access to clean water, reduced water pollution, strengthened urban wastewater management, promoted pilot water-saving irrigation technology, and improved nonstructural aspects of flood management in the Yellow River and Hunan Province. ADB has also supported the restoration of key river basins and wetlands such as the Songhua River Basin, Hai River Basin, Sanjiang Plain, Baiyangdian Lake, and Chao Lake.

We are proud that the ADB–PRC partnership has contributed to a fundamental change in water resources management. Consistent with the priorities of the PRC's 13th Five-Year Plan (2016–2020), ADB hopes to deepen this important partnership and continue its support in the key strategic areas of water management and water security.

This report summarizes the key risks that the low level of water security poses to the sustainable development of the PRC, as well as the progress that the Government of the PRC has made in strengthening the country's water and environmental policies over the past 5 years. It then examines the performance of the 12th Five-Year Plan (2011–2015) in addressing the key water-related risks. The recommendations section aims to build on the progress achieved in implementing the 12th Five-Year Plan, as well as to address the gaps and problematic areas.

As the PRC has just adopted its 13th Five-Year Plan, we sincerely hope that this report will be useful for its implementation, particularly in the formulation of sector-specific guiding principles, main targets, and policy directions on water management.

The PRC is fast approaching the 2020 and 2030 projections of water supply and demand that both PRC and international experts have warned about. The challenges are imminent and real. The country's renewable water resources cannot meet the projected demand arising from rapid urbanization as planned. The PRC can either meet or miss the marks on water security, depending on the way it implements the 13th Five-Year Plan. To achieve the vision of an "ecological civilization," the PRC will need to revisit some of its earlier plans for urbanization and economic development.

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Acknowledgments

This publication is derived from the inputs of the Asian Development Bank (ADB) to the 13th Five-Year Plan (2016–2020) of the People's Republic of China (PRC) in addressing the country's water security issue. The analytical framework and substantial amount of data used in this report were based on previous research endeavors. In particular, the Asian Water Development Outlook (2013 and 2016 editions), copublished by ADB, the Global Water Partnership, and the Asia-Pacific Water Forum, provided regional and national quantitative scoring of water security. The World Resources Institute's Aqueduct Water Risk Atlas offered insights into the hidden water resources of the PRC that were either overexploited or undervalued: groundwater, stormwater, wastewater, and the infrastructure to carry them to productive market and environmental ends.

Qingfeng Zhang, director of the Environment, Natural Resources, and Agriculture Division of ADB's East Asia Department and concurrently chair of the Water Sector Group, initiated the conception and drafting of this knowledge product and provided overall guidance in the production of this publication. Rabindra Osti, water resources specialist at ADB, facilitated the finalization and publishing of the report.

The report benefited from close cooperation with the Government of the PRC, particularly the Ministry of Water Resources. ADB is grateful to the following World Resources Institute specialists who shared their expertise and contributed to the publication: Lijin Zhong, China Water lead/senior associate, and Tien Shiao, former Aqueduct senior associate. Betsy Otto, Global Water director, peer reviewed this report. Xiaotao Cheng, professor at the China Institute of Water Resources and Hydropower Research, updated the information, reviewed the final draft, and provided insightful comments. Li Yuanyuan and Tian Qi from the Ministry of Water Resources also reviewed the final draft of this report and provided suggestions and latest updates on the PRC's water management situation.

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Abbreviations

ADB	Asian Development Bank
GDP	gross domestic product
IBT	increasing block tariff
NDRC	National Development and Reform Commission
PES	payment for ecosystem services
PRC	People's Republic of China

Weights and Measures

bcm	billion cubic meter
ha	hectare
kg	kilogram
km	kilometer
m^3	cubic meter
mcm	million cubic meter
mm	millimeter

Currency Equivalents

(as of 1 June 2016)

Currency Unit	=	yuan (CNY)
CNY1.00	=	$0.15
$1.00	=	CNY6.58

Executive Summary

The People's Republic of China (PRC) is known as one of the most water-stressed countries in the world. Its water security faces several serious challenges. First, the demand for water continues to increase in all sectors (agriculture, energy, and industry) and in cities. Second, the country's water shortage is worsening because of the increase in water pollution, degraded ecosystems, and the impacts of climate change. Third, there is still insufficient understanding about the urgency of water risks, particularly the economic and energy impacts from low levels of water security. Among several contributing factors influencing inherent water insecurity, the reality of low water availability per capita due to population growth cannot be ignored.[1]

Change is needed to build a water-secure future in the PRC. To employ smarter, climate-resilient solutions, a systematic approach must be used to comprehensively understand water security. The Asian Development Bank (ADB) and the World Resources Institute have attempted to measure water security through peer-reviewed frameworks. ADB's Asian Water Development Outlook measures water security in five dimensions: (i) household water security (i.e., household access to piped potable water and improved sanitation facilities), (ii) economic water security, (iii) urban water security (i.e., progress in providing better urban water services to build more livable cities), (iv) environmental water security (i.e., restoring healthy rivers and ecosystems), and (v) resilience to water-related disasters.[2] The World Resources Institute measures water security based on physical (water availability and quality) and governance perspectives.

ADB has undertaken a review of the PRC's water security to provide recommendations for the government's 13th Five-Year Plan (2016–2020). This report summarizes key findings and recommendations to help increase the PRC's water security. Better water resources management, more cross-sector planning, deeper water pricing system reforms, and effective water markets are among the factors that will influence the country's ability to provide more water for agricultural, domestic, environmental, and industrial uses. The 13th Five-Year Plan period will test the country's ability to narrow the supply–demand gap and its commitment to hold the national water consumption level at 670 billion cubic meters (bcm) by 2020 and implement its Three Red Lines policy, which highlights the three binding water-related targets for water use quantity, water use efficiency, and water quality.

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[1] Q. Zhang, Y. Kobayashi, M. Howell Alipalo, and Y. Zheng. 2012. *Drying Up: What to Do about Droughts in the People's Republic of China*. Manila: ADB.

[2] ADB. 2013. *Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific*. Manila; ADB. 2016. *Asian Water Development Outlook 2016: Strengthening Water Security in Asia and the Pacific*. Manila.

A. Major Policy Progress toward Water Security during the 12th Five-Year Plan

Several high-level reports and policies have given water security higher political attention. In 2011, the No. 1 Policy Document issued by the Central Committee of the Communist Party of China placed water security at the top of the political agenda. Subsequently, a series of high-level PRC policy papers emphasized the importance of ecosystem health and water security. In 2012, the term "ecological civilization" appeared in a top political report of the National People's Congress of the PRC. The report emphasized that a healthy water ecosystem is essential for the PRC's sustainable development. In the same year, the central government implemented its Most Stringent Water Resources Management System and the Three Red Lines policy. The amended Environmental Protection Law (2014) and the newly issued Water Pollution Prevention and Control Action Plan (2015)[3] reemphasized the importance of establishing a water-secure future.

The central government has attempted to empower economic and market-based mechanism in water management. Central and lower-level governments are experimenting with water prices, private sector participation, payment for ecosystem services, and water rights and water quality trading to enable the market to develop local water supply and protect water quality. On 23 July 2014, the PRC announced that seven provinces and autonomous regions had been selected as pilots for a water rights trading scheme. To encourage better use of water resources, the PRC launched in June 2016 the China Water Exchange, which will enable the trading of water rights between different areas and users.

The PRC experimented with different models of integrated water resources management. To help the PRC address the prevailing fragmented management of water resources and establish integrated basin water resources management, ADB provided support for institutional innovations in major lake basins, including Chao Lake and Poyang Lake. In 2011, establishment of the Chao Lake Management Authority as a separate organization directly under Anhui Provincial Government demonstrated the need to incorporate different water management functions across traditional departments. Although the Chao Lake Management Authority faces coordination problems, its establishment was an important development for integrated basin water resources management in the PRC.

B. Challenges and Options in Addressing Water Security

Population growth, urbanization, economic development, increases in energy demand and food needs, prevalent clamor for better water services, and climate change impacts are on a

[3] On 16 April 2015, the State Council of the PRC issued the Water Pollution Prevention and Control Action Plan (also known as the Water Ten Plan). See China Water Risk. 2015. New "Water Ten Plan" to Safeguard China's Waters. http://chinawaterrisk.org/notices/new-water-ten-plan-to-safeguard-chinas-waters/#sthash.sxnZfzzs.dpuf

collision course with water shortage. Much of the increase in water demand—mainly driven by urbanization and economic growth—will be in areas where water supply is limited.

According to ADB's Asian Water Development Outlook, the PRC's water security composite index reveals the challenging water situation the country faces, particularly in the areas of urban water security, environmental water security, and resilience to water-related disasters. As a country poised to become a developed one in the near future, the PRC needs to address water security issues at a reasonable and comparable level with other developed countries.

In 2012, the PRC's 18th National People's Congress prioritized urbanization as a core development component, with plans to increase the share of the urban population to 60% of the total population by 2020. At the same time, the PRC set a water use target of 670 bcm by 2020 and 700 bcm by 2030, requiring an abrupt slowdown in the growth of water demand in 2020–2030. This means that the PRC must improve water efficiency across all sectors during the 13th Five-Year Plan period.

Water is naturally linked to energy and food, but the PRC policy makers have often neglected this water–energy–food nexus. Such nexus will continue to grow in importance as the demand for water in the PRC increases due to rapid urban population growth and escalating demand in energy and food production. The PRC has become one of the biggest energy consumers and producers in the world, but the mismatched locations of energy and water resources are threatening long-term energy production. The PRC's scarce water supply may be entirely depleted if energy or food production exceeds the total capacity of local water reserves.

Agriculture is the biggest water user, accounting for 65% (in 2014) of total freshwater withdrawals in the PRC. To increase the country's agricultural water productivity, which was fairly low at $3.6 per cubic meter ($m^3$), the PRC needs to increase investments in irrigation infrastructure and irrigation system modernization. Productivity gains, however, are not solely attributable to infrastructure, but are rather a combination of infrastructure, improved farmland and water management practices, and institutional strengthening for effective operation and maintenance.

Many cities in the PRC suffer from weak management of toxic chemicals, and toxic chemical spills have aggravated water shortages. Recent incidents include the Jingjiang pollution accident in May 2014, the Lanzhou pollution accident in April 2014, and the leakage of aniline-containing wastewater into the downstream section of the Zhanjiang River in Shanxi in January 2013. These toxic chemical spills have heavily threatened water security in the PRC's cities. The risk to water supply security is aggravated by reliance of many cities on a single water source, with no dependable options if that source gets contaminated or depleted.

The PRC is behind in constructing sewer and drainage pipes and developing sewerage systems. Being underground, these systems are often invisible but necessary to protect cities against flooding. A survey by the Ministry of Housing and Urban–Rural Development concluded that between 2008 and 2010, over 60% of the 351 surveyed cities suffered from urban flooding. During the same period, the 10 worst water disasters each year affected more than 280 million people and cost more than CNY250.0 billion ($38.0 billion) in economic losses. Beijing's stormwater disaster in July 2012 killed 79 people, affected 1.6 million people, and cost CNY11.6 billion ($1.8 billion) in direct economic losses.

Healthy ecosystems, especially healthy water systems, provide beneficial services to people and nature. According to ADB's *Asian Water Development Outlook 2016*, the PRC's river health index continues to register very low values, especially in the lower Yangtze River Basin. Water resources development, along with population density and agricultural density, is seen as the biggest threat in the PRC's river health. Pollution, especially nonpoint pollution from agriculture and sediment loads, is damaging the health of rivers and adding stress on the availability of water resources. Furthermore, an alarming rate of overuse and pollution are depleting precious groundwater resources.

A viable mechanism for protecting the health of ecosystems and internalizing the costs of restoring and maintaining ecosystem services into the economy is payment for ecosystem services (PES). The PRC has been implementing "eco-compensation," a variation of the PES concept, on the largest scale in the world. For eco-compensation to work for water resources, the government will need to build capacity for place-based monitoring and assessment, identify services in the context of the entire flow regime, consider trade-offs and conflicts among multiple uses, and take into account uncertainty.

Climate change, which has exacerbated the PRC's water challenges, will likely lead to three key water-related consequences: increase in temperature, change in water distribution geographically and seasonally, and sea level rise. The National Development and Reform Commission (NDRC) estimated that, since 1990, the effects of climate change have already cost the country more than CNY200.0 billion ($30.4 billion). If climate change goes unmitigated and economic sectors and vulnerable communities do not aggressively adapt, the country can only expect costly risk to human lives and damage to infrastructure, natural resources, personal property, and livelihoods.

C. International Comparison of Water Sector Performance

The PRC can improve its current water security conditions based on the understanding of recent trends and opportunities for improvements. However, it would be worthwhile to incorporate the lessons learned by other countries so as to prevent duplicating the same mistakes made by others while addressing existing and emerging issues and challenges. The good examples and comparative studies will help the PRC maintain a good track of progress in water security management and achieve its sustainable development goals.

The performance of the PRC's water sector has been compared with that of other countries in several recent studies by ADB, the World Resources Institute, and McKinsey & Company and the 2030 Water Resources Group. The following is a summary of how the PRC fares against other countries on key indicators.

(i) **Lower pricing or tariffs.** Water tariffs in the PRC are much lower than in other countries. The tariffs in the Republic of Korea, Mexico, and the Russian Federation are about 1.5–2.0 times higher than in the PRC, while those in the European Union countries are 10 times higher. The PRC's current water tariffs are still below the price needed for full financial cost recovery. The average combined water and wastewater tariff for residential consumers for 36 key PRC cities was $0.44 per cubic meter in April 2014.

(ii) **Lower productivity.** The PRC's total water productivity of $10 per cubic meter in 2014 is low in comparison with the world average of $15 per cubic meter, and the average of countries in East Asia and the Pacific ($13 per cubic meter), North America ($31 per cubic meter), and the European Union ($87 per cubic meter).[4] Water productivity in agriculture also remains low due to low irrigation efficiency.

(iii) **Potentially significant changes in water withdrawal.** Water withdrawals greater than 40% of the total water available are considered by some experts to be a rough indication of severe water scarcity. Areas facing this level of scarcity or worse in the 2050s under the middle-of-the-road scenario will be northeast PRC, central-east PRC, and the urban areas along the PRC's coastlines. The PRC's domestic water use in 2014 was lower than most other countries, including Brazil, Japan, the Republic of Korea, and the United States. However, its population growth is higher than these other countries. Hence, the PRC's domestic water usage may significantly change with urban population growth, economic growth, climate change impacts, and policy targets.

(iv) **Slower urban sewerage system development.** Compared to the growth of urban areas, the development of the urban sewerage system has been much slower. The sewer pipe length per 10,000 urban population was 6.27 km in 2013, which was 17% of Japan's rate in 2006. Likewise, the share of anthropogenic wastewater that receives treatment in the PRC was on the low side at 18.2% in 2012, which is slightly higher than in Brazil or India but much lower than in Japan, the Republic of Korea, or the United States.[5]

(v) **Moderate water stress.** The World Resources Institute's Aqueduct Water Risk Atlas shows that the PRC has medium-to-high water stress—i.e., it faces medium-to-high levels of competition between major water users in the watershed.[6] In terms of global baseline water stress (2010), the PRC is ranked close to the middle, at 69th out of 180 countries. The PRC has lower water stress than India, Japan, and the Republic of Korea, but the same stress level as the United States. Brazil, though, has lower water stress than the PRC, because it has abundant water resources. However, due to an uneven spatial and temporal distribution of water resources, the PRC faces more water stress in the north compared with the south.

D. Recommendations for Increased Water Security during the 13th Five-Year Plan

ADB has reviewed the water security levels in the PRC and concluded that the 13th Five-Year Plan should approach the country's imminent water scarcity through the following:

[4] World Bank. 2015. *World Development Indicators*. Washington, DC.

[5] O. Malik. 2013. Global Database of National Wastewater Treatment. New Haven, CT: Yale Center for Environmental Law and Policy.

[6] World Resources Institute. Aqueduct Water Risk Atlas. http://www.wri.org/resources/maps/aqueduct-water-risk-atlas

1. Elevate Water Security to the Appropriate High-Level Authority and Ensure Proper Implementation of National Water Security Strategy

Establish a state water security committee. Governance is critical to integrated water resources management. This national-level committee should serve as the highest water policy-making body in the country, similar to the National Energy Commission, and be headed by the premier or vice premier. It would coordinate water policies and streamline supervision across all sectors. To provide effective oversight of the country's water resources and policy implementation, the committee needs the support of the river basin management commissions for the country's seven major river basins.

Formulate a national water security strategy in the 13th Five-Year Plan. The government should formulate a long-term national water security strategy (up to 2050) and plans based on careful analysis of (i) the increasing demand from agricultural intensification, energy development, industrialization, and urbanization; (ii) implications from water pollution, degraded ecosystems, and climate change on water scarcity; (iii) the implications on water supply options from the natural limitations caused by uneven (spatial and temporal) distribution of water; and (iv) optimal infrastructure, including water-saving technologies and other technical, nonstructural investments.

Strictly enforce water and wastewater management and treatment reform policies during the 13th Five-Year Plan period. The river basin management commissions for the seven major rivers should be reformed and required to formulate implementation procedures for provincial and local governments on how to develop more effective enforcement plans of key water policies, particularly the 2011 No. 1 Central Policy Document on the PRC's water conservancy issues and the Three Red Lines policy. An informed and legally entitled public will also be crucial in keeping local agencies accountable for law enforcement.

2. Deepen Reform of Water Governance System and Strengthen Water Management

Launch the legal reform to clarify responsibilities and encourage collaboration among the water-related sectors. The National People's Congress should revise water-related laws to improve clarity, remove contradictions, and bring to focus the enforcement of integrated water management. The legal reform should address two fundamentals: (i) rights and authorities over water management, and (ii) coordination between jurisdictions and institutions.

Reform the seven river basin management commissions. The river basin management commissions for the country's seven major river basins should be made independent from the Ministry of Water Resources and accountable to the proposed state water security committee. These commissions should be reformed to have more diverse representation of relevant line agencies and local governments.

Invest in data infrastructure and improve information accessibility and transparency. Development of data infrastructure and information accessibility in the 13th Five-Year Plan should focus on (i) financing a real-time monitoring system based on a geographic information system (GIS) to collect various types of water supply, water quality, and water infrastructure information; (ii) mainstreaming remote sensing technologies in water resources management; and (iii) building a comprehensive water information platform that integrates data from all key authorities from the local levels up.

3. Build Optimal Water Infrastructure Capacity to Enhance Water Security

Promote metering and better meter management. The 13th Five-Year Plan should pursue installation of water meters for agricultural use (which is not metered at present) and continue to extend meter coverage in cities. Metering is a critical infrastructure for demand management. The PRC's low ratio of metered water users and its weak meter management are major barriers to the implementation of block tariffs, which is a basic strategy for reducing water demand by charging higher rates for luxury water consumption.

Rehabilitate urban pipes and invest in leak detection. Sewer pipes should be regularly checked for leakages, as leaking pipes are a cause of major revenue loss, water shortages, and water pollution. Separate pipes for sewage and stormwater should be installed, especially in newly developed areas, while slowly replacing the existing combined system of wastewater and stormwater pipe into separated ones. The capacity of sewer pipes should also be increased to accommodate both municipal wastewater and industrial wastes. Investments in sewerage systems, however, are not likely to come from private and capital markets, which regard piping systems as sunk costs. The government will have to invest over the next 5 years in rehabilitating the sewer pipes, building more climate-resilient water infrastructure, and increasing the coverage of urban piped networks.

Make use of recycled water. Development has only begun in reclaiming wastewater to recharge rivers and lakes, city greening, and partial flushing in households. Facilities for recycling wastewater should be situated near locations where the reclaimed water will be used. Making better use of high-quality reclaimed wastewater (such as NEWater in Singapore)[7] can sharply decrease the energy intensity and cost of water production and at much better rates than desalination. Yet, having dual quality network systems (i.e., for clean and recycled water), especially within the homes, can be very costly and unsafe.

Invest in conservation and efficiency measures. Some of the highly cost-effective measures to decrease total water demand for the same economic output include: (i) installation of water-saving fixtures for residential and commercial buildings; (ii) improvement of water efficiency in the energy sector through new technologies; (iii) reduction of water use in industrial processes and equipment; and (iv) broader use of rainwater-harvesting systems in cities for landscape irrigation, heating and cooling systems, and toilets. These measures can be achieved by establishing quality control mechanisms and basic efficiency standards at the central and local government levels. The mandatory application of these standards should be imposed on public facilities, including business

[7] NEWater is the brand name given to reclaimed water produced by Singapore's Public Utilities Board.

districts, schools, and hospitals. Government subsidies may, in some instances, be needed, particularly by the poor rural households.

Increase agricultural water productivity. More investments are needed to achieve the irrigation efficiency targets of 0.55 by 2020, and 0.60 or above by 2030. Government must support research funding and extension. The promotion of agricultural best practices can maximize "crop per drop" yields. This includes proper crop selection for local soil and hydrologic conditions, seed development and selection of more heat- and drought-tolerant varieties, and best management practices that can increase soil moisture capacity and hold more rainwater to recharge groundwater tables. Remote sensing can be a useful tool for benchmarking productivity and supporting investment projects.

Safeguard groundwater resources. The central government should establish a groundwater management organization to coordinate, consolidate, and share groundwater information. This requires independent and professional monitoring of groundwater resources and regulatory measures in the provinces. In addition, limits on groundwater extraction should be imposed. Financial resources should be allocated to (i) conduct specific hydrogeological studies, (ii) develop groundwater management plans with all local stakeholders, and (iii) invest in measures and establish monitoring mechanisms for sustainable groundwater management. The Asia-Pacific Center for Water Security can be a suitable institute to work more closely on groundwater resource monitoring.

4. Reform Water Pricing to Reflect Scarcity and Create Water Services to Address Externalities

Support local governments in implementing tariff regulations. Local authorities have been slow in implementing tariff regulations. The state needs to inform local governments on how to use block tariffs in socially acceptable and financially sound ways. Cost tiers need a scientific and justifiable basis for charging different rates to different sectors and households. Full cost recovery should be reflected in regional and national water management and economic planning. When local governments and the public begin to understand the true costs of water and sewerage, a market consciousness will grow and positively affect how water is allocated and used.

Strengthen water rights administration and pilot water markets. The river basin commissions, with support from the central government, should jointly develop and issue a technical handbook on allocating river basin water resources that would contribute to more consistent preparation of water resources allocation plans at the local levels. These plans must be based on scientific accounting of water availability, water consumption, and the amounts that must be retained or returned to the environment. The 13th Five-Year Plan should pilot temporary trading in areas which have some experience and where there is some monitoring infrastructure in place.

Develop a watershed services market that attracts the private sector. The government has been the predominant buyer of watershed services in its eco-compensation schemes, which has left little room for the private sector. In developing a national eco-compensation policy framework, the government should shift its role to "enabler," focusing on establishing the regulatory requirements that can create a market that would attract private sector participation.

Convert the water resources fee to water tax. Local governments use the water resources fee to fund local water resources management programs. These revenues could be put to better use if they were collected as a tax, which the central government could allocate to priority basin water projects. Allocations from annual central and local government budgets could support local water resources management activities.

5. Focus on the Weakest Spots of the Country's Water Security and Develop Water Risk Management

Build a water risk management system to increase resilience. The government should adopt the following measures in the 13th Five-Year Plan: (i) build a long-term national water risk mapping and monitoring system, including floods, landslides, drought, supply variability, water stress, and pollution incidents; (ii) establish an early warning system to increase resilience of cities and farms; (iii) prioritize vulnerable and sensitive areas; and (iv) introduce insurance schemes, such as crop insurance.

Improve domestic water security through chemical management and improved chemical disaster response. During the 13th Five-Year Plan period, the government should (i) develop and enforce stringent controls on pollutant discharges from industrial point sources, especially toxic chemicals near urban drinking water sources; (ii) disclose information on chemical pollution and set up training programs for basic emergency response; and (iii) assess chemical-related water risks for new urban areas. New urban development projects should consider potential chemical pollution of water resources.

6. Promote Education and Public Awareness Programs

Education is critical in generating basic understanding of water security issues, sound water resources management and planning, and the associated benefits of water conservation efforts.

Better access to information on water-related resources, policies, and institutions would help raise public awareness of water conservation and empower citizens to actively participate in water management. The PRC should also provide support for the development and participation of civil society and nongovernment organizations as they play an important role in improving access to safe water, disseminating education and information materials on different water and health issues, and sharing good practices and technical solutions for water resources management and protection.

E. Issues for the Near Future: The Water–Energy–Food Nexus

The implications of development on water resources should be considered at more strategic levels, particularly in agriculture and energy development—two socially and economically imperative sectors where competition for water resources is not being managed to reflect the scarcity of local water resources.

Water for energy. The power sector in the PRC is the largest industrial water user, and 94.3% of total power generation capacity is heavily reliant on water. For a more balanced and sustainable development of the energy and water sectors, the PRC government needs to (i) incorporate the impacts of medium- to long-term energy sector development plans on the freshwater resources; (ii) introduce incentives and enforce water use targets in energy facilities to improve water use efficiency levels and water recycling ratio; (iii) establish effective regulatory and compliance mechanisms to ensure that the deployment of new technologies aimed at climate change mitigation and air pollution control does not adversely affect the groundwater resources; and (iv) increase water tariffs for energy and industrial consumers to reflect the value of water and send price signals to conserve water.

Water for food. The PRC is beset with problems of rising food prices, food shortages, and adverse market interventions, which are seriously contributing to social instability. The ministries responsible for water management and agriculture development need to collaborate on a national plan to modernize irrigation and drainage using improved technical and managerial systems to enhance resource utilization rates and water services to farms. The government can also attract private sector financing for irrigation and drainage by establishing performance targets and shifting to private sector management of irrigation water supply and management.

I. Water Security and the 13th Five-Year Plan

The 13th Five-Year Plan of the People's Republic of China (PRC) is a critical period for substantial improvements called for in the 2011 No. 1 Policy Document issued by the Central Committee of the Communist Party of China, which focused on the country's water conservancy issues. The PRC's rapid economic growth and development successes have stressed freshwater resources and exposed people to water shortages and health problems. As population increases in the PRC, and urbanization and industrialization escalate, demand for water, energy, and food likewise grows exponentially. Water usage rates and ecological damage must be contained during this next 5-year period in order to avoid water shortages that have been projected to occur by 2030, and as early as 2020.

The PRC's Ministry of Environmental Protection has warned that the 13th Five-Year Plan period of 2016–2020 will "still be [a] period of rapid growth of gross domestic product, energy consumption, and population of our country. Urbanization process will be accelerated with increasing environmental pressure and environmental risk."[1] The ministry anticipates that the public will assert its growing expectations for environmental improvement, and more strongly than ever. Environmental integrity is now a matter of social stability.

Previous five-year plans have certainly increased the awareness of lower levels of government to environmental issues. The plans have used compulsory targets and focused on prioritized geographic areas. But the general environment and natural resource base have not improved at a rate or scale that is commensurate with current realities or imminent challenges. The Ministry of Environmental Protection has reported that "environmental pollution is more complex and diversified, showing evident compressed, combined, and structural feature[s] and expanding from local to regional level. It is difficult to bring comprehensive improvement of the environment if we only control certain pollutants or accelerate pollution control of a certain region."

National policies must consider a myriad of natural and imposed limitations to water resource use, including uneven water resource distribution, water pollution, inefficient water use, and climate change.

- **Uneven distribution.** The PRC is home to about 20% of the world's population, but endowed with only 7% of global water resources. Table 1 presents the country's annual available water resources. Water resources in the PRC are remarkably

[1] Ministry of Environmental Protection (MEP) of the PRC. 2014. Relevant Work on National 13th Five-Year Plan for Environmental Protection. Presented at the First MEP–Asian Development Bank (ADB) Environmental Policy Dialogue Meeting. Beijing. 5 March.

Table 1: Average Annual Renewable Water Resources in the People's Republic of China

Water Resources	Amount
Long-term average annual precipitation in depth (mm/year)	645.00
Surface water produced internally (bcm/year)	2,712.00
Groundwater produced internally (bcm/year)	828.80
Total internal renewable water resources per capita (m^3/capita/year)	1,999.00
Total renewable surface water (bcm/year)	2,739.00
Total renewable groundwater (bcm/year)	828.80
Total renewable water resources per capita (m^3/capita/year)	2,018.00

bcm = billion cubic meter, m^3 = cubic meter, mm = millimeter.

Note: The Renewable Water Resources statistics provided in AQUASTAT are long-term annual averages (typically 1961–1990, although the specific period of reference information is provided where known).

Source: Food and Agriculture Organization of the United Nations. AQUASTAT. http://www.fao.org/nr/water/aquastat/countries_regions/chn/index.stm (accessed 17 May 2016).

unevenly distributed, both spatially and temporally. Southern PRC encompasses 69% of the country's available water supply and has four times the groundwater resources of northern PRC; whereas, the north only has one-fifth of the PRC's total water resources, yet it covers roughly 60% of arable land for agriculture and is home to some of the country's largest cities. Both regions register seriously low per capita water availability ratios. The south, with water availability at 1,100 cubic meters (m^3) per capita, is within a hairline of the international water scarcity threshold of 1,000 m^3 per capita, while the north is operating at only 424 m^3 per capita or nearly 50% below the threshold.[2] Rainfall in most parts of the country is concentrated in several consecutive months, thereby causing frequent drought–flood problems.

About 32% of the total PRC population has at its disposal approximately 1,000 m^3 of water resources per capita per year (Figure 1), which is commonly defined as the threshold for water scarcity. The Falkenmark indicator or water stress index—one of the most commonly used measures of water scarcity—calculates water scarcity as the amount of renewable freshwater that is available for each person per year. A Falkenmark indicator below 1,700 m^3 per capita per year indicates that a country is experiencing water stress; below 1,000 m^3 water scarcity; and below 500 m^3 absolute water scarcity.[3]

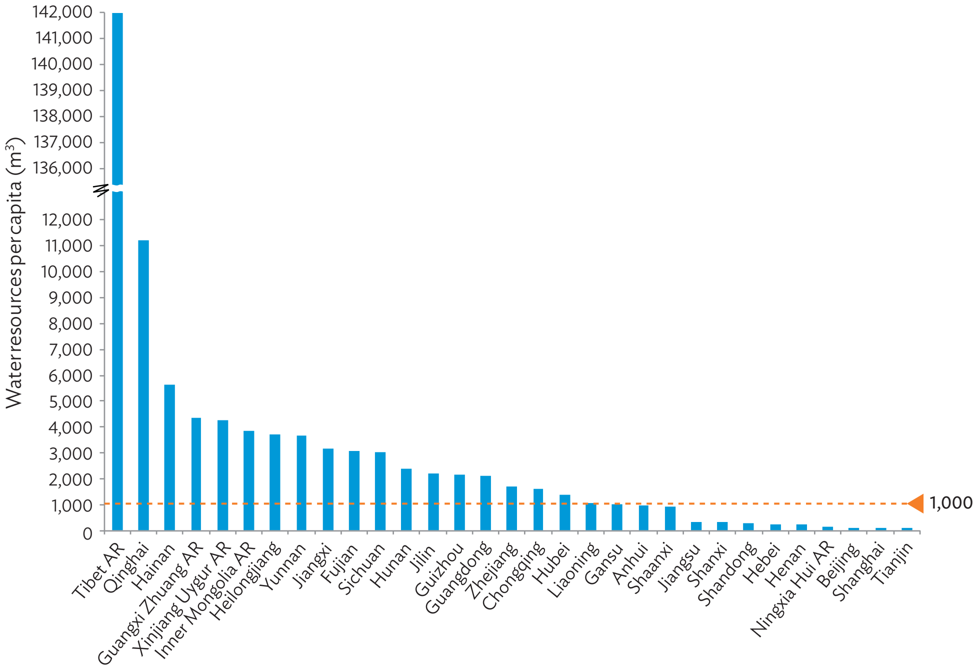
- **Water pollution.** Water shortage is worsening in the PRC because of increasing water pollution and ecosystems degradation. Over a third of surface water[4] and

2 Q. Zhang, Y. Kobayashi, M. Howell Alipalo, and Y. Zheng. 2012. *Drying Up: What to Do about Droughts in the People's Republic of China*. Manila: ADB.

3 M. Falkenmark, J. Lundquist, and C. Widstrand. 1989. Macro-scale Water Scarcity Requires Micro-scale Approaches: Aspects of Vulnerability in Semi-arid Development. *Natural Resources Forum*. 13 (4). pp. 258–267.

4 Ministry of Environmental Protection of the PRC. 2012. *China Environmental Quality Bulletin*. Beijing.

Figure 1: Water Scarcity Threshold and Water Resources per Capita per Year by Province in the People's Republic of China, 2014



AR = Autonomous Region, m^3 = cubic meter.

Notes: The figure 1,000 m^3 per capita per year is commonly defined as the threshold for water scarcity. Extreme water scarcity is commonly defined as 500 m^3 per capita per year, representing 9 of the 31 provinces in the country.

Source: National Bureau of Statistics of the People's Republic of China. 2014. *China Statistical Yearbook*. Beijing.

four-fifths of shallow groundwater[5] are heavily polluted. Mortality rates for liver and stomach cancer (an epidemiological indicator of polluted drinking water) in the PRC are well above the world average.[6] Recent pollution accidents in the water

5 According to the Groundwater Monthly Report for January 2016 by the PRC Ministry of Water Resources, monitoring data for shallow groundwater from 2,103 wells distributed in Songliao Plain, Huang–Huai–Hai Plain, basins and plains in Shanxi and the northwest region, and Jianghan Plain indicate that the water quality of 691 wells are class IV, accounting for 32.8%, and 994 of them are class V, accounting for 47.3%, which means that 80.1% of shallow groundwater wells are heavily polluted, and thereby not fit for human consumption. According to the Quality Standard for Groundwater of [the People's Republic of] China, class IV is suitable for industrial and agricultural use, while class V water is defined as not suitable for drinking.

6 Several studies have indicated that the incidence of digestive cancer mortality is remarkably associated with organic pollution in drinking water. See, e.g., H. Ren, X. Wan, F. Yang, X. Shi, J. Xu, D. Zhuang, and G. Yang. 2015. Association between Changing Mortality of Digestive Tract Cancers and Water Pollution: A Case Study in the Huai River Basin, China. *International Journal of Environmental Research and Public Health*. 12 (1). pp. 214–226; N.-F. Lin, J. Tang, and H.S.M. Ismael. 2000. Study on Environmental Etiology of High Incidence Areas of Liver Cancer in China. *World Journal of Gastroenterology*. 6 (4). pp. 572–576; Z.Q. Wang, J. He, W. Chen, Y. Chen, T.-S. Zhou, and Y.-C. Lin. 1998. Relationship between Different Sources of Drinking Water, Water Quality Improvement and Gastric Cancer Mortality in Changle County: A Retrospective-Cohort Study in High Incidence Area. *World Journal of Gastroenterology*. 4. pp. 45–47; H. Xu, Y. Han, H. Ping, et al. 1995. The Case-Control Study on the Human Liver Cancer Risk Factors in the Nansihu. *Journal of Environment and Health*. 12 (5). pp. 210–212.

supply plants of Lanzhou (Gansu Province) and Jingjiang (Jiangsu Province) have triggered debates around urban water security, water risk management, and conflicts with old petrochemical plants located near residential districts and water sources.

Statistical data from the Ministry of Land and Resources present interesting trends, for the period 2011–2015, in groundwater quality at monitoring points across the country (Figure 2). There appears to be an increase in groundwater of bad and poor quality.

- **Inefficient water use.** Water productivity serves as a measure of water use efficiency. It indicates how much economic output is produced per cubic meter of freshwater abstracted. Total water productivity in the PRC was estimated at $10 (constant 2005 $ gross domestic product per cubic meter of total freshwater withdrawal) in 2014—low compared with the world average of $15, and the average of countries in East Asia and the Pacific ($13), North America ($31), and the European Union ($87).[7] The water productivity of agriculture has the lowest productive rates of all sectors due to low irrigation efficiency. Irrigation efficiency is the ratio of the amount of water consumed by the crop to the amount of water supplied through irrigation (surface, sprinkler, or drip irrigation); it is used to express which percentage of irrigation water is used efficiently and which percentage is lost.[8] About half of the water withdrawn for irrigation is not effectively used.[9]

- **Climate change.** Climate change, in the form of more severe hydrometeorological events (like droughts) and floods, could further threaten the water security of the PRC. Recent droughts have been experienced in southwest PRC (such as in Guizhou and Yunnan provinces) and in Guangxi Zhuang Autonomous Region, which have historically been water abundant. The ongoing El Niño weather pattern, which started in September 2015 and considered the worst weather pattern in the PRC since 1998, is expected to cause severe floods along the Yangtze River.[10] Global warming has also led to increased water demand for agricultural irrigation.

The PRC is dangerously short of water and needs responses that integrate water resources management with land use to reverse ecological damage. Institutional, technical, and infrastructure solutions must be coordinated. Many countries have learned that demand

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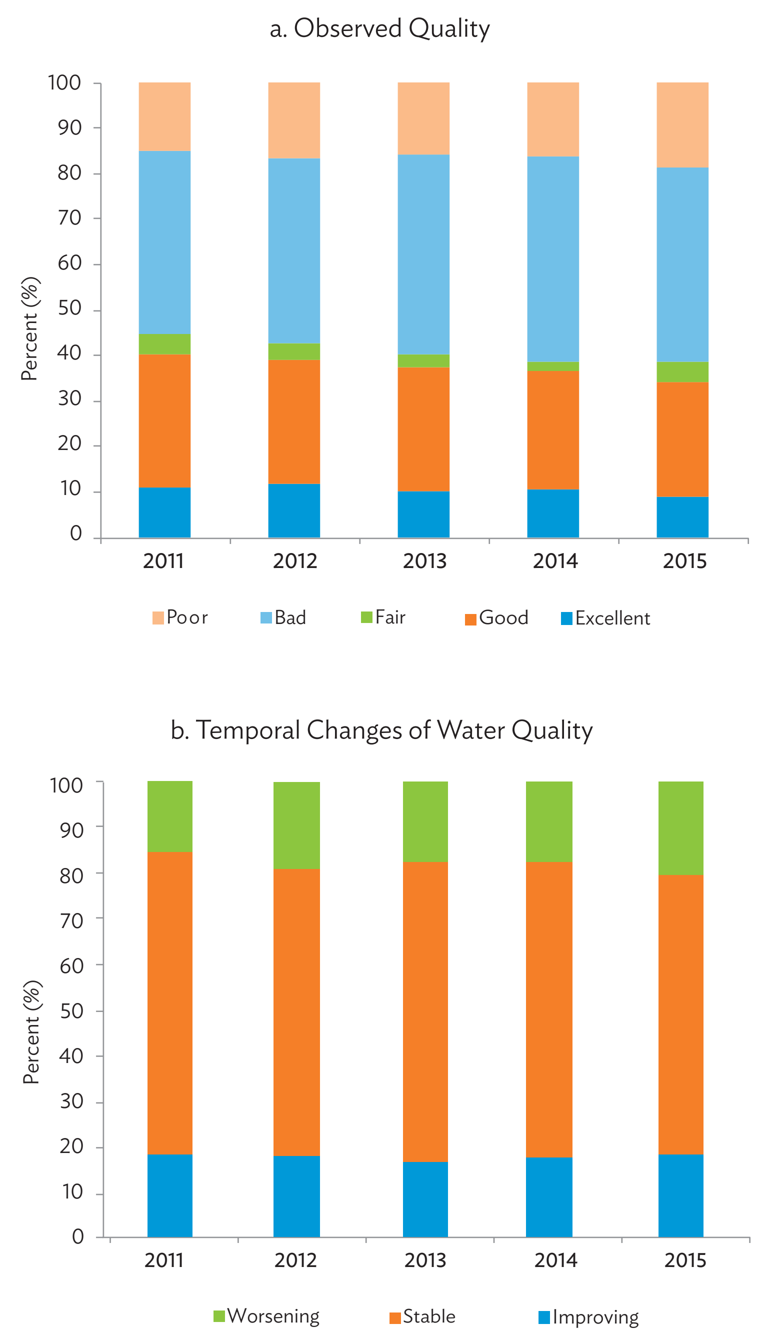
7 World Bank. 2015. *World Development Indicators*. Washington, DC; World Resources Institute estimates.

8 M. Machibya, M. Mdemu, and B. Lankford. 2004. Irrigation Efficiency and Productivity Manual: Tools for Irrigation Professionals and Practitioners. Department for International Development. http://r4d.dfid.gov.uk/PDF/Outputs/Water/R8064-Irrigation_Efficiency_Productivity_Manual-1.pdf; FAO. 1989. Irrigation Water Management: Irrigation Scheduling. Annex I: Irrigation Efficiencies. http://www.fao.org/docrep/T7202E/t7202e08.htm.

9 According to the PRC Ministry of Water Resources, the water use efficiency for irrigation in 2013 was 0.52 (*People's News*. 2014. Water Consumption in 31 Provinces within the Annual Target of Control. 29 September. http://politics.people.com.cn/n/2014/0929/c1001-25759813.html [in Chinese]).

10 According to the Yangtze River Flood Control and Drought Relief Headquarters, precipitation along the Yangtze River will be between 10% and 50% higher this year, even reaching 80% higher in some areas. (*People's Daily Online*. 2016. China Warns of Severe Flooding on Yangtze River Brought about by Strong El Niño. 5 April. http://en.people.cn/n3/2016/0405/c90000-9039617.html)

Figure 2: Groundwater Quality at Monitoring Points across the People's Republic of China, 2011–2015



Source: Ministry of Land and Resources of the People's Republic of China. 2015. *Bulletin of Land and Resources*. Beijing.

management is an economically, socially, and environmentally viable strategy. Demand management measures come in both structural and nonstructural forms, and are mainstreamed into strategies for risk reduction and infrastructure investment. The benefits multiply across sectors and address the triple threat of environmental unsustainability, shortfalls in natural resources for economic growth, and social instability. The Asian Development Bank (ADB) advocates demand management—increased water efficiency, conservation, and protection—as a way for the PRC to improve water quantity, water quality, and climate resilience.

This publication provides recommended policy initiatives that would ensure the 13th Five-Year Plan contributes to exponential improvements in national water security, particularly in extreme water-scarce provinces. Chapter II examines policy progress in water governance and technological applications during the 12th Five-Year Plan period. Chapter III looks at the projections for rates of water demand and the availability of renewable supplies in 2030 and 2050. Chapter IV examines the PRC's water security using the framework, data, and analyses from ADB's Asian Water Development Outlook (2013 and 2016 editions), which measures the water security levels of countries in the region by using indexes for five key dimensions of water security: (i) household, (ii) economic, (iii) urban, (iv) environmental, and (v) climate resilience. The chapter also assesses the PRC's security ratings for these key dimensions and identifies problematic trends. Chapter V recommends key actions for improving the PRC's water security and water management during the 13th Five-Year Plan period. Finally, Chapter VI summarizes issues for the near future.

II. Current Water Policy Context for the 13th Five-Year Plan

Water security recently gained focus in the PRC and was given unprecedented priority during the 12th Five-Year Plan (2011–2015). The 2011 No. 1 Central Policy Document placed water security at the top of the political agenda. The document committed CNY2.0 trillion ($303.8 billion) to water investments during the 12th Five-Year Plan. Subsequently, a series of high-level Chinese policy papers emphasized the importance of healthy ecosystems and water security. In 2012, the National People's Congress included the concept of an "ecological civilization" (the PRC's model of sustainable economic growth that protects the environment) in its top political report.[11] The report emphasized that a healthy water ecosystem is essential for the PRC's sustainable development. The State Council's 2012 declaration for a "most stringent water resources management system" introduced a new standard for water and environmental management. The central government implemented the Three Red Lines initiative—three binding water-related targets for water use quantity, water use efficiency, and water quality.

During the 12th Five-Year Plan period, from 2011 to 2015, progress toward achieving the binding or compulsory targets of the 17 water-related indicators was swift. Table 2 presents the baselines going into the 12th Five-Year Plan period, and the actual results for indicators that had data from the 2013 and 2014/2015 interim monitoring. The indicators that do not have interim data—i.e., discharges of chemical oxygen demand and ammonia nitrogen in both paper and textile industries—are all related to water quality. The following can be said of the indicators with interim data:

(i) All are on course to achieve their targets by 2015.

(ii) Five indicators have already achieved (and even exceeded) the 2015 target by 2014—the percentage of municipal wastewater treatment, total chemical oxygen demand (COD) discharge, industrial COD discharge, silver COD discharge, and industrial ammonia nitrogen discharge. Although data on the current utilization rates of installed wastewater treatment capacity are not known, the progress in wastewater treatment volumes is notable considering that municipal wastewater treatment was just 36.4% in 2001 and reached 91.0% in 2014, with most of these gains belonging to the 11th Five-Year Plan (2006–2010).

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11 Ecological civilization was adopted in response to rising public concern over widespread environmental degradation that resulted from the PRC's rapid economic growth. The concept was first proposed in 2007 by Hu Jintao, general secretary of the Central Committee of the Communist Party of China (CPC), in his report to the 17th National Congress of the CPC. At the Third Plenary Session of the 18th Central Committee in 2013, implementation of "ecological civilization reforms"—reforms to reconcile contradictions between economic development and the environment—was stressed, and acceleration of such reforms was restated in a document released in April 2015. (C. Zhang. 2015. China's New Blueprint for an "Ecological Civilization." *The Diplomat*. 30 September. http://thediplomat.com/2015/09/chinas-new-blueprint-for-an-ecological-civilization/)

Table 2: Water-Related Binding Targets in the 12th Five-Year Plan (2011–2015) of the People's Republic of China

Indicators	Units	2010 Baseline	2013 Performance	2014/2015 Performance	Targets 2015	Targets 2020	Targets 2030
Total water use	bcm	602.22	617[a]	618[b] (2015)	635	670	700
Water use per unit GDP	m^3/CNY10,000	150	121[a]	104[b] (2015)	Below 105	–	–
Water use per unit industrial added value	m^3/CNY10,000	90	68[a]	58[b] (2015)	Below 63	65	Below 40
Effective agricultural irrigation efficiency	–	0.50	0.52[c]	0.53[d] (2014)	0.53	0.55	Above 0.60
Water quality of function zones	%	–	NA	51.8[d] (2014)	60	80	Above 95
Urban source water protection zones	%	–	84.5[e]	–	–	100	–
Municipal wastewater treatment	%	77	87.9[a]	91.0[d] (201)	85	–	–
Total COD discharge	10,000 ton	2,551.7	2,352.7[a]	2,294.6[f] (2014)	2,347.6 [–8%]	–	–
Industrial COD discharge	10,000 ton	355	319.5[g]	311.3[f] (2014)	319 [–10%]	–	–
COD discharge in paper industry	10,000 ton	72	NA	–	64.8 [–10%]	–	–
COD discharge in textile industry	10,000 ton	29.9	NA	–	26.9 [–10%]	–	–
Ag COD discharge	10,000 ton	1,204	1,125.7[g]	1,102.4[f] (2014)	1,108 [–8%]	–	–
Total NH_3-N discharge	10,000 ton	264.4	245.7[g]	238.5[f] (2015)	238 [–10%]	–	–
Industrial NH_3-N discharge	10,000 ton	28.5	24.6[g]	23.2[f] (2014)	24.2 [–10%]	–	–
NH_3-N discharge in paper industry	10,000 ton	2.14	NA	–	1.93 [–10%]	–	–
NH_3-N discharge in textile industry	10,000 ton	1.99	NA	–	1.75 [–12%]	–	–
Ag NH_3-N discharge	10,000 ton	82.9	77.9[a]	75.5[f] (2014)	74.6 [–10%]	–	–

Ag = silver, bcm = billion cubic meter, CNY = yuan, COD = chemical oxygen demand, GDP = gross domestic product, m^3 = cubic meter, NA = not available, NH_3-N = ammonia nitrogen.

[a] National Bureau of Statistics of the People's Republic of China. 2014. *2013 National Economic and Social Development Statistical Bulletin*. 24 February. http://www.stats.gov.cn/tjsj/zxfb/201402/t20140224_514970.html (in Chinese).

[b] National Bureau of Statistics of the People's Republic of China. 2016. *2015 National Economic and Social Development Statistical Bulletin*. 29 February. http://www.stats.gov.cn/tjsj/zxfb/201602/t20160229_1323991.html (in Chinese).

[c] Ministry of Water Resources of the People's Republic of China. 2014. Total Water Use in 31 Provinces under the Annual Control Target. *People's Daily Online*. 29 September. http://politics.people.com.cn/n/2014/0929/c1001-25759813.html (in Chinese).

[d] Ministry of Water Resources of the People's Republic of China. 2014. *China Water Resources Bulletin*. http://www.mwr.gov.cn/zwzc/hygb/szygb/qgszygb/201508/t20150828_719423.html (in Chinese).

[e] According to data from the Ministry of Environmental Protection, among 329 cities inspected, 278 (84.5%) have urban source water quality that is up to the standard of protection.

[f] Ministry of Environmental Protection of the People's Republic of China. 2015. Pollutant Emissions. http://jcs.mep.gov.cn/hjzl/zkgb/2014zkgb/201506/t20150605_303007.shtml (in Chinese).

[g] Ministry of Environmental Protection of the People's Republic of China. 2014. *2013 China Environment Bulletin*. 5 June. http://jcs.mep.gov.cn/hjzl/zkgb/2013zkgb/201406/t20140605_276485.htm (in Chinese).

(iii) Rates of progress have been rapid and, if continued, all but one indicator (total water use) will exceed their 2015 mark.

(iv) The indicator for total water use is slightly behind, reporting a rate of progress of 2.4% in the first half of the 12th Five-Year Plan period and needing a 2.9% rate of progress in the second half of the same period to meet the target.

Toward the second half of the 12th Five-Year Plan period, the government has shifted to an action planning approach. The Action Plan for the Prevention and Control of Air Pollution was approved in August 2013, committing CNY1.7 billion ($258.3 million) in investment, and was followed by amendments to the Environmental Protection Law in April 2014. The State Council received a draft of the national action plan for clean water in June 2014, which calls for an estimated total investment of CNY2.0 billion ($303.8 million). The new clean water plan, Action Plan for the Prevention and Control of Water Pollution (also known as the Water Ten Plan), was finally issued on 16 April 2015. The plan focuses on water quality by controlling both industrial and municipal point sources as well as agricultural and stormwater nonpoint sources. The plan also aims to reduce the number of rivers and lakes classified as class V and worse. Class V quality water is suitable only for irrigation and landscaping, and class V+ (worse than class V) is unsuitable for any use.[12] An effectively implemented plan would mean improved ecosystems and water quality over the next 5 years.

A. Growth of Economic and Market Mechanisms for Water Security

Water management in the PRC has mainly relied on administrative command-and-control measures rather than on market mechanisms. This is consistent with the country's long tradition of a planned economy and centralized power.[13] For years now, the PRC has been initiating pilot tests and reforms with economic and market-based mechanisms for water management, including adjusting water prices, private sector participation, payment for ecosystem services (PES), and water rights and water quality trading. The establishment of a regulatory environment governing water allocations, rights, trading, and monitoring has lagged behind, along with private sector participation. Until the situation improves, the impacts of the PRC government's attempts at financial and economic methods in water management will remain limited.

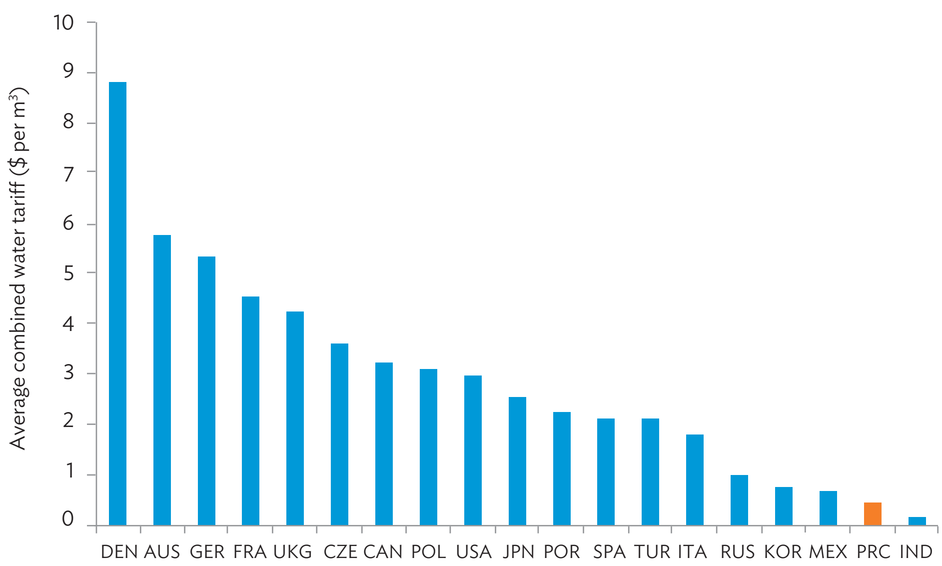
12 According to the PRC Ministry of Environmental Protection, the Environmental Quality Standards for Surface Water were formulated for implementing the Environmental Protection Law and Law of Water Pollution Prevention and Control of the PRC, and to control water pollution and protect water resources. The standard is applicable to surface water bodies of rivers, lakes, and reservoirs within the PRC's territory. The water bodies are divided into five classes according to the utilization purposes and protection objectives: (i) class I is mainly applicable to the water from sources and the national nature reserves; (ii) class II is mainly applicable to the first class of protected areas for centralized sources of drinking water, the protected areas for rare fish, and the spawning fields of fish and shrimps; (iii) class III is mainly applicable to the second class of protected areas for centralized sources of drinking water, protected areas for the common fish, and swimming areas; (iv) class IV is mainly applicable to the water areas for industrial use and entertainment not directly touched by human bodies; and (v) class V is mainly applicable to the water bodies for agricultural use and landscape requirement.

13 J. Xie. 2009. *Addressing China's Water Scarcity*. Washington, DC: World Bank.

1. Economic and Pricing Instruments

Water tariffs (e.g., water supply and wastewater) in the PRC are still below the price needed to recover the full financial cost of services. The water pricing, which is historically established by the government, is generally set below the costs of water transfer, protection, and treatment (particularly for irrigation water). Notwithstanding the spate of price increases in recent years, average water tariffs remain 70%-80% below the international standard.[14] The average combined water and wastewater tariff for residential consumers of 36 PRC cities[15] was $0.44 per cubic meter in April 2014, with the average price for water supply at $0.32 per cubic meter and the average price for wastewater treatment at $0.13 per cubic meter.[16] Figure 3 shows that water tariffs in the PRC are much lower compared to other countries. The tariffs in the Republic of Korea, Mexico, and the Russian Federation

Figure 3: Average Combined Water Tariffs in Selected Countries



AUS = Australia, CAN = Canada, CZE = Czech Republic, DEN = Denmark, FRA = France, GER = Germany, IND = India, ITA = Italy, JPN = Japan, KOR = Republic of Korea, m^3 = cubic meter, MEX = Mexico, POL = Poland, POR = Portugal, PRC = People's Republic of China, RUS = Russian Federation, SPA = Spain, TUR = Turkey, UKG = United Kingdom, USA = United States.

Note: The average combined water tariff in the People's Republic of China was based on the tariffs of 36 cities in April 2014; the tariffs for other countries were based on 2011.

Sources: Global Water Intelligence and Organisation for Economic Co-operation and Development. 2011. Global Water Tariff Survey. *Global Water Intelligence*. 12 (9); China Water Net Water Tariff Database. http://price.h2o-china.com/ (in Chinese).

[14] B. Walker, I. Hilton, C. Huiyi, H. Yunqing, and Y. Chen. 2014. China's Water Security Crisis. Europe China Research and Advice Network. https://eeas.europa.eu/china/docs/division_ecran/isl22_chinas_water_security_crisis_beth_walker_et_al_en.docx

[15] The 36 key cities include 31 provincial capitals and 5 subprovincial cities.

[16] China Water Net Water Tariff Database. http://price.h2o-china.com/ (in Chinese).

are about 1.5–2.0 times that in the PRC, while tariffs in the European Union countries are 10 times higher.

In December 2013, the National Development and Reform Commission (NDRC) and the Ministry of Housing and Urban–Rural Development issued the Guidance on Accelerating the Establishment of Increasing Block Water Tariff System for Residential Water Use (No. 2676 Pricing Policy Paper) to advance water tariff reforms. Many countries practice an increasing block tariff (IBT) approach to motivate residential consumers to use water more conservatively or efficiently. The IBT structure is a stepwise pricing model that charges a higher rate per unit (e.g., cubic meter) at higher levels of water consumption and a lower rate at lower consumption levels. An ideal IBT scheme would contain three blocks or tiers: (i) the first block (also called "baseline" or "lifeline") corresponds to the essential minimum household water consumption; (ii) the "normal" block corresponds to the average consumption defined on the basis of the marginal cost; and (iii) the "high" block is set at a price designed to finance the full cost of the service. Each successive block has a higher price per unit of water consumed, such that the more consumers use water, the higher the average price. This pricing design encourages consumers to save water through appropriate price signals.

Box 1 presents the European experience in water (and wastewater) pricing system.

Box 1: Europe's "Water Pays for Water"—and Wastewater—with Right Mix of Revenues

The European experience shows that water resources management can be effectively improved through a pricing system that reflects the full cost of water supply and wastewater treatment and includes environmental costs. In order to achieve sustainable cost recovery, the right mix of revenues from the sector (tariffs, taxes, and transfers) needs to be established.

Water resources management is decentralized to the river basin level in most European countries: municipalities own their infrastructure and manage it directly or through a contract for a limited time to a specialized public or private operator. The state has a regulatory role and establishes general rules for the utilities' management, public health, environmental protection, and guaranteed access to water for everyone.

Water agencies are tasked with the collection of funds according to the "polluter pays" or "user pays" principle: they levy taxes on water abstractions and discharges from all users who affect the water quality or modify the water regime. Revenues from these taxes are allocated to water resources conservation activities. Other contributions to the financing of water policies are transfers from the European Union, the central government and relevant ministries, as well as regional governments and municipalities.

Water taxes are levied on water users (and are differentiated from income taxes) through the water bill. The tax rates are broadly regulated by the parliaments and are then modulated by each river basin commission according to the uses and fragility of the environment.

continued on next page

Box 1 *continued*

In France, for example, the water bill includes the costs (capital and operation and maintenance) of drinking water supply (40%) and sanitation services (46%), as well as the taxes levied by the water agencies and the value-added tax (14%). In 2004, this amounted to about €177 per capita per year, representing about 0.8% of the household budget. The water bill consists of a fixed part, which gives the right to drinking water and sanitation and covers the fixed management costs (about €56 in 2004), and a variable part, which strictly depends on the consumed volume measured by meter.

The European experience on integrated river basin management has proved successful in fostering a coordinated approach between upstream and downstream, quantity and quality, and surface and ground water. The integrated river basin management approach is based, however, on clear coordination mandates of independent river basin commissions (or agencies), which can ensure consistency of actions and implementation of management plans over the entire river basin, beyond administrative boundaries.

In most European countries, the driver for reforms in the water management sector and the trend toward privatization were the huge bills in the 1980s needed to comply with the European Union standards for drinking water and effluents. In some instances, the decision itself to privatize water services stimulated a careful examination of the regulatory framework and provided an opportunity to separate operations from regulation and to improve environmental regulation.

Piped water supply and sewerage systems characterized by economies of scale are considered natural monopolies, since building more than one system to serve the same location is not economical. In the absence of competition, utility regulation is needed to incentivize efficiency by improving access, quality, and efficiency in the production and consumption of services. In the United Kingdom (as in the United States), the practice is to create independent regulatory authorities to regulate water prices, encourage sound investment programs and financial viability, and monitor the quality of service and consumer affairs. The independence of the regulator is supported to ensure objectivity, predictability, and freedom from short-term political interference in regulatory decisions. In contrast, in other countries (e.g., France), the regulatory approach is closely linked to the democratic political process, and operators' fees are established based on common interests of local governments and private operators.

Source: X. Yang, J.-F. Donzier, and C. Noël. 2009. A Comparison between French and Chinese Legal Systems in Terms of Integrated Water Resources Management. http://www.inbo-news.org/IMG/pdf/Article_France-China-comparison.pdf

The Beijing Municipal Commission of Development and Reform began implementing a three-tier IBT for residential consumers on 1 May 2014. It is considered risky because the first or baseline block limits consumption to 180 m^3 per year per household, which is much higher than what the World Health Organization recommends as needed—i.e., about 5 m^3 per month (or 60 m^3 per year) for a household of four (footnote 13). Experts warn that an IBT may fail to control water consumption if the allowable limit for the first consumption block is too high. As a result, the first block tariff will not differentiate basic water uses (e.g., for cooking, drinking, and hygiene) from extraneous water uses (e.g., on cars, gardens, etc.).

The government has also continued to increase wastewater tariffs and to push the reform of the current water resources fee into a tax during the 12th Five-Year Plan. The Ordinance on Municipal Sewage and Wastewater Treatment (effective 1 January 2014) suggested increasing the rate of wastewater treatment to cover the cost of wastewater treatment and sludge disposal. The PRC has ushered in a new round of full-scale water tariff reform covering water resources, water supply, and wastewater. It has announced a progressive pricing scheme for water use—a new multitiered water pricing system, which is being implemented nationwide since 2015. The status of the full-scale water tariff, as of May 2014, is shown in Table 3.

Table 3: Urban Household Water Tariffs in 36 Major Cities of the People's Republic of China (as of May 2014)

City	Tier	Water (m^3)	Water Tariff (CNY/m^3)	Commencement
Beijing	I	≤ 180[a]	5.00	1 May 2014
	II	181 to 260[a]	7.00	
	III	> 260[a]	9.00	
Tianjin		NA	4.90	1 Nov 2011
Shijiazhuang		NA	3.63	1 Sep 2008
Taiyuan	I	≤ 3[b]	2.80	1 Sep 2008
	II	> 3 to 4.5[b]	5.10	
	III	> 4.5[b]	7.40	
Huhehaote	I	≤ 10[c]	3.00	15 Dec 2009
	II	> 10[c]	4.15	
Shenyang	I	≤ 12[c]	2.40	1 July 2009
	II	> 12 to 17[c]	3.60	
	III	> 17[c]	4.80	
Dalian	I	≤ 8[c]	3.10	1 Jan 2011
	II	> 8[c]	10.80	
Changchun		NA	2.50	1 Oct 2001
Harbin		NA	3.20	1 Jan 2010
Shanghai	I	≤ 220[a]	3.45	1 Aug 2013
	II	> 220 to 300[a]	4.83	
	III	> 300[a]	5.83	
	Shared		3.65	
Nanjing	I	≤ 20[c]	3.10	1 June 2012
	II	> 20 to 30[c]	3.81	
	III	> 30[c]	4.52	
Hangzhou		NA	1.85	
Ningbo	I	≤ 17[c]	3.20	1 July 2010
	II	> 17 to 30[c]	5.12	
	III	> 30[c]	6.8	
Hefei	I	≤ 12[c]	2.31	1 Oct 2010
	II	> 12 to 20[c]	2.77	
	III	> 20[c]	3.79	
Fuzhou	I	≤ 18[c]	2.55	1 Sep 2011
	II	> 18 to 25[c]	3.40	
	III	> 25[c]	4.25	
Xiamen	I	≤ 15[c]	2.80	1 Oct 2008
	II	> 15[c]	3.30	

continued on next page

Table 3 *continued*

City	Tier	Water (m^3)	Water Tariff (CNY/m^3)	Commencement
Nanchang	I	≤ 360[c]	2.38	1 Apr 2014
	II	> 360 to 480[a]	3.45	
	III	> 480[a]	5.54	
Jinan		NA	3.15	1 Jan 2010
Qingdao		NA	2.50	1 Apr 2005
Zhengzhou		NA	2.40	
Wuhan	I	≤ 25[d]	2.32	1 Feb 2013
	II	> 25 to 33[d]	3.08	
	III	> 33[d]	3.84	
Changsha	I	≤ 15[c]	2.28	1 Feb 2012
	II	> 15 to 22[c]	3.04	
	III	> 22[c]	3.79	
Guangzhou	I	≤ 26[c]	2.88	1 May 2012
	II	27 to 34[c]	4.17	
	III	> 34[c]	5.46	
Shenzhen	I	≤ 22[c]	3.11	1 Apr 2011
	II	23 to 30[c]	4.35	
	III	> 30[c]	5.99	
Nanning	I	≤ 32[c]	2.28	1 Jan 2010
	II	> 32 to 48[c]	3.01	
	III	> 48[c]	3.73	
Haikou		NA	2.35	2008
Chongqing		NA	3.50	1 Jan 2010
Chengdu		NA	2.94	20 Dec 2013
Guiyang	I	≤ 21[e]	2.70	1 Apr 2010
	II	> 21 to 36[e]	3.70	
	III	> 36[e]	4.70	
Kunming	I	≤ 10[c]	3.45	1 June 2009
	II	> 10 to 15[c]	5.90	
	III	> 15 to 20[c]	7.13	
	IV	> 20[c]	8.35	
Lhasa		NA	0.60	
Xi'an		NA	2.90	1 Jan 2010
Lanzhou		NA	2.25	1 Nov 2009
Xining		NA	2.05	1 Dec 2006
Yinchuan	I	≤ 12[c]	2.31	1 Jan 2011
	II	> 12 to 18[c]	3.41	
	III	> 18[c]	4.61	
Urumqi (Wulumuqi)	I	≤ 4[b]	2.10	1 Nov 2005
	II	> 4 to 6[b]	3.15	
	III	> 6[b]	4.20	
Average			2.70	

CNY = yuan, m^3 = cubic meter, NA = not available.

Note: For cities implementing multi-tier water price, the first stage is used for calculating the average value.

[a] per household per year
[b] per capita per month
[c] per household per month
[d] per household per month (for a household consisting of four persons)
[e] per household per month (for a household consisting of three persons)

Source: *China Report Hall*. 2014. Some Cities Residential Water Price Statistics in 2014. 12 August. http://www.chinabgao.com/stat/stats/36263.html (in Chinese).

2. Public–Private Partnership

The NDRC recently announced a plan for public–private management of infrastructure and public utilities.[17] Since the NDRC's first official build–operate–transfer scheme in 1997, over 51% of wastewater treatment projects (about 2,000 projects) and around 30% of water supply projects have involved private sector participation under various schemes. Although the private and the public sectors have come together to finance this infrastructure, there has been grave oversight in investment for the wastewater and water delivery systems that support the full functioning of the treatment and supply plants. The percentage of cities and counties with wastewater treatment plants has increased tremendously in the past decade, and the capacity of treatment plants are often excessive. Yet, the actual connectivity to the sewerage and treatment systems is only 58% in cities.[18]

3. Eco-Compensation Efforts

In the face of challenges to the PRC's water security, the central and local governments have been investing and seeking new measures and approaches for improving both supply-side and demand-side management of water resources and implementing integrated river basin management.[19] This has included several market-based environmental policy tools under the broad heading of "eco-compensation." Tasked with developing a national eco-compensation ordinance, the NDRC defines eco-compensation as a policy instrument or market-based mechanism that seeks to compensate those who sustainably manage the natural resources in exchange for the provision of one or more ecosystem services—e.g., water filtration, erosion control by maintaining forest cover, and improved watershed management (footnote 19). The PRC is in the forefront of eco-compensation efforts in Asia and can set a good example, particularly since basin and river health management and monitoring are major gaps in the region.

The 18th National Congress in 2012 and subsequent policies emphasized market-based approaches for water management. In 2010, the State Council organized an ad hoc working group of 11 departments and organizations to draft an eco-compensation policy paper.[20] In May of the same year, the Ministry of Finance, the Ministry of Environmental Protection, and the United Nations Development Programme signed a memorandum of understanding to invest $22.75 million from 2011 to 2015 in piloting eco-compensation schemes in the Liao River Basin. The State Council released, in April 2013, "Progress and Development of Establishing Eco-Compensation Mechanism," calling for market-based approaches to raise funds for implementing eco-compensation.

The PRC has bolstered its status as a global leader in applying compensation to promote ecological protection and restoration—$7.40 billion out of $8.17 billion in global payments for watershed services (about 91%) is from the PRC. Figure 4 illustrates the growth in

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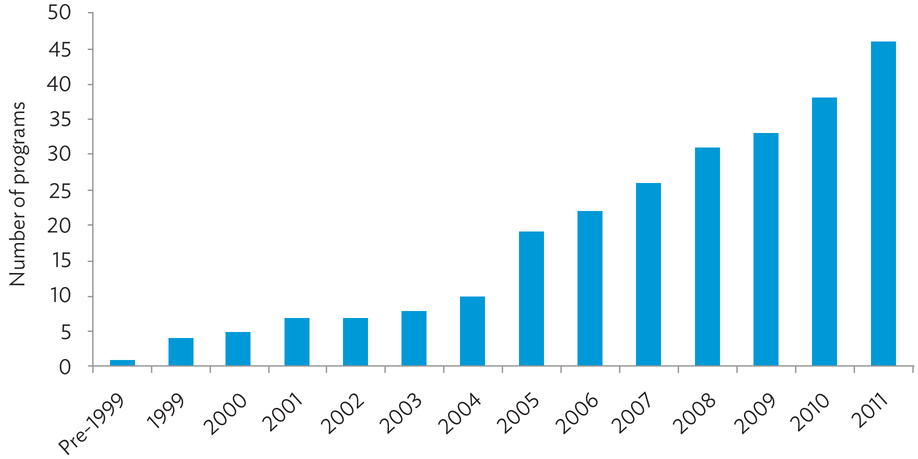
17 *Sina*. 2014. National Development and Reform Commission to Promote Infrastructure and Public Utilities. 22 April. http://finance.sina.com.cn/china/20140422/195918884395.shtml (in Chinese).

18 ADB. 2013. *Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific*. Manila; ADB. 2016. *Asian Water Development Outlook 2016: Strengthening Water Security in Asia and the Pacific*. Manila.

19 Q. Zhang and M. Bennett. 2011. *Eco-Compensation for Watershed Services in the People's Republic of China*. Manila: ADB.

20 National People's Congress of the PRC. 2014. Draft Ecological Compensation Ordinance Has Been Formed. 28 February. http://www.npc.gov.cn/npc/xinwen/dbgz/yajy/2014-02/28/content_1832491.htm (in Chinese).

Figure 4: Growth in Eco-Compensation for Watershed Services in the People's Republic of China, 1999–2011



Source: G. Bennett, N. Carroll, and K. Hamilton. 2013. *Charting New Waters: State of Watershed Payments 2012*. Washington, DC: Forest Trends.

eco-compensation programs for watershed services in the PRC, leading into the 12th Five-Year Plan. The eco-compensation programs by area of focus are illustrated in Figure 5. There has been clear growth in eco-compensation programs for cross-boundary water protection and watershed protection.

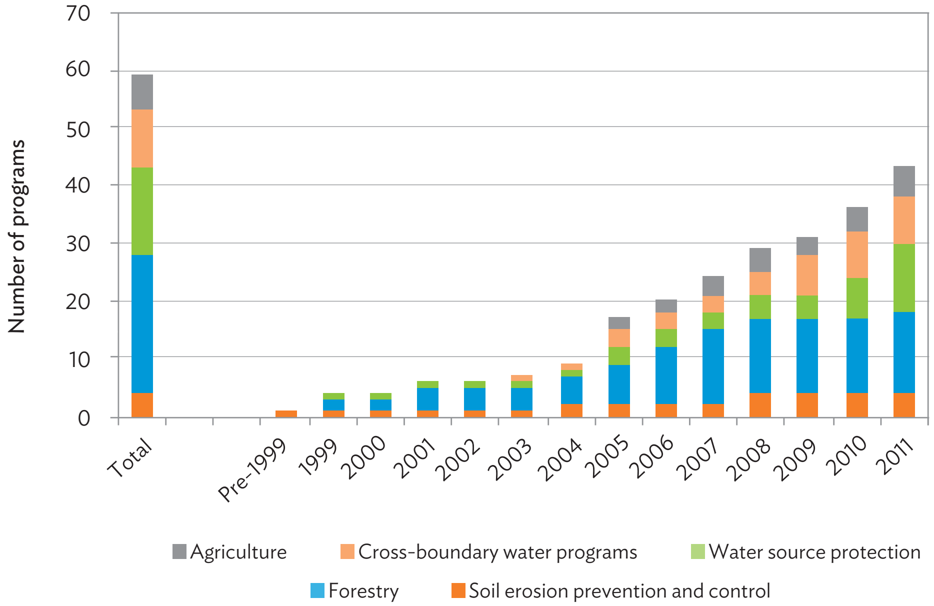
ADB, in partnership with the NDRC, has made great efforts to help the PRC build up eco-compensation, such as assisting in preparing the PRC's eco-compensation or PES regulation framework, investing in piloting eco-compensation or PES concepts in lending and technical assistance projects, and organizing international eco-compensation conferences and other knowledge-sharing events. In 2014, ADB, the NDRC, and the China Agricultural University signed a memorandum of understanding to set up the Regional Knowledge Hub on Green Growth and Eco-compensation to boost greener economies in the Asia and Pacific region.

4. Water Rights and Water Quality Trading

The first step in building water markets is the establishment of clear water rights, and the first step toward assuring these water rights is to have water resources allocation plans. The PRC Water Law provides the legal foundation for water rights and trading, but the setup of trading schemes needs to be improved, especially with allocating the initial water rights, establishing the trading platforms, and building the capacity of an agreeable intermediary organization for trading.[21] The sale or lease of water rights can help address the PRC's poor water productivity rates and increase environmental returns.

[21] Z. Wang. 2014. History and Current Development of Water Rights Trading in China. Presentation at the Harvard–Tsinghua Workshop on Market Mechanism to Achieve Low Carbon Future for China. Tsinghua University, Beijing, PRC. 4 June.

Figure 5: New Watershed Investment Programs by Area of Focus in the People's Republic of China, 1999–2011



Note: The yearly figures may not add up to the total due to lack of data in the starting years, particularly for provincial forest ecosystem compensation funds.

Source: G. Bennett, N. Carroll, and K. Hamilton. 2013. *Charting New Waters: State of Watershed Payments 2012*. Washington, DC: Forest Trends.

Although trading schemes have been growing, they have been limited to point sources and chemical oxygen demand only (in the case of nonpoint sources). Based on a 2012 feasibility study of nutrient trading in the Chao Lake Basin, ADB is now piloting a pollution trading scheme between industries (point sources) and agriculture (nonpoint sources).[22]

On 23 July 2014, the PRC announced that seven selected provinces and autonomous regions would host pilot markets for a water rights trading scheme. The provinces of Gansu, Guangdong, Henan, Hubei, and Jiangxi, along with Inner Mongolia Autonomous Region and Ningxia Hui Autonomous Region would draw up rules for their respective water markets and study how water rights can be distributed and usage rights registered. In June 2016, the PRC launched a national water rights exchange, as part of government efforts to encourage countrywide water conservation. The China Water Exchange will facilitate the trading of rights to use water between different areas and users, as well as provide consultation and technical services.

22 World Resources Institute. 2013. ADB Pilot and Demonstration Activity for the People's Republic of China: Assessing the Feasibility of Nutrient Trading between Point Sources and Nonpoint Sources in the Chao Lake Basin. Final report.

B. Integrated Water Resources Management and Institutional Innovation

To address its well-documented fragmented water management, the PRC has attempted to introduce integrated river basin management by establishing seven river basin commissions. As of 2014, the 1,539 integrated water authorities have been established at various levels across the country: 4 provincial, 7 subprovincial, 219 prefecture, and 1,309 county-level.[23] However, no significant progress has been made toward achieving integrated river basin management primarily because of administrative and political barriers.[24] The river basin commissions are subordinate agencies of the Ministry of Water Resources, which has no power to coordinate between provinces, municipal administrations, and other stakeholders in the river basin.

To help the PRC establish integrated river basin management, ADB provided support for major lake basins, such as the Chao Lake and Poyang Lake basins. In 2011, the Chao Lake Management Authority was created to address weak watershed management and coordination in the basin. The lake management authority was positioned directly under Anhui Provincial Government and reported directly to Hefei Municipal Government. It has different functions across traditional departments, including designing basinwide regulations, developing strategic plans, and overseeing water resources, environmental protection, fishery, tourism, and navigation in the basin. Although the Chao Lake Management Authority still faces challenges in coordinating with other departments, its establishment signaled an important step forward in the development of innovative institutional reform for integrated river basin management in the PRC. In 2013, Zhejiang Province also attempted to practice innovative integrated water governance by "Governing Five Waters Integrally"—i.e., overall coordination of flood control, pollution treatment, drainage enhancement, water supply, and water conservation activities.

The World Bank has suggested a national-level organization for integrated water resources management to serve as a high-level water policy-making body. Said organization would be responsible for coordinating water-related affairs across the country at the highest level of government. This addresses the issue of the seven existing river basin commissions being disempowered as subordinates of the Ministry of Water Resources. Under a national organization, they could operate more effectively as intersector and intergovernment commissions, with representatives from relevant line agencies and local governments. This national-level organization would be made independent from the Ministry of Water Resources and directly accountable to the State Council (footnote 13).

[23] Ministry of Water Resources of the PRC. 2014. *China Water Conservancy Development Statistical Bulletin.* http://www.mwr.gov.cn/zwzc/hygb/slfztjgb/201512/P020151201324918901407.pdf (in Chinese).

[24] ADB. 2014. Managing the Water Resources of Poyang Lake Watershed. Volume I: Main Report. Draft final consultant (AECOM) report. Manila (TA-7860 PRC).

III. The 2030 Demand Dilemma

Growth in the PRC's population, cities, and economies will drive continuous growth in water demand, leading international studies to conclude with almost certainty that the country will be water-deficient by 2030.

Using the 2005 water consumption total of 555 billion cubic meters (bcm) as a baseline, McKinsey & Company and the 2030 Water Resources Group estimate that annual water demand will be 818 bcm by 2030, while supply will only be 619 bcm—a 25% gap in projected total water demand in 2030. Total water demand in 2030 is expected to come mostly from agriculture (420 bcm), followed by industry (265 bcm), and municipal and residential (133 bcm).[25] McKinsey's forecast of industrial water demand in 2030 is double that of the actual water demand in 2010, with an annual growth rate of 3.1%. This is also significantly higher than the 2.5% annual growth rate for water use during 2000–2010. On the other hand, the government's plan may underestimate the potential rise in demand from industry and residences. The implied growth rates in these sectors are only half their historical rates.

In contradiction, the National Comprehensive Plan for Water Resources, approved by the State Council in 2010, uses an optimistic outlook. The plan aims to contain total water consumption at or below 670 bcm by 2020 and below 700 bcm by 2030. The targets were included in the 2011 No. 1 Policy Document issued by the Central Committee of the Communist Party of China. Also under the plan, water use in agriculture is set at 407.8 bcm by 2030, but sets a drastically lower consumption rate for industry at just 171.8 bcm in comparison to the rates proposed by McKinsey & Company and the 2030 Water Resources Group. Residential consumption is targeted at 102.1 bcm. The National Comprehensive Plan for Water Resources calls for aggressive water conservation.

Against the backdrop of rapid economic development and high urbanization and population growth, water resources in the PRC are getting scarcer. Annual gross domestic product (GDP) growth of just 4% would cause water demand to double by 2050.[26] The PRC has not come close to a GDP growth rate of just 4% since 1990. From 1980 until 2000, the PRC's average annual GDP growth was 9.9%, reaching a historical high of 15.2% in 1984 and a record low of 3.9% in 1990.[27] Given these trends, current planning and investment

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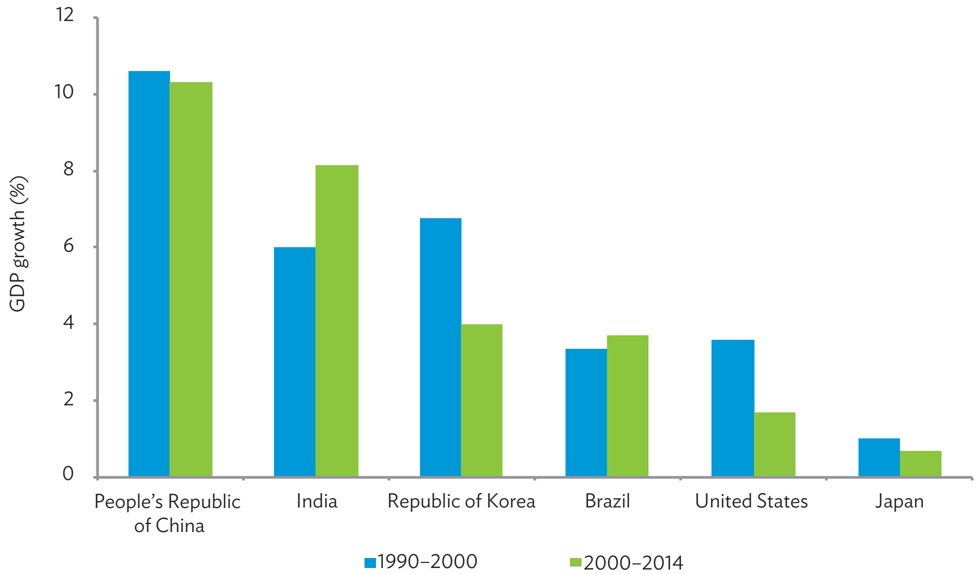
[25] 2030 Water Resources Group. 2009. *Charting Our Water Future: Economic Frameworks to Inform Decision-Making*. New York: McKinsey & Company.

[26] Z. Shalizi. 2008. Water and Urbanization. In S. Yusuf and T. Saich, eds. *China Urbanizes: Consequences, Strategies, and Policies*. Washington, DC: World Bank. pp. 157–179 (Chapter 7).

[27] World Bank. World Development Indicators: GDP Growth. http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG (accessed 4 May 2016).

Figure 6: Comparative Average Annual Growth in Gross Domestic Product in Selected Countries, 1990–2014



GDP = gross domestic product.

Source: World Bank. 2015. *World Development Indicators*. Washington, DC.

need to address the challenging issue of water governance. The PRC's economic growth was reported at an annual average of 10.6% for the period 1990–2000 and 10.3% during 2000–2014, much higher than the rates of Brazil, India, Japan, the Republic of Korea, and the United States (Figure 6).

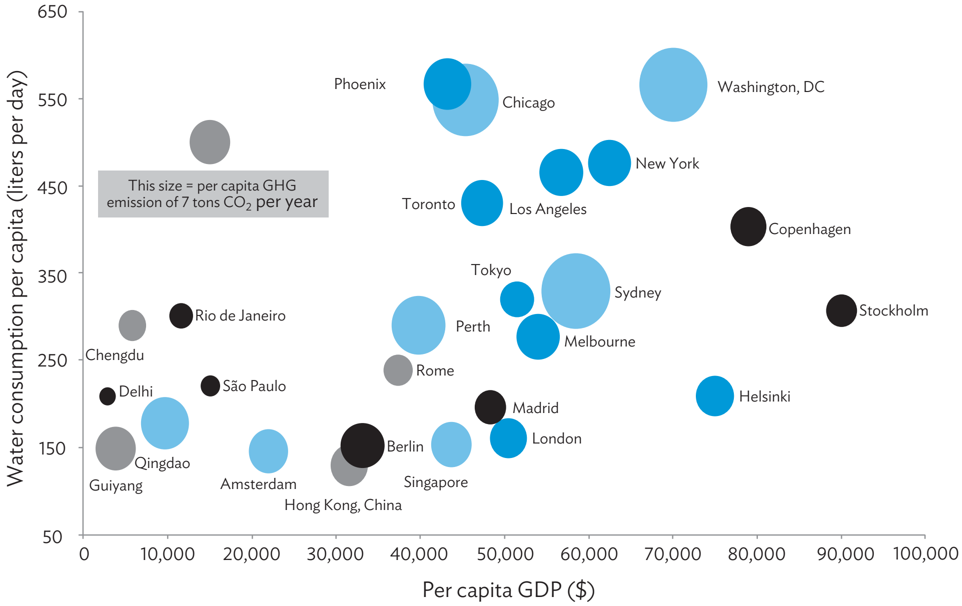
A rise in the urban population would have a larger impact on water demand compared to an increase in the overall population. A simple simulation model undertaken by the World Bank concluded that "the doubling of overall population growth rate from 0.20% to 0.45% p.a. has a negligible impact on water demand. The increase in the urban share of the population, however, is more significant particularly if the average demand for water of urban households continues to grow rapidly."[28]

Many European cities have found a balance between high income and moderate municipal water use (Figure 7). To feed a fifth of the global population with limited water resources, the PRC cannot follow the water use pattern of North America. The PRC has to take actions to cap the residential water use per capita at a moderate level.

Climate change projections for the PRC add support to the 2030 supply–demand gap. Changes in water distribution across the country and the seasons are highly likely, which will

[28] Z. Shalizi. 2006. Addressing China's Growing Water Shortages and Associated Social and Environmental Consequences. World Bank Policy Research Working Paper 3895. Washington, DC: World Bank. p. 19. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2006/04/18/000016406_20060418155242/Rendered/PDF/wps3895.pdf

Figure 7: Gross Domestic Product per Capita, Daily Residential Water Use, and Greenhouse Gas Emissions per Capita of Selected Cities, 2014



CO_2 = carbon dioxide, GDP = gross domestic product, GHG = greenhouse gas.
Source: Adopted from the World Resources Institute, 2014.

be an additional stress to the expected increase in water demand and urbanization. Water demand will expectedly increase due to socioeconomic growth, and it will likely be more concentrated in urban areas.[29] In addition, water supply will become less certain and will not be enough to meet demand. The droughts and excessive rain will not only compromise residential and industrial water supply, but also food production.

The PRC has opted for increasing water supply without seriously considering how to reduce demand by increasing water use efficiency. The country has relied on increasing reservoirs, long-distance water transfers and, to a much lesser degree, desalination, reclaimed wastewater, and rainwater harvesting. The South–North Water Transfer Project aims to curb the over-withdrawal of groundwater and supply more water to industries, cities, and the PRC's breadbasket in the north. This massive water diversion scheme, which is planned for completion in 2050, targets to divert 44.8 bcm of water annually from the Yangtze River in southern PRC to the Yellow River Basin in the arid northern region of the country.[30] It will link the PRC's four main rivers—Yangtze, Yellow, Huai, and Hai—and requires the construction of three diversion routes, stretching south to north across the eastern, central,

[29] S. Piao, P. Ciais, Y. Huang, Z. Shen, S. Peng, J. Li, L. Zhou, H. Liu, Y. Ma, Y. Ding, P. Friedlingstein, C. Liu, K. Tan, Y. Yu, T. Zhang, and J. Fang. 2010. The Impacts of Climate Change on Water Resources and Agriculture in China. *Nature*. 467 (7311). pp. 43–51.

[30] South-to-North Water Diversion. http://www.nsbd.gov.cn/zx/english/; Water Technology. South-to-North Water Diversion Project, China. http://www.water-technology.net/projects/south_north/

and western parts of the country.[31] Unfortunately, the project will not be enough to bridge the water supply–demand gap. The north, in particular, will need to continue saving water and enhancing water efficiency. Moreover, the diversion scheme has raised numerous environmental concerns, such as worsening of pollution problems (particularly, with respect to the diverted water), destruction of pasture land, loss of antiquities, and displacement of large population groups.

Aside from the problem of the excessively high water withdrawal rate, withdrawn water is chronically unproductive. The comparatively low total water productivity of the PRC reflects its inefficient water use. The PRC's water productivity of wheat averages 0.82 kilogram per cubic meter (kg/m^3), while other countries can reach almost twice as much—e.g., South Africa (1.57 kg/m^3), Ireland (1.45 kg/m^3), Chile (1.42 kg/m^3), and France (1.42 kg/m^3).[32] To achieve the efficiency targets of the Three Red Lines policy, the PRC must turn to demand management through both structural and nonstructural technological approaches that provide the assurance to engineers and governments for investments.

The PRC is facing several serious challenges to its water security—e.g., risks associated with reliability of water supply infrastructure, risks associated with capacity of water treatment and storage facilities, risks to water supply caused by reliance on a single water source, and other risks due to climate change impacts. Yet, there is still insufficient understanding about the urgency of the water risks that cities in particular face, especially in terms of the economic and energy impacts of insufficient water supplies. In order to employ smarter, more climate-resilient policies and programs, it is necessary to understand water security comprehensively, which often requires a systematic approach.

In 2013, the United Nations interagency coordination mechanism for all freshwater related issues (i.e., UN-Water), in its *Analytical Brief on Water Security and the Global Water Agenda*, provided a working definition of water security as "the capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socioeconomic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."[33] UN-Water also emphasized that water security can only be attained through transboundary cooperation and collaboration across sectors, communities, and states for the formulation of a collective response to water security threats and challenges. As a country poised to become a developed nation in the near future, the PRC should address water security issues at a reasonable and comparable level with other developed countries.

31 Phase 1 of the project is expected to convey 600 m^3 per second from the Yangtze River in the reach of Jiangsu Province to Jiaodong region in Shandong Province through the Eastern Route, and 630 m^3 per second from the Han River, the largest tributary of the Yangtze River, to Henan, Hebei, Beijing, and Tianjin through the Middle Route.

32 S.J. Zwart, W.G.M. Bastiaanssen, C. de Fraiture, and D. Molden. 2010. A Global Benchmark Map of Water Productivity for Rainfed and Irrigated Wheat. *Agricultural Water Management*. 97 (10). pp. 1617–1627.

33 UN-Water. Water Security. http://www.unwater.org/topics/water-security/en/

IV. State of Water Security

To inform the recommendations for the 13th Five-Year Plan preparations, ADB has used the water security framework of its Asian Water Development Outlook (2013 and 2016 editions) to examine the PRC's current state of water security. The Asian Water Development Outlook provides a quantitative framework for scoring the water security levels of 48 countries in Asia and the Pacific (footnote 18). Country-based scores, comparative regional rankings, and key messages provide directions and priorities for higher investments, improved governance, and capacity development.

The Asian Water Development Outlook measures water security in five dimensions: (i) household (i.e., access to piped potable water and improved sanitation facilities), (ii) economic, (iii) urban (i.e., progress in providing better urban water services to build more livable cities), (iv) environmental (i.e., restoring healthy rivers and ecosystems), and (v) resilience to water-related disasters (Figure 8). Country scores for each key dimension are based on an index of several indicators, proxies, and subindexes (Table 4). Focusing on just one of these dimensions would have been insufficient to guide decisions or assess

Figure 8: Water Security Framework of Five Interdependent Key Dimensions

Source: Asian Development Bank (ADB). 2013. *Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific*. Manila ; ADB. 2016. *Asian Water Development Outlook 2016: Strengthening Water Security in Asia and the Pacific*. Manila.

Table 4: Asian Water Development Outlook Framework for Assessing National Water Security

Key Dimension	Index	What the Index Measures
National Water Security	National water security	How far countries have progressed toward national water security. The index combines the five dimensions of water security, measured by key dimensions 1–5.
Key Dimension 1	Household water security	To what extent countries are satisfying their household water and sanitation needs and improving hygiene for public health. The household water security index is a composite of three subindexes.
Key Dimension 2	Economic waster security	The productive use of water to sustain economic growth in food production, industry, and energy. The index is a composite of three subindexes.
Key Dimension 3	Urban water security	Progress toward better urban water services and management to develop vibrant, livable cities and towns. The index is a composite of three subindexes.
Key Dimension 4	Environmental water security	How well river basins are being developed and managed to sustain ecosystem services. The index is determined by spatial analysis of four subindexes of river health.
Key Dimension 5	Resilience to water-related disasters	The capacity to cope with and recover from the impacts of water-related disasters. The index is a composite of three subindexes.

Note: Full definitions of the derivation of the indicators are provided in the *Asian Water Development Outlook 2013* supplementary DVD.

Source: Asian Development Bank (ADB). 2013. *Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific*. Manila; ADB. 2016. *Asian Water Development Outlook 2016: Strengthening Water Security in Asia and the Pacific*. Manila.

outcomes in the water sector. The analysis of water security using the five key dimensions with the developed indicator systems has made the Asian Water Development Outlook methodology a systematic and comprehensive water security monitoring framework. The indicators used to assess each of the five dimensions are summarized in Table 5, along with the scores for the PRC and the regional median scores for Asia and the Pacific.[34]

The PRC scored "low" for overall water security. It was rated 2 out of a possible 5 on the Asian Water Development Outlook's water security index, due to low scores for urban water security, environmental water security, and resilience to water-related disasters. These low scores identify hot spots for additional investments and efforts.

[34] Updates for the *Asian Water Development Outlook 2016* have refined indicators for each key dimension and included more recent datasets and more detailed levels of spatial aggregation. The new edition tracks progress in water security in Asia and the Pacific for the period 2011–2015.

Table 5: Water Security Index of the People's Republic of China and Median Scores for Asia and the Pacific, 2013

Key Dimensions and Indicators	PRC Score (Raw Value)	Median for 49 Countries in Asia and the Pacific
OVERALL WATER SECURITY INDEX	**2**	**2**
Household Water Security Index	**3**	**3**
Access to piped water supply	2 (68%)	NA
Access to improved sanitation	2 (64%)	NA
Hygiene (age-standardized disability-adjusted life years per 100,000 people for the incidence of diarrhea)	3 (324)	NA
Economic Water Security Index	**4**	**3**
Agricultural water security	(7.22)	NA
Industrial water security	(6.22)	NA
Energy water security	(7.11)	NA
Urban Water Security Index	**2**	**2**
Water supply	5 (95%)	NA
Wastewater treatment	1 (58%)	NA
Drainage (the extent of economic damage caused by floods and storms measured in $ per capita)	4 (119.58)	NA
Environmental Water Security Index	**2 (0.26)**	**2**
Resilience to Water-Related Disasters Index	**2**	**2**
Flood indicator	(0.44)	NA
Drought indicator	(0.43)	NA
Coastal indicator	(0.48)	NA

NA = not available, PRC = People's Republic of China.

Notes:

1. The overall national water security of each country is assessed as the composite result of the five key dimensions, measured on a scale of 1 to 5. A national water security index of 1 means the national water situation is hazardous, whereas an index of 5 means the country is as water-secure as possible under current circumstances.
2. Numbers in parenthesis are the values of the subindex, while numbers outside the parenthesis are the corresponding score for that subindex.
3. Each subindex of the economic water security index is evaluated on a scale of 1 to 10, with 1 being insecure and 10 being secure. The mean scores for each subindex give the total economic water security of the country's economy.
4. The water-related disasters resilience index is a composite of subindexes based on type of hazard (floods, droughts, and coastal flooding) evaluated in terms of the following factors: exposure (e.g., population density, growth rate), basic population vulnerability (e.g., poverty rate, land use), and country's coping capacities (e.g., telecommunications development level, literacy rate).

Source: Asian Development Bank. 2013. *Asian Water Development Outlook 2013: Measuring Water Security in Asia and the Pacific*. Manila.

Good governance and water security are inseparable factors. Preliminary assessments show that the more positive the governance assessment, the higher the water security assessment. The PRC's stage of water security equates with what the Asian Water Development Outlook describes as "engaged"—i.e., there are government capacity-building programs supporting policy and legislation; institutional measures are improving; and public investment levels are rising, albeit still insufficient.

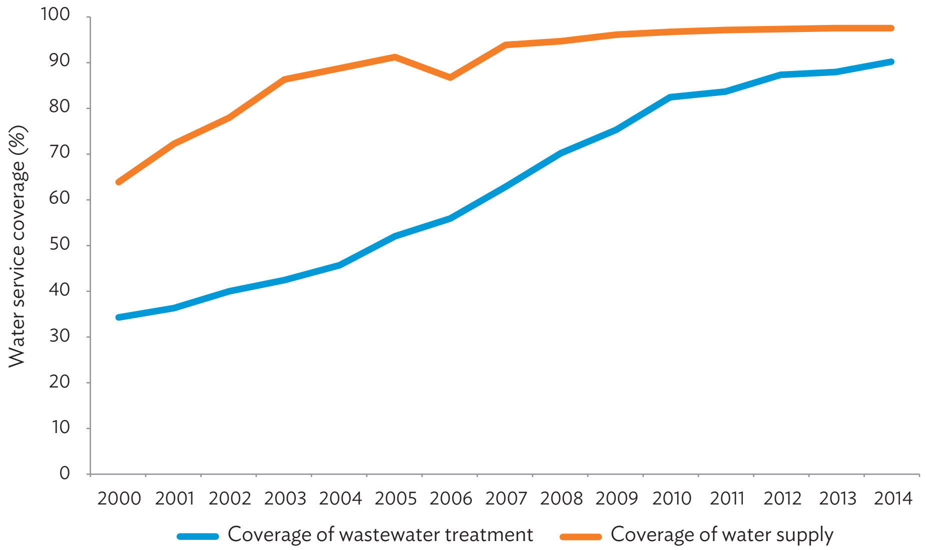
A. Key Dimension 1: Household Water Security

The past decade saw a continuous increase in water infrastructure, in particular the growth of urban wastewater infrastructure. Since 2006, a total of over 3,000 new wastewater treatment plants were constructed and valued at a total investment of around CNY270 billion ($41.0 billion). This growth increased urban wastewater treatment from 52.0% in 2005 to 90.2% in 2014 (Figure 9).

About two-thirds of the 31 provinces in the PRC have accelerated the development of wastewater treatment plants since 2000 (Figure 10).

In addition to urban water services, the PRC has made great progress in expanding rural access to water services. In the 12th Five-Year Plan period, the central government has continued to enhance access to improved water sources in rural areas. The government plans on providing a safe water supply to an additional 298 million rural people that do not have access to a safe water supply by 2015. The interim estimate for the rural population with a safe water supply increased by 160 million from 2011 to the middle of 2013—this is about 53.6% of the 12th Five-Year Plan target.[35] From 2006 to 2012, a total of

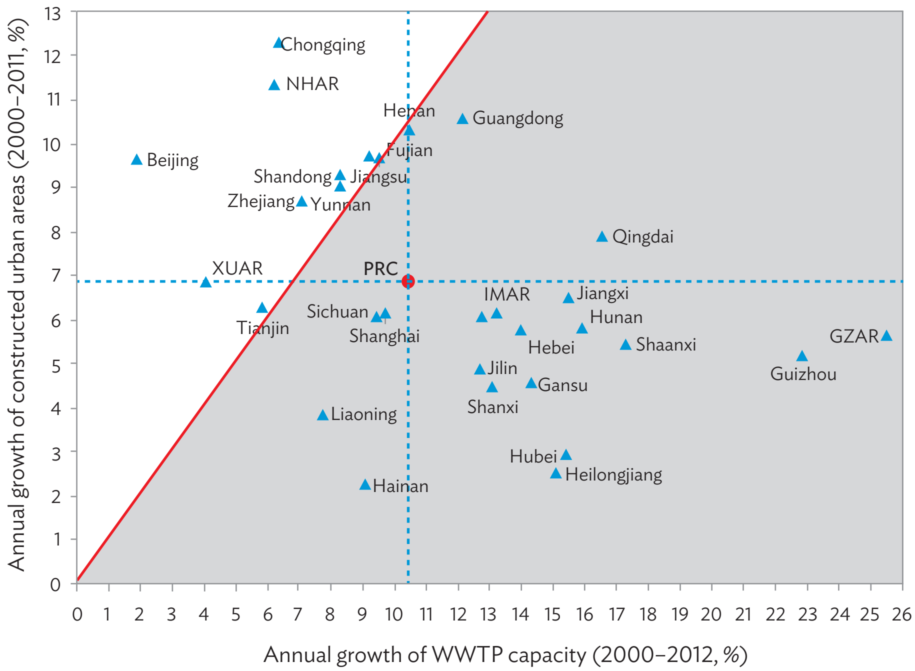
Figure 9: Coverage of Urban Water Supply and Wastewater Treatment Services in the People's Republic of China, 2000–2014



Source: Ministry of Housing and Urban–Rural Development of the People's Republic of China. Various years. *China Urban Construction Statistical Yearbook*. Beijing: China Planning Press.

[35] Ministry of Water Resources of the PRC. 2014. Mid-Term Evaluation for the 12th Five-Year-Plan for Water Conservancy. Beijing.

Figure 10: Average Annual Growth of Constructed Urban Areas and Wastewater Treatment Capacity by Province in the People's Republic of China, 2000–2011/12



GZAR = Guangxi Zhuang Autonomous Region, IMAR = Inner Mongolia Autonomous Region, NHAR = Ningxia Hui Autonomous Region, PRC = People's Republic of China, WWTP = wastewater treatment plant, XUAR = Xinjiang Uygur Autonomous Region.

Notes:

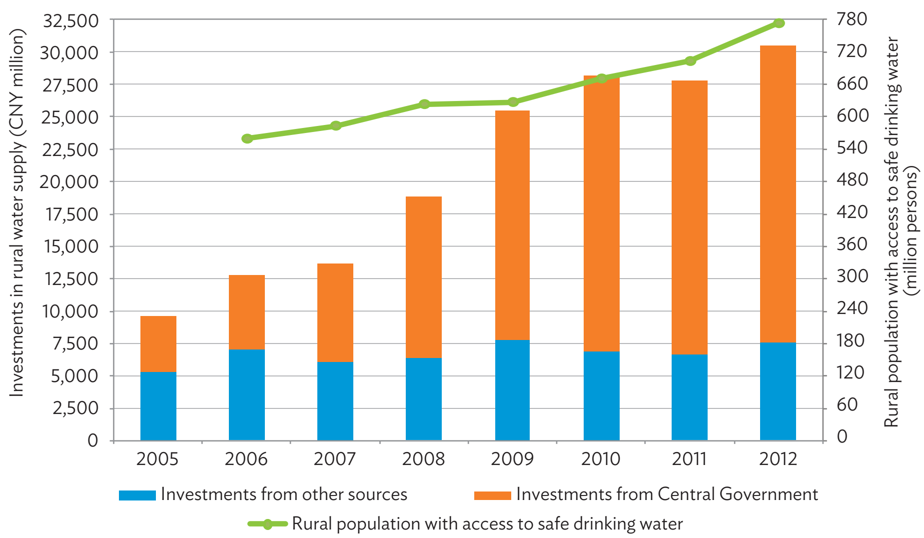
1. The red line indicates equality (i.e., on par growth between new urban areas and WWTP capacity).
2. The blue dotted lines are the average national growth in both urban areas and WWTP capacity.
3. Constructed urban area is land developed for nonagricultural purposes, characterized by public infrastructure, such as airport, railway, wastewater treatment, communication, etc.

Sources: Ministry of Housing and Urban–Rural Development of the People's Republic of China (MHURD). Various years. *National Wastewater Treatment Facilities Report*. Beijing; MHURD. Various years. *China Urban Construction Statistical Yearbook*. Beijing: China Planning Press; and World Resources Institute estimates.

CNY157 billion ($23.9 billion) was invested in rural water supply infrastructure. The central government increased its investment share from 45% in 2006 to about 75% in 2012. With these efforts, the total rural population with access to safe drinking water increased by 38% from 2006 to 2012 (Figure 11).

The PRC surpassed the 2015 targets for improving water and sanitation under the Millennium Development Goals. However, the combination of a rising population and living standards with increased per capita income suggests that the demand for water in the PRC will continue to escalate. The PRC should continue investing in water to satisfy the new targets for 2030 under the Sustainable Development Goals, which aim at safe and affordable drinking water as well as sanitation for all.

Figure 11: Investments in Rural Water Supply and Rural Population with Access to Safe Drinking Water in the People's Republic of China, 2005–2012



Note: The rural population with access to safe drinking water in 2012 is an estimated value.

Sources: Ministry of Environmental Protection of the People's Republic of China. Various years. *Environmental Statistics Yearbook*. Beijing; Ministry of Water Resources of the People's Republic of China. Various years. *Water Conservancy Statistics Yearbook*. Beijing; World Resources Institute estimates.

B. Key Dimension 2: Economic Water Security and the Water–Energy–Food Nexus

The PRC recognizes the importance of water to sustain advances in poverty reduction and economic growth, and the country scored 4 out of 5 on the economic water security index of the Asian Water Development Outlook. The Asian Water Development Outlook treats economic water security as assurance of sufficient quality and quantity of water to sustainably satisfy a country's economic requirements. It measures economic water security by evaluating the productive use of water in food, industrial, and energy production.[36] Yet, productivity needs to be coupled with efficiency to curtail the pending threat of increased competition as demands increase while per capita freshwater availability shrinks.

36 The indicators within the agricultural water security subindex are (i) productivity of irrigated agriculture, (ii) independence from imported water and goods, and (iii) resilience (percentage of renewable water resources stored in large dams). The indicators within the industrial water security subindex are (i) productivity (financial value of industrial goods relative to industrial water withdrawal) and (ii) consumption rate (net virtual water consumed relative to water withdrawn for industry). The indicators within the energy water security subindex are (i) utilization of total hydropower capacity and (ii) ratio of hydropower to total energy supply.

Competition for water, particularly between the agriculture and energy sectors, is a major factor of water stress in the PRC. Water stress happens either when water demand exceeds the available water supply in a particular period or when water quality is poor, thereby limiting its usage. Water use for thermal energy generation is substantial, and improving water efficiency in the energy sector (along with diversification of energy sources) is essential. Increases in agricultural water productivity and efficiency will be required to contribute to food security for the growing population.

The World Resources Institute's Aqueduct Water Risk Atlas shows that the PRC has medium-to-high water stress, meaning that it faces medium-to-high levels of competition between major water users in the watershed.[37] Globally, in terms of baseline water stress (2010), the PRC is ranked close to the middle, at 69th out of 180 countries. Comparatively, water stress levels in India, Japan, and the Republic of Korea are higher than in the PRC, and that in the United States is the same as in the PRC. The water stress level in Brazil, though, is lower than in the PRC because Brazil has abundant water resources (Figure 12).[38] However, due to an uneven spatial and temporal distribution of water resources, the PRC faces more water stress in the north as compared with the south.

The government's Three Red Lines policy caps the total national water abstraction at 700 bcm in 2030 in a bid to drive investments in improved water productivity, water use efficiency across the economy, and improved water quality in rivers and lakes.

A case study on competition over water resources between agriculture and energy sectors in Israel is presented in Box 2.

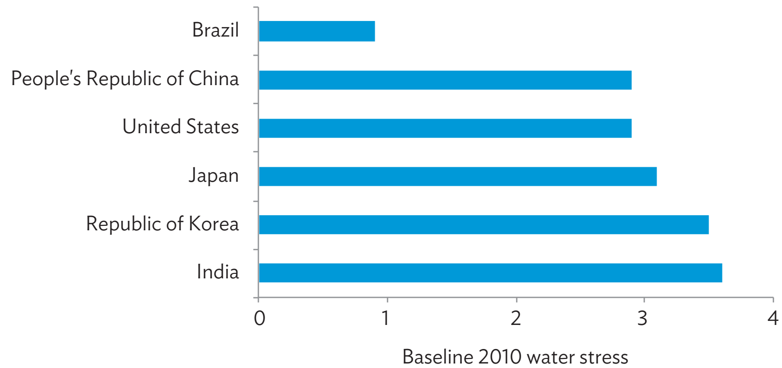
1. Threat 1: Low Water Productivity

Compared to developed countries like Japan ($59 per cubic meter), Republic of Korea ($42 per cubic meter), and the United States ($31 per cubic meter), the PRC's total water productivity at $10 per cubic meter in 2014 is low (Figure 13). It is also low in comparison with the world average of $15 per cubic meter, and the average of countries in East Asia and the Pacific ($13 per cubic meter) and the European Union ($87 per cubic meter) (footnote 7). However, water productivity and water use efficiency vary greatly across the PRC. This is because water resources in the PRC are unevenly distributed, both spatially and temporally, and the climate varies significantly across the country. There is also an evident mismatch of water resources with land resources and population. For example, the Yangtze River, the source of 80% of the PRC's water resources, serves only 36% of the

37 Water stress is defined as the ratio between total water withdrawals and available renewable surface water at a subcatchment level. Higher scores on the scale from 0 to 5 correspond to greater competition among water users relative to available surface water resources (T. Luo, R. Young, and P. Reig. 2015. Aqueduct Projected Water Stress Rankings. Technical note. Washington, DC: World Resources Institute. August. http://www.wri.org/publication/aqueduct-projected-water-stress-country-rankings; World Resources Institute. Aqueduct Water Risk Atlas. http://www.wri.org/resources/maps/aqueduct-water-risk-atlas)

38 World Resources Institute. Aqueduct Country and River Basin Rankings. Baseline Water Stress Indicator. http://www.wri.org/applications/maps/aqueduct-country-river-basin-rankings/#x=-150.58&y=-30.00&l=5&v=home&d=bws&f=0&o=32

Figure 12: Baseline Water Stress (2010) in Selected Countries



Score	Value
0–1	Low (<10%)
1–2	Low to medium (10%–20%)
2–3	Medium to high (20%–40%)
3–4	High (40%–80%)
4–5	Extremely high (>80%)

Notes: Baseline water stress measures how much water is withdrawn every year from rivers, streams, and shallow aquifers for domestic, agricultural, and industrial uses. It is the ratio of total annual water withdrawals to total available annual renewable supply. Higher values indicate more competition among users.

Source: World Resources Institute. Aqueduct Country and River Basin Rankings. Baseline Water Stress Indicator. http://www.wri.org/applications/maps/aqueduct-country-river-basin-rankings/#x=-150.58&y=-30.00&l=5&v=home&d=bws&f=0&o=32

country's land resources; conversely, northern PRC, which has only 20% of the PRC's water resources, serves 60% of the national cropped area and 40% of the population.[39]

In 2012, total water use per capita in Xinjiang Uygur Autonomous Region (2,657 m^3) was approximately 16 times as much as in Tianjin (167 m^3), partly because 95% of Xinjiang Uygur Autonomous Region's water consumption is for agricultural production (Figure 14).

To produce CNY10,000 ($1,519.20) of GDP, the PRC consumes an average of 118 m^3 of water. Among the PRC's areas, Tianjin consumes about 12 m^3 of water to produce CNY10,000 ($1,519.20) of GDP, while Xinjiang Uygur Autonomous Region consumes 786 m^3 (Figure 15). Due to extreme water scarcity in Tianjin, households in the province have to adopt a water-saving livelihood style.

The regional differences for industrial water productivity are even greater. The average water use for CNY10,000 ($1,519.20) of industrial value added in the country was about 69 m^3 in 2012. Tibet Autonomous Region needs 102 times more water to produce the same industrial value added as Tianjin (Figure 16).

[39] Global Water Partnership. 2015. *China's Water Resources Management Challenge: The "Three Red Lines."* Stockholm. http://www.gwp.org/Global/ToolBox/Publications/Technical%20Focus%20Papers/TFPChina_2015.pdf

Box 2: Israel's Water–Energy–Food Nexus

Israel, with climate varying from semi-arid to arid and hyper-arid, has high levels of solar radiation and, thus, evapotranspiration, accompanied by a low precipitation rate.[a] Most freshwater sources in Israel either originate from other countries (e.g., rivers), or are shared with them, including its two main aquifers—the coastal aquifer and the mountain aquifer. Allocations of transnational water systems are often disputed with its neighbors—Gaza and West Bank. In addition, Israel's scarce water resources have been overexploited, thereby compromising their quality and availability. The natural and geopolitical challenges of water management in the country have been exacerbated by its increase in population and affluence, which has also increased demand of water and its quality. Currently, demand is still higher than supply.[b]

To face these challenges, Israel has become a leader in water management. On governance, Israel has consolidated the water-related efforts of seven government ministries into a new Water Authority in 2007 that implements 50-year plans. Governmental market incentives include pricing mechanisms, and incentives to rehabilitate wells and to increase the use of recycled water in agriculture. Technologically, the Water Authority has been responsible for innovations such as the invention and dissemination of drip irrigation that covers 90% of irrigated agricultural land.[b] Another advancement is the use of 80% of treated wastewater for agricultural irrigation, with a goal to reach 90% by 2017.[b] The development of new technologies is continuously fostered by the government's Israel NewTech program. Upcoming innovations include a digital metering system that allows real-time monitoring of leakage (10% of loss), as well as technologies to fix pipes without shutting down the water supply.

To continue to increase water supply, the government is planning desalination, a very energy-intensive practice. Desalination is more cost-effective than other technology, though, since the country has a long coastline that allows easy access to seawater. As an energy importer for many years, the development of desalination plants could lead to an increase in dependence on energy-exporting nations.[c] Nonetheless, its foreign energy dependency will likely decrease, as many natural gas reserves have been recently found during intensive energy exploration.[d] As agriculture is the main consumer of water (58% of total use in 2006), and 50% of its supply comes from waste and saline water sources, food production can be severely impacted if the energy is not sufficient to provide water for irrigation. In summary, water management in Israel has been aligned with the country's food and energy measures due to the intricate relationship among water, energy, and food that needs to be continuously managed by the government.

Sources:

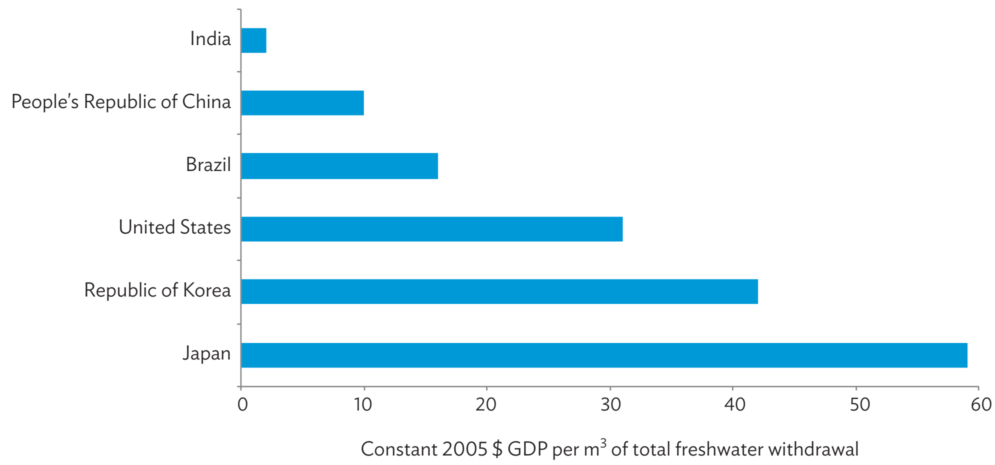
[a] M. Zaide. 2014. Drought and Arid Land Water Management. CSD-16/17. United Nations. http://www.un.org/esa/agenda21/natlinfo/countr/israel/drought.pdf (accessed 1 July 2014).

[b] Knowledge @ Wharton. 2012. What Other Nations Can Learn from Israel's Solutions to the Scarce Water Challenge. https://knowledge.wharton.upenn.edu/article/what-other-nations-can-learn-from-israels-solutions-to-the-scarce-water-challenge/

[c] Forbes. 2014. Israel's Water Challenge. http://www.forbes.com/sites/stratfor/2013/12/26/israels-water-challenge/ (accessed 30 June 2014).

[d] United States Energy Information Administration. 2014. Israel. http://www.eia.gov/countries/country-data.cfm?fips=IS

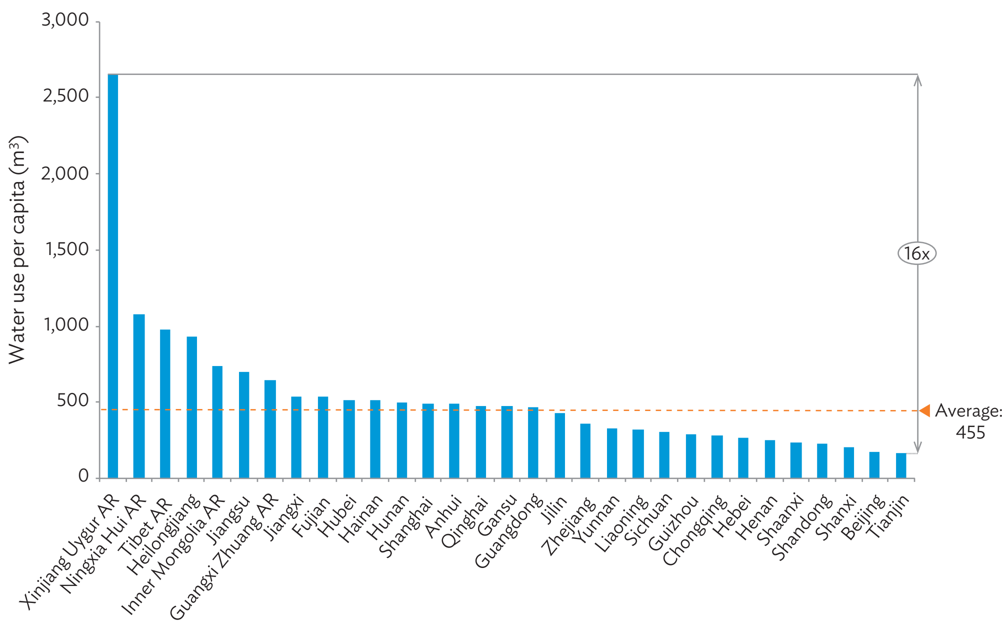
Figure 13: Total Water Productivity in Selected Countries, 2014



GDP = gross domestic product, m^3 = cubic meter.

Source: World Bank. World Development Indicators: Water Productivity. http://data.worldbank.org/indicator/ER.GDP.FWTL.M3.KD (accessed 6 May 2016).

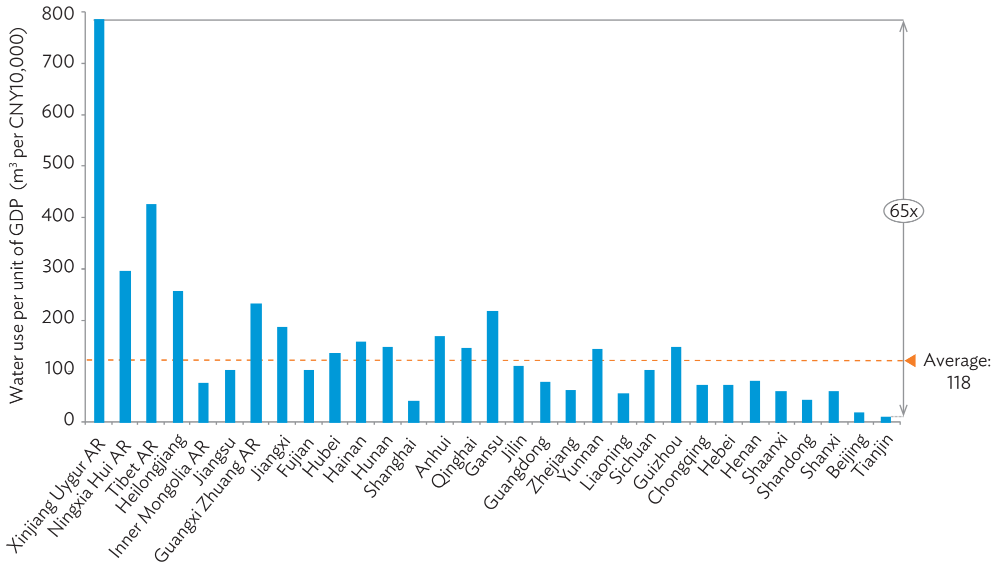
Figure 14: Water Use per Capita by Province in the People's Republic of China, 2012



AR = Autonomous Region, m^3 = cubic meter.

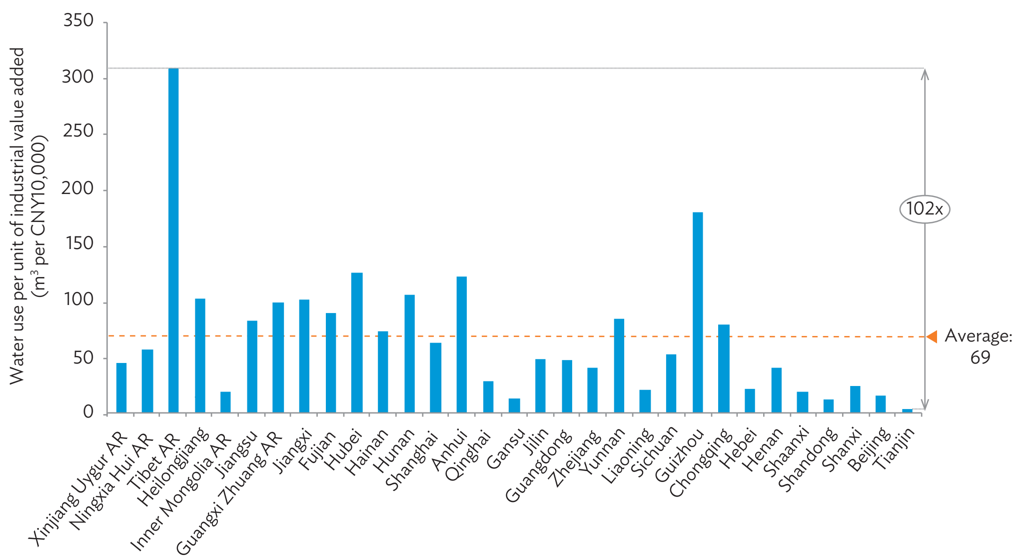
Source: World Resources Institute estimates.

Figure 15: Water Use per Unit of Gross Domestic Product by Province in the People's Republic of China, 2012



AR = Autonomous Region, CNY = yuan, GDP = gross domestic product, m^3 = cubic meter.
Source: World Resources Institute estimates.

Figure 16: Water Use per Unit of Industrial Value Added by Province in the People's Republic of China, 2012



AR = Autonomous Region, CNY = yuan, m^3 = cubic meter.
Source: World Resources Institute estimates.

2. Threat 2: Energy Development in Water-Stressed Areas

The PRC has become one of the biggest energy consumers and producers in the world. Its energy production poses a major threat to water resource sustainability due to the mismatched locations of energy (mainly coal mines) and water resources. An estimated 70% of operating coal mines are located in water-scarce regions and 40% are located in regions with serious water shortage, especially in the north. The World Resources Institute found that, as of July 2012, more than half of the total proposed coal-fired power plants are located in areas with either high or extremely high baseline water stress. Alternative energy sources face the same issue of being located in highly water-scarce areas. Synthetic natural gas (a coal-to-gas process) is one of the countermeasures in the Action Plan for the Prevention and Control of Air Pollution of August 2013. According to the World Resources Institute's Aqueduct Baseline Water Stress map, however, 70% of the 17 approved synthetic natural gas projects are likewise located in extremely high water-stressed regions and will likely compete for water resources that are already in very high demand.

Coal-related industries—i.e., mining production, coal-to-chemical, and power generation—are particularly water-intensive. Coal mines use water for extracting, washing, and processing the coal, while coal-burning power plants require water for creating steam and cooling generating systems.[40] Such developments are therefore quite worrisome, because, if all of the proposed plants are built, they could withdraw as much as 10 bcm of water annually by 2015.[41]

3. Threat 3: Low Agricultural Water Productivity

The agriculture sector is the biggest water user, accounting for 65% of total freshwater withdrawals in 2014, and it is also the biggest polluter of water. Overuse and misuse of fertilizers and agricultural chemicals have become the most serious pollution sources.

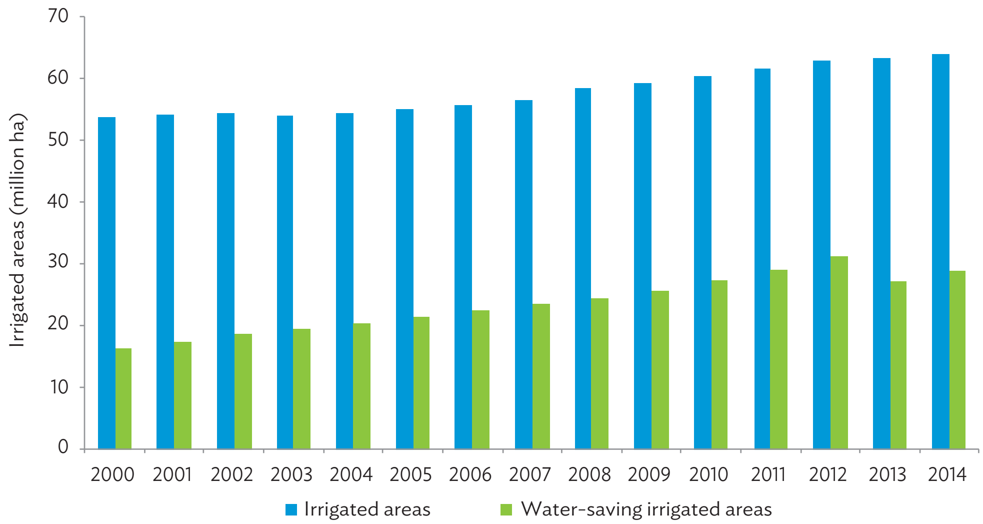
Agricultural water productivity remains low at $3.6 per cubic meter, despite substantial increases in irrigation investments, including total irrigated areas and water-saving irrigated areas (i.e., irrigated areas employing water-saving measures such as low-pressure pipes, spray irrigation, and drip irrigation) (Figure 17).

Investments in irrigation have been growing steadily and rapidly from the 6th Five-Year Plan period (1981–1985) to the 11th Five-Year Plan period (2006–2010) (Figure 18). The increase in irrigation investments continued during the 12th Five-Year Plan (2011–2015), with investments for 2011 alone reported at CNY47 billion ($7.1 billion), thereby accounting for more than 50% of the total investments during the 11th Five-Year Plan period. Irrigation

[40] T. Luo, B. Otto, and A. Maddocks. 2013. Majority of China's Proposed Coal-Fired Power Plants Located in Water-Stressed Regions. World Resources Institute – Blog. 26 August. http://www.wri.org/blog/2013/08/majority-china%E2%80%99s-proposed-coal-fired-power-plants-located-water-stressed-regions

[41] Greenpeace. 2012. *Thirsty Coal: A Water Crisis Exacerbated by China's New Mega Coal Power Bases*. Beijing. http://www.greenpeace.org/eastasia/Global/eastasia/publications/reports/climate-energy/2012/Greenpeace%20Thirsty%20Coal%20Report.pdf

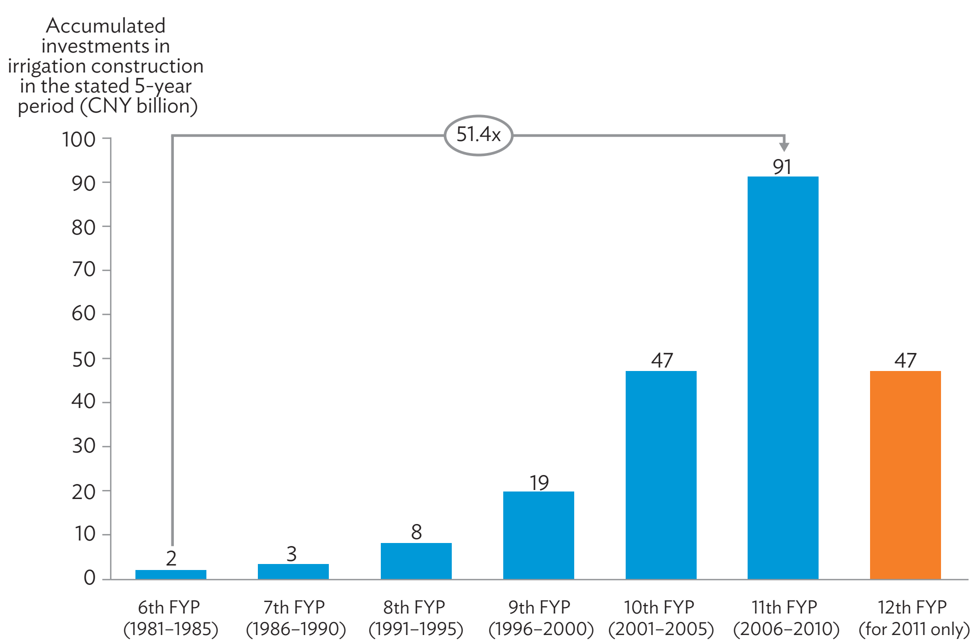
Figure 17: Irrigated Areas in the People's Republic of China, 2000–2014



ha = hectare.

Source: National Bureau of Statistics of the People's Republic of China. 2015. *China Statistical Yearbook*. Beijing.

Figure 18: Irrigation Investments by Five-Year Plans in the People's Republic of China, 1981–2011



CNY = yuan, FYP = Five-Year Plan.

Sources: Ministry of Water Resources of the People's Republic of China. Various years. *China Water Conservancy Statistical Yearbook*. Beijing: China Water Conservancy and Hydropower Press; World Resources Institute estimates.

efficiency increased to 0.516 in 2012 but is still lower than the rates of Australia, the Russian Federation, the European Union countries, and some African countries.[42]

As a core part of the PRC's New Urbanization Strategy, Premier Li Keqiang emphasized the significance of agricultural modernization across the PRC, calling for improvements in agricultural production efficiency, restructuring, and enhancing the quality of life for farmers. The Three Red Lines policy includes the compulsory targets of increasing irrigation efficiency to 0.55 by 2020, and to 0.60 or above by 2030. This requires at least CNY400 billion ($60.8 billion) worth of investments in infrastructure construction and management to improve irrigation. Productivity gains, though, are not solely attributable to infrastructure, but rather a combination of infrastructure, improved farmland and water management practices, and institutional strengthening for effective operation and maintenance.

C. Key Dimension 3: Urban Water Security

Cities around the world are growing rapidly, which is posing challenges for water service providers who must develop improved water services and management systems. These water services are the foundation for sustainable urban economies, employment, and overall quality of city life.[43] The growth of cities requires the development of new water sources, extended networks, new connections, as well as the associated facilities needed for expansion, such as sewer pipe networks and efficient wastewater treatment systems.

The Asian Water Development Outlook's urban water security index measures how countries are creating better water services and management systems to develop vibrant, livable cities and towns. The index uses three indicators: (i) coverage of water supply, (ii) sanitation, and (iii) drainage (measured as the extent of economic damage caused by urban flooding). Final scores were adjusted to reflect the impacts of urban growth rates and scores from the environmental water security index, which measures river health.

While the PRC scored 95% on water supply coverage, the country scored low on urban water security because of persistent problems with urban flooding and the moderate levels of access of urban households to wastewater treatment systems.

1. Threat 1: Increased Water Demand from Increased Urbanization

A major threat to the PRC's urban water security is the increased consumption that the current high urbanization policy is likely to cause, putting pressure on limited supply and already underdeveloped urban drainage and wastewater connections. In many cities, the risk to water supply security is aggravated by reliance on a single water source, with no dependable options if that source gets contaminated or depleted.

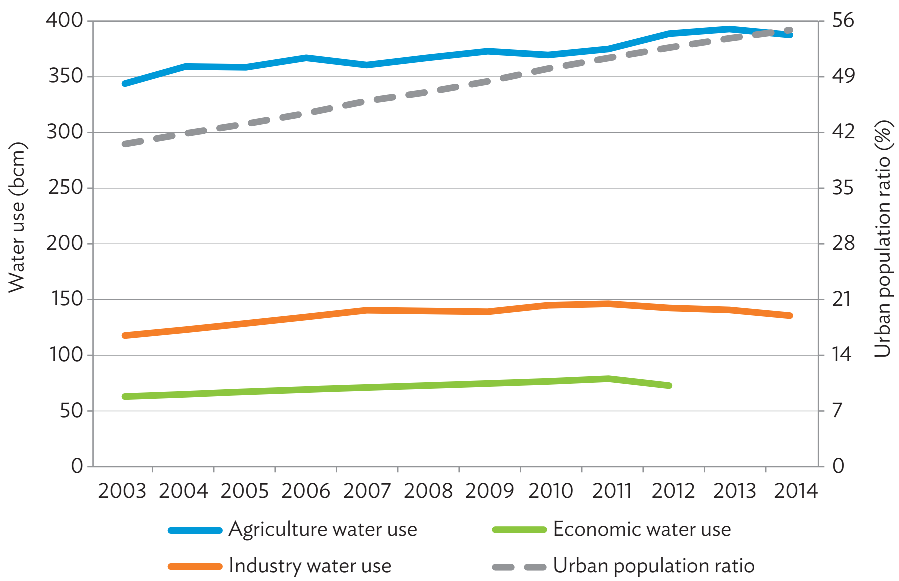
42 A. Calzadilla, K. Rehdanz, and R.S.J. Tol. 2012. Water Scarcity and the Impact of Improved Irrigation Management: A CGE Analysis. Presentation for the 2012 World Water Week in Stockholm. http://www.worldwaterweek.org/documents/WWW_PDF/2012/Tue/Best-use-of-Blue-Water/Calzadilla.pdf

43 ADB. Urban Development. http://www.adb.org/themes/urban-development/main

Over the past decade, the urban population ratio in the PRC increased from 40.5% in 2003 to 54.8% in 2014 (Figure 19), with the western undeveloped regions experiencing faster growth than the eastern developed regions (Figure 20). The PRC's average annual urban population growth over the past 50 years is faster than any other developed or developing country (Figure 21), yet total water use grew at a stable rate of 15% during the same time period. The PRC has prioritized urbanization as a core development component at the 18th National Congress in 2012. It aims to increase the urban population to 60% by 2020, which implies that about 300 million people will relocate to urban areas.[44]

At the same time as setting a higher urban growth rate, the central government set a lower water use target of 670 bcm by 2020 and 700 bcm by 2030. For this to happen under an urban growth scenario, the average annual growth of water use from 2012–2020 must decrease by 22% from the 2003–2012 average of 1.61%. This means an average water use growth rate of only 1.25% by 2020 and 0.44% average annual growth from 2020–2030. The actual growth rate between 2010 and 2013 was 2.4%.[45]

Figure 19: Urbanization and Changes in Water Use of Various Sectors in the People's Republic of China, 2003–2014



bcm = billion cubic meter.

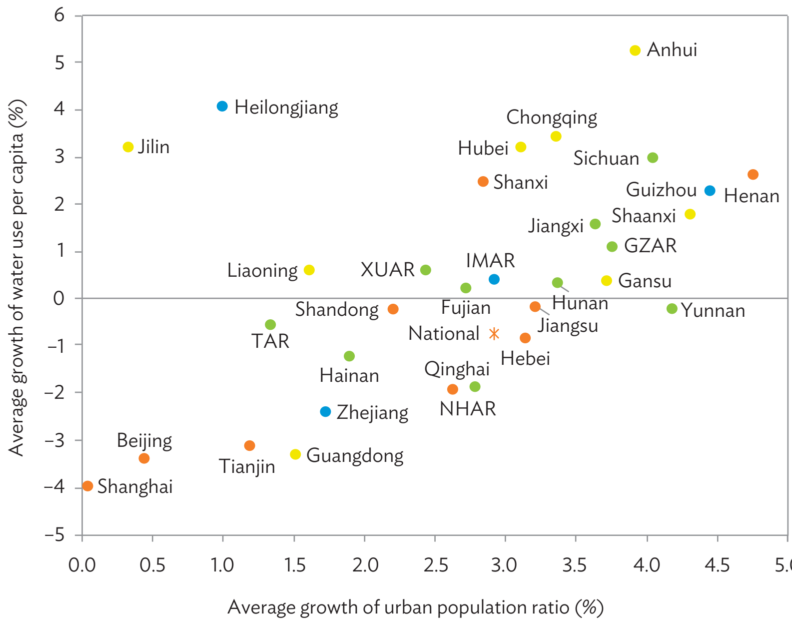
Sources: National Bureau of Statistics of the People's Republic of China. 2015. *China Statistical Yearbook*. Beijing; World Resources Institute estimates.

[44] Central Committee of the Communist Party of China and the State Council of the PRC. 2014. *National Plan for the New Urbanization (2014–2020)*. Beijing. http://finance.ifeng.com/a/20140317/11902147_0.shtml (in Chinese).

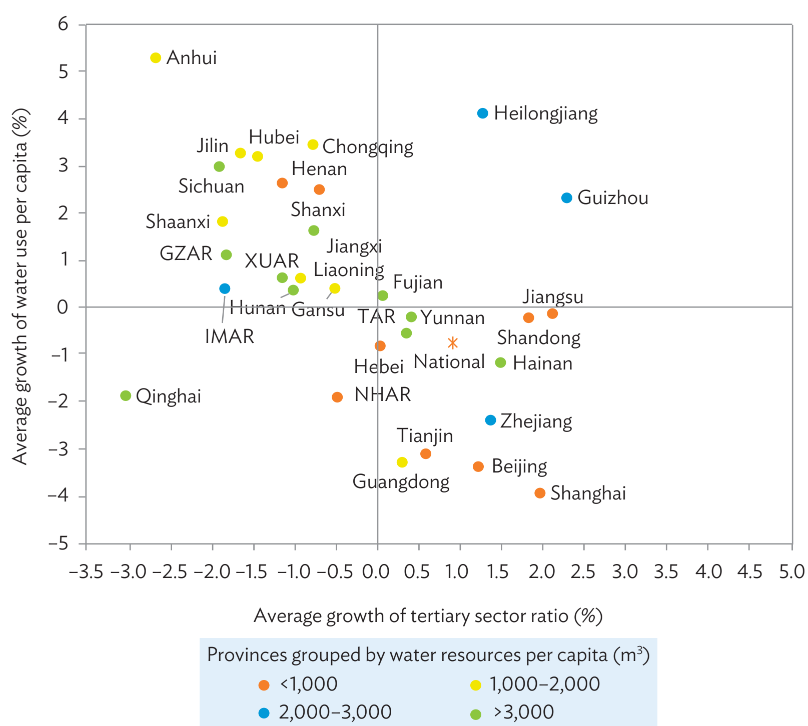
[45] National Bureau of Statistics of the PRC. 2014. *2013 National Economic and Social Development Statistical Bulletin*. 24 February. http://www.stats.gov.cn/tjsj/zxfb/201402/t20140223_514970.html (in Chinese, accessed 8 October 2014).

Figure 20: Average Growth of Urban Population, Economic Sector, and Water Use per Capita by Province in the People's Republic of China, 2012

a. Average Growth of Urban Population and Growth of Water Use per Capita



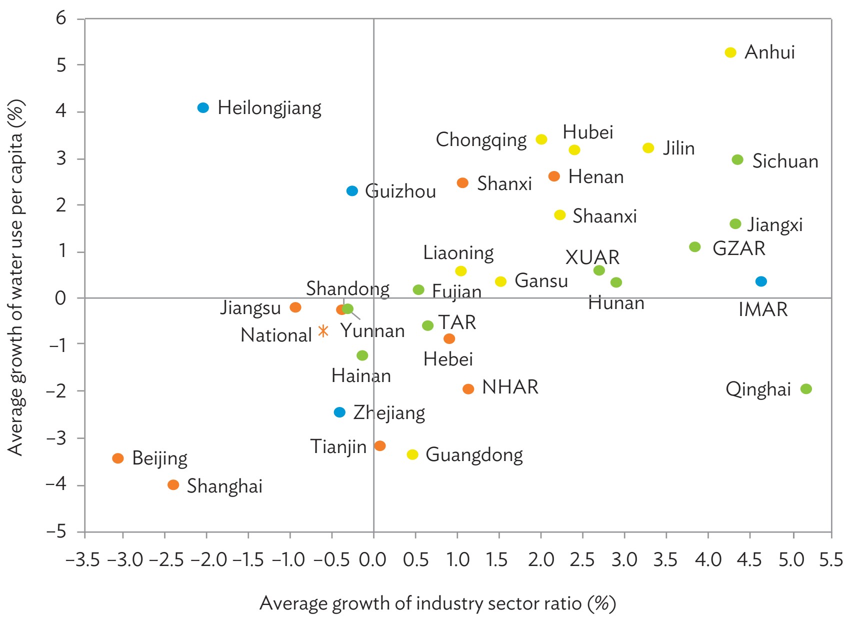
b. Average Growth of Tertiary Sector and Growth of Water Use per Capita



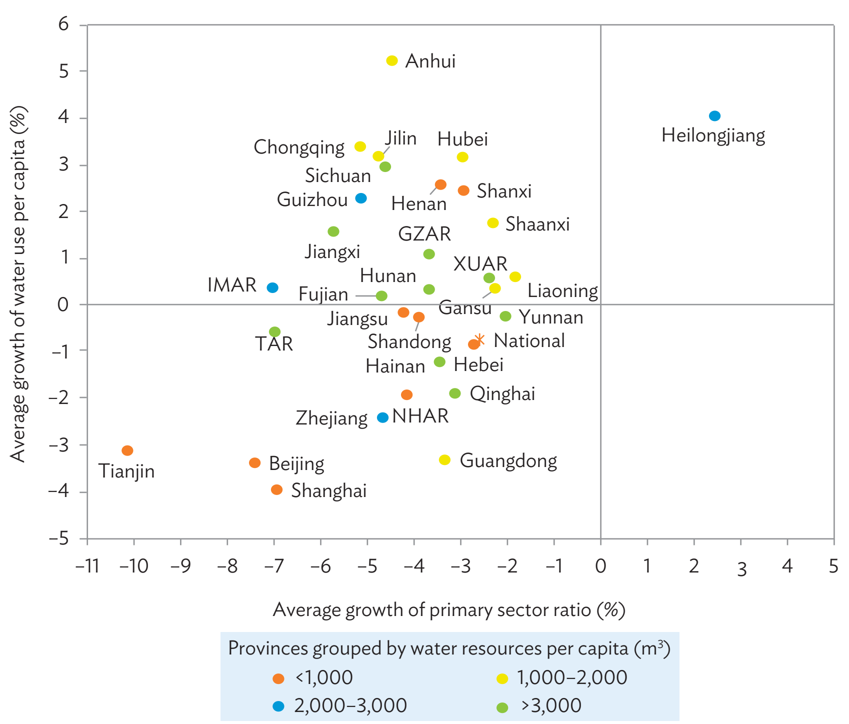
continued on next page

Figure 20 *continued*

c. Average Growth of Industry and Growth of Water Use per Capita



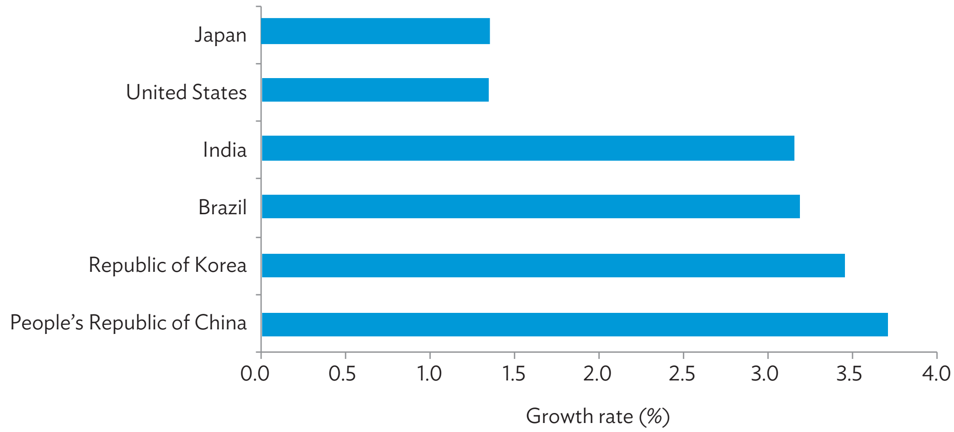
d. Average Growth of Agriculture and Growth of Water Use per Capita



GZAR = Guangxi Zhuang Autonomous Region, IMAR = Inner Mongolia Autonomous Region, m^3 = cubic meter, NHAR = Ningxia Hui Autonomous Region, TAR = Tibet Autonomous Region, XUAR = Xinjiang Uygur Autonomous Region.

Sources: National Bureau of Statistics of the People's Republic of China; World Resources Institute estimates.

Figure 21: Average Annual Growth of Urban Population in Selected Countries, 1960–2014



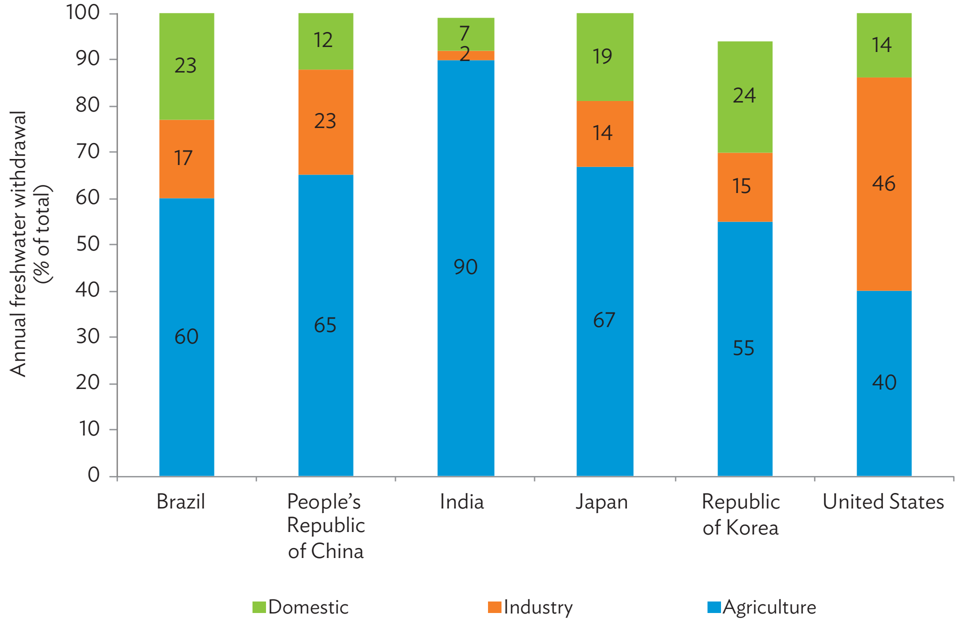
Source: World Bank. World Development Indicators: Urban Population. http://data.worldbank.org/indicator/SP.URB.TOTL?display=default (accessed 6 May 2016).

The International Institute for Applied Systems Analysis (IIASA) uses the "withdrawal-to-availability" indicator (i.e., the ratio of water withdrawals to total renewable water resources) in its water resources analyses. According to this indicator, water stress increases when either water withdrawals grow (related to changes in population and economic growth) and/or water availability decreases (due to population or climate change).[46] It considers water withdrawals greater than 40% of the total water available as severely water scarce. Areas facing this level of scarcity or worse in the 2050s under the middle-of-the-road scenario will be northeast PRC, central-east PRC, and the urban areas along the PRC's coastlines. While the PRC's domestic water use in 2014 was lower than most other countries (Figure 22), this may change depending on urban population growth, economic growth, climate change impacts, and policy targets. The figure indicates that a faster growth in urbanization may cause faster growth in water use per capita within the same province. The PRC is one of the most water-stressed countries in the world, with population being the main driver of per capita availability. Both urban population and industry growth rates had a positive correlation with increased water use. Studies by the IIASA found that, in countries like Brazil, India, and the PRC where economic growth is expected to accelerate in the coming decades, industrial water withdrawals are projected to increase more than twofold by 2050.[47]

[46] P. Raskin, P. Gleick, P. Kirshen, G. Pontius, and K. Strzepek. 1997. Water Futures: Assessment of Long-Range Patterns and Problems. Background document for the SEI/United Nations Comprehensive Assessment of the Freshwater Resources of the World. Stockholm: Stockholm Environment Institute.

[47] Y. Wada, M. Flörke, N. Hanasaki, S. Eisner, G. Fischer, S. Tramberend, Y. Satoh, M.T.H. Van Vliet, P. Yillia, C. Ringler, P. Burek, and D. Wiberg. 2016. Modeling Global Water Use for the 21st Century: The Water Futures and Solutions (WFaS) Initiative and Its Approaches. *Geoscientific Model Development*. 9 (1). pp. 175–222; S. Tramberend, D. Wiberg, Y. Wada, M. Flörke, G. Fischer, Y. Satoh, P. Yillia, M. van Vliet, E. Hizsnyik, L.F. Nava, M. Blokker, and N. Hanasaki. 2015. Building Global Water Use Scenarios. IIASA Interim Report. May. http://pure.iiasa.ac.at/11675/1/IR-15-014.pdf

Figure 22: Annual Freshwater Withdrawal by Sectors in Selected Countries, 2014



Source: World Bank. World Development Indicators: Freshwater. http://wdi.worldbank.org/table/3.5 (accessed 6 May 2016).

Current water use targets will be a big challenge under the current urbanization thrust of the government. To drastically reduce the current average water use rates to meet the new targets, all sectors must embrace water efficiency strategies and technologies.

2. Threat 2: Urban Relocation and Industrial Layout

Water pollution incidents triggered a heated debate on urban water security and the proximity of chemical plants to cities and water resources. In January 2013, aniline-containing wastewater leaked into the downstream section of the Zhanjiang River in Shanxi. On 11 April 2014, a chemical leak (benzene) from a pipeline of Lanzhou Petrochemical resulted in contaminated water supply, causing public panic and frenzy to buy bottled water.[48] On 9 May 2014, the urban water supply in Jingjiang, Jiangsu Province shut down for 7 hours due to abnormal water quality, which was thought to be caused by pollution from surrounding chemical plants.[49]

48 *Phoenix News*. 2014. Cause of Lanzhou Water Contamination Identified. 13 April. http://news.ifeng.com/gundong/detail_2014_04/13/35726780_0.shtml (in Chinese).

49 BBC. 2014. Jingjiang, Jiangsu Cuts Off City's Water Supply due to Abnormalities in Yangtze River Water Quality. 9 May. http://www.bbc.co.uk/zhongwen/simp/china/2014/05/140509_china_zhenjiang_water_pollution.shtml (in Chinese).

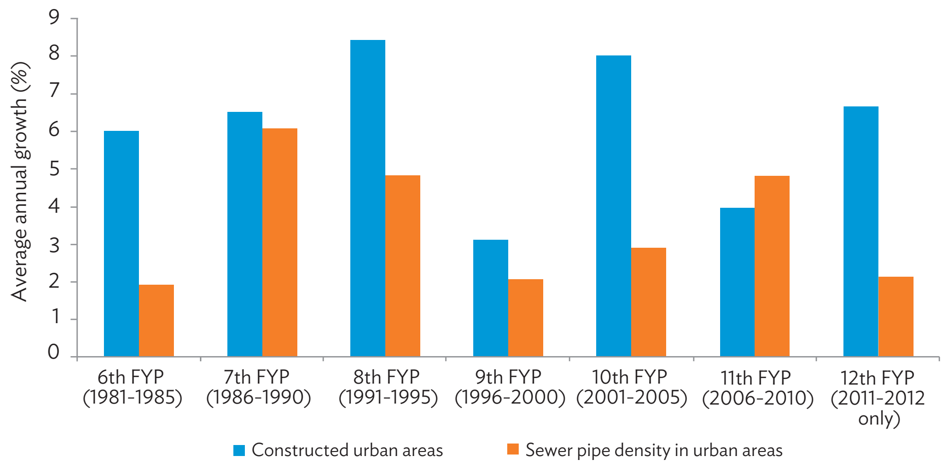
As more cities are constructed to meet the urbanization target of 60% by 2020, the selection of new city locations and their proximity to existing industry—especially chemical factories—will produce direct or indirect impacts on water security. In the PRC, many big petrochemical firms operate along rivers or lakes because the proximity allows them to meet the huge production need for water as well as discharge wastewater. For example, more than 400,000 chemical plants operate along the Yangtze River, discharging wastewater to the river.[50]

To safeguard urban water supplies, the government must identify potential threats from industry and urban construction sites. New cities and their industrial layouts must be designed with water security as a priority.

3. Threat 3: Urban Stormwater Floods

Urban stormwater drainage, which is usually combined with the sewerage system in the PRC, has not kept pace with urbanization (Figures 23 and 24). Urban environmental and water pollution due to insufficient sewer pipes or drains and pluvial floods due to the lack of sufficient drainage have resulted in a lower livability level in cities. Urban floods as a

Figure 23: Average Annual Growth of Constructed Urban Areas and Sewer Pipe Density by Five-Year Plans in the People's Republic of China, 1981–2012



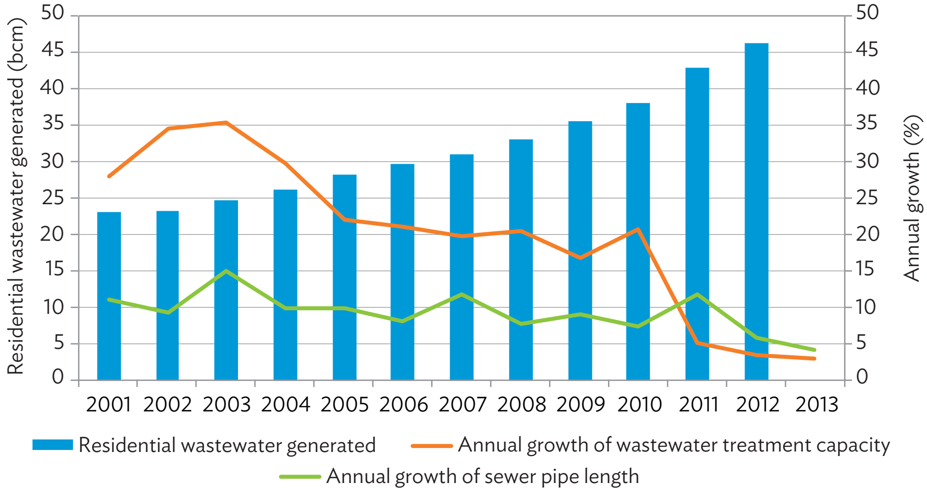
FYP = Five-Year Plan.

Note: Constructed urban area is land developed for nonagricultural purposes, characterized by public infrastructure such as airport, railway, wastewater treatment, communication, etc.

Sources: Ministry of Housing and Urban–Rural Development of the People's Republic of China. Various years. *China Urban Construction Statistical Yearbook*. Beijing: China Planning Press; National Bureau of Statistics of the People's Republic of China. Various years. *China Statistical Yearbook*. Beijing; World Resources Institute estimates.

50 Alibaba China. 2011. Chemical Industrial Pollution along the Yangtze River Causes Surge in Cancer Patients. 17 November. http://club.1688.com/article/30933613.html (in Chinese).

Figure 24: Residential Wastewater Generated and Growth of Wastewater Treatment Capacity and Sewer Pipe Length in the People's Republic of China, 2001–2013



bcm = billion cubic meter.

Sources: Ministry of Housing and Urban–Rural Development of the People's Republic of China. Various years. *China Urban Construction Statistical Yearbook*. Beijing: China Planning Press; Ministry of Environmental Protection of the People's Republic of China. Various years. *China Environmental Statistical Bulletin*. Beijing; World Resources Institute estimates.

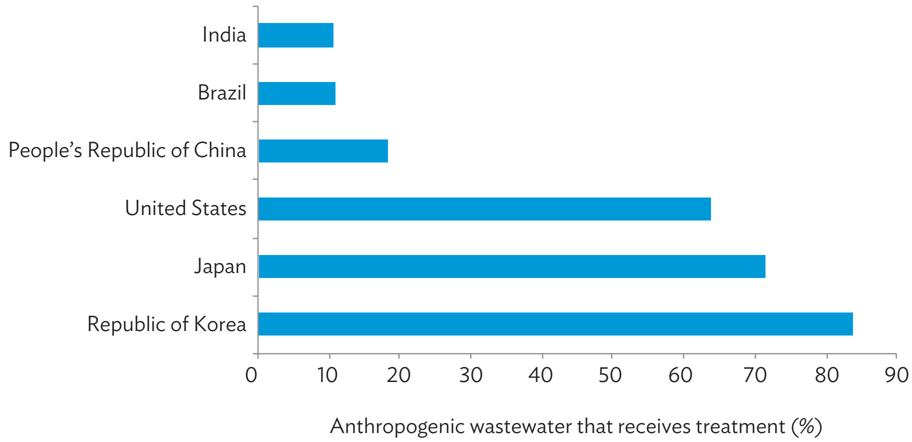
result of poor drainage cost the PRC about $119.57 per capita. Although the percentage of cities and counties with wastewater treatment plants has increased tremendously in the past decade (and the capacities of these treatment plants are often excessive), actual connectivity to the sewerage and treatment systems is only 58% in cities (footnote 18). A separate but related issue is the quality of wastewater being produced, which appears as a factor in river health and environmental water security.

After constructing wastewater treatment plants in all cities and in 85% of all counties, the PRC has slowed down its investments in treatment plants starting from the 11th Five-Year Plan period (Figure 23). However, insufficient coverage of sewer pipes and drains is still a constraint in collecting and treating wastewater in many areas. This affects the financial viability of wastewater treatment plants that are usually built for higher capacity than what sewer pipe networks can collect (Figure 24).

The sewer pipe length per 10,000 urban population was 6.27 kilometers in 2013, which is only 17% that of Japan in 2006.[51] Furthermore, the percentage of anthropogenic wastewater that received treatment in the PRC in 2012 was relatively low at 18.2%, which is only slightly higher than in Brazil or India but much lower than in Japan, the Republic of Korea, or the United States (Figure 25). Segregated data on sources of domestic pollution from cities,

[51] Estimated according to Japan's constructed sewer length (Ministry of Land, Infrastructure, Transport and Tourism of Japan. http://www.mlit.go.jp/crd/sewerage/policy/03.html) and urban population in 2006 (World Bank. World Development Indicators: Urban Population. http://data.worldbank.org/indicator/SP.URB.TOTL/countries?page=1).

Figure 25: Comparative Percentage of Treated Anthropogenic Wastewater in Selected Countries, 2012



Source: O. Malik. 2013. Global Database of National Wastewater Treatment. New Haven, CT: Yale Center for Environmental Law and Policy.

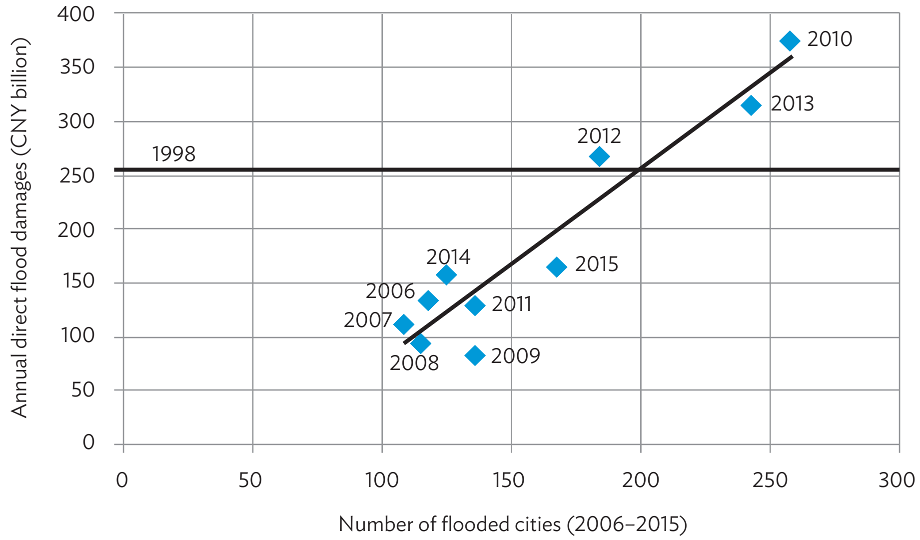
towns, and rural areas would have provided a better and more realistic comparison, but these data are not available.

More than 60% of the 351 surveyed cities suffered from urban flooding between 2008 and 2010, according to a study by the Ministry of Housing and Urban–Rural Development.[52] The Wuhan Research Institute for Stormwater also found that the top 10 worst annual stormwater disasters in 2008–2010 have affected over 280 million people and resulted in more than CNY250 billion ($38.0 billion) in direct economic losses. Since 2006, the annual number of flooded cities in the PRC reached more than 100, most of them caused by heavy local rainstorms. Annual direct flood damages are proportional to the number of affected cities. In 2010, 2012, and 2013, annual flood damages were more than those reported in 1998, when the country was hit by severe basin floods (Figure 26). In July 2012, the stormwater disaster in Beijing resulted in at least 77 deaths, affected 1.9 million people, and caused about CNY11 billion ($1.6 billion) in direct economic losses.[53] In May 2014, heavy stormwater in Shenzhen caused at least CNY80 million ($12.2 million) in direct economic losses.[54]

Actual pipe performance is unknown because no monitoring system for stormwater management exists. Most of the existing constructed sewer pipes, which also served as stormwater drainage system (combined type for wastewater and stormwater), are only designed for floods with a return period of 2 years, but many cities have been experiencing

[52] *People's News*. 2012. Why Mega Cities Often Suffer from Urban Flooding? 24 July. http://paper.people.com.cn/rmrb/html/2012-07/24/nw.D110000renmrb_20120724_7-04.htm (in Chinese).
[53] C. MacLeod. 2012. China Accused of Downplaying Beijing Flood Damage, Deaths. *USA Today*. 8 August. http://usatoday30.usatoday.com/news/world/story/2012-07-26/china-beijing-floods-censor/56514570/1
[54] F. Jun. 2014. Shenzhen Torrential Rain Caused Direct Economic Losses of About 80 Million Yuan. *NTV China*. 14 May. http://www.ntv.cn/a/20140514/31147.shtml (in Chinese).

Figure 26: Annual Direct Flood Damages and Number of Flooded Cities in the People's Republic of China, 2006–2015



CNY = yuan.

Source: State Flood Control and Drought Relief Headquarters, Ministry of Water Resources of the People's Republic of China. Various years. *Bulletin of Flood and Drought Disasters in China*. Beijing.

50-year floods over the past 5 years. Investments in sewerage systems are often bypassed for urban construction, as sewer pipes are underground and invisible. Urban construction focuses on paved roads, which are impermeable and prone to flooding. The sewerage systems in many cities also have insufficient capacity for both stormwater and wastewater. In the past, combined sewerage systems for both wastewater and stormwater were widely used. In recent years, however, the development of separate systems for stormwater and sewage is being considered, especially for newly developed areas.

On 25 March 2013, the General Office of the State Council issued a policy paper calling for well-constructed urban sewerage systems, including investigating existing pipes, amending the construction standards for urban sewer pipes and drains, developing urban sewer pipe and drain construction plans, accelerating the construction of separate piping systems, and promoting low-impact development.[55] This is a long and arduous task, requiring a huge amount of investments, but is essential to urban water security.

Box 3 examines how Singapore, as a city-state, illustrates many of the PRC's urban water challenges, including population growth, increases in water demand, and the need for urban water infrastructure and management.

55 Central Government of the PRC. 2013. State Council on Notification for the Construction of Urban Drainage Facilities. http://www.gov.cn/zwgk/2013-04/01/content_2367368.htm (in Chinese).

Box 3: Singapore's Urban Water Challenges and Responses

Singapore is an island city-state of only 716 square kilometers with a population of 5.4 million. The island naturally has many water supply constraints, but they are exacerbated by high demand. The annual average rainfall is very high (2,340 millimeters), but the capacity to store water is small as a result of the limited land area. The situation is worsened by extreme weather events, such as recent droughts, which will likely increase in intensity and frequency due to climate change. The use of groundwater has also not been feasible due to the low recharge capacity. Despite these challenges, Singapore is a global model of successful urban water supply and management that balances supply and demand.

In Singapore, 100% of the population has improved drinking water sources and sanitation. There are four sources of water: (i) water imported from Johor, Malaysia (60% in 2014); (ii) reservoirs filled with local catchment; (iii) NEWater, which is high-grade reclaimed water; and (iv) desalinated ocean water. Singapore's institutions have developed a good governance system that focuses on long-term comprehensive planning and sustainable development. Its water agency, the Public Utilities Board, practices integrated water resources management to oversee the whole water cycle, including the collection of rainwater, purification, distribution, and reclamation. Along with political will, the country's efforts in water supply and management are diverse:

(i) **Physical Infrastructure.** First, the government must ensure the physical infrastructure is properly built and separates wastewater from clean runoff. Second, integrated land use planning and water management prevent water pollution and contribute to successful catchment management. Third, the city-state guarantees that new buildings as well as additions and alterations on existing ones are properly regulated not to encroach on the public water system. And finally, Singapore invests in the maintenance of drains and canals to guarantee free flow with low leakage.

(ii) **Legislation and enforcement.** Singapore aims to ensure the infrastructure is properly used, thus incorporating regulations on the effluent discharge limits, stormwater and used water disposal, and water quality limits of effluents and drinking water. Enforcement is made possible by a well-coordinated institutional framework for the different relevant government agencies, which includes land-use planning, water, and environmental management.

(iii) **Water pricing and public education.** Prices reflect the scarcity of water and the full costs of production, including developing new water sources. As residential use accounts for 58% of water consumption, households that consume more are charged higher rates. In addition, there are sector campaigns with specific goals to incentivize all users to reduce water use.

(iv) **Research and technology.** The Public Utilities Board works closely with national and international organizations in all sectors to foster innovation around water management. Singapore's Institute of Water Policy, for example, aims to increase the profile of national policy issues across Asia.

Source: Public Utilities Board. The Singapore Water Story. http://www.pub.gov.sg/water/Pages/singaporewaterstory.aspx

D. Key Dimension 4: Environmental Water Security

The PRC received a score of 0.26 out of a possible 1.0 on the Asian Water Development Outlook's river health index, meaning the country's rivers are generally in poor health, especially in the lower Yangtze River Basin. The PRC ranked 31st out of 59 countries on the index. The Asian Water Development Outlook's environmental water security index uses the river health index to measure the health of the river and its capacity to maintain its natural functions and associated goods and services. The river health index uses four stress indicators: watershed disturbance, pollution, water resources development, and biotic factors (footnote 18).

Inadequately planned and poorly implemented water resources development programs often result in poor river health. Some of the common challenges include improperly constructed or poorly managed irrigation systems, weakly regulated point sources (e.g., mine tailings, industrial and municipal wastewater), and uncontrolled nonpoint source pollution (e.g., animal wastes, fertilizers, agrochemical and pesticides) (footnote 18). Healthy water systems can also be threatened by watershed "disturbance," including deforestation, road and building construction, loss of natural wetlands, increased storage and diversions that alter natural flows, and structural changes that affect biodiversity, drainage paths, and so on (footnote 18). For instance, dams alter natural flows, reduce floodplains, and affect the connectivity between small river systems.

According to the Asian Water Development Outlook analysis, the main drivers of the PRC's poor river health are population density and agricultural intensity. The PRC's underground rivers—its aquifers—face a similar worrisome outlook.

1. Threat 1: Population Density

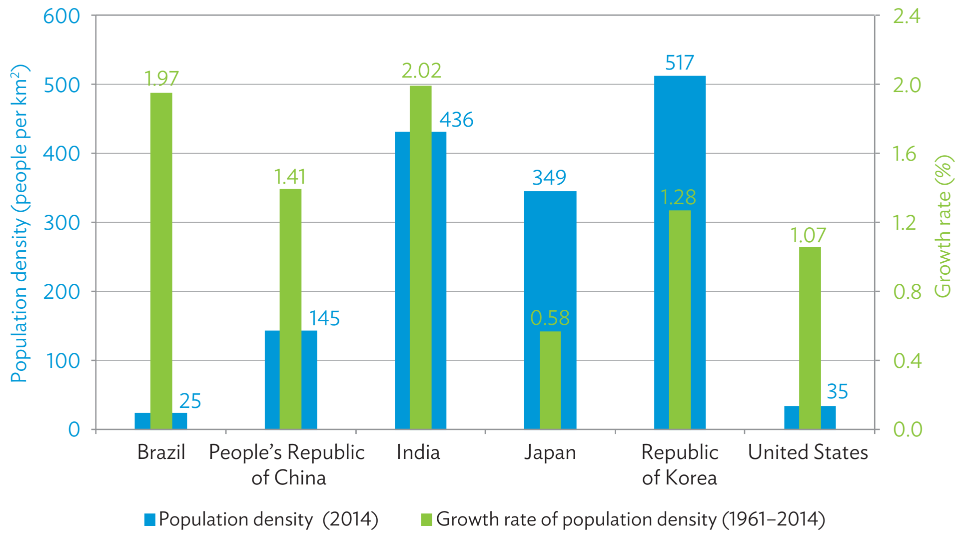
The PRC's population density is not as high compared with that of India, Japan, or the Republic of Korea, but it does have one of the fastest rates of growth in population density, right behind India and Brazil (Figure 27). Population density will be a long-term issue for development because of the PRC's policy bias for rapid urbanization and the trend in population growth rates (Figure 28). As stated earlier, a rise in the urban population growth rate would have a larger impact on water demand than an increase in the overall population.

2. Threat 2: Agricultural Intensity

Intensive agriculture not only changes land cover, but it also displaces indigenous vegetation, and introduces monocrop cultivation, which leads to greater nonpoint source pollution from increased usage of agrochemical and fertilizer inputs. These excessive amounts of nutrients, along with sediment loads entering rivers and new irrigation diversions, are stressing water resources. Pollution also raises the costs of treating water for domestic and industrial supply (footnote 18).

The growth in irrigation is also a stress factor to consider in environmental flow and ecological balance. Between 2003 and 2011, the share of irrigated land in the PRC jumped

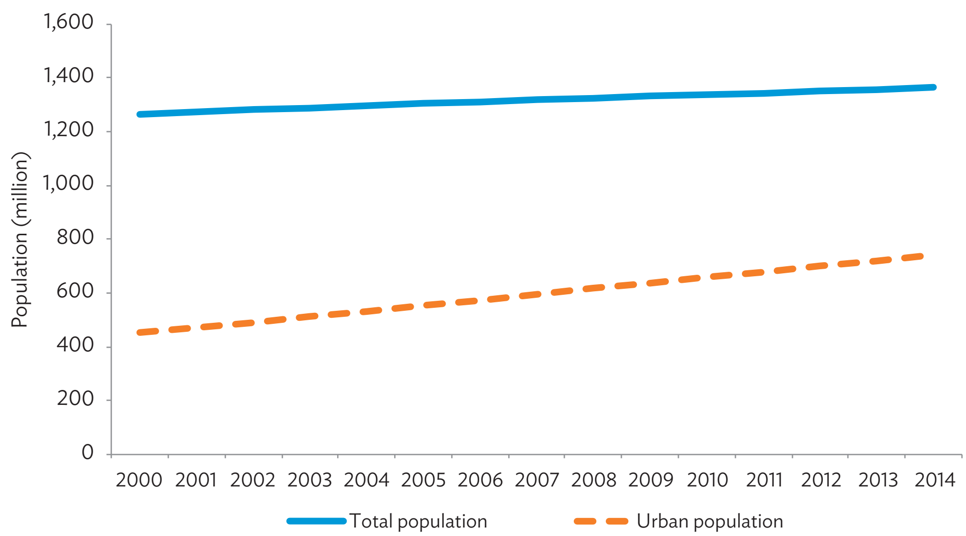
Figure 27: Comparative Level and Growth of Population Density in Selected Countries



km^2 = square kilometer.

Source: World Bank. World Development Indicators: Population Density. http://data.worldbank.org/indicator/EN.POP.DNST/countries?display=default (accessed 6 May 2016).

Figure 28: Population Trends in the People's Republic of China, 2000–2014

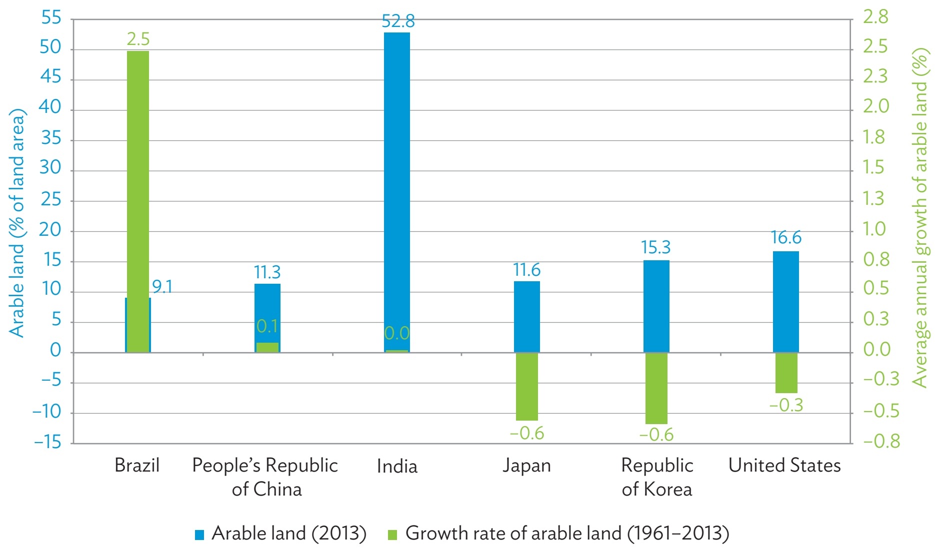


Sources: World Bank. World Development Indicators: Total Population. http://data.worldbank.org/indicator/SP.POP.TOTL?display=default (accessed 6 May 2016); World Bank. World Development Indicators: Urban Population. http://data.worldbank.org/indicator/SP.URB.TOTL?display=default (accessed 6 May 2016).

from 9.2% to 10.5% of total agricultural land, an indicator of increasing demand.[56] While the PRC has a relatively low percentage of arable land, it has a higher growth rate of arable land—second only to Brazil during the period 1961–2013 (Figure 29).

Around the mid-1990s, there were an estimated 50,000 rivers in the PRC covering a flow area of 60 square miles. According to the PRC's First National Census of Water in 2013, more than 28,000 of these rivers are now missing.[57] Official explanations from the government attribute the significant reduction to statistical discrepancies, water and soil loss, and climate change.[58] However, the disappearance of major rivers may also likely be from overuse and contamination from agriculture and industry.[59] About 60% of the surface water harvested in the PRC is from rivers, but 37.6% is harvested from reservoirs and 1.5% from lakes (footnote 57). In total, the PRC also has 98,002 reservoirs with a total capacity of 932 bcm (Table 6). Both lakes and reservoirs are closed systems (i.e., water remains

Figure 29: Comparative Proportion and Growth of Arable Lands in Selected Countries



Source: World Bank. World Development Indicators: Arable Land. http://data.worldbank.org/indicator/AG.LND.ARBL.HA?display=default (accessed 10 May 2016) and http://data.worldbank.org/indicator/AG.LND.ARBL.ZS?display=default (accessed 10 May 2016).

56 World Bank. World Development Indicators: Agricultural Irrigated Land. http://data.worldbank.org/indicator/AG.LND.IRIG.AG.ZS (accessed 13 May 2016).

57 Ministry of Water Resources and National Bureau of Statistics of the People's Republic of China. 2013. China Census for Water. *Bulletin of First National Census for Water*. http://www.mwr.gov.cn/2013pcgb/merge1.pdf (in Chinese).

58 C. Luo. 2013. New Study Shows Dramatic Fall in Number of Rivers in China. *South China Morning Post*. 27 March. http://www.scmp.com/news/china/article/1200961/new-study-shows-dramatic-fall-number-rivers-china

59 A. Hsu and W. Miao. 2013. 28,000 Rivers Disappeared in China: What Happened? *The Atlantic*. 29 April. http://www.theatlantic.com/china/archive/2013/04/28-000-rivers-disappeared-in-china-what-happened/275365/

Table 6: Summary Statistics of Reservoirs of Various Scales and Total Storage Capacities in the People's Republic of China, 2013

		Large Size			Medium Size	Small Size		
Scale of Reservoir	Total	Subtotal	Large Type I	Large Type II		Subtotal	Small Type I	Small Type II
Number	**98,002**	756	127	629	3,938	93,308	17,949	75,359
Total Storage (bcm)	**932.31**	749.98	566.51	183.48	111.98	70.35	49.64	20.71

bcm = billion cubic meter.

Notes:

1. The capacity of a large type I reservoir is greater than 1 billion cubic meters (bcm), while that of a large type II reservoir is between 0.1 bcm and 1 bcm.
2. The capacity of a small type I reservoir is between 1 mcm and 10 mcm, while that of a small type II reservoir is less than 1 mcm.

Source: Ministry of Water Resources and National Bureau of Statistics of the People's Republic of China. 2013. China Census for Water. *Bulletin of First National Census for Water*. http://www.mwr.gov.cn/2013pcgb/merge1.pdf (in Chinese).

inside indefinitely), which make their water quality and availability more sensitive to changes in land use and pollution.

Soil management, which is also the subject of one of the country's latest national action plans, is important to counter the effects (mostly erosion and leaching) of agricultural intensification. In 2011–2013, the World Bank ranked the PRC as among the top 20 countries (out of more than 160 countries) with the highest use of fertilizers. The PRC uses 364.4 kilograms per hectare (kg/ha) of arable land—much higher than other agricultural countries, such as Brazil (175.7 kg/ha), India (157.5 kg/ha), and the United States (131.9 kg/ha).[60]

3. Threat 3: Groundwater Overextraction and Pollution

Groundwater contributes to about 26% of global water supply. However, abstraction is concentrated and the PRC is one of only 10 countries responsible for around 72% of global abstraction.[61] According to data compiled by the United States National Ground Water Association, the PRC is among the largest users of groundwater in the world, second only to India.[62] This is a critical challenge, particularly with the energy impacts and environmental consequences of groundwater extraction, which has already depleted the aquifers and deteriorated the country's water quality. The monitoring data show that in January 2016, the groundwater storage for major plains in the PRC was 8.24 bcm, less than that in the same period in the previous year.

60 World Bank. World Development Indicators: Agricultural Inputs. http://wdi.worldbank.org/table/3.2 (accessed 13 May 2016).

61 J. Pittock. 2014. Global Growth in Groundwater Abstraction: In Search of Sustainable Solutions. *Water21*. pp. 20–23. 4 April.

62 National Ground Water Association. 2016. Factsheet on Global Groundwater Usage. http://www.ngwa.org/Fundamentals/use/Documents/global-groundwater-use-fact-sheet.pdf

Table 7: Summary Statistics of the Various Types of Groundwater Abstraction Wells in the People's Republic of China, 2013

Type of Water Abstraction Wells			Number of Wells	Water Withdrawal (bcm)
Tube well	***Irrigation***	Inner diameter of well tube ≥200 mm	407	61.3
		Inner diameter of well tube <200 mm	441	14.0
		Subtotal (Irrigation)	***848***	***75.3***
	Water supply	Daily water abstraction ≥20 m^3	39	21.7
		Daily water abstraction <20 m^3	4,496	7.0
		Subtotal (Water supply)	***4,535***	***28.7***
Subtotal (Tube well)			**5,383**	**104.0**
Manual well			**4,366**	**4.4**
TOTAL			**9,749**	**108.4**

bcm = billion cubic meter, m^3 = cubic meter, mm = millimeter.

Source: Ministry of Water Resources and National Bureau of Statistics of the People's Republic of China. 2013. China Census for Water. *Bulletin of First National Census for Water*. http://www.mwr.gov.cn/2013pcgb/merge1.pdf

A total of 9,749 groundwater abstraction wells were drilled in the PRC for 108.4 bcm, which is close to 18% (or 621.3 bcm) of the country's total water withdrawal (Table 7). More specifically, in the North China Plain, roughly 70% of the agricultural area was irrigated with groundwater.[63] Given the national economy's dependence on groundwater, sustainable groundwater management is critical to healthy environmental water flow.

In regions experiencing rapid economic development, such as in southern and southeastern PRC, groundwater is now contaminated with heavy metals and other pollutants. According to a PRC geological survey, 90% of shallow groundwater is polluted and 60% seriously so.[64] Beijing, Hebei, and Tianjin groundwater resources are already overexploited. Henan, Shandong, and Shanghai groundwater consumption has reached 80%–100% of recharge (footnote 2).

Protecting groundwater from pollution is also important to guaranteeing supply and the need to increase water storage in aquifers. Some provinces are taking exemplary steps (Box 4).

4. Ecosystem Services and Water Resources

Ecosystem services are the benefits that nature provides for people.[65] Rivers, lakes, and wetlands meet human needs by providing freshwater for irrigation, domestic water,

63 Y. Hu, J.P. Moiwo, Y. Yang, S. Han, and Y. Yang. 2010. Agricultural Water-Saving and Sustainable Groundwater Management in Shijiazhuang Irrigation District, North China Plain. *Journal of Hydrology*. 393 (3–4). pp. 219–232.

64 J. Qiu. 2010. China Faces up to Groundwater Crisis. *Nature*. 466 (7304). p. 308.

65 China Council for International Cooperation on Environment and Development (CCICED). 2010. Ecosystem and Management Strategy in China. CCICED Task Force Report.

Box 4: Progress in Groundwater Management in the People's Republic of China Evident, but Full Recovery Elusive

Responding to the issue of dropping levels of groundwater tables across the People's Republic of China (PRC) due to overuse and pollution, a few provinces have taken exemplary actions. However, they discovered that their deepest, most critical, most damaged aquifers are resistant to saving.

The Ministry of Water Resources reports that the PRC depends on groundwater for about 20% of its water supply, with 60% of that used by agriculture. In the water-scarce Northern PRC, about 65% of drinking water comes from groundwater. More than 400 of the country's 661 cities use groundwater as their primary source for water. The importance of groundwater is not evident in how it is being managed. In April 2014, the Ministry of Land Resources reported that the quality of groundwater for 60% of the 4,778 spots in 203 cities that it monitors was too poor for drinking.

Several provinces and cities in the PRC are learning that, despite their best effort, damage to groundwater aquifers is often an irreversible process. Shandong Provincial Government is trying to protect the groundwater tables of the North China Plain—the largest alluvial plain in eastern Asia—through better water efficiency, reuse, and strict regulation on groundwater pumping. The provincial government is also counting on the large South–North water transfer scheme to replace groundwater abstraction with surface water supplies. Shandong is already receiving limited amounts of water from the transfer, but the diverted water, which is mainly intended for municipal and industrial uses, will not be sufficient to mitigate the current overexploitation of groundwater resources in the North China Plain.

The Asian Development Bank (ADB) is supporting Shandong to address groundwater overexploitation in the Zibo–Weifang area, which is the second most overexploited aquifer in the PRC, stretching across 5,800 square kilometers. A cone of depression in the area developed after the drought of 2002–2004, during which the depth of groundwater increased to about 49 meters. As a result of high rainfall and different recharge measures, the groundwater table has been somewhat restored and the cone of depression slightly reduced. Recharge of groundwater resources is still insufficient to recover from the excessive pumping during the dry periods.

Following the central government's requirements to tighten controls of water resources, Shanxi Provincial Government is relying on five regulations to limit water use, control pollution, and improve efficiency: (i) regulation of the total amount of groundwater abstracted from source areas, (ii) compulsory water resource assessments for investment projects, (iii) licensing of well drillers, (iv) administration of water withdrawal, and (v) payment for the use of groundwater resources. The next challenge for Shanxi is to implement the measures systematically and effectively.

ADB has helped county governments in Shanxi modernize its agriculture, which is helping to save water, energy, fertilizers, and pesticides. In the upland areas, groundwater overuse is not yet a problem, but agriculture will likely expand to those areas to keep up with the increasing demand for high-quality food.

Several districts in Hebei, Shanxi, and Gangsu provinces have also demonstrated a potential for tradable quota systems combined with tiered pricing, swipe cards, automatic water level recorders, and data control centers. In some progressive cities, groundwater is allocated to

continued on next page

Box 4 *continued*

industries on the basis of their water productivity. To reduce groundwater abstraction, farmers in Xiliuzhi Village of Qi Xian County changed irrigation practices in their greenhouses from flood irrigation to drip irrigation. The new system has pressure meters, dual distribution lines, a centrifugal filter to remove impurities from water, and a frequency converter, which reduced energy consumption by 40%.

These good examples need to be scaled up to all areas where unsustainable groundwater abstraction is a concern. Effective groundwater protection and management require resolving the problem at the regional basin, where groundwater is a resource shared by several jurisdictions, as well as at the local levels, where smaller aquifers are critical for many rural communities in the PRC and are an important way of adapting to changing climate conditions.

Source: COWI. 2013. Groundwater in China: Part 1—Occurrence and Use. Copenhagen: Danish Nature Agency, Ministry of Environment and Food of Denmark. http://cewp.org/wp-content/uploads/2014/08/Groundwater-in-China_Part-1_Occurrence-and-Use_COWI.pdf

power, and transport. They also contribute to human well-being by naturally maintaining fisheries and biodiversity, balanced ecosystems, recreation, and scenic values.[66] The economic function of water sources in the PRC has been exploited, destroying inland water ecosystems. To avoid negative socioeconomic impacts, better ecosystem management is required to sustain the ecosystem services that underpin quality of life (footnote 19). For the 12th Five-Year Plan period, the central government planned to cover all key national-level ecological function zones under some form of eco-compensation or ecological payment transfer systems (footnote 65). Provincial governments plan to set up a similar system from provincial and subprovincial systems.

Unplanned or poorly managed development usually leads to overexploitation and pollution of water bodies due to soil erosion, construction, and extensive use of fertilizers. These imposed changes on water bodies transform the aquatic and terrestrial biodiversity, alter the natural flow of water, and impact water ecosystem services such as filtration, and thus compromise water availability and quality. They will also have an eventual impact on economic growth when unsustainable use of water, air, food, fibers, and other commodities lead to environmental collapse (footnote 65).

To internalize the costs of restoring and maintaining these ecosystem services into the economy, many have suggested the implementation of payment for ecosystem services (PES) mechanisms. The PRC has developed the largest PES-type program in the world, known as eco-compensation (footnote 19). Water comprises one of seven key areas of the PRC's eco-compensation system. Examples of these efforts include two large PES projects—the National Forest Conservation Program and the Grain for Green Program. These long-term and large-scale projects offer valuation of environmental services.[67]

[66] B. Aylward, J. Bandyopadhyay, and J.C. Belausteguigotia. 2005. Freshwater Ecosystem Services. In K. Chopra, R. Leemans, P. Kumar, and H. Simons, eds. *Ecosystems and Human Well-Being: Policy Responses*, Volume 3. Millennium Ecosystem Assessment. Washington, DC: Island Press. pp. 213–255.

[67] R. Costanza and S. Liu. 2014. Ecosystem Services and Environment Governance: Comparing China and the US. *Asia and the Pacific Policy Studies*. 1 (1). pp. 160–170.

These initiatives have been possible due to the centralized political power, which is the same system that has allowed the PRC to secure the resources to conduct some of the world's most extreme projects—the Three Gorges Dam, the South–North water diversion project, and the orchestrated rapid development of western PRC, which has led to huge environmental challenges (footnote 67).

The key challenges in developing the eco-compensation water initiatives are having to cope with the low capacity for place-based monitoring and assessment, identifying services in the context of the entire flow regime, considering the trade-offs and conflicts among multiple uses, and taking into account uncertainty (footnote 66). These issues need to be incorporated into the government's future initiatives with ecosystem services.

There are several other types of policy instruments that can enhance, protect, or maintain ecosystem services: regulation, economic and market instruments, ecosystem preservation and restoration, and public outreach and education.[68] Local governments can implement these measures when they are empowered and transparent, have the right capacity, and are properly funded and staffed (footnote 68).

The Catskills in New York in the United States also faced many of the challenges the PRC is facing today, including rapid growth leading to overuse and pollution of water resources (Box 5).

During the International River Symposium held in Brisbane, Australia on 26-29 September 2011, it was reported that many of the PRC's water resources undergo morphological and hydrological changes, and suffer quality deterioration and habitat degradation. To improve river health in the basins of Hai River, Tarim River, and Yellow River, water reallocation has been undertaken since the 1990s. Pilot projects to rehabilitate and protect rivers and lakes have also been carried out in 12 PRC cities since 2004. The lessons should be shared with other river basins. Monitoring the river health index is imperative and should be placed on high priority with consistency in approach and database system.

E. Key Dimension 5: Water Security for Climate Resilience

The PRC scored only 2 out of 5 on the Asian Water Development Outlook's climate resilience index (footnote 18). The Asian Water Development Outlook measures a country's resilience to water-related disasters by evaluating progress toward creating resilient communities that are adaptive to change. It is a composite indicator that involves assessment of three types of water-related shocks—floods and windstorms, droughts, and storm surges and coastal floods—by examining exposure, basic population vulnerability, hard-coping capabilities, and soft-coping capacities.

[68] S. Greenhalgh and M. Selman. 2014. *Review of Policy Instruments for Ecosystem Services*. Landcare Research Science Series No. 42. http://www.mwpress.co.nz/__data/assets/pdf_file/0019/74521/Policy_Instruments_for_Ecosystem_Services.pdf

Box 5: New York Catskills and Ecosystem Services

In 1997, the Government of the City of New York embarked on buying thousands of acres of land upstate in the Catskill Mountains to shield the city's reservoirs from pollution—a more cost-effective way of cleaning up its water supply. In current dollar terms, a filtration plant to clean up New York City's water supply would have cost \$8 billion–\$10 billion and another \$250 million annually for maintenance. On the other hand, preserving the watershed was estimated to cost only \$1.5 billion.

After 7 years of tense negotiations, the city brokered a deal with various stakeholders to preserve and enhance the upstate watershed. These deals included purchasing land, convincing communities to change their zoning to minimize population growth, and providing runoff protection measures. Farmers fenced their pastures so that animal waste did not flow straight into the reservoirs. Wastewater treatment plants were upgraded and septic tanks fixed. This required a groundbreaking effort in the new concept of ecosystem services based on concrete accounting.

The Catskills are now the largest unfiltered water system in the world. New York City's watershed spans nearly 2,000 square miles (5,180 square kilometers), with 19 reservoirs and aqueducts cutting across nine counties. The city's watershed provides 1.2 billion gallons (4.5 million cubic meters) of drinking water daily to 9 million New Yorkers. New York City's water is cleaner, with one fewer reservoir labeled as having excess amounts of nutrients. Farmers are pocketing profits and environmentalists are pointing to the city's watershed agreement as the prime example of how ecological solutions reap financial benefits.

Source: A. Kenny. 2006. Ecosystem Services in the New York City Watershed. Ecosystem Marketplace. http://www.ecosystemmarketplace.com/articles/ecosystem-services-in-the-new-york-city-watershed-1969-12-31/

Climate change will likely lead to three key water-related consequences in the PRC: (i) increase in temperature, (ii) change in water distribution geographically and seasonally, and (iii) sea level rise.[69] Temperature rise could trigger more glacier melt, which can critically affect river runoff and flooding (footnote 29). In the coming decades, a continuing increase in glacial runoff can reasonably be expected in response to warming, especially during the spring and early summer.[70] In the short term, this could be beneficial for irrigated agriculture in arid PRC, although runoff may be reduced in the late summer and autumn.[71] In the long term, if a large fraction of the glaciers melt, water shortage may return and become the norm; but uncertainties are larger for longer-term scenarios. Sea level rise would impact cities and coastal zones. Cities that are facing land subsidence due to overpumping of groundwater will likely notice higher water levels and perhaps even saltwater intrusion into freshwater aquifers. Storm surge and sea level rise can also cause massive flooding of coastal zones and low-lying areas.

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69 X. Li, G. Turner, and L. Jiang. 2012. *Grow in Concert with Nature: Sustaining East Asia's Water Resources through Green Water Defense*. Washington, DC: World Bank.

70 T.P. Barnett, J.C. Adam, and D.P. Lettenmaier. 2005. Potential Impacts of a Warming Climate on Water Availability in Snow-Dominated Regions. *Nature*. 438 (7066). pp. 303–309; S.Y. Liu, Y. Zhang, Y.S. Zhang, and Y.J. Ding. 2009. Estimation of Glacier Runoff and Future Trends in the Yangtze River Source Region, China. *Journal of Glaciology*. 55 (190). pp. 353–362.

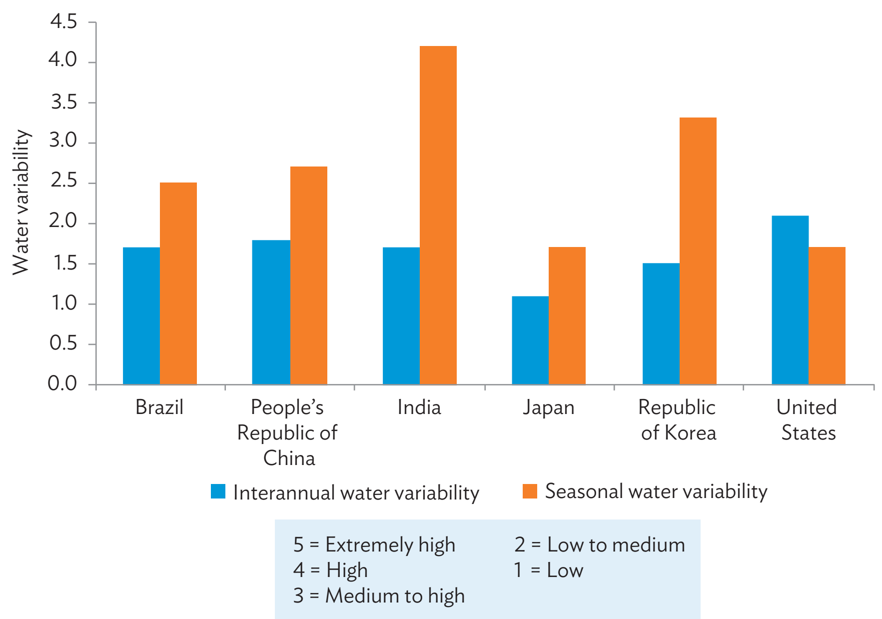
71 Liu et al., 2009 (footnote 70).

The PRC's low to medium year-to-year water supply variability will also be affected by more frequent and extreme incidents of drought and flooding, sea level rise, and changes in glacier mass balance (Figure 30). Climate change projections show that annual runoff over the PRC will increase 3%–10% by 2050, with uneven spatial and temporal distribution (Table 8). Meteorological droughts will become more common and severe (footnote 2). Overall, the current water resources pattern of "dry North and wet South" may deepen.[72]

The NDRC has calculated that climate change has already cost the PRC more than CNY200 billion ($30.4 billion) since 1990. In the same period, more than 2,000 people have died because of extreme weather-related disasters, such as floods, droughts, typhoons, and storms.[73]

Climate change may put an extra burden on the PRC by hampering the achievement of important goals or targets in the region, particularly sustainable development and poverty reduction. A country's exposure to disaster-related risks and its capacity to overcome such disasters define its resilience. Resilience to water-related disasters includes the ability to

Figure 30: Interannual and Seasonal Water Variability in Selected Countries



Source: World Resources Institute. Aqueduct Water Risk Atlas. http://www.wri.org/resources/maps/aqueduct-water-risk-atlas

72 While it is necessary to prepare for climate scenarios, projections of future water resources carry uncertainty from emissions scenarios, general circulation models, downscaling approaches, and in the assessment model itself.

73 *The Wall Street Journal*. 2013. China Releases Blueprint for Adapting to Climate Change. 10 December. http://blogs.wsj.com/chinarealtime/2013/12/10/china-issues-blueprint-to-help-minimize-effects-of-global-warming-and-climate-change/

Table 8: Projected Changes in Runoff for 2021–2050 for the People's Republic of China's 10 River Basins under A1B, A2, and B2 Climate Scenarios

No.	River Basin	Changes in Annual Runoff (%)			Runoff Change in Jun–Sep (%)		
		A1B	A2	B2	A1B	A2	B2
I	Songhua	1.1	(4.1)	(10.8)	1.4	(5.5)	(11.7)
II	Liao	20.8	2.6	(6.4)	21.4	1.5	(7.4)
III	Hai	11.3	5.2	(3.3)	10.3	3.3	(7.7)
IV	Yellow	(2.1)	(4.1)	(6.4)	(4.2)	(7.7)	(10.8)
V	Huai	12.9	6.0	(1.2)	10.5	6.1	(3.1)
VI	Yangtze	8.2	6.6	0.7	4.2	8.2	3.1
VII	Region of SE PRC	13.2	9.1	8.3	12.3	11.4	12.0
VIII	Pearl	11.8	0.9	(3.0)	10.1	0.5	1.1
IX	Region of SW PRC	3.6	0.8	0.3	4.6	0.7	(0.4)
X	Region of NW PRC	2.6	0.2	2.4	0.6	(0.9)	2.4
PRC as a Whole		**11.3**	**2.9**	**(0.7)**	**9.1**	**3.4**	**0.9**

( ) = negative, NW = northwest, PRC = People's Republic of China, SE = southeast, SW = southwest.

Notes: The Special Report on Emissions Scenarios published by the Intergovernmental Panel on Climate Change in 2000 described various greenhouse gas emissions scenarios used to make projections of possible future climate change.

1. The A1B scenario describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies (balanced fossil and nonfossil energy sources).

2. The A2 scenario describes a very heterogeneous world with continuously increasing population, primarily regionally oriented economic development, as well as slower and more fragmented per capita economic growth and technological change.

3. The B2 scenario describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1B scenario.

Source: G. Wang, J.Y. Zhang, J.L. Jin, T.C. Pagano, R. Calow, Z.X. Bao, C.S. Liu, Y.S. Liu, and X.L. Yan. 2012. Assessing Water Resources in China using PRECIS Projections and a VIC Model. *Hydrology and Earth System Sciences*. 16 (1). pp. 231–240.

overcome several types of water-related shocks including floods, droughts, storm surges, and coastal flooding.

Industrialization, urbanization, climate change, and population rise are stressing the PRC's freshwater resources and exposing people to higher risks of droughts, floods, and water pollution disasters. Because of natural, human, and ecological drivers—such as uneven distribution of water resources, uneven rainfall patterns, degraded ecosystems, increasing climate change, and high concentration of chemical enterprises in the key river basins—the recurrence of droughts, floods, and pollution incidents in recent years in the PRC may be an indicator of a "new normal."

The country may have a finely tuned and, at times, incredibly agile emergency response system, but it is lacking a corresponding risk reduction and management system (footnote 2). In the absence of a separate risk management agency, risk management responsibilities are distributed to several agencies pooled together by a strong central authority.

V. Priority Actions for Increased Water Security Under the 13th Five-Year Plan

The literature on water security in the PRC resounds with calls for demand management in the form of increased system and technological efficiency as well as calls for more aggressive use of financial and market-based approaches to address the scale of environmental loss. The major thrust of the 13th Five-Year Plan should be providing all sectors and their major actors with the technical guidance and resources they need to meet higher legally compulsory standards for both water efficiency and productivity.

Employing the strategic principle of comprehensive and improved water efficiency and innovative financing across all sectors would support the scientific goals of the country of developing more resource-efficient and productive technologies. To achieve efficiency standards and demand coming from energy, industry, agriculture, and the household and consumer sectors, higher-value industries as well as the consumer market have to be strengthened.

The PRC should approach the country's imminent water scarcity using the following six recommendations, which center on the need for more knowledgeable and coordinated leadership at high levels; the use of international best practices and technology for more efficient and productive use of water; and the strengthening of a regulatory environment that enables the private sector to fill the gaps left by insufficient financing, technical capacity, and a lack of incentives that are needed for watershed protection and technological uptake.

A. Elevate Water Security to the Appropriate High-Level Authority and Ensure Proper Implementation of National Water Security Strategy

Ecological and environmental degradation will remain an important issue in the 13th Five-Year Plan. The scope (air, soil, water), diverse sources (agricultural, industrial, domestic), and long-term impacts of pollution necessitate stronger regulations, innovative local financing mechanisms, and a more decisive and corrective role for markets and economic policy.

Establish a state water security committee. Governance is critical to integrated water resources management. Such a national-level committee should serve as the highest water policy-making body, similar to the National Energy Commission, and be headed by either the premier or the vice premier. It would coordinate water policy reforms and implementation, as well as streamline supervision, across all sectors. To provide effective oversight of the country's water resources and policy implementation, the committee needs the support of a more effective body of river basin management commissions, particularly the seven commissions for the country's seven major river basins. In the 13th Five-Year Plan period, the committee needs to ensure that water resources availability is integrated into all energy planning and the urbanization strategy. Key members would come from the NDRC, the Ministry of Water Resources, the Ministry of Environmental Protection, the National Energy Commission, the Ministry of Housing and Urban–Rural Development, and the Ministry of Agriculture.

Formulate a national water security strategy in the 13th Five-Year Plan. To bridge the gap between water supply and demand, the government should formulate a long-term national water security strategy (up to 2050) and plans based on careful analysis of (i) the increasing demand by 2050 from agricultural intensification, energy development, industrialization, and urbanization; (ii) the implications from water pollution, degraded ecosystems, and climate change on water scarcity by 2050; (iii) the implications on water supply options from natural limitations caused by uneven water distribution between North and South, uneven rainfall patterns, and a natural proclivity to droughts; and (iv) the optimal infrastructure, including water-saving technologies and other technical, nonstructural investments.

Strictly enforce water and wastewater management and treatment reform policies during the 13th Five-Year Plan period. The 13th Five-Year Plan period is critical to implement the 2011 No. 1 Central Policy Document on the PRC's water conservancy issues and the Three Red Lines policy. A reformed river basin management commission for each of the seven major rivers should be required to formulate implementation procedures for provincial and local governments to follow when drafting enforcement plans for key water management reform policies. Where there is implementation of these plans, there should also be supervision and inspection. National and local congresses and administrative branches should be strengthened for this work. An informed public would also keep local agencies accountable for law enforcement. The public needs to be legally entitled to fulfill such a role.

B. Deepen Reform of Water Governance System and Strengthen Water Management

The PRC needs to move from the traditional system of government as main decision makers toward a modern, more robust approach to water governance that relies on (i) a sound legal framework, (ii) effective institutional arrangements, and (iii) transparent decision making and information disclosure (footnote 13). Governance of water utilities, in particular, would benefit from the separation of ownership of assets from the management of services. This would encourage a more entrepreneurial approach to utility management, attract private capital, and foster the development of a water service industry.

Launch the legal reform to clarify responsibilities and encourage collaboration among the water-related sectors. The National People's Congress should revise water-related laws to improve clarity, remove contradictions, and bring to focus the enforcement of integrated water management. The Water Law needs to be updated to align it with the government initiative of building an "ecological civilization." The legal reform should address two fundamentals: rights and authorities over water management, and coordination between jurisdictions and institutions.

Reform the seven river basin management commissions. The river basin management commissions for the country's seven major river basins should be made independent from the Ministry of Water Resources and accountable to the proposed State Water Security Committee. These commissions should be reformed to have more diverse representation of relevant line agencies and local governments. Energy, environment, agriculture, and urban planning representatives are essential.

Invest in data infrastructure and improve information accessibility and transparency. To help inform decisions and modernize water management, development of data infrastructure and information accessibility in the 13th Five-Year Plan should focus on (i) financing a real-time monitoring system based on a geographic information system (GIS) to collect various types of water supply, water quality, and water infrastructure information; (ii) mainstreaming remote sensing technologies in water resources management; and (iii) building a comprehensive water information platform that integrates data from all key authorities from the local levels upward. Remote sensing technologies would allow extraction of more data in large quantities (e.g., from river basins) over large spatial domains and time periods. They would also facilitate greater scientific understanding of hydrological processes and forecasting models. One of the barriers to better water management is the lack of reliable, up-to-date information (such as pollution sources, locations of sewer pipes, groundwater use, etc.). To ensure a water-secure future, the PRC must be able to understand its current water situation and understand future trends. The first national pollution sources census in 2007 and the first national water resources census in 2013 are a good start. The completion of the first phase of the PRC's national water resources information system would contribute much to information collection, analysis, and dissemination.

C. Build Optimal Water Infrastructure Capacity to Enhance Country Water Security

In the 13th Five-Year Plan, the government should adopt the following mix of traditional and modern measures to strengthen national water security:[74]

[74] The 2030 Water Resources Group charted 55 optimal measures to close the 201 bcm gap it projects for the PRC in 2030. Traditional water supply infrastructure would fill as much as 35% of the supply–demand gap, but most measures are nontraditional or nonstructural. These measures include water-saving fixtures and appliances for domestic users, increased water productivity systems for industry, more efficient irrigation, rehabilitation of damaged irrigation and drainage facilities, extension of small-scale irrigation schemes, multipurpose reservoirs, dams, water-impounding systems, and reclamation of used water.

Promote metering and better meter management. The PRC's Water Law of 2002 has stipulated the universal installation of water meters in order to more accurately measure water usage as well as correctly bill and collect integrated tariffs (water resources fees) from water users. In most parts of the country, domestic and industrial water users are subject to water resources charges based on quantities used. There remains, however, a substantial amount of water use that is not metered, including water used for irrigation and water abstracted from groundwater. The 13th Five-Year Plan should therefore pursue to expand metering for agricultural use (which is not metered at present) and extend meter coverage in cities. Metering is a critical infrastructure for demand management. The PRC's low ratio of metered water users, along with a weak system of regulation, enforcement, and monitoring, poses a major barrier to the implementation of block tariffs, which is a basic strategy for reducing water demand by charging higher rates for luxury water consumption. Water metering, thus, provides an incentive for water conservation.

Rehabilitate urban pipes and invest in leak detection. Sewer pipes should be regularly checked for leakages, particularly for major pipe breaks, as leaking pipes are a cause of substantial revenue loss, water shortages, and water pollution. The existing system of combined wastewater and stormwater pipes needs to be slowly replaced with separate sewerage systems. In newly developed areas, separate pipes for sewage and stormwater should be installed. Municipal wastewater should also be integrated with industrial wastes. Hence, the capacity of sewer pipes should be increased to accommodate wastewater from both industries (chemicals) and municipalities (heavy pollutants). Investments in sewerage systems, however, are not likely to come from private and capital markets, which regard piping systems as sunk costs. The government will have to invest over the next 5 years in rehabilitating the sewer pipes, building more climate-resilient water infrastructure, and increasing the coverage of urban piped networks.

Make use of recycled water. Development has only begun in reclaiming wastewater for recharging rivers and lakes, city greening, and partial flushing in households. Facilities for recycling wastewater should be situated near areas where the reclaimed water will be used. Making better use of high-quality reclaimed wastewater (such as NEWater in Singapore)[75] can sharply decrease the energy intensity and cost of water production and at much better rates than desalination. Nonetheless, having dual quality network systems (i.e., for clean and recycled water), especially within the homes, can be very costly and unsafe (due to the high risk of contamination). In the PRC's industrial sector, water recycling rate is estimated at 40%—this is way below the average rates of 75%-85% in developed countries. Intensifying water recycling and treatment efforts could help cut down water consumption of water-intensive industries by 18% and overall water use of urban industries by 7%. Water recycling from urban usage may be crucial in decelerating groundwater depletion rates (footnote 14).

Invest in conservation and efficiency measures. Some of the highly cost-effective measures to decrease total water demand for the same economic output include: (i) installation of water-saving fixtures for residential and commercial buildings (e.g., water-efficient faucets, showerheads, toilets, etc.); (ii) improvement of water efficiency in the energy sector through new technologies; (iii) reduction of water use in industrial

[75] NEWater is the brand name given to reclaimed water produced by Singapore's Public Utilities Board.

processes and equipment; and (iv) broader use of rainwater-harvesting systems in cities for landscape irrigation, heating and cooling systems, and toilets. These measures can be achieved by setting quality control mechanisms and establishing basic efficiency standards, such as the National Standard for Quality Management, that could be enforced by the Standardization Administration of [the People's Republic of] China both at the central and local governments levels. The mandatory application of these quality standards should be imposed on public facilities, including business districts, schools, hospitals, etc. Incentives can be provided for the early replacement of old and inefficient equipment. In some instances, government subsidies may be required, particularly for the poor households in rural areas.

Increase agricultural water productivity. With agriculture accounting for 65% of total freshwater withdrawal in the PRC (in 2014), more investments are needed to achieve the irrigation efficiency targets of 0.55 by 2020 and 0.60 or above by 2030. Government must support research funding and extension. The promotion of agricultural best practices can maximize "crop per drop" yields. This includes proper crop selection for local soil and hydrologic conditions, seed development, and selection of more heat- and drought-tolerant varieties. Best management practices can also increase soil moisture capacity and hold more rainwater to recharge groundwater tables. Remote sensing can be a useful tool for benchmarking productivity and supporting investment projects. Similarly, water accounting at the basin level can provide a better understanding of how water is being used within the system.

Safeguard groundwater resources. The Ministry of Water Resources is responsible for the overall management of groundwater resources. But the central government may consider establishing an independent groundwater management organization primarily tasked with the regular monitoring of groundwater resources (including inventory of tube wells and their quality and yield) and regulatory measures, particularly in the provinces, including coordination, consolidation, and dissemination of groundwater information.[76] Information culled from groundwater modeling, for example, would be helpful in determining total groundwater availability and defining sustainable levels of groundwater abstraction. Groundwater abstraction should be closely monitored. Moreover, limits on groundwater extraction should be imposed, penalties for over-abstraction levied, and policy incentives resulting in overpumping reviewed and rationalized. Financial resources must be allocated to (i) conduct specific hydrogeological studies, (ii) develop groundwater management plans with all local stakeholders, and (iii) invest in measures and establish monitoring mechanisms for sustainable groundwater management. The Asia-Pacific Center for Water Security can be a suitable institute to work more closely on groundwater resources monitoring.[77]

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[76] The PRC Ministry of Water Resources reports that the country depends on groundwater for about 20% of its water supply, with 60% of that going to agriculture. In the water-scarce northern PRC, about 65% of drinking water comes from groundwater. More than 400 of the PRC's 661 cities use groundwater as their primary source for water. Pollution and overextraction cause irreparable damage to underground aquifers. In April 2014, the PRC Ministry of Land and Resources reported that the quality of groundwater for 60% of the 4,778 spots in 203 cities that it monitors was too poor for drinking.

[77] The center was established in Beijing in 2011 by Tsinghua University and Peking University in collaboration with ADB. It aims to promote research in a range of water security dimensions, risks and resilience, and the water–energy–food nexus, in the context of green growth, urbanization, and climate change.

D. Reform Water Pricing to Reflect Scarcity and Create Water Services to Address Externalities

One reason for the current water crisis in the PRC is that water resources and water services are not being properly priced and valued. Essential to the 13th Five-Year Plan are further reforms of water resource prices and the creation of water service markets to reflect such factors as scarcity of water resources and externalities associated with water services.

Support local governments in implementing tariff regulations. Local authorities have been slow in implementing tariff regulations.[78] They are concerned about the public's reaction, especially that of the poor, toward price changes. Tariff increases elsewhere have been out of step with metering and at irrational rates. The state, therefore, needs to inform local governments on how to use "block tariffs" in socially acceptable and financially sound ways. Cost tiers need a scientific and justifiable basis for charging different rates to different sectors and to households using different amounts of water (total or per capita). Full cost recovery should be reflected in regional and national water management and economic planning. When local governments and the public begin to understand the true costs of water and sewerage services, a market consciousness will grow and positively affect how water is allocated and used. Other means to effect water pricing reforms, such as through subsidies, can also be explored.

Strengthen water rights administration and pilot water markets. The seven river basin commissions, with support from the central government, should jointly develop and issue a technical handbook on allocating river basin water resources for local government users. The handbook would contribute to more consistent preparation of water resources allocation plans and agreements at local levels, which is the basis for functioning water markets. Plans must be based on scientific accounting of water availability, water consumption, and the amounts that must be retained or returned to the environment.

The 13th Five-Year Plan will build confidence for water trading by establishing clear entitlements and demonstrating competence in managing, monitoring, and communicating the water allocation, rights, and trading systems. This begins with information systems that relate to allocations and rights. The plan should pilot temporary trading in areas which have some experience and where there is some monitoring infrastructure in place. Specifically, the plan can help formalize trading of water from agriculture to nonagriculture sectors.

Develop a watershed services market that attracts the private sector. The government has been the predominant buyer of watershed services in its eco-compensation schemes, which has left little room for the private sector. In developing a national eco-compensation policy framework, the government needs to shift its role to "enabler," focusing on establishing the regulatory requirements that can create a market that would build the confidence of and attract private sector participation. However, much work remains

[78] Regulations allow various fees to recover the full costs of water and sewerage services. The water development fee can cover productions costs, the water resources fee can cover environmental and depletion costs, and the sewerage fee can cover waste removal costs.

to be done in ensuring the proper valuation of compensation needs and the long-term sustainability of eco-compensation schemes.

Convert the water resources fee to water tax. Local governments use the water resources fee to fund local water resources management programs. These revenues could be put to better use if they were collected as a tax, which the central government would allocate to priority basin water projects. Allocations from annual central and local government budgets could support local water resources management activities.

E. Focus on the Weakest Spots of the Country's Water Security and Develop Water Risk Management

The government should extend special efforts to geographical areas where floods, droughts, and pollution hazards are high. At the same time, the government needs to shift from an emergency response system to a risk management system.

Build a water risk management system to increase resilience. The government should adopt the following measures in the 13th Five-Year Plan: (i) build a long-term national water risk mapping and monitoring system, including floods, landslides, drought, supply variability, water stress, and pollution incidents; (ii) establish an early warning system to increase resilience of cities and farms; (iii) prioritize vulnerable and sensitive areas; and (iv) introduce insurance schemes (such as crop insurance).

Improve domestic water security through chemical management and improved chemical disaster response. During the 13th Five-Year Plan period, the government should (i) develop and enforce stringent controls on pollutant discharges from industrial point sources, especially toxic chemicals near urban drinking water sources; (ii) disclose information on chemical pollution and set up training programs for basic emergency response; and (iii) assess chemical-related water risks for new urban areas. New urban development projects should consider potential chemical pollution of water resources.[79]

F. Promote Education and Public Awareness Programs

The PRC needs to move away from a water governance system that relies heavily on the government as the main decision maker to a system that promotes public awareness and participation. Education is critical in generating basic understanding of water security

[79] The 2005 chemical spill in Songhua River and the 2014 industrial contamination from the Lanzhou water treatment plant demonstrate the threat of water pollution from chemical incidents. These incidents have polluted precious water supplies, leading to economic loss and potential health risk. Countries such as the United States, United Kingdom, and various European Union member states have developed well-designed chemical management and emergency response systems for clean water. In contrast, both the national emergency response and the chemical management system in the PRC are weak.

issues, sound water resources management and planning, and the associated benefits of water conservation efforts. Better access to information on water-related resources, policies, and institutions would help raise public awareness on the impact of improved water efficiency and empower citizens to actively participate in water management efforts through, for example, public opinion surveys, public hearings, review of development plans, law enforcement, apprehension of violators, and stakeholder coordination. Education and public awareness programs will equip policy makers and water users with adequate knowledge and enhanced capacity to warrant the successful adoption and implementation of water conservation practices.

The PRC should also provide support for the development and participation of civil society and nongovernment organizations as they play an important role in water management, including improving access to safe water as well as access to water-related information needed for both national and local decision making. Nongovernment organizations are likewise effective in publishing and disseminating education and information materials on different water and health issues. They have, through their extensive networks, valuable experiences in terms of good practices and technical solutions for water resources management and protection.

VI. Issues for the Near Future: The Water–Energy–Food Nexus

The implications of development on water resources should be considered at more strategic levels rather than just the project level. This need is most acutely manifested in agriculture and energy development, two socially and economically imperative sectors where competition for water resources is not being managed to reflect the scarcity of local water resources. To gain greater understanding of the water–energy–food nexus in its operations and more effectively identify resource utilization, ADB is working on water auditing in energy projects and energy auditing in agriculture projects.

Water for energy. The power sector in the PRC is the largest industrial water user, and 94.3% of total power generation capacity is heavily reliant on water. Yet, roughly 70% of current coal mines are situated in water-scarce regions, and 9 out of the country's 13 identified key energy bases are experiencing high or extremely high water stress. According to the Ministry of Land and Resources, energy demand in the PRC will continue to grow and is projected to peak in 2030–2035. To meet this escalating energy demand, the central government proposes to double power capacity by 2030 (footnote 14).

The following actions could make development of the energy and water sectors more balanced and sustainable: (i) incorporate the impacts of medium- to long-term national or provincial energy sector development plans on the freshwater resources; (ii) introduce incentives and enforce water-use targets in energy facilities to improve water-use efficiency levels and the water-recycling ratio; (iii) establish effective regulatory and compliance mechanisms to ensure that the deployment of new technologies aimed at climate change mitigation and air pollution control (i.e., shale gas, carbon capture and storage, and coal-to-gas conversion) does not adversely affect the groundwater resources, especially in water-scarce regions; and (iv) increase water tariffs for energy and industrial consumers to reflect the scarcity and value of water, which would also send price signals to conserve water.

Water for food. Agriculture is the PRC's main consumer of water, with the sector accounting for 65% of water demand (albeit down from 88% in 1980). Agricultural water consumption is expected to stabilize; nonetheless, promoting agricultural water efficiency savings remains essential. The PRC's agricultural water use is relatively very inefficient, with water productivity estimated at $3.6 per cubic meter. This amount is lower than the average of $4.8 per cubic meter in middle-income countries, and much lower than the $35.8 per cubic meter in high-income countries (footnote 14). Outdated and poorly-funded water and irrigation infrastructures have resulted in low water use efficiency (e.g., only about half of irrigation water is consumed by crops). Whereas 85% of agricultural water is recycled in developed countries, only about 40% is recycled in the PRC (footnote 14).

The PRC is beset with problems of rising food prices, food shortages, and adverse market interventions, which are seriously contributing to social instability. The separate management of agricultural production and water resources availability by different ministries poses a major challenge to the government. To improve resource utilization rates and water services to farms, the ministries responsible for water management and agricultural development need to closely collaborate on a national plan to modernize irrigation and drainage using more developed technical and managerial systems.

Food processing and beverage companies, breweries, and related trade companies have key interests in adopting good agricultural practices in farms and in improving water efficiency, since they need to ensure that their production lines and supply chains are protected from the increasing water risks. The government can attract private sector financing for irrigation and drainage by establishing performance targets and shifting to private sector management of irrigation water supply and management.

Addressing Water Security in the People's Republic of China:
The 13th Five-Year Plan (2016-2020) and Beyond

Although accounting for about 20% of the global population, the People's Republic of China (PRC) is endowed with only 7% of the world's water resources. The country faces severe water scarcity, high levels of urbanization and population growth, and climate change. For the PRC's continuing development, it must protect and develop its freshwater resources. This publication provides recommended policy initiatives to ensure the PRC's 13th Five-Year Plan (2016–2020) contributes to significant improvements in national water security, particularly in extreme water-scarce provinces. Some actions proposed for increased water security are better water resources management, more cross-sector planning, deeper reform of the water pricing system, and creation of water markets.

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