WATER MANAGEMENT

Water Sustainability for China and Beyond

Despite investments in water infrastructure, China must address human-nature interactions to ensure supply and quality.

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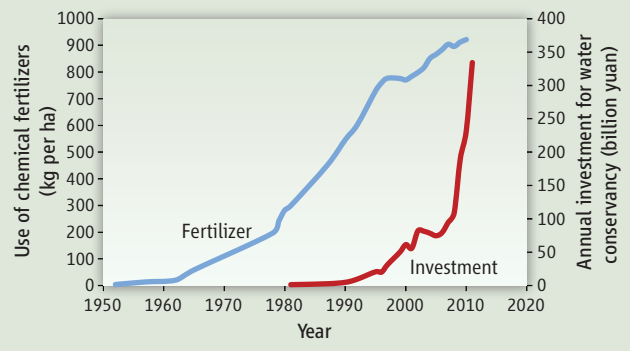
A water crisis has prompted the Chinese government to develop an ambitious water conservancy plan. However, the plan may not achieve water sustainability and may cause unintended environmental and socioeconomic consequences, unless it accounts for complex human-nature interactions (*1*). Water shortages, for example, force people to find alternatives, such as treatment facilities, whose land and energy requirements aggravate food and energy production, which need large amounts of water. Other nations face similar challenges and share real water from China along international rivers and/or virtual water through trade. Water problems are particularly challenging in China, which has the largest population, fastest-growing economy, rising water demand, relatively scarce water, dated infrastructure, and inadequate governance. We highlight China's water crisis and plan, and we offer recommendations.

Water Crisis and Grand Investment

Two-thirds of China's 669 cities have water shortages, more than 40% of its rivers are severely polluted, 80% of its lakes suffer from eutrophication, and about 300 million rural residents lack access to safe drinking water (*2*). China's per capita availability of renewable water resources is about a quarter of the world average, but water consumption per unit of Gross Domestic Product is three times the world average because of water-intensive industrial structure, outdated technologies, low reuse rate, and wastefulness (*2*). Uneven natural water distribution aggravates the crisis. Influenced by a monsoonal climate, precipitation generally declines from the southeast to the northwest and varies greatly from year to year and season to season (*2*). Water-related disasters such as 1998 floods and 2010 droughts saw large losses of life and property, as well as damage to human well-being and the environment.

In January 2011, the government's annual "No. 1 Document," which reflects their top priorities, outlined a plan to expedite water conservancy development and reform and to achieve sustainable use and management of water resources within this decade (see the Supporting Online Materials). The plan is to quadruple total investment in solving water problems to four trillion yuan (U.S. $635 billion) in the next 10 years compared with the investment in the past decade (see the figure) (Fig. 1).



China's investment in water conservancy (*19*–*21*) and use of chemical fertilizers (*22*).

More than 46,000 of the 87,000 dams and reservoirs built since the 1950s have surpassed their life spans, or will within 10 years, which will increase the risk of structural failure (*3*). The central government plans to repair and reinforce them by the end of 2015 (*3*) and also build new dams, reservoirs, and canals. Since the 1950s, China has constructed 12 major projects that annually divert more than 9 billion m^3 of water; many more such projects are being constructed or planned (table S1), including the South-North Water Transfer Scheme—the world's longest and largest water diversion project with a planned investment of 486 billion yuan (U.S. $77 billion) and 45 billion m^3 of annual water transfer.

The plan focuses largely on engineering measures related to water quantity. Except for water-related targets in the 12th Five-Year Plan, the water plan does not set quantitative targets for water quality, which is low in China and severely affects human and ecosystem health [e.g., increased cancer mortality is attributed to water pollution (*4*)].

Policy Recommendations

This planned investment is laudable, but not sufficient. Thus, we offer the following.

Coordination. Many agencies are involved in water governance (table S2) but lack coordination. At the central government level, the Ministry of Water Resources (MWR) leads design and implementation of the new water plan. The Ministry of Environmental Protection (MEP) is supposed to be in charge of water pollution prevention and control, but lacks adequate resources and jurisdiction. Many water projects (e.g., Jinsha River hydropower) were rushed without following the national law of environmental impact assessments and have caused enormous environmental and socioeconomic impacts (*5*). New laws are needed regarding development (e.g., hydropower) of rivers and river basins (*5*). To implement laws, relevant sectors and agencies (e.g., water resources, environmental protection, shipping, and agriculture) must coordinate and punish law-breaking behaviors.

Coordination must cross organizational levels and sectors. Many water-related laws and policies are not implemented because central and local governments' efforts are not coordinated. In 2004, the central government promulgated a policy to stop construction of golf courses, which consume and pollute much water. Yet over 400 golf courses have since been built by local governments (*6*). The government encourages urbanization, but water protection does not receive as much attention as energy (e.g., green building codes tend to focus more on energy and less on water). The number of households has been growing more rapidly than population due partly to increased divorce and shrinking of multigenerational families (*7*). Rapid housing and land development consumes much water, generates wastewater, and expands impermeable surfaces that increase runoff (*8*).

China has achieved remarkable food production, in part through expansion of irrigation and use of pesticides and chemical fertilizers (see the first figure) (Fig. 1), which has

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escalated water pollution and depleted surface and groundwater. More water will be needed by mines as China expands coal production (*9*). Water diversion projects may encourage consumption and increase demand. The Luanhe-to-Tianjin project annually diverted roughly one billion m^3 of water into Tianjin (table S1), but Tianjin's water-fueled growth now demands even more from the South-North Water Transfer Scheme. China's plan aims to reduce water use in irrigated agriculture (61% of total water use in 2010) largely by constructing efficient farm infrastructure. This may actually increase water use and redistribute supply at a larger scale (e.g., water basin), reducing aquifer replenishment and intensifying depletion at large scales (*10*).

Although water demand is growing, supply is increasingly limited. Glaciers are retreating due to climate change (*11*), reducing water supply. Depletion of water reduces biodiversity (thus, ecosystem services such as water purification) and causes pollution such as eutrophication. Pollution and the spread of invasive species through water diversion may compromise water quality and supply.

Coordination requires continued efforts to lower population growth and slow household proliferation; clarify water rights (e.g., setting maximum water-use quotas at various levels and for all entities); reform water pricing (e.g., increasing block tariffs that discourage high usage); and eliminate inefficient practices (e.g., through rebates for water-saving equipment). More secure land rights to farmers may encourage them to sustain their lands by avoiding overuse of fertilizers and thus protect water. Incentive programs alone cannot guarantee less water use (*10*). Both "hard path" (e.g., dams) and "soft path" approaches (e.g., public education, efficient technology, and financial incentives) are needed (*12*).

Institutional innovations are indispensable. An effective entity (e.g., sustainability coordination office) is needed directly under the State Council (the country's highest executive organ) to clarify functions and responsibilities of water management agencies (table S2), reduce institutional mismatches, identify shared interests, avoid conflicts, and bridge gaps. With State Council support, it would have resources and authority to work across agencies and sectors, as well as with the public and nongovernmental organizations. It also would facilitate public communication and disclosure of information to make government transparent and accountable.

Integrated monitoring and proactive measures. Current monitoring programs include indicators such as water quantity and use efficiency (MWR) and water quality (MEP). To more accurately predict changes and take proactive adaptive management measures, it is essential to monitor indicators that drive changes in water quantity and quality directly and indirectly. Ministries should expand monitoring, particularly in areas with severe water shortages, to indicators in human dimensions (e.g., values and attitudes toward water, land use, and development).

To minimize negative legacy effects and avoid irreversible impacts, China can learn from other countries (e.g., the U.S. Clean Water Act). China should take proactive measures (e.g., solicit public opinions before implementation) for major projects; track government officials' responsibilities and performance related to water; and combine the major evaluation and promotion criteria of short-term economic performance.

Integrating social sciences. China has been vigorously promoting natural sciences and technology but lags behind in integrating them with social sciences, development of which was constrained for decades by government's political ideology (*13*). Incorporating social sciences is not a panacea, but can help, e.g., by predicting water demand and long-term effects of China's water plan, and could lead to positive changes in human behaviors. Efficiency of the plan can be enhanced through changing people's values, attitudes, and behaviors toward water. Changing consumption is crucial for water sustainability, because engineering measures (e.g., long-distance water transfer) have caused serious socioeconomic and environmental costs despite enormous benefits (*12*).

Enhancing international cooperation. China's water plan does not consider virtual water in trade or real water in international rivers. China's trade during 1996–2005 caused a net loss of 23.5 billion m^3 of virtual water (*14*). Although virtual water is but one consideration in trade, and there may be other benefits and costs, it is important for achieving water sustainability. Use of real water in international rivers also has broad implications. Headwaters of 12 major international rivers are in China (*15*), and conflicts have increased over their use in recent years (*16*).

It is important for China to take a more active role to reduce its water footprint and to cooperate on the use of international rivers. For example, although the Mekong River Commission (MRC) has been operating since 1995, its effectiveness may be improved by including China. China has been uninterested because joining MRC would compromise sovereign control and limit unilateral action. Thailand was reluctant to admit China because it did not want MRC to be dominated by communist countries (China, Lao PDR, and Vietnam) (*17*). Lessons can be learned from other international cooperative efforts (e.g., the Nile Basin Initiative).

Conclusion

Policies for water and other issues should be jointly designed, implemented, monitored, and evaluated. Integrated Water Resource Management (IWRM) may be a useful approach. China has begun to adopt IWRM concepts, although it is not easy (*18*). But China now has financial resources and motivations to address the water crisis and to generate lessons for achieving sustainability in China and the rest of the world.

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Supplementary Materials

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