

**Water Scarcity in the North China Plain:
Water Saving Irrigation and its Implications for Water
Conservation**

By

Erin Henry
Michigan State University

henryer1@msu.edu

P.R.E.M.I.U.M. Program
Sponsored by the
National Science Foundation and Michigan State University

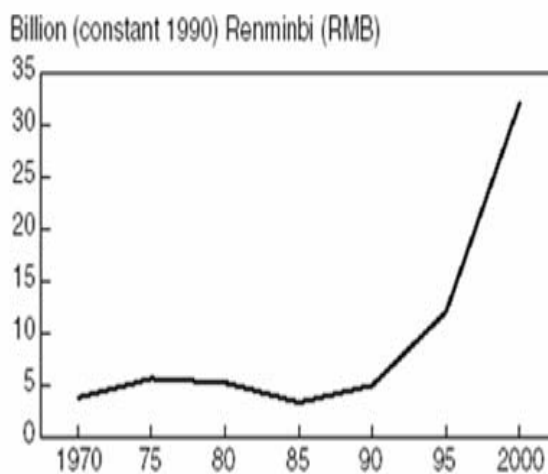
July 8, 2004

Water Problems in China: An Introduction

The North China Plain contains 65% of the country's agricultural land, but only 24% of the country's water resources (USDA 2003). One can see how this dry area would make irrigation difficult. Though China has tried many ways to provide more water to its thirsty farmers, the most sustainable way is to limit the supply. That is, conserve the water that is available now. To do so there needs to be government support, funding, and a technological means to irrigate crops in an ecologically sustainable way. Fortunately, we do see China addressing these issues. Low-flow irrigation (also called Water-Saving irrigation) is breaking ground in China. These systems are being used in experimental plots across China to prove to the government, as well as to farmers, their ecological and economic benefits. Investment in this type of irrigation has also been increasing over the years, both from Chinese government and outside sources (USDA 2003).

Though the future of low-flow systems looks bright, there are some difficulties in the way of implementation. This paper discusses the costs and benefits of such a system, and identifies the ways in which China can overcome the difficulties in order to provide water to generations of farmers.

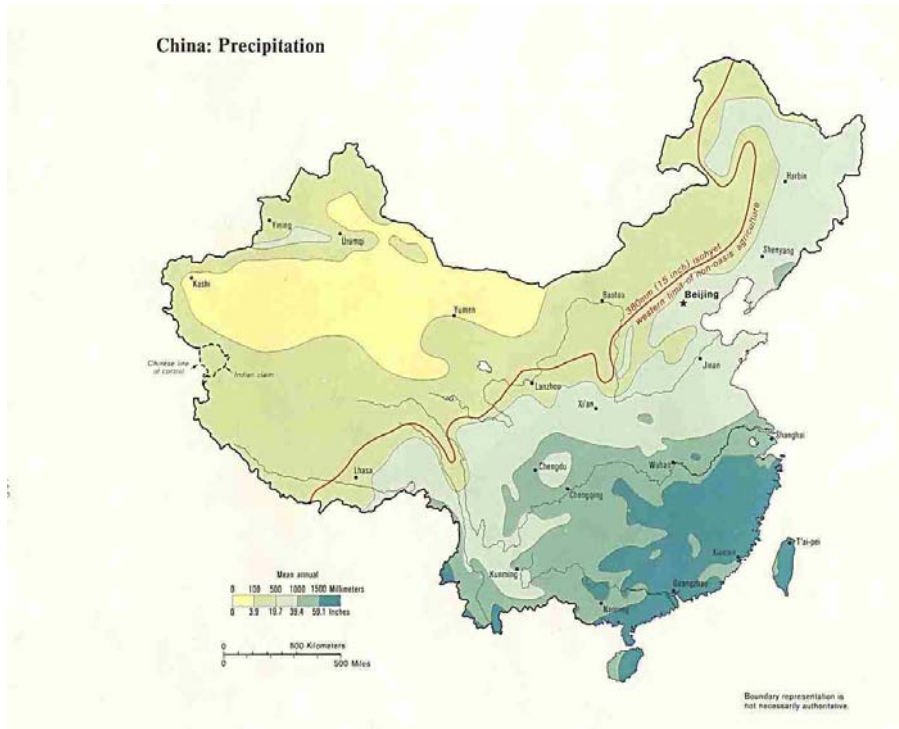
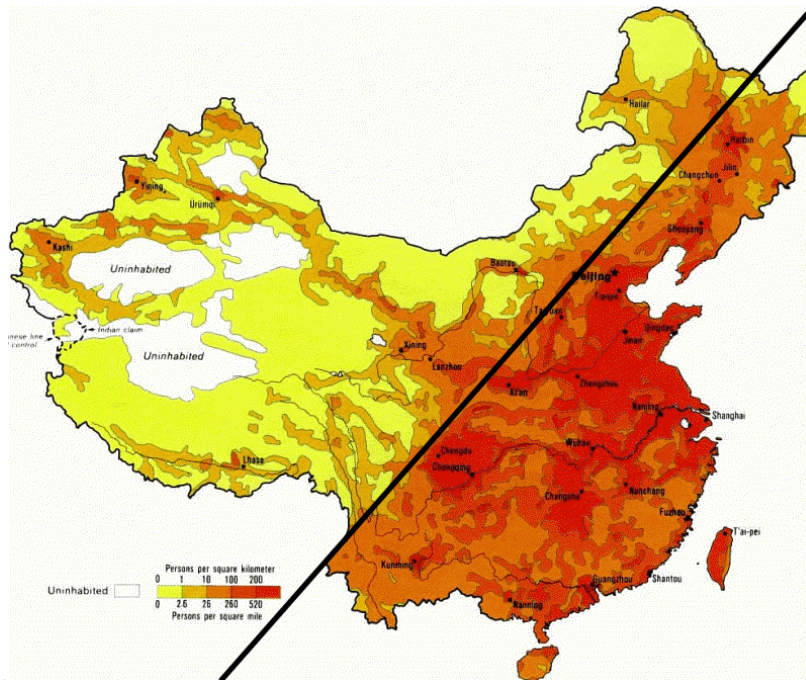
Investment in water conservancy infrastructure, 1970-2000



A small problem in China multiplied by 1.3 billion people can turn into a very large problem, while a small solution multiplied by 1.3 billion people can make a very large change. Apply this to China's large, unevenly distributed population and equally unevenly distributed water resources. Because of this disproportionate per capita water ratio, China has the second lowest per capita water resources in the world, less than one third the world average (World Resources Institute 1998). In the United States the average water use per capita is 190 gallons/day. In northern China, per capita water use averages 1/8 of that figure. The North China Plain is the most water-starved area in China. Here, sparse rainfall has caused droughts and dry rivers. Meanwhile, the water table in the North China Plain is estimated to be falling by nearly 0.125m to 3m per year because of over extraction (Ma 2001).

The North China Plain surrounds the Yellow River, and is generally a very fertile and flat low land, mostly lower than 160 feet above sea level. The river basins contained in this area are the Hai, Huai, and Huang (Yellow). The plain covers an area of 158,000 square miles, and includes Anhui, Beijing, Hebei, Henan, Jiangsu, Shangdong, Shanxi, and Tianjin Counties. This region is one of the most densely populated areas in the world (Encyclopedia 2003). Although only 24% of China's water is found in the north, 65% of the country's agricultural lands are here. Nearly all of China's maize and wheat are grown here, and half of all grain produced comes from this northern area. "Acting at the direction of the Water Law, the Ministry of Water Resources gives priority to domestic, primarily urban, users (over agriculture and industry) in the allocation of all water" (USDA 2003). Though the agricultural sector is the biggest water user, it is given the lowest precedence, below domestic and industrial uses.

These two maps show the abundance of population in the North China Plain, compared to the extreme lack of water resources.



Over 70 percent of total water use in China is used for agriculture, which can be translated to 17 percent of world water use. Around 95 percent of the irrigation is done through overflow methods and open water channels (Xinhua News 2001). These methods are less than 50% efficient, which can mean that 8.5 percent of the world's water is being wasted. The runoff does flow back to the earth, but groundwater recharge rates are so low, and over extraction so high, that recharge is negligible. With more effective irrigation technologies, like low-flow irrigation, this water can be utilized.

Chinese Government: The Powers Rain Down

Before we can begin to tackle the water shortage and allocation problem, the bureaucracy and power structure of the Chinese Government must first be understood. Under the State Council, The Ministry of Water Resources (MWR) mainly controls water management in China. However, other ministries are also involved in developing policy for urban and rural areas. A horizontal tie exists between the MWR and the Ministry of Agriculture. Understandably, their reaches overlap when it comes to water use for agriculture. Under the 1998 Water Law, agricultural use of water is also under the jurisdiction of the Ministry of Agriculture. In particular, this ministry deals with water saving technology in irrigation (USDA 2003). In conjunction with these are the State Price Bureau, under the State Council, and the Subnational Water Resources Bureaus, which set price levels.

There are also many subnational institutions that administer and influence water management and local implementation. These subnational Water Resources Bureaus are found on a provincial, prefecture, county, and township level. The various levels base policy around their own local needs, which lead to problems across jurisdictional

boundaries (Wang 2004). Because of the traditional top-down power system, village leaders control the water management system and assess water fees. Waterways do not follow jurisdictional boundaries; therefore, commissions have been developed to manage water resources on a watershed level (USDA 2003). Though these were given power by the MWR, and are ultimately controlled by the area's Water Resources Bureau. Ultimately, the power is cyclical and remains at the top.

The incentive structure for water resource management also seems backwards.

China does have a National Water Law, which was passed in 1988 and amended in 2002. Though it is in the process of more updates, it still sets water fees at a size of field area, and not on a volumetric level. Because of this low priced scheme, there is no incentive to conserve water. The Chinese rationale is to use as much water as one can, before it runs out. With the current pricing system, this mindset is reasonable. Adding to the problem is the lack of individual water rights in the Water Law, though this is also being discussed (Wang 2004).

Water is now priced in regards to scarcity, type of use (agricultural, industrial, or domestic) and ability

	1998 RMB Water Prices		
	Agricultural	Domestic	Industrial
Hebei	0.75-0.10		
Hubei	0.04	0.08	0.12
Guangdong	0.01		

to pay. Prices typically rise as one moves from south to north, as shown in the graph above. In 1998, the prices for domestic and industrial use were 0.08 and 0.12 RMB per cubic meter in the central Hubei Province. The agricultural water use price in the Hubei was 0.04 RMB per cubic meter, while in the southern province of Guangdong the price

stood at 0.01 RMB per cubic meter. In the northern province of Hebei, where water scarcity is most severe, the price of agricultural water was 0.075 to 0.10 RMB per cubic meter. These prices are still well below the marginal value of water use in the agricultural sector (Water Resources Bureau 1998).

The governmental obstacles of water pricing, rights, and fees may seem overwhelming, but the problem of a water scarcity still exists. If China wants to work towards a solution to this problem, these issues will have to be tackled through governmental policy.

Government Response

Recent historical government responses to water shortages have been supply-side oriented. Instead of implementing water conservation techniques, dams, reservoirs and canals have been built to increase supply for all sectors. From small, village level projects to huge, billion dollar canals and dams, increasing supply has been China's answer to scarcity.

- In 2002 the \$20 billion-plus **South to North Water Diversion** project broke ground. Three canals will link southern water resources to dry northern areas in Beijing, Tianjin, and Hebei province. The project should be completed by 2050, with preliminary action by 2008, for the Olympic Games (Water Technology 2004). While this project will provide a much-needed resource to the north, it will have negative environmental and social impacts, displacing people and degrading the river and path of the canal. The water will also not be available for quite a few years, and the price will be so high, that agricultural use will not be feasible.



- After Beijing became the capital of the PRC in 1949, the rapidly expanding population quickly depleted the city's water supplies. Beijing mandated that Tianjin forfeit its Miyun and Guanting reservoirs for Beijing's use, and build another reservoir. Tianjin was forced to build the

Panjiakou Reservoir to bring water from the Luan River, to provide for its own people (CEF 2004).

- In the Early 1960s, the **Red Flag Canal** was built on the Zhang River, which runs between Hebei and Henan provinces. The human creation became a national model for overcoming natural resource scarcity. However, over the past 30 years, use of this resource has caused conflicts, such as water stealing. Droughts still plague the canal, and water stealing has exacerbated the problems of increasing water needs (CEF 2004). To meet the allocation needs of both villages that share this resource, the government will have to find a better answer than increasing a finite supply.

China must realize that this water is finite, and supply side management will not last forever. Water conservation measures will extend the resource life to provide water for a much longer time. When the rivers run too dry to dam, water saving technologies will become invaluable. By implementing such measures now, China could begin to head off the problem of water shortages, which they are beginning to face now.

Increases in Agriculture, Decreases in Available Water

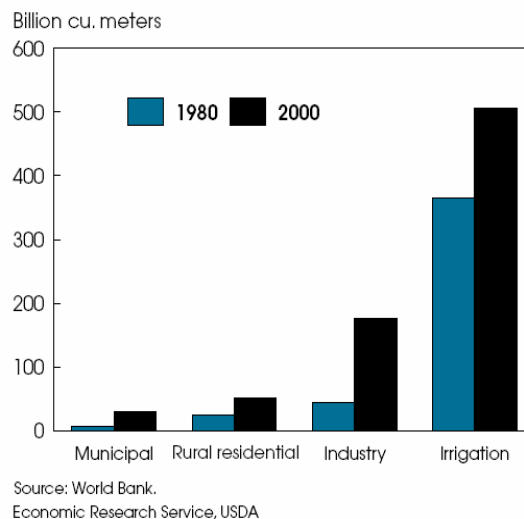
Although China is not in a water crisis, by the international definition, the agricultural sector is experiencing a scarcity situation. For a true water crisis to exist economically, disruptions in water deliveries must be proven, or water prices have risen so high as to threaten economic activity. There have been gate shut-offs, to stop the flow of irrigation water, but these instances are rare (Wang 2004). With China's growing population, agriculture has been expanded.

In 1999, the Gross Output Value of Farming in China was 141.06 (100 billion yuan). In 2002, that figure rose to 149.31 (100 billion yuan). This could be have resulted from an increase in farming activities, or in pricing, but it shows that agriculture is expanding. More evidence comes from statistics on irrigation, which has also increased, as is shown in the table below.

Gross Output Value of	1999	2002	
------------------------------	-------------	-------------	--

Farming in China (100 billion yuan)			
	141.06	149.31	
Irrigated Area in China (Million hectares)	1999	2002	
	53.15	54.35	
Water Saving Irrigation in China (Million hectares)	2000	2002	
	16.38	18.62	
Source: China Statistical Yearbook 2003			

Despite threatening predictions of a water crisis, water use in China is still relatively wasteful and inefficient. There is ample room for improvement in water conservation methods to improve efficiency. Since the agricultural sector is the biggest user of water, using double the quantity of the other two sectors combined, it only makes sense to implement water saving technology here first (USDA 2003).



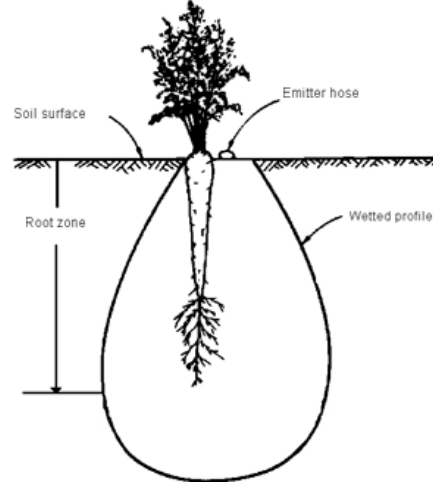
What are the Options?

Many types of irrigation are used worldwide, in China over 90% of farmers use over ground (gravity) flow practices. While straightforward and low cost to implement, they lose over 50 percent of their water. This can translate into huge income losses if there is a disruption in the water supply. Other options exist, pressurized systems use less labor, but more energy. Low flow systems have the highest efficiency rate, but are not well

suited for all types of crops. A comparison between these options highlights the benefits and limitations of each system.

Gravity Flow Systems- This method channels water through soil furrows and borders, usually using aboveground piping. The water is then released at the end of a field through siphons tubes or pipe valves. This type of irrigation is usually used on rectangular fields, with the water running from 1/8 to 1/2 mile lengths. Minimal slopes are preferred as to control advancement of water. Runoff at the end of the field and water loss to percolation below the root zone contributes to a very low efficiency of 35 to 60 percent. This system is used by 95% of Chinese farmers. Management systems have been developed to prevent these major water losses. Measures such as leveling fields, shortening water runs, lining ditches and utilizing pipelines, precision field leveling, and runoff water reuse all help to conserve water.

Pressurized Systems- These systems use energy to pump water through a pressurized sprinkler or low flow system. Water is sprayed to the field by above ground piping. With proper management, application efficiencies usually range from 60 to 85 percent. Sprinklers are better suited for moderately sloping or rolling terrain, and are suitable on coarser soils with higher water infiltration rates. Costs for sprinkler systems are higher than gravity flow techniques, though gravity flow fields require more time and cost inputs for field preparation such as leveling and channeling. The self-propelled types require less labor, but all require more energy than gravity flow systems.



Low Flow (Water Saving) Irrigation- This system lines a field with a pressurized system of small pipes to deliver water in minute, controlled quantities at or below ground level.

Low Flow methods include drip, trickle, and micro-sprinklers. Low flow systems are currently used for production of vegetables and perennial crops such as orchards and vineyards, high value crops that stay rooted each year. When annual crops are overturned at the end of a season, the piping would be ripped up as well. To solve this dilemma, experimentation is occurring with certain row and field crops in the US. Water utilization rates of 95 percent or more can be realized with proper maintenance and design (Gollehon 2001).

Two types of drip irrigation exist, one for row crops, while the other type is used on trees and vines, spaced at larger intervals. Low flow irrigation can be used on slope land and irregularly shaped land areas where flood irrigation is impractical. This system can apply water and fertilizer directly to individual plant or tree root zones, reducing the wetted area, which reduces water inputs (Sanders 2001). Plastic sheet covering, combined with low flow irrigation, have been known to increase yields by three to four times.

A Change for the Better?

While the rise in water saving technology is promising, currently there is not much of an economic incentive to implement the technology. Because of the water pricing system, using less water on a field will not equal a lower fee. In China, water is not priced volumetrically, but rather farmers are charged according to the size of the irrigated

area. Though farmers are charged by the area of their field, recent efforts have been made to modify the system. Along with the fee system is a change in the water fee itself. The fee is being raised to match the marginal value of water use in agriculture, as compared to other sectors. This system has been in reform since shortly after the agricultural reforms of 1978.

The transition from an area to volume based water fee collection system will not be easy. A look at the history between farmers and the government will provide evidence for this. In the past 50 years, little or no fee has been charged by irrigation districts for water delivery to farm fields. Farmers have also resisted paying fees, because the government contracted free labor from the farmers to build irrigation projects in the past. The farmers were not compensated for their labor; the end result of free water was to be their payment (Crook, Diao 2000). Before irrigation districts move towards volumetric pricing, and eventually charge full cost for water, an understanding will have to be reached between both parties. The authorities have to realize the financial burden, and apparent injustice of the fees, while the farmers have to realize the scarcity of water has a price.

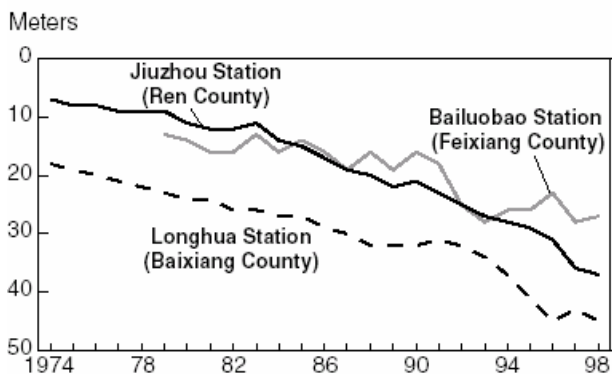
If volumetric water pricing were to become the norm, it could cause a huge financial burden to economically disadvantaged farmers. However, this would also create an incentive to use less water. Volumetric water pricing will increase the price of irrigation water, but using less will decrease costs. With water saving irrigation methods, less water is needed for the same amount of crops. Because of the underground, and near ground pipe systems, barely any water is lost to evapotranspiration or runoff. Another incentive for the new technology is an increase in arable land. Underground watering systems free

up land for cultivation, where there once was a water ditch and canal system, there is now more rows of crops.

There is also an ecological advantage to water saving irrigation. As water is being used at a nonrenewable rate, surface and groundwater sources are being depleted. This puts a strain on all aspects of the environment. At the beginning of the 1990s, the water tables for most of the North China Plain (which produced about 40 percent of the total food of the country) were decreasing at an average rate of 1.5 m per year. Under current Water Law direction, the pumping has become more sustainable, with the water tables falling at an average rate of 0.125 m per year (USDA 2003).

With over pumping of groundwater, the water tables have begun to sink below sea level in some areas. When this happens, seawater intrusion occurs and contaminates the whole aquifer. Also, land subsidence is occurring as

Water table depth measured at three stations in the Fuyang River Basin, Hebei Province



Source: Wang and Huang, 2002b.

cones of depression are forming under major cities, and whole areas are beginning to sink.

In regards to these problems, the government has started working on plans for a solution, through Agenda 21 and other pilot programs. The budget for agriculture has also been increasing, to provide for new irrigation infrastructure and techniques. Between 1996 and 1997, investment in agriculture increased from 8 billion yuan to 17.2

billion yuan (USDA 2003). And in February of 2004, the agricultural budget was increased by 25%, roughly 3 billion US dollars (Brown 2004).

To reach the goal of increased water utilization efficiency of 20-30 percent in agriculture, The Ministry of Water Resources and the Ministry of Agriculture have outlined a plan in Agenda 21 to provide new techniques for water conservation. This section of Agenda 21 deals with sustainable agriculture. Three research stations have been set up, to demonstrate and research water saving agriculture, as well as to train personnel on the technology. The budget is composed of external grants and soft loans, as well as Chinese government input, with a total budget of 109 million US dollars. By the culmination of the project, water consumption will be reduced by 20-30 percent, grain yields will increase by 10 percent, and water use efficiency will increase by 40 percent. If realized and implemented nationwide, the outcomes of this project could be produce huge water savings in China. (Priority Programme nd).

A “Dryland Farming Program” was also initiated by the Ministry of Agriculture in 1999. To confront the problem of a decreasing water supply, the program will include using biotechnology to create seeds that require less water input, developing water conservation field cultivation practices, and terracing fields to reduce runoff. Farmers have begun to apply water saving methods to their fields, such as covering soil with plastic film to prevent evaporation. They have also begun to plant cash crops, which require less water, such as higher valued fruits and vegetables (Xiang and Huang 2000). In the past 11 years, fruit and vegetable crop area has increased by 1.3 million hectares each year (Brown 2004).

In this move to fruit and vegetable cash crops, water saving irrigation is even more valuable. This type of technology does not fit in with all crop types and cultivation methods. When a field is plowed or tilled, the underground piping could easily be ripped up along with the crops. Higher valued crops also will return investment in the technology. While upfront costs are higher than traditional flood irrigation, operating costs and labor are lower in low flow irrigation.

These systems are typically used on larger scale lots, about six hectares in size (Sanders 2001). With an average farm being less than one hectare, the technology would be more efficient when used in a collective farming unit. Since de-collectivization broke up these cooperative farms in 1978, few have begun to come back together. The World Bank did persuade the Chinese government to implement a Water Users Association to start a collective farm where large-scale technology would be most beneficial. Under this example, more have begun to come together through the Chinese government.

Water User Associations (WUA) form a self-governed system where villagers make decisions among themselves about their water supply. Provincial and county water bureaus work with farming communities to share responsibility for water distribution. There are now about 1,500 WUAs in China, 1/3 of which were set up and partially financed by the World Bank. Supply companies sell water volumetrically to villages in a watershed in order to encourage water conservation. In some villages, this method has cut water usage by 20 percent. Through this system, water supply is guaranteed. Farmers don't have to keep watch over their irrigation channels, making sure they are not diverted to another field (Murphy 2002).

With policy changes through the government, low flow irrigation has the potential to create large water savings in China. The technology is cost effective, uses less labor, increases yields, and therefore profits, and conserves water. With experimental plots to educate personnel and farmers on the use and benefits, China may be moving closer to large-scale implementation. Collective farmer associations, with large fields, can benefit the most from this large-scale technology. As more associations start to form, more benefits can be realized. Though water rights do not currently exist in China, volumetric water pricing will create an incentive to conserve water. Past government response may have been to supply more water, but now they are turning to conservation. As pressure on a short resource increases, conservation measures will be a priceless tool to deal with water scarcity.

References

- Brown, Lester, March 12, 2004. "China's Shrinking Grain Harvest." The Globalist. .
<http://www.theglobalist.com/DBweb/StoryId.aspx?StoryId=3827>
- China Environment Forum, January 2004. Water Conflict Resolution in China.
http://wilsoncenter.org/index.cfm?topic_id=1421&fuseaction=topics.event_summary&event_id=64768
- China Satellite Imagery, May 2002. FAS Online.
http://www.fas.usda.gov/remote/china_countrypage/chimagery.html
- Crook F., and X. Diao, 2000. Water Pressure in China: Growth Strains Resources. USDA Agricultural Outlook, Economic Research Service. January-February
<http://www.ers.usda.gov/publications/agoutlook/jan2000/ao268g.pdf>
- Encyclopedia, November 2003 . North China Plain.
<http://www.nationmaster.com/encyclopedia/north-china-plain>
- Gang, G., 2002. China: The People and the Land, The University of Mississippi.
<http://www.olemiss.edu/courses/pol324/peoplant.htm>

- Gollehon, N., February 2001. "Irrigation and Water Use: Questions and Answers"
Economic Research Service, USDA.
<http://www.ers.usda.gov/briefing/wateruse/questions/qa5.htm>
- Ma, M., August 2001. Earth Policy Institute. Northern Cities Sinking as Water Table Falls. South China Morning Post. http://www.earthpolicy.org/Indicators-/indicator7_data2.htm
- Murphy, D., January 2002. Water Conservation, New Streams of Thought. FEER.
http://www.fsa.ulaval.ca/personnel/vernag/EH/F/cause/lectures/water_conservation.htm
- USDA, March 2003. China's Agricultural Water Policy Reforms: Increasing Investment, Resolving Conflicts, and Revising Incentives, By Bryan Lohmar, Jinxia Wang, Scott Rozelle, Jikun Huang, and David Dawe, Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin Number 782.
- US Embassy, October 2003. China's Water Supply Problems. <http://www.usembassy-china.org.cn/sandt/water-supply.htm>
- Wang Y., 2004. Water Disputes in the Yellow River Basin: Challenges to a Centralized System. China Environment Series Issue 6, p 94-98
- Water Technology, 2004. The Website for the Water Industry.
http://www.watertechnology.net/projects/south_north/
- World Resources Institute, 1998. China's Health and Environment: Water scarcity, Water Pollution, and Health. Environmental Change and Human Health.
http://pubs.wri.org/pubs_content_text.cfm?ContentID=1429
- Xinhua News Agency, July 24, 2001. China Plans to Promote Efficient Irrigation.
http://service.china.org.cn/link/wcm/Show_Text?info_id=16509&p_qry=efficient%20and%20irrigation