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Water stress, Water Transfer and Social Equity in Northern China: Implications for Policy Reforms

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1. Introduction

While China's rapid economic development is impressive, water stress in Northern China is a widely recognized crisis. Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. One of the common indicators of water stress is per capita renewable water; 1000 cubic meters per capita is recognized as a critical level for severe water scarcity (Engelman and LeRoy, 1993). The three major basins in Northern China (Huai, Hai, and Huang/Yellow, the 3-H basins, Figure 1) all have less than 1000 cubic meters per capita, and in arid northwestern China the number is even lower (Cai and Rosegrant, 2005). This water stress is also reflected in other indicators. In 1997 the 3-H basins contained about 40 percent of the country's agricultural land and produced 32 percent of the country's GDP, but had less than 8 percent of the country's water resources (CAE, 2001).

Figure 1: The 3-H Basins (Huai, Hai and Huang) in Northern China.

Water stress in Northern China has intensified water use conflicts between upstream and downstream areas and also between agriculture, which is still the largest water consumer, and the municipal and industrial sectors (M&I), which have been growing fast. Water stress has also caused deterioration of fresh water resources in terms of quantity (aquifer over-exploitation and dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.). If left unresolved, such problems may worsten until they threaten social stability. The Chinese Government has initiated strategic changes to reform water resources allocation. especially to transfer agricultural water to other sectors. During the coming adjustment period, agriculture will collide head-on with industry, cities, and ecosystems. Agriculture faces the most difficult adjustment, in order to ensure that sufficient water is available for more essential uses in cities and industries. The critical question is how to implement new allocation policies which cause the least disruption to agricultural output and the livelihoods of farmers (especially poor farmers).

This paper reviews water transfers in Northern China, which are a cause for concern over the social stability, economy and environment of the region. Based on an integrated analysis of economic, environmental, fiscal and social implications, this paper attempts to begins by identifying critical barriers to smooth water redistribution; and ends with implications for policy reforms from a perspective of social equity. Social Equity implies that the decisions of water reallocation under water stress should be shared by communities at all levels, from the local to the national, to ensue equal access of water, especially the availability of the basic water need (Gleick, 1996), for all groups. However, to understand the necessity and complexity of the agricultural water transfers, it is first necessary to discuss the causes of water stress in Northern China.

2. Causes of Water Stress in Northern China

The limited water availability due to low and unevenly distributed rainfall and runoff has been recognized as a natural cause of water stress in Northern China. Research has also found that runoff generation in the region shows a declining trend during recent decades. Compared to the annual average during 1956-1979, average precipitation in the 3-H basins decreased by 9.6 percent, runoff decreased by 23.8 percent, and flow to the ocean decreased by 58.6 percent (CAE, 2001). At the regional scale, surface runoff generation within Hebei Province has declined by 65 percent and inflow declined by 72 percent compared to the average in the 1950s (Li and Wei, 2003). The impact of global climate change on water availability in this region needs further monitoring. As in many other regions in the world, the impacts of human activities on runoff generation include deforestation, agricultural and urban development, and groundwater overdraft. According to the assessment of the Chinese Academy of Science (CAS, 2005), in Northern China during 1988-1999, vegetation coverage (percentage of the total land) decreased from 38% to 32%, urbanized area increased from 5.0~8.2% to 6.5~9.5% (varying over eastern, western and central parts), and the change of agricultural land varies by region. Around urban areas agricultural land has been converted to urban; on the other hand, in mountain areas, which were the primary areas of runoff generation, forest and grass land is being replaced by crop land due to growing population in rural area. This land use conversion reduces soil water storage and increases flooding.

Starting in the early 1950's, the practice of developing engineering facilities to catch and redistribute water has dominated water resources management in Northern China. Huge engineering efforts have been made to catch the precipitation and runoff in the region. In 1995, the reservoir storage of the 3-H basins was 1.6 times of their total annual runoff (Rosegrant et al., 2002). Water storage and water diversion and extraction engineering facilities can easily divert all renewable water in Northern China. One can understand the scope of these diversions by imagining that gates crossing many rivers in this region are used to completely divert flood water for groundwater recharge in the dry floodplains. Since no more water can be caught for use within the region, engineering now turns to trans-boundary water transfer projects. For example, the south-north water transfer (under construction), will transfer 38-48 billion cubic kilometers of water (comparable to the total annual runoff in the Hai River and more than that of the Colorado River) from the Yangtze River in southern China to Northern China (mainly the urban and industrial region in the Hai River Basin) over a distance of more than 1000 kilometers. Water resources engineering development in Northern China is impressive and has indeed supported growing water demands. However, it is widely believed that there is little potential for engineering left within the region. Even the Ministry of Water Resources (MWR) has attempted to change the engineering-dominated water management. A new strategy has been proposed, called resource-based water management, which is an economic-theory approach centered on water demand management (Wang, 2003).

The water stress problem in Northern China should be re-examined from a water demand management perspective given excessive and still growing demand due to population growth, food demand increase, and industrial and municipal development. According to the assessment of CAE (2001), between 1980-1999, water use in Northern China (withdrawal) has increased by 41.7 cubic kilometers (CAE, 2001), which is about the average total annual runoff in the Hai River Basin, and 1.3 times of that in the Colorado River Basin. In 2004, the total water withdrawal in the 3-H basins was 137 billion cubic meters (km^3), which was 70 percent of the total annual runoff in the basins. Water demand, particularly M&I, will continue to increase. According to a medium projection made by CAE (2001), in the 3-H basins, between 1997 and 2010, water demand will increase by 13.0 cubic kilometers (8 percent); and between 1997 and 2030, 31.4 cubic kilometers (20 percent). For the same region, Rosegrant et al. (2002) made a business-as-usual projection of the water demand increase between 1995 and 2025 as 49 cubic kilometers, close to the high projection of CAE. The continuous increase will make the water supply system more vulnerable.

Agriculture is the largest water user in Northern China. In the 3-H basins, agriculture was responsible for 84 percent of total water consumption in the region; the fraction declined in recent years but it is still over 75 percent (Rosegrant et al., 2002). Like in many other countries and regions, low irrigation water use efficiency is accused to be responsible for water stress at present. According to the statistics in the Annual Book of Water Resources in China over 85 percent of the irrigation is done through overflow methods and open water channels (MWR, 2001). Starting from the middle 1990's, the Chinese government has greatly increased investment for irrigation system updating. However, the implementation of advanced irrigation technologies faces many technical difficulties (Henry, 2004) and social-economic blocks, which will be discussed later in this paper.

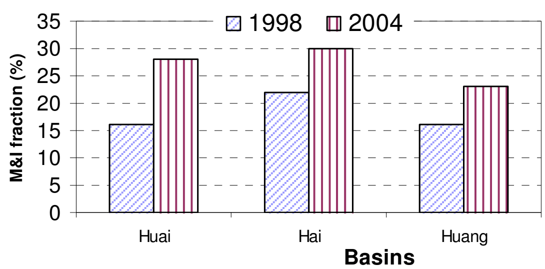
Moreover, many Chinese researchers believe that water pollution is the biggest cause of water stress, particularly Northern China (Jiang et al., 2004). Due to rapid industrial and municipal development and a large increase in agricultural fertilizer and pesticide use in the past two decades, cases of downstream users receiving polluted water from upstream lands have dramatically increased. During 1980 – 2004, sewage water discharge doubled in the 3-H basins, and it increased by 160 percent and 140 percent in the Huai and Huang River, respectively, according to the annual water resources bulletins of the 3-H basins.

3. Water Transfer and Social Equity

Under water stress, conflicts in water allocation and the damages to the public environment have intensified, and a pressing concern for "social equity" has appeared in Northern China. Social equity implies fair access to resources and livelihood; the concept of what is "fair" reflects the ethical values shared by the society, as well as economic values associated with resource uses. Social equity reflects a principle that each citizen regardless of economic statuses or personal traits deserves and has a right to be given fair treatment by the political system, giving special attention to the needs of weak and vulnerable populations. In the context of resource allocation, social equity refers to a bundle of rights and duties of government, collective, and/or individuals, which are applied to protect weak and vulnerable populations in society. With social equity in water resources in mind, it is interesting to see that Chinese Government is promoting a national strategy called "building a harmonious society". Challenges of social equity in water allocation under aggravated water stress are worth great attention, since water is a basic resource for life and production in society, and is an essential part of any harmonious society.

3.1. Setoral water use conflicts and agricultural water transfers

With water supplies in Northern China declining in absolute and quality-adjusted terms and water resources already over-allocated, one of the key questions facing water managers and residents will be how to meet growing demand in the municipal and industrial (M&I) sectors. According to CAE's assessment based on various statistics, during 1980-1999, in Northern China, the fraction of agricultural use decreased from 84 percent to 73 percent, while the fraction of M&I water use increased from 22 to 28 percent. The assessment and projection of M&I fraction in the 3-H basins are shown in Figure 2(a, b)



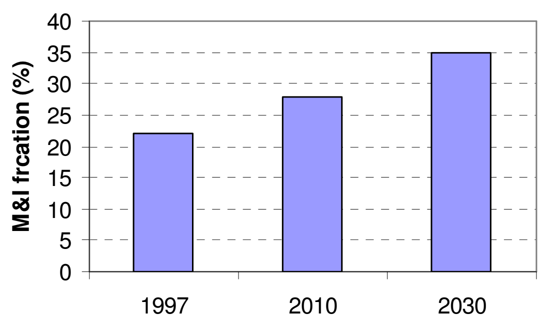


Figure 2: M&I fraction in the 3-H basins (a) individual basins in 1998 and 2004 (sources: bulletins of 3-H basins); (b) 3-H basins together in 1997 (assessment) 2010, and 2030 (projections) (source: CAE, 2001).

One clear opportunity to meet the growing M&I demand is through change in inter-sectoral allocations. In the competition for scarce water, local authorities generally give higher priority to industry than agriculture, while municipal and domestic uses receive the highest priority. This is because water used in industry has a much higher economic value, and China's local officials want to facilitate growth in industrial production more than agriculture. Hence, when there is a decision to be made on whether water should be sent to an industrial facility or kept for agriculture, industry often wins out (Lohmar et al., 2002). Sectoral transfers have already occurred within large basins, provinces, cities, or counties. Table 1 compares water uses by sector in two periods (1988-92 and 2002-2004) in the Yellow River Basin. In the middle and lower parts of the basin, agricultural water use decreases significantly while industrial and domestic increases dramatically. The only increase of agricultural water occurs the upper basin, but the increase is relatively small. Table 1 also illustrates a common upstream-downstream water allocation problem. In the Yellow River, more than half of the runoff generated by rainfall comes from the upper reach and fewer people live there, therefore, upstream water users suffer less water stress. Furthermore, upstream provinces such as Ningxia and Inner Mongolia (autonomous region) are less urbanized and irrigation has a more important economic role than in the middle and downstream provinces. This explains why there is an increase of irrigation water use in the upper reach (Table 1). The double threat of continuous increase of water use in the upstream provinces and increasing local M&I water use has escalated the agricultural water shortage in downstream provinces. In 1987, the State Council of China issued the "Water Allocation Programme" along the Yellow River, which specifies water withdrawal quotas for each province along the basin. For example, the downstream Shandong Province can withdraw 7.0 cubic kilometers, about 19% of the total allowable water withdrawal in the basin. However, the actual water withdrawal by Shandong depends on how much those upstream provinces withdraw, as well as the runoff generated in a specific year. The Yellow River Conservation Commission (YRCC) has been responsible for the realization of this policy, but actual water allocation has not followed the rules until the policy was strengthened in most recent years to prevent flow cutoffs in downstream main channel. YRCC has also improved the monitoring system including monitoring facilities and institutions along the River.

Table 1. Yellow River water uses by sector (billion cubic meters), 1988-92 and 2002-2004

Years	Reach	Total	Agricultural	Industrial	Domestic
1988-1992 [a]	Upper	13.11	12.38	0.51	0.22
	Middle	5.44	4.77	0.38	0.28
	Lower	12.18	11.24	0.55	0.38
	Basin	30.72	28.39	1.45	0.89
2002-2004 [b]	Upper	17.54	15.71	1.42	0.41
	Middle	5.71	4.16	0.97	0.58
	Lower	8.44	7.04	0.82	0.58
	Basin	31.69	26.91	3.21	1.57
Difference	Upper	34%	27%	179%	84%
	Middle	5%	-13%	155%	108%
	Lower	-31%	-37%	49%	54%
	Basin	3%	-5%	121%	77%

a) Data from Chen, 2002
b) YRCC Water Resources Bulletins of 2002-2004.

Agricultural water transfers have occurred in large irrigation districts of China. Hong et al. (2001) presented such an example with the Zhanghe Irrigation District located in northern Hubei Province. Although this area belongs to Central China, it is on the boundary of Northern China and represents typical agricultural water transfers in large irrigation districts in China. As shown in Figure 3, there has been substantial reallocation of water from agriculture to hydropower generation and industrial and domestic uses over the past several decades, especially during the 1980s and 1990s. In late 1970s, agriculture covered 80 percent of total water use in the region; while around the middle 1990s, agriculture only used less than 25 percent of the water and non-agriculture used over 75 percent. This sharp decline in water supply for agriculture led to a 40 percent decline in irrigated rice area (Figure 4). Although the irrigated area decline is considerable (40 percent), it is much less than the decline in deliveries of irrigation water (about 67 percent). Moreover, the crop yield per hectare has doubled from the 1960s to the 1990s (mainly due to the use of hybrid rice), and the yield per cubic meter of water supplied has tripled, which shows that there have been considerable water savings. A number of factors have contributed to the water saving, including new irrigation techniques (e.g., alternate wetting and drying at the farm level, canal lining, etc), development of alternate sources such as rainfall harvest by small reservoirs, groundwater, and reuse of return flow, as well as crop pattern change from two to one crops of rice. It is believed that the sharp reduction of irrigation water has forced farmers to adopt cost-effective water saving techniques. Meanwhile, the government investment in the improvement of irrigation systems and adoption of the new technology (e.g., hybrid rice) has played a critical role in maintaining the livelihood of farmers in the area. A major challenge is to identify those practices that could be successfully extended to other regions, both inside and outside China.

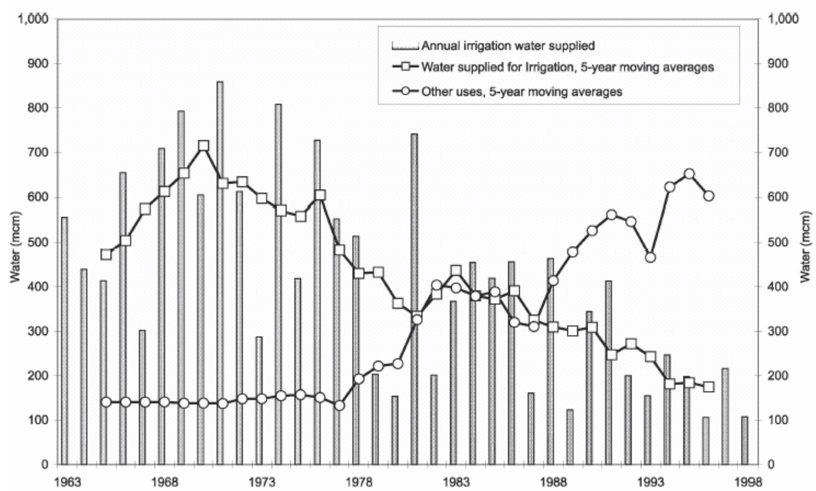


Figure 3: Annual water allocations for irrigation and other uses (in the unit of million cubic meter [mcm]) Zhanghe Irrigation District, 1965–1998 (Source: Hong et al., 2001).

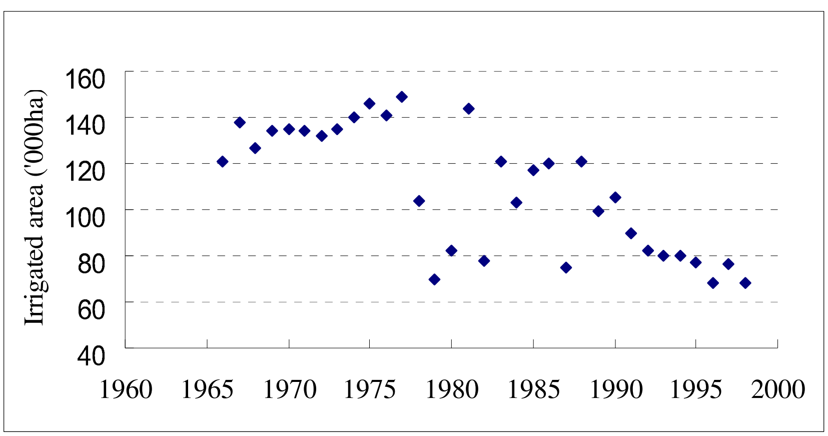


Figure 4: Irrigated area (mainly rice) in Zhanghe Irrigation District, 1966-1998 (Source: Hong et al., 2001)

Large and medium irrigation districts in China often use reservoirs for flow regulation (i.e., storing water in wet periods and releasing water in dry periods) for irrigation water supply, and some of the reservoirs also have other functions such as hydropower generation and flooding control. Water transfers are often implemented through modification of reservoir operations. For the Zhanghe Irrigation District, reservoirs and diversion canals were originally designed for irrigation, but now larger priorities are given to hydropower generation and urban water supply. Consequently, reservoir release is driven by energy demand and domestic water use timing instead of crop water requirements. Such reservoir function and operation changes might have far-reached impacts if they are extended to other parts of China. In the summer of 2000, the author of this paper visited a county in northeastern Hubei Province, which was hit by a serious drought in that year. The county has a medium-size irrigation district fed by a reservoir. Farmers used to get water from the reservoir through canals when drought occurred. However, in that year, farmers did not get water for quite many days. Ponds for drinking water dried up in most villages. Farmers complained that the reservoir authority tried to hold water as long as possible for the newly developed tour business at the reservoir site, unfairly withholding the farmers' water.

Agricultural water transfers are even more needed and have been undertaken much more extensively around urban areas. A typical case about Beijing municipality and neighboring agricultural counties was described by Peisert and Sternfeld (2004). The administration of Beijing includes several agricultural counties such as Miyun, Huairou and Yanqing. To protect water quantity and quality supplied to the Beijing municipality, restrictions have been established for land and water uses and agricultural development in those counties. The cause of the urban-rural water conflicts sparked by Beijing's growing municipal water demands is the burden of restructuring the counties' agricultural sector. In 2001 the government of Miyun county announced it would completely abandon growing cereals, and instead develop perennial cultures, mainly fruit trees. Another major shift in the county's agricultural sector coming in 2001 was a complete ban on chemical fertilizers within the next five years, in favor of organic fertilizers. Miyun's land conversion and organic programs are in line with a general restructuring of Beijing's agricultural policy, as announced in March 2001: Grain-growing areas will be reduced to save ground water, and more trees will be planted. Animal breeding and 'highly efficient' agriculture with modern water-saving irrigation methods will be developed. It is predicted that the water used in agriculture will drop to 35 percent of the city's water consumption in 2010 from 43 percent in 1998, and the figure will continue to drop to 28- 30 percent in 2020. Regulations lay out some compensation and alternative economic development strategies for the counties, including funds for cereal to fruit field conversion and organic programs. However, these have not yet been fully carried out. Peisert and Sternfeld (2004) argued that there is still a long way to go for the transition of land use and other agricultural practices to be completed, due to the current lack of an institutionalized compensation system to replace the current ad hoc downstream-upstream compensation payment occurring annually. Peisert and Sternfeld think that any format of payment in the system "must be transparent and include mechanisms to directly reward upstream farmers and cities for protecting the watershed".

Agricultural water use reduction also has other causes. For example, On the North China Plain, prolonged extraction of ground water for industry has greatly lowered the water table under many urban districts, which enforced farmers in and around these urban regions to draw their water from deeper and deeper wells (Lohmar et al., 2002). Another cause is the quality degradation of agricultural water caused by industrial waste water discharge. Although industrial wastewater treatment capacity has grown tremendously in the past several years, in most cities a large portion of industrial effluents are still discharged directly into rivers. Surface-water is often too polluted to be used for irrigation. Following the Environmental Protection Law of China (approved in 1989), all provinces have established quotas of pollutant discharge in waste water for urban communities and various industrial sectors. However, "local officials often sidestep legislation and regulations designed to curb such pollution in order to keep local industries profitable" (Lohmar et al., 2002). Effective inspection and monitoring is needed to ensure the full execution of those regulations.

There is evidence that agricultural water transfers requested by local industry were denied despite the fact that industry is generally a higher value use (Lohmar et al. 2002). Upstream irrigation districts that have built their own reservoirs and canal systems have little incentive to provide water to industrial centers, since their own agricultural activities would be adversely affected. For example, several major cities in Henan Province failed to access water from reservoirs controlled by local agricultural authorities; as a result they had to shut down some factories even as rice production was expanded in the region. These conflicts usually represent the divergent goals and interests of the urban construction authorities versus the local water resource bureaus and agriculture bureaus.

Finally, it is noticed that several large-scale agricultural water transfers have been undertaken to restore ecological systems in Northern China. The most high-profile example occurs with the Yellow (Huang) River. Due to excessive river diversion and a prolonged drought cycle, flow cutoffs had been experienced in the main channel downstream from 1972-1998. Flow in the main channel was cut off in 21 of 30 years with both the duration of time and the distance from the river mouth increasing each year. The flow interruption left users in Shandong and Henan Provinces without their traditional sources of surface water, and more seriously, it precluded sediment flushing to the ocean and threatened the downstream ecosystems (Li, 2002). Starting from the year 2000, the Yellow River Conservation Commission (the basin management authority under MWR) has undertaken firm administrative measures to prevent the river cutoffs, including water withdrawal monitoring and more strict execution of the "Water Allocation Programme" with the provinces in the upstream of the basin. The status of the river has since been improved, and there has been no absolute flow cut-off in recent years. Meanwhile, irrigation water withdrawal by the upstream provinces has declined. According to a news report from MWR (MWR, 2005), irrigation districts in Ningxia reduced water withdrawals by 2.2 km^3 during 2001-2005, which is about one-quarter of the total withdrawal by Ningxia in 2000.

Another example of agricultural water transfer to ecosystem has occurred in the Hei River Basin, an inland basin in northwestern China (Liu et al., 2005). The Hei River flows from the upstream Gansu Province to downstream Inner Mongolia region, where the river water feeds the Erjina Oasis and traditional pasturelands around the Oasis. Starting from the early 1980s, large expansion in irrigation water diversion in the middle stream of the basin has resulted in downstream ecosystem degradation including a shrinking oasis area, declining vegetation coverage, and a complete dry-up of the outlet lake. The environmental change threatens the homeland of more than one million people who depend on the pastureland for livestock breeding. In the late 1990s, the Chinese government initiated activities for the ecological restoration of the region, including annual flow releases to downstream by administrative order. These activities followed institutional development including activating the "Gansu-Inner Mongolia Water Allocation Plan (GIWAP)" approved by State Council and establishing the Bureau of Hei River Management, an agency that is authorized to coordinate and supervise the implementation of the new water allocation plan. These releases have prevented further degradation of the downstream ecosystem. Meanwhile middle stream irrigation water withdrawal is required to decline by one-quarter, which has led to significant crop pattern change and also stimulated irrigation system updating with financial support from the central government (Liu et al., 2005). In Zhangye City, the major agricultural district in the middle stream of the Hei River Basin, the shares of agricultural land were 65% cropland, 16% forestland, and 19% pastureland in 1999; and recently the shares were adjusted to 52%, 26%, and 22%; during 2000-2003, canal lining was improved for 585 km of main canals and 1160 km of branch canals, and advanced irrigation systems such as low-pressure pipe, drip, and sprinkler systems were established for 29,000 hectares (10 percent of the total irrigated area in the district). Moreover, in 2000 the MWR approved an experimental program for water conservation in Zhangye, which is the first program for testing comprehensive water demand management measures in China. The program is intended for determining both primary water use rights and water use permits and facilitating both water trade and public participation in water allocation.

3.2. Dilemmas in water transfers

Given the growing supply/demand imbalance in Northern China, it will be increasingly difficult if not impossible to meet new water demands from one sector without decreasing supplies to another. Since agriculture is now by far the largest consumer of water resources in the region and appears to have relatively low economic output levels, meeting growing industrial and domestic demands is likely going to mean a reduction in supplies to the agricultural sector. However, agriculture in China, as in many other countries, holds a special place in rural livelihoods and national food security, so it remains a high priority. Furthermore, the rural agricultural sector that is most impoverished and has probably benefited least from recent economic growth. Shifting water away from those already relatively disadvantaged has clear implications for equity and, perhaps, social stability. At the same time, it is industrial growth, which is dependent on increasing water supplies, which is seen as the driving force in powering China's transformation to a modern, world class economy.

The premise for successful water transfers out of agriculture is that farmers can use less water while food production is not affected. There is no doubt that advanced irrigation technology is needed to replace traditional gravity systems. Starting from the mid-1990's, the Chinese government has significantly increased investment for irrigation system updating, and low-flow irrigation such as drip and sprinkler is now gaining ground in China (Henry, 2004). However, the implementation of advanced irrigation technologies means a higher cost for water, and it is up to farmers to pay at least part of the cost. The question is whether farmers can afford the cost of advanced irrigation technology, and if farmers will and can pay a water price that is closer to the true value of water. The answer might be no, given the current low income of farmers due to low food prices and high costs of agricultural inputs such as fertilizer. If water prices cause lower or negative net profits from irrigated agriculture, it may force farmers simply to use less water and give up high crop yields.

There is a “dead lock” with agricultural water management in China, which blocks effective agricultural water savings and smooth water transfers. The dead lock exists with the following conflicts, which are inter-related to each other: 1) farmers are wasting water even as they suffer water shortage themselves and leave increasing industrial and municipal sectors thirsty (Henry, 2004); 2) the society needs agricultural water savings, but farmers may not afford the costs of water savings and because of low profits from crops their willingness-to-pay for water is much lower than the true water value; 3) the national policy of food self –sufficiency requires the maintenance of high crop yields and production that depend on irrigation, even when the government can not maintain the required water for agriculture given the growing requirements of non-agricultural sectors. China must break this dead lock which will continue to damage the country’s growing economy.

Difficulties also exist with the governance of water transfers in China. Current water transfers follow the priorities of local government that are often driven by short-sighted economic profits. There is no formal institution for mediation, so large water disputes between agriculture and other sectors (and also between regions) often are resolved by the government in an ad hoc, case-by-case fashion. Ideally, water transfers would go through markets based on a deal made by both water buyers and sellers and without negative social impacts (Rosegrant and Binswanger, 1994). The establishment of water rights is the pre-request of water markets. In recent years, researchers and government officers begin to embrace the modern concept of water right and water market (e.g., Wang, 2003; Liu, 2004). In China, water right is a kind of usufruct right and only the nation has the property right of natural resources. There is no clear delineation of the usufruct right, formal and consistent institutional support for water rights does not exist, and thus no mechanism for economically-efficient water rights trading exists. Although the China Water Law approved in 1988 and amended in 2002 provides codes for water allocation and use, current water use rights, both their identification and supervision, are heavily manipulated by the powerful water bureaucracy. Conflict resolution related to water rights is usually handled by administrative measures as individual cases, following some government guidelines such as the Implementation Measures for Water Use Permit Systems (issued by the State Council in 1993). This system, which lacks a consistent legislative framework, may not guarantee the security of water rights and is subject to high transaction costs, as well as social-economic loss with the two sides involved in water transfer. Furthermore, the current water use permit for agriculture is defined as a collective right for farmers in a town or even in a county, and individual farmers need to share the water right within their group. This may add to the difficulty of water right management and affect the efficiency of water right in water allocation. This situation has given rise to grass-root institutions in China, called water users associations (World Bank, 1997). Moreover, in recent years, in rural regions of the country, individual farmers are involved in small pilot trials of water right transfers, which are different from sporadic trades at the village level. The purpose of those experiments is to develop formal and institutionalized in nature from the bottom level to higher levels (Turner and Hildebrandt, 2005). Several specific examples of the water right trade developments are discussed by Turner and Hildebrandt (2005) and Liu (2004). Local government is involved in the initial market development, but the challenge remains to build a bottom-up mechanism that allows farmers at the root level to be actively involved.

3.3. Consequences and risks in water transfers

On one hand, farmers lose water that they once used without appropriate compensation; on the other hand, cities and industry are thirsty and expect to access more water. Both situations have resulted in significant negative consequences to the regional economy and environment. Huge losses of food production and economic losses in industry due to water shortage have been reported every year by national and provincial statistics. According to the estimate by MWR, food production loss in the country is 25 to 30 million tons, and economic loss in industry is about 200 billion RMB. For the future, risk of even more serious socio-economic and environmental loss is apparent if current practices continue (Jiang et al., 2004). From a management point of view, part of the current loss can be considered as a consequence of water transfer failures, including the current transfers which hurt farmers' livelihood and income, and the needed transfers, which industry and cities have been waiting for but have not received.

The government has made various efforts in adequate and/or equitable water supply across the country, particularly in compensating farmers who have to reduce irrigation water use significantly and in assisting the agricultural areas to undertake new development strategies. Examples include the compensation to farmers in the middle stream of the Hei River Basin (Liu et al., 2005) and farmers in Miyun County, Beijing (Peisert and Sternfeld, 2004). However, whether the compensation is sufficient to maintain farmers' income and livelihood and whether it can be fully carried out, remains a concern. It has been noticed that farmers in Northern China have been struggling to reduce the income loss due to water shortage. One effort is using waste water for irrigation. Irrigated area using waste water increased from 42 thousand hectares in 1963 to 3.6 million hectares in 1998, of which the major is in Northern China, surrounding large cities such as Beijing and Tianjin (Li et al., 2005). Using waste water for irrigation has brought up a high risk of soil contamination (CER, 1999). An interesting question is: Where do farmers sell the agricultural products such as vegetables and fruits irrigated by waste water? Another effort for farmers to reduce food production loss is to seek help from private entrepreneurs to use deep wells in order to restore irrigation (Lohmar et al., 2002). Obviously such approaches are neither sustainable nor adequate regarding public health. When there is no way to sustain irrigation, the problem is not only with farmers' income and the way they depend for life, but also, more seriously, with the national food production target. China never wants to see a large reduction of food production in Northern China as predicted by Brown (1995).

Moreover, drinking water supply in rural area of Northern China is connected with the irrigation systems. According to Li et al. (2005), water quality for drinking water in China is worsening due to reasons including excessive use of chemicals. In those regions where irrigation water is polluted or is largely reduced in quantity, drinking water will be affected in both quantity and quality. The most notorious case is the extremely high cancer rate in a number of villages located along some tributaries of the Huai River. Farmers have used the rivers running around their villages for drinking and irrigation hundreds of years, but now they find that not only the water directly taken from the rivers, but also the water pumped from wells nearby the rivers, is poisonous (news report, visiting a cancer village in the Huai River Basin, http://www.people.com.cn/GB/14576/33320/33321/33754/2919537.html, in Chinese). One could not question the importance of industrial water users which have contributed to local economy; however, industrial water use that ignores the existence of downstream farmers can deplete the basic needs of clean, healthy water for farmers.

When effective water transfer does not occur under water stress, water stress usually causes deterioration of both water quantity and quality. It is not difficult to understand why instream flow and deep groundwater has been depleted and polluted in Northern China given the following facts: although agricultural water savings have not yet been implemented, part of the irrigation water has already been transferred, and although M&I has received some water from agriculture, it is still not fully supplied. Therefore both sides, to sustain irrigated agriculture under the current irrigation technology level and to maintain fast growth of economy, drive excessive water withdrawal from rivers and aquifers. For local governments, the strong wish for economic development always overrides the responsibility of environment protection.

So far in Northern China the environment, not the farmers, has borne the largest sacrifices from water stress. From the limited text of this paper, one sees the drying Yellow River, the second largest river in China, the nearly "closed" Hai River (little flow discharge to the ocean), groundwater depletion in the North China Plain, and ecosystem degradation in the downstream of the Hei River. In addition, for many rivers, there is not enough water available for pollutant dilution, which has partially caused the water quality problem, and groundwater overdraft in coastal areas has caused sea water intrusion. Hebei Province, located in north of the Yellow River and covering a major part of the Hai River Basin, is a typical case of the changed water environment in Northern China. According to Li and Wei (2003), the province changed itself from a water-rich region in the 1950's to a water-poor region at present. Fifty years ago, Hebei had perennial rivers with over 3000-kilometer long navigation channels, large lakes including the well-know Baiyangdian Lake, and widely distributed wetlands, and the region suffered frequent disasters of flooding and waterlogging (associated with land salinization). Today, rivers are dry most of the time, lakes and wetlands have shrunk and even disappeared (including the Baiyangdian Lake, "pearl" on the land of North China), and the region suffers damages caused by water shortage every year. Such a change is caused by excessive water consumption, as well as regional climate variability and environmental change.

4. Implications for Policy Reforms

Some choices must be made. Even if initially painful, properly conceived policies executed correctly can bring tremendous long-term benefits. Since farmers are the least able to cope with the policy changes needed to rationalize water supply, the key solution is then to help farmers to get ready for the changes, which essentially means that farmers *can* and *will* save water. First of all, it is important to replace traditional low-efficiency irrigation systems by advanced irrigation systems, which has been occuring since the 1990s (Henry, 2004). This will strengthen the physical feasibility for farmers to save water while maintaining production. The concern is whether the traditional focus on water supply engineering during the past 50 years can be switched to engineering centered on efficient water uses. Second, farmers may not volunteer to save water unless they must pay higher water prices that at least partially reflect the costs of irrigation system updates and the economic value of water. The economic value of water is much higher when water is allowed to transfer between agricultural and other sectors than when water use is constrained within agriculture (Briscoe, 1997). Currently what farmers can afford for water is far below the true economic value of water in Northern China. Under their current income level, farmers are the least able to cope with the price hikes to rationalize water supply.

Therefore, agricultural water saving in China is not only a technological problem, but also a socio-economic problem, which is related to national and regional agricultural policies and markets and even the international food markets. For policy makers in China, efficient agricultural water use needs to be considered within the framework of the nation's gross economy. A research question is that at what level of income, farmers' willingness-to-pay to water will match the economic value of water assessed from the gross economy of Northern China. Starting in 2006, the Chinese government stops levying agricultural taxes, and the prices of agricultural products are increased one more level. The impact of these changes will be positive and broad although they will take time to emerge. It is expected that such measures, if they are stable, will enable farmers to pay a reasonable price for water so that water prices can become an effective economic incentive for water saving.

Third, an institutional establishment is needed to allow farmers and other groups to fairly exchange water. The role of government in water transfers has been demonstrated in this paper. At least for now and in the foreseeable future, administrative means of water allocation will take the lead with other means such as water markets as a supplement (Turner and Hildebrandt, 2005). Appropriate governance is still needed to guide and manage the ongoing water transfers. In particular, the mechanism is expected to provide a negotiation and mediation mechanism for officials and representatives from competing sectors to resolve the conflicts, and to protect the benefits of all, especially the weak groups. Many provinces and municipalities are promoting reforms to merge the functions of different water management units into a single authority, called Water Affairs Bureau (WAB). At the root level of irrigation management, the government has been sponsoring the development of water users associations (WUA), who not only take charge of water allocation among individual farmers within a WUA, but also represent a group of farmers (World Bank, 1997).

Fourth, deliniation of secure and consistent water rights for various water users will be the basis for equitable water transfers among farmers and other groups. According to Wang (2003), implementing water rights and water markets seems to be a long-term target for the so-called "resource-based water resources management" being promoted by the MWR in recent years. Although formal water markets are still in the experimental stage in China, they are increasingly playing an important role to solve water conflicts (Turner and Hildebrandt, 2005; Liu, 2004). Water researchers and managers in the western world might be curious about the rapid spread of the western economics based water management approaches in China, which have even not been very successful in their countries. Given the extensive studies and practices sponsored by the government of China, the results and impacts might be worth of attention as time goes on. The involvement of government and administrative institutions in the markets under development is particularly interesting. In the demonstration examples for market-based water allocations, which have been widely posted and discussed in China (Liu, 2004), local governments act as buyers or sellers in the trades between two administrative regions; meanwhile, local governments start to build up more formal markets based on the informal markets which have existed for long time. Although water markets are certain to develop further in China, there is no doubt for people both inside and outside China that water markets will simply supplement the administrative allocation methods in the foreseeable future before consistent water rights are mature in China.

The long-term planning strategies discussed above allow people in China to take time to perform trial-and-errors. Due to the strong water bureaucracy in China, the need of capacity building in water management, and the limitations of governmental control, a “smooth” water transfer will take a long time- although some gradual progress can be expected. However, what are the actions that need to be undertaken immediately to avoid serious social instability? First of all, the basic water needs, including those for drinking and ordinary living (Gleick, 1996), should be protected firmly for farmers and also for residents in cities. For this purpose, some transfers that deplete farmers’ water below their basic needs should be prohibited, and for the same purpose, some transfers must be undertaken to ensure the basic needs of residents in cities during drought periods. It will be necessary for relevant government agencies to conduct careful monitoring and quick responses to water transfer events that impact the basic needs of humans.

Also, given the current serious situation of environmental flow depletion, it is critical to restore, at least partially, environmental flow to prevent irreversible environmental disasters. Facing the risk of environmental damage, China is beginning to recognize the spirituality of “human harmony with nature,” which is rooted with Chinese historical ethics of Confucius. This is a philosophy emphasizing education, mastery of natural phenomena, discipline, and social harmony, as well as Taoism, a philosophy of non-interference (Li et al., 2004). As illustrated by the environmental flow restoration in the Yellow River and the Hei River, projects have been initialized in Northern China. Although current measures under administrative orders impose large transaction costs, they show some positive signs for the restoration of environment. The challenge will be to convert the short-term emergency measures into long-term, sustainable water management and regional development plans (Liu et al., 2005). To balance environmental flow requirements and offstream water consumption will be a long-term strategy in Northern China from generation to generation.

A major tension behind the water stress is the premise of food self-sufficiency in China, which is important for China with a population of 1.4 billion, but also for the entire world given the concern of Brown (1995) - “who will feed China?” However, there is no doubt that with the growth of China’s economy, the solutions to the problems related water and food must be flexible. When there is no way to hit all targets of food production, environment restoration and non-agricultural water demand, a compromise solution must be found. In a preliminary study, Cai and Rosegrant (2004) explored some strategies for sustainable groundwater use in Northern China given the fact that groundwater depletion is already a serious problem in the region. It was found that to reduce the current groundwater use to a sustainable level by 2025, food production in the Hai and Huang (Yellow) River Basins will decline by 15 and 9 percent, respectively. Although improvements of water use efficiency directed at overdrafting basins could, in theory, compensate the food production declines, they would be unlikely in reality due to technology constraints. In light of this fact, will it be possible for the Chinese government to reconsider the food self sufficiency policy, taking into account food production conditions in China, food security, environmental sustainability, as well as international food markets? This paper concludes with a potential alternative that could eliminate the growing water stress in Northern China and provide smooth water transfers between agriculture, thirsty cities, industry, and the dried-up environment. It should be taken as a research suggestion, not a policy to challenge the national food self-sufficiency policy. The international community is now exploring the policy implications of “virtual water flow” (Allan, 1998), which basically means water is transferred from one country or region to another with food export/import. The concept of virtual water links a large range of sectors and issues that revolve around relieving pressures on water resources, ensuring food security, developing global and regional water markets. In the future, higher international food demand may increase food commodity prices, which will hurt poorer countries that must import food. The ideal result of a global strategy of virtual water flow is that more food will be produced in those countries with enough water for crop growth, so that the impact of higher demand (increasing prices) will be balanced by the impact of higher production (decreasing prices) in the international market. Hoekstra and Hung (2002) identified China as one of the top ten countries that import virtual water. Regarding such an international virtual water market, China faces both challenges and opportunities. China's recent ascension to the World Trade Organization may provide larger opportunities to begin discussing such options. A better understanding of the role of water in economic growth in Northern China, the trade-offs between equity and efficiency in sectoral water allocation, and the range of possibilities for institutionalizing water allocation decisions would serve to better inform upcoming critical decisions on inter-sectoral transfers.

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References

Allan, T., 1998. Moving water to satisfy uneven global needs: Trading water as an alternative to engineering it. *ICID Journal*, 47 (2):1-8.

Briscoe, J., 1997. Managing Water as an Economic Good: Rules for Reformers. International Commission on Irrigation and Drainage (ICID), Oxford, United Kingdom, 25 pages.

Brown, L., 1995. *Who Will Feed China? Wake-Up Call for a Small Planet*. New York: W. W. Norton/ Worldwatch Institute, 160 pp.

Cai, X., and M.W. Rosegrant, 2005. Water management and food production in China and India: A comparative assessment. *Water Policy*, **7**:643-663.

Cai, X. and M.W. Rosegrant, 2004. China's water and food: Future perspectives in *China's Agricultural in 2050*, Tao CT et al. (eds.), Chinese Agricultural Press.

Chen, Z.K., 2002. *Impact of the Successive Drought on the North China Plain Ecological Environment*. Working paper of the China Institute of Water and Hydropower Research. (In Chinese)

China Environmental Review (CER), 1999. The development of Soil/ Groundwater, *Quarterly newsletter for China Environment, Health & Safety Managers*, Winter issue.

http://www.environmental-expert.com/magazine/aer/china/winter/article2.htm, assessed in Dec. 2005.

Chinese Academy of Engineering (CAE), 2001. *Water resources assessments and supply and demand projections*. Vol. 2, Reports on Water Resources Development Strategies / Sustainable Development in China.

Chinese Academy of Science (CAS), 2005. The impacts of human activities on droughts in arid regions, http://pd973.tea.ac.cn/download/middle/kt4.pdf, assessed in Dec. 2005 (in Chinese).

Engelman, R., and P. LeRoy, 1993. *Sustaining Water: Population and the Future of Renewable Water Supplies*. Washington, D.C.: Population Action International.

Gleick, P.H., 1996. Basic water requirements for human activities: Meeting basic needs. *Water International*, 21 (2):83-92.

Hai River Conservancy Commission, 2005. *1998-2004, Hai River Water Resources Bulletins*, http://www.hwcc.com.cn/haiwei/static/szygb.asp, assessed in Dec. 2005. (In Chinese)

Henry E., 2004. *Water Scarcity in the North China Plain: Water Saving Irrigation and its Implications for Water Conservation.* Michigan State University, P.R.E.M.I.U.M. Program.

Hoekstra, A.Y., and P.Q. Hung, 2002. *Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade*. Research report, IHE delft.

Hong, L., Y. Li, L. Deng, C. Chen, D. Dawe, and R. Barker, 2001. Analysis of Changes in Water Allocations and Crop Production in the Zhanghe Irrigation System and District, 1966-98. *Proceedings of International Workshop on Water-saving Irrigation for Paddy Rice*, Wuhan, China, 23-25 March 2001.

Huai River Conservancy Commission, 2005. *1998-2004, Huai River Water Resources Bulletins*, http://www.hrc.gov.cn/index_zhyw.aspx?LM_ID=LANMU_SZYGB, assessed in Dec. 2005 (in Chinese).

Li, B., D. Wang, and Y. Zhu, 2005. *Causes and countermeasures of water environment deterioration in rural regions of China*. Chinese Hydraulic Engineering Society (in Chinese).

Li, G.Y., 2002. Regulation of water flow and sediment flushing in the downstream of the Yellow River. *Chinese Water Magazine*, 474(12) (in Chinese).

Li, R., E.V. Beek, P. Gijsbers, 2004. Integrated water resources management for the Yellow River in China: Discussion on scientific and ethical approaches. In the proceedings of the

International Association of Hydrological Sciences symposium: *The Basis of Civilization – Water Science?* IAHS Press.

Li, Z.Q., and Z.M. Wei, 2003. *Water resources changes in Heibei Province and implications for the development of western China.* Science and Technology in South-North Water Transfer Project, no.1.

Liu, B., 2004. *Institutional design considerations for water rights development in China, in Water rights reform: Lessons for institutional design edited by Bryan Randolph Bruns, Claudia Ringler, and Ruth Meinzen-Dick.* International Food Policy Research Institute (IFPRI), Washington DC.

Liu, H., X. Cai, L. Geng, and H. Zhong, 2005. Restoration of pastureland ecosystems: A case study of western Inner Mongolia. *Journal of Water Resources Planning and Management*, 131 (6):420-430.

Lohmar, B., J.X. Wang, S. Rozelle, J.K. Huang, and D. Dawe, 2002. *China's Agricultural Water Policy Reforms: Increasing Investment, Resolving Conflicts, and Revising Incentives*. Market and Trade Economics Division, Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin Number 782.

Ministry of Water Resources of China (MWR), 2004. *The Annual Book of Water Resources in China*. China Water Press, Beijing, China (in Chinese).

________, 2005. News release, http://www.mwr.gov.cn/index/20060103/63451.asp, assessed in Dec. 2005 (in Chinese).

Peisert, C. and E. Sternfeld, 2005. Quenching Beijing's thirst: the need for integrated management for the endangered Miyun reservoir. *China Environmen Series*, 7:33-45.

Rosegrant, M., and H. Binswanger, 1994. Markets in tradeable water rights: Potential for efficiency gains in developing country water resource allocation. *World Development*, 22 (11):1613-1625.

Rosegrant, M.W., X. Cai, and S. Cline, 2002. *World Water and Food to 2025: Dealing with Scarcity.* The International Food Policy Research Institute, Washington DC.

Turner, J., and T. Hildebrandt, 2005. Navigating peace: Forging new water partnerships U.S-China water conflict resolution water working group. *China Environment Series*, 7:89-98.

Wang, S.C., 2003. *Resource-based water management – human harmony with nature*. China Water Press, Beijing, China.

World Bank, 1997. *At China's Table*. World Bank, Washington, DC.

Yellow River Conservancy Commission, 2005. *1998-2004 Yellow River Water Resources Bulletins*, YRCC website. http://www.yrcc.gov.cn/. Dec., 2005 (in Chinese).