Water, environment and food security: a case study of the Haihe River basin in China

H. Yang
Swiss Federal Institute for Environmental Science and Technology
Uberlandstrasse 133, 8600 Dubendorf, Switzerland

Abstract

The Haihe River basin is one of the most developed regions in China. With the rapid economic development and associated increases in water demand, the river basin has been enduring increasing water stress. Water for the ecosystem use has been compromised and the environment has been deteriorating. Water shortage has become a bottleneck to the further development of the economy and grain production, particularly wheat. This paper analyses the interrelationship between water scarcity, food security and environment sustainability at the river basin level. The magnitude of sectoral water deficits at present and in the coming years is assessed with reference to the existing projections. The feasibility and the scale of transferring the Yangtze River water to the north are discussed. An alternative river basin water allocation scenario is developed taking into consideration food production, environmental objectives, virtual water trade and inter-river basin water transfer.

1 Introduction

Water, environment, and food security are closely interrelated at the local, regional and global level. With rapidly increasing water demands while the available resources are more or less fixed, the competition between different water users has been escalating in many areas of the world. The result has typically been a reallocation of agricultural water to the industrial and municipal sectors and a compromise of environmental water needs. Solutions are urgently needed to accommodate these competing demands while improving both food security and environmental sustainability. This paper analyzes the interrelationship among these elements in the Haihe River basin in China.

The Haihe River basin involves primarily Hebei province and two mega

cities, Beijing and Tianjin. Other seven provinces partially fall into the region. The basin extends over 3.3 percent of China's total areas with a population accounting for about 10 percent of the nation. 15 percent of China's industrial production and 10 percent of the total agricultural output are concentrated in the region. Of the total crop areas of 10.8 million hectares, 6.8 million hectares are irrigated. The region produces some 30 percent of wheat and 20 percent of corn of the nation. In recent years, however, water scarcity has imposed an increasing constraint to the region's economic development. Major rivers are basically fully developed, leaving little or no water flowing to the sea. Overdraft of groundwater has caused a rapid decline in water tables [1]. Facing the aggravating water stress in the region, a massive water transfer scheme that diverts water from the Yangtze River to the north has been under intensive planning. While alleviating the water shortage, the implementation of the project will inevitably impose strong impacts on the environment and ecosystem in the region.

Considering water, environment, and food security, the Haihe River basin and many other river basins in the world face the following questions: What are the implications of increasing competition for water uses across sectors for agriculture and the environment? How can increasing food demands be met in the future based on the available water resources? And what are alternative scenarios in water supply and demand to meet competing water demands and food security in a sustainable manner? This paper addresses these issues through identifying interrelationships among water, food and environment at the river basin level. An alternative scenario of river basin water allocation is provided taking into consideration the impacts on the environment and local food production.

The rest of the paper is organized as follows. Section 2 presents an overview of the water endowment in the Haihe River basin. In Section 3, water deficit at present and in the coming 10 to 30 years in the river basin is assessed with reference to the existing projections in the literature. Section 4 develops a framework for river basin water allocation and Section 5 provides river basin options for food supply and environmental sustainability under the open boundary conditions. Section 6 summaries the founding.

2 Water endowment in the Haihe River basin

According to the official statistics, China's annual total available water resources amount to 2812 billion m^3. Dividing the figure by the total population of 1.281 billion in 1998 gives the per capita average water availability of 2195 m^3/year [1]. Nevertheless, the spatial water resources distribution is uneven in China. While water resources are relatively abundant in the south, the northern part of the country is generally poor in water resources. Figure 1 shows the spatial setting of China's water distribution. Of the nine watersheds, the Haihe watershed has the lowest water availability on a per capita basis, merely 358 m^3/year. In the adjacent Huanghe (Yellow River) and Huaihe watersheds, the per capita water availability is also low.

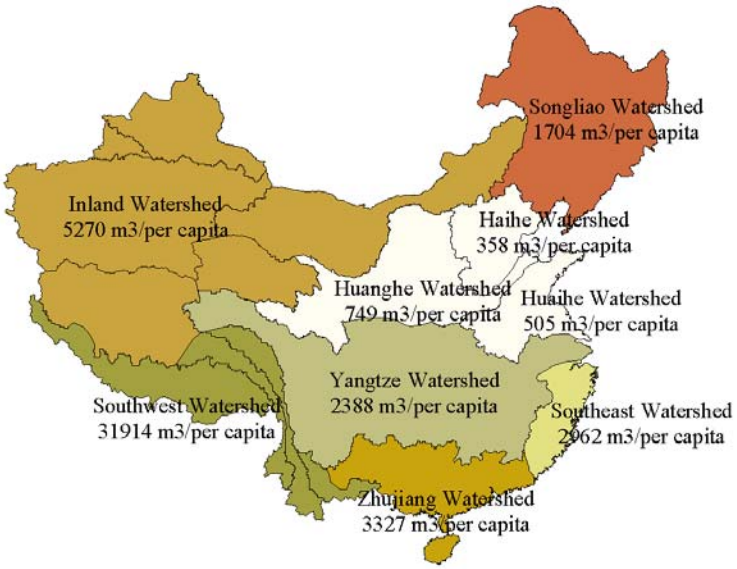

Figure 1. Watersheds in China

The Haihe River basin is dominated by the continental temperate monsoon climate. Precipitation is highly concentrated in a few months of the year. Rainfall is often insufficient to meet the water demand of crops in the whole growing period or part of it. Irrigation is crucial for achieving high yields. In the areas where multiple cropping is practiced, irrigation is simply essential. For this reason, irrigated areas have expanded over the years, contributed greatly to the growth of grain production.

During the last two decades, water demand in the region has increased rapidly in association with the population growth, industrialization and urbanization. Agricultural and ecosystem water uses have been squeezed. To compensate the loss of water, agriculture has been relying increasingly on pumping groundwater, causing rapid depletion of aquifers [2]. The rapid economic development and expanding water use have also increased the production of wastewater. Currently, only some 30 percent of the urban wastewater is treated. In the rural areas, the percentage is even lower. The rest is released without any treatment. Meanwhile, the intensive use of chemical fertilizers and pesticides in pursuing higher yields has led to a rampage of non-point pollution, rapidly becoming environmental hazards in the region [3]. The official source reported that the percentage of the river length with water quality satisfying the minimum standard of Class III (below this class, water is too polluted to be used directly without treatment) is below 30 percent of the

total river length. Pollution and environmental degradation have aggravated the water scarcity by reducing the availability of usable fresh water.

With the water shortage becoming intensified, irrigation has been facing unprecedented challenges. Grain production, the largest irrigation water user, has been under increasing pressure. Meanwhile, the environment has been victimized by both the deprivation of its water use and the water pollution. The situation has drawn much concern in recent years. Finding measures to deal with the water problems is urgent. Central to the issues is a long-term strategy for food production and supply and environmental sustainability.

3 Water deficit and demand projection

It has been a general consensus that the Haihe River basin is short of water resources. However, debates on the magnitude of the water shortage in the basin at present and in the future have been intense. There are many projections on the water demand and supply in the coming 10 to 30 years. The latest and also the most authoritarian projection is conducted by the Chinese Academy of Engineering in a key consulting project on the Water Resources Allocation in Northern China and South-North Water Transfer [4]. Table 1 gives the projected water demand, supply and deficit from this study.

Table 1. Water deficit and demand projection

	Water supply					Water demand					Water
Year	Surface and ground water	Deversion from the Yellow River	Reuse of waste water	Others	Sum of supply	Industry	Municipal	Agriculture	Ecosystem	Sum of demand	deficit
Current	31	5.5	0.25	0.38	37.1	6.71	4.68	30.47	0.05	41.9	4.78
2010	31	4.61	1.7	1	38.8	8.53	6.24	30.08	1.08	45.9	7.12
2030	31	4.61	3.5	1.44	41	10.02	8.39	29.88	2.43	50.7	9.67

The large and widening gap between water supply and demand in the projection suggests that the Haihe River basin is facing a severe and worsening water deficit. Given the scale of the deficit, relying on water saving measures is unlikely to solve the problem. This seems to justify the implementation of the envisaged south-north water transfer project. However, before such a conclusion can be made, it is necessary to examine how the sectoral demand figures were estimated and to what extent the future demands in different sectors could have been overstated.

Inefficient use of water is a common phenomenon in developing countries, as well as in some developed countries. Despite the water scarcity, the current industrial water use per unit of product value in the Haihe River basin exceeds by a big margin the average of developed countries in the 1980s. During the last two decades, a declining trend in industrial water use has been seen in many developed countries. In some large cities in the Haihe River basin, notably Beijing, the total industrial water use has more or less unchanged since

the 1980s [4]. Given the fact that urban economics in the Haihe River basin have been experiencing a rapid structural transformation and water saving measures have been given increasing emphases, it is reasonable to expect that the water demand in the urban industrial sector will be relatively stable in the coming years. Holding the water use in the urban industrial sector constant, while allowing an increasing water use in the rural industry as postulated in the projection, the total water use in the industrial sector in 2010 and 2030 could be reduced to 7.12 billion m^3 and 7.28 billion m^3, respectively.

For the municipal water use (including rural households water use), the projected demand is also overstated. The projection for 2010 is based on a quota of 190 L/(person.day). It is significantly higher than the average of 120-160 L/(person.day) in the EU countries in the mid-1990s [5]. As the projected income in the Haihe region in 2010 is only one third of that of the EU countries in the mid-1990s, the municipal water use in the region is unlikely to exceed the average of those countries. Given the scarce water resources in the region, more water saving measures are expected to put into use. This may further lower the municipal water demand on the per capita basis. The quota of 190 L/(person.day) thus is largely overstated. Using the average of 140 L/(person.day) as a gauge, the total water demand in the municipal sector would be 5.27 billion m^3 and 6.66 billion m^3 in 2010 and 2030, respectively, with the projected population growth in the region.

Apparently, the projection on the magnitude of water deficit in the industrial and municipal sectors is strongly influenced by the quota used. The projection based on the lower water demand quotas specified above leads to reductions of water demand in the industrial and municipal sectors by 2.38 billion m^3 in 2010 and 4.47 billion m^3 in 2030, significantly narrowing the water deficit gaps in the coming years.

As the largest water user, agricultural water demand has a significant impact on the total demand and the scale of water deficit in the river basin. Table 1 shows a stable water use figure for agriculture over the projection periods while the irrigated areas increase. There are two questions regarding this projection. One is the feasibility of expanding irrigated areas. With water becoming increasingly scarce and thus costly, it is very doubtful that irrigated areas will increase. In fact, the experience in Beijing and Tianjin during the past decade has shown that irrigated areas declined in response to the increase in water prices and water scarcity. The second question is the potential for increasing irrigation water use efficiency. The poor irrigation efficiency is widely known. There is a high potential for water saving. During the past two decades, the water use per unit of land in the Haihe River basin has decreased by some 20 percent, while the yield increased [4]. Currently, the water use efficiency in the region is typically around 50-60 percent [6]. If the irrigation efficiency can be increased by 10 percent, 2.9 billion m^3 of water may be spared. This, together with the lowered projections on water demand in the industrial and municipal sectors, will reduce the water deficit in the region to some 2-3 billion m^3 in the next 10-30 years, in comparison to the projected 7.12 million m^3 and 9.67 million m^3 shown in Table 1.

Overstating future water demand has led to a perceived need for a large incremental response to meet rapidly growing needs. This has made the incline to large projects because they seem to be the only adequate response to the large gap between existing supply and forecast demand. Such a tendency is largely related to the fact that in many countries the agencies that are responsible for building supply infrastructure are also charged with undertaking demand forecasts [7]. In the case of the Haihe River basin, the primitive methodologies and static perspectives adopted in the projections are only a minor reason for the overestimation. The interests of the policy markers and the entities involved in water management and project implementation have been the underlying reason. It has strongly affected the methodologies used for the projections and led to a deliberate overestimation of the future water demand in the river basin.

4 Balancing water demand and supply at the river basin level

4.1 South-north water transfer

'In order to radically alleviate the severe water shortage in the northern areas, it is necessary to implement the South-North Water Transfer Project'

President Jiang Zeming [8]

The overstated scale of water deficit and the depleting groundwater aquifers, together with the degradation of ecosystem and environment in the Haihe River basin, have led to the search of additional water supply beyond the regional boundaries. Diverting water from the Yangtze River to the north has been a favored option by the top leaders.

Debates, however, are intense on the ecological impact of the water diversion and the quantity of water the northern regions actually needs today and in the years to come. Meanwhile, as the origins and destinations of the diversion involve different jurisdictions, conflicts between receiving and supplying areas also arise. Furthermore, even if the water diversion project were to be started now, the water from the diversion would not be available some 10 years later. The severe water shortage currently facing the Haihe River basin requires measures that can show results much sooner.

4.2 A conceptual framework for integrated river basin water management

The situation of water demand and supply in a country or region is closely related to its socio-economic development level and the national development strategies, political system, institutional setting as well as the natural conditions. The degree of participation of stakeholders also exerts impacts on the objectives of the management and the policies implemented for achieving the goals. Water management at the river basin level, thus, is a multi-objective process involving various factors in these aspects. Figure 2 depicts a conceptual framework that shows the interactions among these aspects and the factors involved.

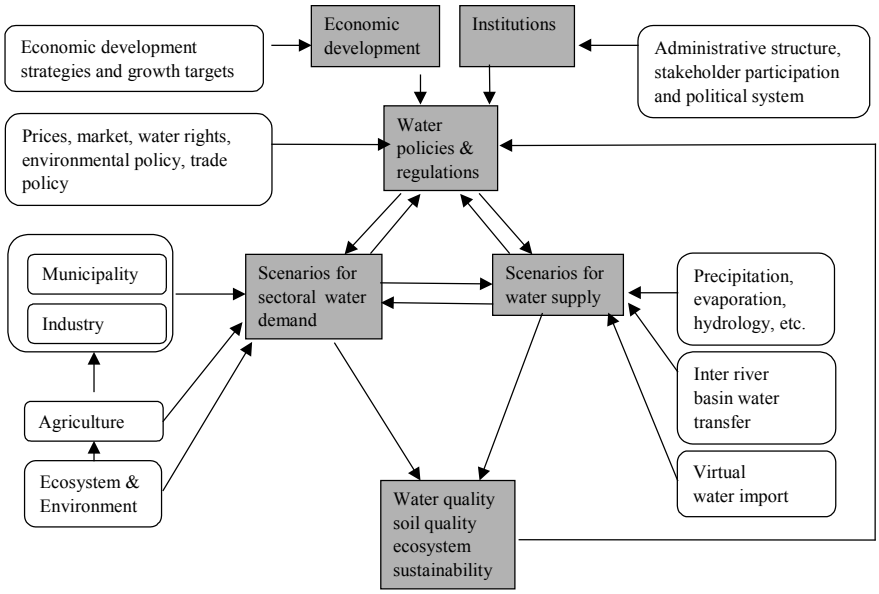

Figure 2. A conceptual framework in the river basin water management

Water policies and regulations, such as prices, market, water rights, environmental and trade policies can influence the total water demand and the allocation among different sectors. The scenarios for water supply are composed of the development of local resources, the transfer of water from outside and the virtual water (food) import into the region. As food production is a water intensive activity, importing food from outside can effectively reduce the water needed for local production. This is equivalent to transfer water into the region. Both water demand and supply scenarios have strong impacts on water and soil quality and ecosystem through the extraction of freshwater and the release of wastewater. In this framework, the balance of water demand and supply is a dynamic concept and is influenced by changes in internal and external factors of the river basin. For this reason, in projecting water demand and supply, a dynamic perspective with consideration of social, economic and natural environmental conditions within the river basin and across the system boundary must be taken.

Because of the higher value of per unit water use in the industrial and municipal sectors, priorities have been invariably given to them in water supply plans. Agricultural water use has the secondary priority. Ecosystem water use typically has the lowest priority. When water supply is in shortage, the industrial and municipal water demand needs to be met first. The conventional way of meeting this demand has been to transfer agricultural water to these sectors. The loss of agricultural water, in turn, is compensated with depriving the ecosystem water use. There have been tradeoffs between food production and the environment. Reconciling the competing water uses in the two sectors is of significance for a sustainable water management at the river basin level.

5 Crop substitution and virtual water import

Irrigation is the largest water user. By the same token, reducing the water use in irrigation would significantly reduce the total water demand. For this reason, in dealing with water scarcity, the agricultural sector has been targeted. The reduction in agricultural water use can be realized in two ways: improving irrigation efficiency (including water use efficiency of crops) and cutting irrigated areas. So far, the focus has been primarily on the first way while little consideration has been given to the second.

5.1 Crop substitution

Water demand varies among crops. Genetically, producing a same amount of calories, rice needs more water than wheat and the latter needs more water than corn. In the Haihe River basin, reducing rice and wheat areas and substituting them with corn would be an option of crop structure adjustment to serve the purpose of water saving. The substitution of corn is also rationalized by the consistence of its growing season with the summer rainfall in the region.

Substituting grain crops by high value cash crops is another option of crop structural adjustment for water saving. The idea is to increase the value of output per unit of water use. Many cash crops demand more water on a given unit of land. However, they usually have much higher net returns than grain crops for each unit of water use. A same amount of income can thus be generated by a less amount of water. In China, substituting grain crops by cash crops has been a trend evident during the past two decades [9]. The substitution, however, is partly driven by relatively high profits of cash crops. Many people have pointed out that this substitution is in line with China's comparative advantage of abundant labour resources [10]. It is expected that implementing the pricing and market mechanisms in the water management will encourage more transfer of land from grain crops to cash crops. In the Haihe River basin, the shift will be further reinforced by the rapid industrialization and urbanization and the associated increase in the demand for vegetables and horticultural products.

5.2 Virtual water import

Currently, the average water use on irrigated land for grain production is about 4500-6000 m^3/hectare in the Haihe River basin. The average yield of grain on the irrigated land is around 6000 kg/hectare [11]. This gives a rough ratio of 1 kg grain to 1 m^3 water. Hence, if the region reduces grain production by 2-3 million tons, the water deficit of 2-3 billion m^3 in the region specified previously would be filled. The market cost of purchasing this amount of grain from outside is only a very small fraction of the cost of the envisaged south-north water transfer project. Such an option, however, may have a significant impact on China's grain international trade, particularly wheat because its production is highly dependent on irrigation. Wheat imports would increase as the result. The question remains is whether the Chinese government will opt for this seemingly more efficient and instant way to alleviate the water stress and ecosystem degradation in the region. There are some intertwined issues that have made the Chinese government unwilling to take bold steps in this direction. The main issues include: 1) domestic food security and social stability; 2) the impact on rural employment when grain production remains the major provider of employment in the rural areas; and 3) the pressure of rural-urban migration and the social economic impact on cities. The adoption of a virtual water import, therefore, needs to be incorporated into a simultaneous address of these issues.

So far, the water management in the Haihe River basin has taken little consideration the spatial grain production arrangement and the international grain trade. However, with the intensification of water shortages in the river basin, it is expected that these factors will become increasingly influential in shaping the water management policies. The worsening of water scarcity and resource depletion may force the government to relax the control over grain import. Virtual water trade is expected to play a growing role in China's grain economy and the river basin water management.

6 Concluding remarks

Water scarcity and associated problems have imposed increasing constraints to the economic development in the Haihe River basin. Agricultural water has been continuously transferred to the industrial and municipal sectors. Irrigation has relied increasingly on depriving ecosystem water use and non-renewable fossil groundwater.

Of the options for balancing water demand and supply in the Haihe River basin, transferring water from the Yangtze River has been favored by the Chinese leaders. Because of this preference, other measures, including pricing and market mechanisms and water saving and wastewater treatment technologies, have not been given adequate emphases or been ignored completely. The result has been an overall overestimation of water deficit in the Haihe River basin. Using the average water demand per person in developed countries in the mid-1990s as a gauge, the water deficit in the industrial and municipal sectors in the Haihe River basin in the coming 10 to

30 years will be much smaller than the prevalent projection. This situation implies that implementing effective water saving measures in the industrial and municipal sectors is necessary and significant.

Agricultural water use holds a large weight in the water balance in the Haihe River basin. Given the low irrigation efficiency, the potential for water saving is relatively large. Meanwhile, crop structural adjustment can also reduce the water use per unit of product value. Some measures have been implemented in recent years to encourage the move in this direction. However, the option of importing food into the region to replace part of the irrigation water use has not been given appropriate consideration. This study emphasizes the importance to incorporate this option in the river basin management. Such an option can effectively reduce the irrigation water use and improve the ecosystem. It may even make the transfer of the Yangtze River water no longer needed.

References

[1] Yang, H. & Zehnder, A. J. B. 2001. China's regional water scarcity and implications for grain supply and trade. *Environment and Planning A*, **33**, pp. 79-95, 2001.

[2] Shi, P. China's water crisis: difficulties and policies. *Strategy and Management*, **(6)**, pp. 40-47, 1997.

[3] Huang J, Pray, C., & Rozelle, S. Enhancing the crops to feed the poor. Nature, **418**, pp. 678-684, 2002.

[4] Pang, J. Z. & Zhang, Z. Z. (eds). *Issues on Rational Allocation of Water Resources in Northern China and South-North Water Transfer*. China Water Publishing House: Beijing. 2001.

[5] Kallis, G. & Goccossis, H. Metropolitan areas, planning and sustainable use of water, thematic literature report. Environmental Planning Laboratory, University of the Aegean, 1999.

[6] Qian, Z. Y. & Zhang G. D. (eds). *Report on the Research on Sustainable Water Resources Strategy in China*. China Water Publishing House: Beijing, 2001.

[7] World Commission on Dams (WCD). *Dams and Development - A New Framework For Decision-Making*. Earthscan: London and Sterling, VA, 2000.

[8] Jiang, Z. M. The speech in Zhengzhou, June 1999. Correspondents of *China's Water Science*, **(3)**, p. 5, 2000.

[9] State Statistical Bureau (SSB). *Statistical Yearbook of China (ZTN)*. Statistical Publishing House: Beijing, 1999.

[10] Ash, R. & Edmonds, R. Land resources, environment and agricultural production. *The China Quarterly*, **(156)**, pp. 836-879, 1998.

[11] Liu C. M. & He X. W. *Water Strategy for China's 21st Century*. Science Publishing House: Beijing, 1996.