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Chinese agricultural water resource utilization: problems and challenges

Han Hongyun[a] and Zhao Liange[b]

[a]*Corresponding author. Zhejiang University, 268 Kaixuan Road, Hangzhou, Zhejiang, China. E-mail: hhyzlg@yahoo.com.cn*

[b]*Zhejiang Gomgshang University, Hangzhou, Zhejiang, China*

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Abstract

With rapid industrialization and urbanization, scarce water resources are more and more being transferred from low-value agricultural use to high-value industrial and domestic uses in China. Along with water shortages, inefficiencies are apparent in Chinese agricultural water utilization. The causes of these inefficiencies include attenuated property rights, artificially low water prices, lack of farmer participation in irrigation districts management and fragmented government management. It is concluded, against the background of a transitional economy, that the lack of economic incentives in the allocation of water is the principal reason why shortage and waste coexists in Chinese irrigated agriculture. The challenge now facing decision makers is how to resolve the conflict between increasing food demand and decreasing water supply without undermining the growth of cities and the industrial sector. Owing to failures in both markets and government in water allocation, it is argued that it is necessary to establish a quasi-market for water.

Keywords: Agricultural water resources; Inefficiencies; Quasi-market

1. Introduction

With rapid industrialization and urbanization, as is occurring all over the world, scarce water resources more and more are being transferred from low-value agricultural use to high-value industrial and domestic uses; water shortage is becoming the bottleneck of agriculture development in China. Along with water shortages, inefficiencies are apparent in Chinese agricultural water utilization. It is our view that clearer and more transparent analyses of the causes for the coexistence of shortages and waste in agricultural water utilization are essential prerequisites of any development policy that puts food security at its heart. A big challenge now facing decision makers in China is how to resolve the conflict

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between increasing food demand and decreasing water supply without undermining the growth of cities and the industrial sector.

The purpose of this paper is to identify problems for agricultural water utilization in China. This assessment is expected to aid the planning of policies so that policies ensuring food security in China can take account of the characteristics of agricultural water use and the likely challenges for future water policies. This paper aims to provide a basic understanding of the current status of water resources, causes for the inefficiency of agricultural water use, as well as challenges for future water policies in China.

The reminder of this paper is organized into five sections: first, Chinese water resources are presented; second, a picture of the present situation in Chinese agriculture is given; third, the causes of inefficient agricultural water use are analyzed; fourth, challenges to future agricultural water use are outlined; and finally, brief conclusions are drawn.

2. Chinese water resources

2.1. Water supply

China is geographically large yet relatively poor in terms of water resources per capita (Table 1). The total volume of water runoff in China was roughly 2412 billion m^3 and the per capita water runoff per annum was 1856 m^3 in 2004. This is less than one-quarter of the world's average. Northern China is especially water poor, with an average 750 m^3 of runoff available per capita per annum. Water availability in the Hai-Luan basin is particularly low (355 m^3/head/year). Availability in the Huai and Huang basins is higher, but still below the internationally accepted definition of water scarcity (1 000 m^3/head/year) (World Bank, 2001).

Since 2000, the use rate of water resources has been around 20% of available total water resources; it reached 22.99% in 2004. The Chinese population is expected to reach 1.6 billion (1 billion $= 10^9$) by the middle of the 21st century. At that point, the amount of runoff per capita per annum will be reduced to 1750 m^3 compared with 1856.5 m^3 in 2004. In 2004, in the whole country there were 85,160 reservoirs of various kinds with a total storage capacity of 554.78 billion m^3. According to "The Ninth-five Plan

Table 1. Water resources in China.

Year	Total volume of water runoff in China (billion m^3) (1)	Water used (billion m^3) (2)	(2)/(1) (%)	Population (10 000 persons) (3)	Per capita water resources (m^3/person) (1)/(3)	Per capita water use (m^3/person) (2)/(3)
1997	2785.5	556.60	19.98	123626	2253.17	450.2
1998	3401.7	543.54	15.98	124761	2726.57	435.7
1999	2819.6	559.09	19.83	125786	2241.59	444.5
2000	2770.08	549.76	19.84	126743	2185.59	433.8
2001	2686.78	556.74	20.72	127627	2105.18	436.2
2002	2826.13	549.73	19.45	128453	2200.13	428.0
2003	2746.02	532.04	19.37	129227	2124.96	411.7
2004	2412.96	554.78	22.99	129988	1856.29	426.8

Sources: National Bureau of Statistics of China (2004) *China Statistic Yearbook 2004*, p. 425. National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, pp. 93 & 399.

and 2010 Program of Chinese Water Conservancy Development" (The People's Republic of China (PRC), 1997), China's water storage capability will continue to be extended by 120 billion m^3 until 2010. The total water storage capacity then will stand at around 620–650 billion m^3.

2.2. Increasing water demand

With the increase of water storage capacity, China's population (excluding the population of the Hong Kong and Macao Special Administrative Regions and Taiwan province) exceeded 1.29 billion by the end of 2004. The total amount of water use all over the country in 2004 was 554.78 billion m^3, of which domestic water use accounted for 11.7%, industrial water use accounted for 22.2%, agricultural water use accounted for 64.6% and ecological water use accounted for 1.5% (Table 2). Deng & He (1997) predicted that a water supply deficit of 100 billion m^3 will exist by 2010 and this will widen by 2030, when it will reach 230 billion m^3. The huge population exerts a big burden on limited water resources in China (Table 3).

The World Bank (2001) predicts that the urbanization rate will increase to around 40% by 2015. In fact, the urbanization rate reached 41.76% in 2004. Along with rapid urbanization, the Chinese people are shifting their food preferences toward less grain and more meat (Li *et al.*, 1997). Farmers are adjusting the pattern of cultivation to meet changing market preference and improve the quality of farm produce, which is resulting in increased demand for water. Along with urbanization, the demands for vegetables, fruits and livestock products are growing strongly. As a response to changes in consumer tastes since the mid-1980s, Chinese farmers have rapidly expanded the area used for cash crops and other high value crops. The total grain area has declined since 1978, with its percentage to total sown area down from 80.3% in 1978 to 66.2% in 2004; while the areas planted for cash crops increased from 9.6%

Table 2. Increase of water used in China.

Year	Water used	Agricultural use	Industrial use	Domestic use	Biological protection
1997	Water used (billion m^3)	391.972	112.116	52.515	
	percentage	70.42	20.14	9.43	
1998	Water used (billion m^3)	376.626	112.621	54.292	
	percentage	69.29	20.72	9.99	
1999	Water used (billion m^3)	386.916	115.895	56.277	
	percentage	69.20	20.73	10.07	
2000	Water used (billion m^3)	378.354	113.913	57.492	
	Percentage	68.82	20.72	10.46	
2001	Water used (billion m^3)	382.573	114.181	59.989	
	percentage	68.71	20.51	10.77	
2002	Water used (billion m^3)	373.618	114.236	61.874	
	Percentage	67.64	20.78	11.26	
2003	Water used (billion m^3)	343.28	117.72	63.09	7.95
	percentage	64.52	22.13	11.86	1.40
2004	Water used (billion m^3)	358.57	122.89	65.12	8.20
	Percentage	64.6	22.2	11.7	1.5

Sources: National Bureau of Statistics of China (2004) *China Statistic Yearbook 2004*, p. 425. National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, p. 399.

Table 3. Composition of the population in China 10,000s of persons.

Year	Urban population	Proportion (%)	Rural population	Proportion (%)
1978	17,245	17.92	79,014	82.08
1980	19,140	19.39	79,565	80.61
1985	25,094	23.71	80,757	76.29
1989	29,540	26.21	83,164	73.79
1990	30,195	26.41	84,138	73.59
1991	31,203	26.94	84,620	73.06
1992	32,175	27.46	84,996	72.54
1993	33,173	27.99	85,344	72.01
1994	34,169	28.51	85,681	71.49
1995	35,174	29.04	85,947	70.96
1996	37,304	30.48	85,085	69.52
1997	39,449	31.91	84,177	68.09
1998	41,608	33.35	83,153	66.65
1999	43,748	34.78	82,038	65.22
2000	45,906	36.22	80,837	63.78
2001	48,064	37.66	79,563	62.34
2002	50,212	39.09	78,241	60.91
2003	52,376	40.53	76,851	59.47
2004	54,283	41.76	75,705	58.24

Source: National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, p. 93.

in 1978 to 15.2% in 2004; the area of vegetables increased from 2.2% in 1978 to 11.4% in 2004; and the area of tea plantations and orchards increased from 1.8% in 1978 to 7.2% in 2004. Agricultural activities (including crop farming and livestock raising) consumed about 391.972 billion m^3 in 1997, this accounted for 70.42% of the total water use and irrigated land accounted for 33.2% of the total sown area (see Table 4). Both the high urbanization rate and the changing food preferences of the Chinese people will tend to boost the per capita demand for water.

Although the demand for water arising from intensified industrial and human needs is increasing fast, the extent of irrigation demand has not grown in recent years. Agriculture, however, is still the main water user. In 2004, agricultural production still consumed 64.6% of total water resources (see Table 2).

2.3. Uneven pattern of water supply and demand

There are striking differences in the allocation of water resources across different regions in China. With regard to the geography of water, there are two Chinas. The Yangtze River is often called the equator of China, which divides the country between a humid south and a dry north. The humid south includes the Yangtze River and has a population of 722 million. The arid north includes the Yellow, Liao, Hai and Huai Rivers and supports 568 million people. However, whilst 81% of Chinese water resources are in the southern part of the country, the largest part of the arable land, 64%, is in the north. As a result, the water per hectare of cropland in the north is only one-eighth that in the south. Furthermore, the northeast of China accounts for 26% of the total population of China, but it receives only 20% of the total water resource. The distribution of groundwater is similarly skewed. Average groundwater resources in the south are more than four times greater than in the north. The naturally

Table 4. Cropping pattern in China: 1978–2004 (unit: million hectares).

Year	Total sown area	Area of grain crops		Area of cash crops		Area of vegetables		Areas of tea plantation and orchards	
		Share (%)	Area	Share (%)	Area	Share (%)	Area	Share (%)	Area
1978	150.105	80.3	120.587	9.6	14.44	2.2	3.331	1.8	2.705
1980	146.381	80.1	117.234	10.8	15.921	2.2	3.163	1.9	2.824
1985	143.626	75.8	108.845	15.6	22.378	3.3	4.753	2.7	3.813
1989	146.554	76.6	112.205	13.4	19.596	4.3	6.29	4.4	6.437
1990	148.363	76.5	113.466	13.7	20.255	4.3	6.338	4.2	6.24
1991	149.586	75.1	112.314	14.9	22.242	4.4	6.546	4.3	6.378
1992	149.008	74.2	110.56	15.3	22.755	4.7	7.031	4.6	6.902
1993	147.741	74.8	110.509	13.8	20.323	5.5	8.084	5.1	7.603
1994	148.241	73.9	109.544	14.3	21.206	6.0	8.921	5.7	8.399
1995	149.879	73.4	110.06	14.8	22.189	6.3	9.515	6.1	9.213
1996	152.381	73.9	112.548	14.0	21.292	6.9	10.491	6.3	9.656
1997	153.969	73.3	112.912	13.9	21.474	7.3	11.288	6.3	9.724
1998	155.706	73.1	113.787	13.4	20.877	7.9	12.293	6.2	9.592
1999	156.373	72.4	113.161	13.3	20.855	8.5	13.347	6.3	9.797
2000	156.3	69.4	108.463	14.5	22.654	9.7	15.237	6.4	10.021
2001	155.708	68.1	106.08	14.6	22.758	10.5	16.402	6.5	10.184
2002	154.636	67.2	103.891	14.5	22.434	11.2	17.353	7.1	11.042
2003	152.415	65.2	99.41	15.3	23.359	11.8	17.954	7.0	10.644
2004	153.553	66.2	101.606	15.2	23.290	11.4	17.560	7.2	11.030

Source: National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, pp. 458–460.

uneven spatial distribution of water resources constitutes a threat to sustainable economic and social development in China. The extent of uneven distribution of water resources in different regions is given in Table 5. The water per hectare, per capita water resources and per capita water used in different regions are a good reflection of the uneven distribution of water resources.

Natural precipitation is also unevenly distributed over time. There are significant seasonal variations in rainfall among the different areas of China as well as from year to year. About 70% of precipitation falls in the "high-water" season from June to September. Rainstorms and floods are common in that season. The ratio of maximum to minimum annual runoff on a yearly basis is 2–3:1 for the Yangtze and Zhujiang rivers in the south, 4:1 for the Yellow River and 15–20:1 for the Huaihe and Haihe Rivers in the north (Li *et al.*, 1997). Dramatic shifts in annual and monthly precipitation cause floods and droughts (see Table 8).

2.4. Environmental issues

The deterioration of riverine environments is an issue of concern in many countries around the world, including China. For instance, the Yellow River first appeared to stop flowing in 1978. Subsequently, flow ceased each year from 1985 up until 1997. The accumulated period of zero flow was 226 days in 1999 (Ministry of Water Resources, 2000). Although it is perhaps the most visible manifestation of water scarcity in China, the drying up of the Yellow River is only one of many such signs.

Table 5. Distribution of water resources across regions in 2004.

Regions	Amount of water resource (billion m^3)	Water supply (billion m^3) (1)	Cultivated land (1000 hectares) (2)	(1)/(2) m^3/hectare	Per capita water resources (m^3/person)	Per capita water use (m^3/person)
Beijing	1.84	3.46	343.9	10,061.06	143	231.4
Tianjin	1.06	2.21	485.6	4,551.071	139.7	215.4
Hebei	15.31	19.59	6,883.3	2,846.019	226.5	287.7
Shanxi	13.49	5.59	4,588.6	1,218.236	277.4	167.6
Inner Mongolia	45.96	17.15	8,201.0	2,091.208	1,835.6	719.3
Liaoning	22.00	13.02	4,174.8	3,118.712	677.4	308.8
Jilin	32.65	9.92	5,578.4	1,778.288	1,194.9	366.1
Heilongjiag	82.68	25.94	11,773.0	2,203.347	1,708.5	679.7
Shanghai	1.51	11.81	315.1	37,480.17	143.4	678.2
Jiangsu	61.94	52.56	5,061.7	10,383.86	274.5	707.1
Zhejiang	57.45	20.78	2,125.3	9,777.443	1,431.5	440.2
Anhui	108.30	20.97	5,971.7	3,511.563	774.9	324.6
Fujian	80.66	18.49	1,434.7	12,887.71	2,028.6	526.7
Jiangxi	136.27	20.35	2,993.4	6,798.29	2,415.1	475.1
Shandong	48.97	21.49	7,689.3	2,794.793	380.7	234.1
Henna	69.77	20.07	8,110.3	2,474.631	418.4	206.5
Hubei	123.41	24.27	4,949.5	4,903.526	1,539.8	403.4
Hunan	179.92	32.36	3,953.0	8,186.188	2,450.4	483.2
Guangdong	145.84	46.48	3,722.2	12,487.24	1,430.2	560
Guangxi	190.10	29.08	4,407.9	6,597.246	3,281.9	594.8
Hainan	29.18	4.63	762.1	6,075.318	2,092.2	566
Sichuan	258.98	21.04	9,169.1	2,294.664	2,789.9	241.1
Guizhou	91.55	9.43	4,903.5	1,923.116	2,538.4	241.6
Yuannan	169.94	14.69	6,421.6	2,287.592	4,770.8	332.8
Tibet	475.71	2.8	362.6	7,722.008	17,026.13	1,021.5
Shannxi	57.46	7.55	5,140.5	1,468.729	835.1	203.9
Gansu	24.72	12.18	5,024.7	2,424.025	656.5	464.9
Qinghai	63.47	3.02	688.0	4,389.535	11,258.1	559.7
Ningxia	1.23	7.4	1,268.8	5,832.282	167.7	1,259.3
Xinjiang	92.01	49.71	3,985.7	12,472.09	4,357.6	2,532.1

Source: National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, pp. 398, 399.

Over-exploitation of water in Chinese arid areas is profoundly changing hydrological conditions in northern China. The supply deficits in surface water resources have led to intensified use of the groundwater beyond their "safe yield", where recharge balances withdrawals. Hence the water table has fallen under both rural and urban areas. Other consequences have included land subsidence and saltwater intrusion in coastal areas. Over-extraction of groundwater has become a serious problem in a number of cities including Nanjing, Taiyuan, Shijiazhuang and Xi'an. Groundwater depletion is most problematic in coastal cities, including Dalian, Qingdao, Yantai and Beihai, where saltwater intrusion is on the rise. Soil erosion and wetland degradation related to water use are also occurring.

All of China's water bodies are polluted to various degrees of severity. Serious pollution has been documented in seven of the country's major watersheds: Huai, Hai, Liao, Songhua, Chang Jiang, Zhu Hai and Huang He. More than 90% of urban water supply sources are polluted to varying extents. In the upstream and middle reach areas of rivers, the water conservation capacity has been reduced because of vegetation clearing (World Resource Institute, 1998–1999).

Meanwhile, China has suffered seriously from water and soil loss. Croplands are increasingly affected by pollution, arising from industrial discharge of contaminated wastewater, but mostly through pollution of irrigation water. Less than 20% of wastewater is treated before being discharged into rivers and lakes. Agriculture is a primary and important source of pollution. Agricultural pollution is the main source of non-point pollution owing to fertilizer runoff, pesticide runoff and discharges from intensive animal production enterprises. Nearly 70% of the total nutrient load flowing into Dianchi Lake in Yunnan Province is derived from agricultural runoff. About 75% of total phosphate and 60% of total nitrogen is derived from agricultural non-point sources (World Bank, 2001). Total fertilizer consumption in China increased by more than 307% between 1978 and 2004 (see Table 6).

3. Present situation in Chinese agriculture

3.1. Trends in irrigated agriculture in China

Feeding China's population is a continuing major challenge for Central Chinese Government. "It is a matter of mounting concern, not just to agricultural officials but increasingly to national leaders and security advisers, to know more precisely what happens to land productivity as the supply of irrigation water plummets" (Brown & Halweil, 1998: 2). In China, 70% of the grain harvest comes from irrigated land. One way to secure food supply into the future is through increased production from irrigated arable land because of its land limitation and high productivity. The irrigated area has increased from 45.0 million hectares in 1978 to 54.5 million hectares in 2004. However, although it is the main staple food of the Chinese people, the area under rice production has been continuously declining at an annual rate of 0.92% in China since 1978 (see Table 7). Irrigated rice will play a key role in future Chinese food security because of the high productivity of irrigated rice and the traditional food preferences of the Chinese people.

As a growing open economy, China can import more grain to support its huge population. From the perspective of Chinese decision makers, maintaining food security means attaining high food

Table 6. Consumption of chemical fertilizer over time in 10,000s of tonnes.

Year	Consumption of chemical fertilizer	Year	Consumption of chemical fertilizer
1978	884	1996	3,827.9
1980	1,269.4	1997	3,980.7
1985	1,775.8	1998	4,083.7
1989	2,357.1	1999	4,124.3
1990	2,590.3	2000	4,146.4
1991	2,805.1	2001	4,253.8
1992	2,930.2	2002	4,339.4
1993	3,150.1	2003	4,411.6
1994	3,317.9	2004	4,636.6
1995	3,593.7		

Source: National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, p. 451.

Table 7. Area of irrigation in China in millions of hectares.

Year	Total sown area (1)	Irrigated area (2)	(2)/(1) (%)	Rice area
1978	150.1	45.0	30.0	34.4
1980	146.3	44.9	30.7	33.9
1985	143.6	44.0	30.6	32.1
1989	146.6	44.9	30.6	32.7
1990	148.3	47.4	32.0	33.1
1991	149.6	47.8	32.0	32.6
1992	149.0	48.6	32.6	32.1
1993	147.7	48.7	33.0	30.4
1994	148.2	48.8	32.9	30.2
1995	149.9	49.3	32.9	30.7
1996	152.4	50.4	33.1	31.4
1997	154.0	51.2	33.2	31.8
1998	155.7	52.3	33.6	31.2
1999	156.3	53.2	34.0	31.3
2000	156.3	53.8	34.4	30.0
2001	155.7	54.2	34.8	28.8
2002	154.6	54.4	35.2	28.2
2003	152.4	54.0	35.4	26.5
2004	153.6	54.5	35.5	28.4

Source: National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, pp. 451, 458.

self-sufficiency for China because importing even a small share of China's grain consumption would constitute a large proportion of the world export market. For example, in 1995 when there was a severe drought in China, the grain deficit in China reached an unprecedented level of 20 million metric tonnes in that year. The 20 million metric tonnes of grain imported in 1995 covered only 4% of China's grain consumption, but accounted for 10% of world grain trade (Ministry of Agriculture, 1999). In this case, the Chinese authorities feared the economic risk of grain prices soaring and/or the political risk of a large-scale embargo on grain trade. Hence, irrigated agriculture has played and will continue to play a crucial role in the support of the policy of food self-sufficiency in China.

With the development of a market-oriented economy in China, the market mechanism can be expected to play an increasing role in the allocation of resources. Because of the difference in value between industrial, agricultural and domestic water use, more and more water has been transferred from agricultural use to industrial and domestic uses. "It is the swelling diversion of irrigation water, combined with heavy losses to aquifer depletion, that has emerged as the most imminent threat to China's food security" (Brown & Halweil, 1998: 2).

3.2. Heavy dependence of agriculture on irrigation

"Worldwide, 70–80% of all developed water resources is used for agricultural production. In arid countries where rainfall is insufficient for rain-fed agriculture, this percentage may be as high as 90%" (Fraiture & Perry, 2002). China's agricultural land is small in area relative to its population. However, the most limiting current constraint to agricultural production in China is water rather than land (see Table 8). This is particularly the case given the uneven distribution of water between the north, which is drought prone and the south, which is frequently threatened by flooding. Irrigation provides supplementary water for agriculture where rainfall is not sufficient for the needs of crops. It is crucial for the survival of China's agriculture, because 64% of China's arable land is in north China, where natural rainfall does not match the needs of crops in quantity, nor in time. Large parts of the existing agricultural areas in the north cannot be cultivated to their full potential owing to insufficient rainfall. An example is the Huanghe, Huaihe and Haihe River plain, which is considered to have the greatest potential for agricultural development owing to its vast area of arable land and relatively low current yields. This area covers about 10% of China's territory but has less than 2% of the nation's water resources. The gap between water supply and potential demand is equivalent to about three-quarters of the annual rainfall. In arid west China, agricultural activities are even impossible without irrigation. This, therefore, results in the heavy dependence of agriculture on irrigation.

The challenge now facing the Chinese economy is how to resolve the conflict between increasing food demand and decreasing water supply without undermining the growth of cities and the industrial sector. Irrigated agriculture faces two kinds of pressure: increasing demands for agricultural products and a decreasing water supply. In order to alleviate the water supply deficit in irrigated agriculture, the Chinese Government has adopted many technological advances and policy instruments to increase the productivity of irrigated land, including the China Water Conserving Development Program for Irrigation Agriculture, water-conserving irrigation projects and the construction of large-scale water-conserving irrigation demonstrations at the national level. After the decades' development of water

Table 8. Areas covered and affected by flood and drought in millions of hectares.

Year	Areas affected by flood (1)	Areas affected by drought (2)	(2)/(1)
1978	2.012	17.970	8.9
1980	6.070	14.174	2.3
1985	8.949	10.063	1.1
1989	5.917	15.262	2.6
1990	5.605	7.805	1.4
1991	14.614	10.559	0.74
1992	4.464	17.049	3.84
1993	8.611	8.657	1.04
1994	10.744	17.409	1.64
1995	7.630	10.401	1.4
1996	10.855	6.247	0.6
1997	5.840	20.250	3.5
1998	13.785	5.060	0.7
1999	5.071	16.614	3.3
2000	4.321	26.784	6.2
2001	3.614	23.698	6.6
2002	7.474	13.247	1.8
2003	12.289	14.470	1.2
2004	3.747	8.482	2.3

Source: National Bureau of Statistics of China (2005) *China Statistic Yearbook 2005*, p. 478.

conservation, it is crucial to increase the efficiency of agricultural utilization against the background of a water deficit for agriculture.

Whilst the water supply deficit for Chinese agriculture is increasing over time, efficiency of water use is still poor. At present, the average efficiency of the canal water delivery system is only 0.3–0.4, compared with a rate of 0.7–0.9 in most developed countries. In 1995 the use rate in China was only one-eighth of the rate in the United States of America in 1990 and one-twenty-fifth of the rate in Israel in 1989. Mean grain output per cubic meter of water is only 0.85 kg, less than half of that of some developed countries. By contrast, it is 2.32 kg /m^3 in Israel. In other words, inefficiency in water withdrawal is making the Chinese water deficit even more serious. What are the causes of inefficient agricultural water utilization in China?

4. Causes of inefficient water use in Chinese agriculture

4.1. Attenuated property rights over water

"Property rights form an open-ended bundle of rights to possess, to use, to benefit from and to dispose of valuable and scarce assets" (Kasper, 1998: 63). According to the Water Law, all water resources in China belong to the state except for the water in dams established by local communities. In the absence of an integrated management organization, the Water Conservancy Department, the Department of Construction and the Environment Department, co-owned the control rights of the water resource on behalf of the state before 1997. In an attempt to improve water resource use efficiency, the central government implemented a license permit system in 1994. The presence of many small, fragmented farms makes it costly to measure the amount of water used by a farmer. Lack of metering devices makes it difficult for the license permit system to be implemented in agriculture. Hence, the water resource in a given rural area remains an open access resource.

Attenuated property rights over water can provide little incentive to water authorities to reduce irrigation water supply and farmers are not motivated to conserve scarce water. For water authorities, an increase in water supply means an increase in revenue to alleviate budget constraints because they obtain water from the state freely; for farmers, lack of effective water licensing and extraction control means all farmers co-own the water resources in a given region.

4.2. Low water prices

Historically, the price of water has been held at an artificially low level. In October 1965, the method of use and collection of water fees was promulgated by the State Council. This was the first system for water fee collection in China. The price of water at that time was set at 0.3–1 cents/m^3 for industry and 0.2–0.5 cents/m^3 for residents[1]; the price for agriculture was nearly free of charge. The price of water was set without regard for the costs of supply. Hence, the Chinese government subsidized the use of water. The heavy financial burden of subsidies forced the government to enact a new method for the

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[1] 1 US$ is 8.27 Chinese Yuan. 1 Chinese Yuan is 100 cents.

accounting, collection and management of the water fee in 1985. Under this new method, water fees were accounted on the basis of cost. Where the price of water for agriculture was concerned, the price of water for food crops should have covered the cost of supply and the price for industrial crops was more than the cost of supply.

In 1992, the State Council attempted to establish a new management method for the price of water. This new method tried to decentralize the authority for pricing water, to implement an incremental price for extra water and to carry out a two-part-tariff price for water. Because of many difficulties in practice, it finally failed. However, it pushed forward the reform of water prices considerably. Since then water fees have been called water prices. This was not playing with words; it signaled the start of water being treated as an economic good.

In 1999, the prices of water supplied by water conservancy projects were 2.7 cents/m^3 on average, 8 cents/m^3 for industry, 5.5 cents/m^3 for residents and 2.7 cents/m^3 for agriculture. The water price for agriculture incorporated only the operation cost of water conservancy projects. It did not include labor cost, depreciation and management expenses. The water used by agriculture was therefore constrained to be subsidized. More problematic is that the subsidies were paid directly to the enterprise supplying the water resource, not to farmers. The beneficiaries of the subsidies were the supply authorities not the farmers. The water price was thus regarded as a fee for administration, not the price of an economic good.

In sum, the problems of pricing agricultural water use are two-fold. First, the water price does not reflect the true economic cost of supply. Second, the prevailing pattern of subsidies exerts a heavy burden on government.

4.3. Lack of property rights over water infrastructure

Historically, many large irrigation schemes constructed in the 1950s and 1960s were designed hastily, constructed to low standards and built with poor quality materials and equipment. Many were not completed or lack distribution and drainage networks at the tertiary and farm level currently. Most systems require major upgrading, rehabilitation and completion.

Under the Home Responsibility System, farmers hold relatively independent land use rights. However, with regard to water supply systems, rights are held by the states. The physical infrastructure is again open access. Although the management responsibility of irrigation districts (ID) is now being transferred to water users associations (WUAs), owing to the poor quality of the infrastructure, the WUAs are unwilling to take over the responsibility for management. Furthermore, the authorities that have been responsible for the infrastructure are unwilling to give up their monopolistic position.

After two decades of reform, large- and medium-sized irrigation schemes are still state-owned and managed by water authorities at different administrative levels on behalf of the state. The management of small irrigation projects is taken primarily by collectives at village level and, to a much lesser extent, by individual farmers who acquire leases from collectives. In 2004, in the whole country there were 85,160 reservoirs of various kinds with a total storage capacity of 554.78 billion m^3. The total water storage of 462 large reservoirs and 2,771 medium size reservoirs all over the country was 221.9 billion m^3 by the end of 2004. The allocation of property rights over large- and medium-sized irrigation projects is the main issue in the reform of irrigation management in the future.

4.4. Fragmented government management

Before 1997, the Ministry of Water Resources (MWR) was responsible for overall water resources planning and management, major hydro infrastructure and large hydropower generation. The Ministry of Construction was responsible for wastewater treatment investment and the National Environmental Protection Agency was responsible for wastewater legislation and discharge compliance monitoring. Since 1998, the Ministry of Construction has turned over most control rights to the surface water to the MWR; this has made the MWR fully responsible for allocating water resources. However, there is no unified agency responsible for water management.

To realize comprehensive control on overall quantity, water quality and ecology of water resources, the state has been developing plans for management for water resources based on watersheds. Rivers Basin Committees, such as the Huanghe Water Conservancy Committee and the Yangtze Water Conservancy Committee have been established. However, owing to the lack of the support of laws, all these committees only partly hold control rights over water resources.

In sum, shortage and waste coexist in Chinese agricultural water utilization. An increase in agricultural water use efficiency is a necessary condition, not only for future agricultural development, but also for Chinese social and economic development. Against the background of a transitional economy, the lack of economic incentives is the fundamental reason for inefficiency in Chinese agricultural water utilization. Continuing macroeconomic reform in China will require further market development at the micro level. Growing non-agricultural demand will push for increasingly open water markets, farmers will continue to lobby for easily transferable water rights and the general climate of decentralization favors the continued development of water markets. However, there are some problems deserving special attention in establishing a water market.

5. Establishing a quasi-market for water: rationale and challenges

5.1. Market failures in water allocation

Markets are institutions that exist to facilitate exchange and in order to reduce the cost of carrying out exchange transactions. Under the conditions of complete information and perfect competition, markets will achieve first-best allocations. Markets can only function well under the following preconditions: water rights excludable, transferable and separable from land rights, a flexible infrastructure, internalized third party effects (externalities) and equity concerns (Johansson, 2000). Crase *et al*. (2000) outlined five basic factors hindering the development of a permanent water market: unclear or poorly defined rights to access and use the resource, variability of supply, infrastructure obstacles, excessive transaction and transfer costs and hoarding behavior and speculation. All these will lead to market failure in agricultural water utilization.

There are three basic reasons for market failure in agricultural water use. First, individuals may not have sufficient control of a resource to undertake the necessary exchange. Second, high transaction and information costs can erode the advantages of trade. Finally, the individuals involved in trade may be unable to negotiate and agree upon the terms of a mutually advantageous exchange owing to the lack of flexible conveyance facilities in rural areas. According to China's constitution, the ownership of all water resources belongs to the state. Water authorities manage the water on behalf of the state and collect the payment from farmers who use the water. Although the transfer of water from agriculture to the urban sector has been a trend since the 1980s, it has been conducted mostly by administrative means. The water transfer is not compensated or only involves a nominal sum. Water authorities and individual farmers generally do not benefit from the transfer of water from their irrigation districts. Attenuated property rights over water are the main constraint on a quasi-market for water.

5.2. Government failures in water allocation

It has been argued that externalities constitute a prima facie case for government intervention in a market economy (Coase, 1988). However, public intervention has problems of its own. These include misallocated project investments, over-extended government agencies, inadequate service delivery to the poor, neglect of water quality and environmental concerns and the under-pricing of water resources. The government faces the same problems as the market: incomplete information and high externalities resulting from incomplete information. The central water authority often lacks complete information on water supply, demand and consumption.

Meanwhile, government regulation faces administrative costs, including the costs of investigation and administration. Sometimes the costs are sufficiently high that the expected gains from governmental intervention are less than the costs involved. Under public management the dominant incentive to comply is coercion: that is, setting regulations and using sanctions on those who break them. But this type of incentive is only effective if the state detects infractions and imposes penalties. In many cases, the state lacks the local information and ability to penalize for breaking water delivery structures or for excessive water withdrawals (Dinar *et al.*, 2001). In particular, the existence of externalities does not imply that there is a prima facie case for governmental intervention, and whether there is a presumption that government intervention is desirable depends on the cost conditions and the expected gains.

In China, lack of a unified agency responsible for water management, difficulty in coordination of plans between different agencies and lack of information about water resources concerned with quantity, quality and ecology, are all factors that mean that government cannot function well. Because of market and government failures, the simple market or government may not allocate water resources efficiently. "What one can observe in the world, however, is that neither the state nor the market is uniformly successful in enabling individuals to sustain long-term, productive use of natural resource systems. Further, communities of individuals have relied on institutions resembling neither the state nor the market to govern some resource systems, with reasonable degrees of success over long periods of time." (Ostrom, 1991: 1).

5.3. Establishing a quasi-market for water

The aim of economic policy is to ensure that resource allocation conforms to social objectives, notably efficiency and equity considerations. Economic efficiency is concerned with the amount of wealth that can be generated by a given resource base, but equity deals with the distribution of the total wealth among the sectors and individuals of society. While there are many reasons why markets fail, at the heart of the issue here are poorly defined property rights. Hence, there is a key role for governments in natural resource management which is to provide a secure and transparent system of property rights. Similarly, government can also "assist in monitoring and regulating externalities and third-party effects of irrigation" (Johansson, 2000: 17).

Given the nature of the resource and the need to avoid conflicts, there are also many excuses for government involvement in the water market. First, water resources are non-fungible resources for human existence. Second, there are many uses for water, drinking and domestic purposes, irrigation, fishing and navigation, hydropower generation, flood management, recreation, tourism and conservation for future use. The uses are often in conflict and the satisfaction of one obstructs the fulfillment of another. Meanwhile, there are some characteristics of water resource development that lead to public intervention. They are large capital investment and monopoly pricing. Besides these, "there are a number of legislative or administrative caveats at the local level which complicate the operation of the water market. These limitations are largely designed to reflect environmental, physical and operational constraints but have developed on an *ad hoc* basis " (Crase *et al.*, 2000: 299–321). Furthermore, some of the environmental benefits provided by water, for instance, in-stream biodiversity protection, have public good characteristics, which means that property rights cannot be defined. Hence the government's role may extend beyond the defining, or enforcing of property rights. The market for water, especially in an economy in transition, can thus best be seen as a quasi-market.

5.4. Challenges for establishing a quasi-market

5.4.1. Institutional arrangements. An intricate system of rules and regulations would normally be needed to approach perfect competition. Water institutions are the rules that prescribe actions for both individual and collective decision making. They involve the legal framework, policy environment and administrative arrangements. Institutional arrangements governing the water sector are undergoing remarkable changes worldwide. The Chinese government has been attaching great importance to work on the laws and regulations concerned with water resources.

Since the 1970s, the MWR had begun work on water pollution monitoring. More importantly, the Act on Water Pollution Prevention of the People's Republic of China, enacted in May 1984, provided the legal basis for water environmental protection. In 1988, the first law on water resources, the Water Law of The People's Republic of China, was formulated "for the purpose of rational development, utilization and protection of water resources, control of water disasters, fully deriving the comprehensive benefits of water resources and meeting the needs of national economic development and the livelihood of the people"(Water Law, Article 1, 1988). Considering water as the people's property, the law distinguishes the management and allocation rights of the state from the usage rights of the people. It advocates a water permit system and full cost recovery, stipulates the river basin as the basic management unit and mandates the formulation of national, regional and sectoral water plans (Saleth & Dinar, 2000).

The Chinese government also intensified legislation and law enforcement relating to water resource utilization and environmental protection. In July 1991, the National People's Congress approved the Water and Soil Conservation Act of the People's Republic of China. In 1993, regulations regarding the law on water and soil conservation were put into effect. A comprehensive system of administrative agencies for water and soil conservation ranging from the central to local authorities was established.

The Water Law passed in 1988 not only strengthened the water administration with the formalization of coordination and conflict resolution mechanisms, but also led to a fundamental change in water policy. The Water Law was revised on August 29, 2002, in which water conservation was given the highest priority. In 1997, China created the Law of Flood Control, promulgated the national policy on Pollution Control and passed the Aquatic Protection legislation. Meanwhile, the State Water Industry Policy was declared. "It is unique for a socialist country as it allows the entry of private investors into the water sector and also requires all public water projects to operate on commercial lines" (Saleth & Dinar, 2000: 175–199).

"While water planning and development functions as well as legislative and regulatory powers are with the national governments, the actual management and maintenance functions are with the lower level governments" (Saleth & Dinar, 2000). Most agencies dealing with water resources have only sectoral responsibility (for example, to deal with irrigation or drinking water or industry or environment). It should be recognized that any sector-related policy affects the relationship between the particular sector and other sectors. So the policy framework will acknowledge the interactions between various elements comprising the water catchment area, incorporating cross-sectoral and environmental considerations into the design of investment of programs for different sectors. The coordination of sectoral policies and responsibilities is the precondition of fulfilling the sustainability of natural resources.

5.4.2. Non-attenuated property rights over water. It is a precondition of a quasi-market for water that non-attenuated property rights be established. Market transactions are the exchange of rights pertaining to goods and services. What is bought and sold consists of a bundle of rights. The establishment of non-attenuated property rights is a precondition for market development. It assures that the market will be predictable, stable and certain. Meanwhile, through the establishment of non-attenuated property rights, the relationships between government, consumer and producer will be clearly defined.

In 2004, water resources management was further strengthened. Water resources justification was implemented for abstraction by construction projects, and review and approval of water abstraction was intensified. The items needing administrative review and approval and administrative licensing by Ministry of Water Resources (MWR) were clarified gradually. Water use norms were publicized in 17 provincial administrative divisions. The development of national agricultural water use norms was basically finished. A pilot of initial water right assignment was implemented at the Daling River in the Liaohe River Basin. How to allocate the initial water rights among farmers is still a big challenge facing policy makers in China.

5.4.3. Property rights over irrigation infrastructure. A market involves the exchange of goods and services between producers and consumers. For a long time, the units supplying water to users were a kind of economic organization controlled by government in China. On the one hand, they supplied water to the farmers at a price subsidized by government. On the other hand, they owned a monopolistic position in water supply. Meanwhile, farmers of small and fragmented farms had little power in the bargaining process. Establishing the WUAs in irrigated agriculture development is a step toward redressing this situation. In the process of ID reform, the establishment of Water Supply Companies (WSCs) and WUAs are the basis of developing water market. More importantly, WUAs is critical to allocation of property rights over infrastructure.

WUAs are organizations managed by farmers responsible for a wide range of management activities. In China, most WUAs are based on social boundaries, which incorporate farmers in smaller organization units. Some of them are based on hydraulic boundaries. Since WUAs are managed by farmers and operated with the interests of water users in mind, they tend to reduce the costs of implementing water pricing, including monitoring and enforcement costs. Volumetric wholesaling is the practice by which the WSCs sell water to WUAs at points where volumetric measurement is possible. WUAs are responsible for delivering water in the branch canals and collecting fees from each user. Meanwhile, WUAs can also provide important brokering services for water trades. Of course, all these practices require strong leadership and organization, but because of the social networks, WUAs can achieve the high rate of collection of water fees. However, there are many factors affecting the viability of WUAs. Of all the factors, it is crucial to allocate property rights over irrigation infrastructure between WSCs and WUAs. Well-defined property rights over irrigation infrastructure can provide farmers with incentives to participate in the operation and maintenance of water supply facilities. Those rights can be assigned to individuals or to a small, tightly knit group of farmers.

5.4.4. Pricing polices for water. Efficiency and equity should be taken into consideration in the establishment of a quasi-market for water resources. A water market would need to reflect environmental and social costs in water prices or in the economic analyses for water supply investments to ensure efficient allocation between competing uses for scarce water resources. The allocation of water resources should not only take into account the expected efficiency but also the equity. Equity of water allocation is concerned with the "fairness" of the economics. The "fairness" of water allocation across economically disparate groups in a society or across time may not be compatible with efficiency objectives. How to coordinate the conflict between efficiency objectives and equity objectives is a critical problem faced by policy-makers.

Volumetric pricing for irrigation water is a key component of a water market based on well-defined property rights. This requires information on the volume of water used by each user or some other method of infering a measurement of water consumption. Transaction costs associated with volumetric pricing are relatively high and require monitoring of use. When water flow is reasonably constant, implicit volumetric pricing is possible by charging for time of delivery. If the volume of water delivered by the water source per hour varies throughout the cropping season, then the efficient price per water unit will vary by crop and by season. This requires sophisticated monitoring technology.

Non-volumetric methods may be used when the transaction costs of volumetric pricing are emerging. There are several such pricing methods: output prices, input pricing, or area pricing. Area pricing is very popular in China. Under this pricing mechanism, users are charged for water by irrigated area, often depending on crop choice, extent of crop irrigated, irrigation method and season. This method is easy to implement and administer and is best suited to continuous flow irrigation. It may however be unable to send clear signals to farmers regarding water scarcity and may be subject to manipulation.

6. Conclusions and policy implications

Water shortage, deterioration of water environments and the inequitable distribution of the water resource between different users are common throughout the world. Shortage and waste coexists in Chinese agriculture, the potential conflict between decreasing water supply and increasing water demand will become more prominent in the near future. Attenuated property rights over water, low water prices, lack of property rights over water supply infrastructure and fragmented government management are the fundamental causes of low efficiency in agricultural water utilization.

Against the background of continuing macroeconomic reform in China, the Central Chinese Government has established the necessary institutional arrangements for a water market, including laws and regulations concerned with water use. Although laws and regulations concerned with water resources have been established, the following work needs to be done beforehand: clearly defined and legally enforceable water rights and allocation of responsibilities between water authorities and farmers are imperative for generating endogenous forces for improvement of water use efficiency. These conditions are also prerequisite for water transfers to more efficient and higher value uses.

Water scarcity has become an increasing constraint to agricultural development in China. Ignoring the efficiency of agricultural water use will exclude the Chinese economy from maintaining its growth in urban areas and in industrial production without jeopardizing its agricultural output. It is critical to increase the efficiency of agricultural water use because of the decreasing water supply for irrigated agriculture. Faced with limited physical, financial and ecological resources for potential water supplies, establishing a quasi-market for water is a necessary precondition for the improvement of water use efficiency. Low water prices have been widely blamed as a root cause of the poor water use efficiency in agricultural water utilization. To create incentives for conserving water and improving water use efficiency, the Chinese government must implement a program to establish well-defined non-attenuated property rights that will allow trading in water at set prices. Water prices set in this way will ensure that the cost effectiveness of infrastructure with respect to the relative scarcity of resources is taken into account by those responsible for managing the water supply infrastructure and farmers undertaking irrigated agriculture.

It is worth noting that establishing WUAs at the village level is a first step in the reform of rural irrigation institutions. Typically, WUAs are responsible for water distribution, fee collection, operation and maintenance of the minor irrigation network and dissolving conflicts. WUAs will play a role as an interface between water authorities and farmers. By setting up WUAs, the coordination role of the market can be permitted to function whilst considering the pitfalls of monopoly power.

In sum, improving water use efficiency through better management is the best way to deal with the challenges facing irrigated agriculture. With social and economic development, there is much room for improvement in the institutional settings of water resources.

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