# Water Rights Transfers and Regional Development in China

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## 1. Introduction

Since its policies of reform and openness began in 1978, China has continued to enjoy rapid economic growth, although the country's coastal areas have been the main drivers of this growth. Meanwhile, the economic ripple effects reaching inland from coastal areas are minimal, and the regional disparities may become bigger in the future.[1] In recent years, along with rapid population growth and industrial concentration in urban centers, driven by economic growth, power shortages have become a problem particularly in coastal areas, and water shortages have occurred in northern China, particularly in the Yellow River basin. These factors are predicted to become important constraints upon future economic growth in China.[2]

In order to address such problems, in 1999 the central government of China announced that Western Development strategy would be a national strategy as a core part of its Tenth Five-Year Plan.[3] This strategy includes as key projects the West-to-East Natural Gas Transportation Project and the West-to-East electricity transmission project, to address power shortages in coastal areas, and South-to-North water diversion project to address water shortages in the north. The water diversion project aims to divert water northwards from the Yangtze (Changjiang) River, and work has already begun on the eastern and central routes that are intended to carry water to Beijing, Tianjin and other large cities. However, the western route—intended to relieve water shortages in the upper and middle reaches of the Yellow River—is still at the planning phase, as this is reportedly the most difficult one to build.[4]

The northern route of the West-to-East electricity transmission project is intended to carry electricity to Beijing and Tianjin from areas such as Inner Mongolia and Shanxi Province, in the upper and middle reaches of the Yellow River (the area targeted by the western route of the South-to-North water diversion project). Responding to this plan, the Inner Mongolia Autonomous Region considered establishing a new energy production base using its abundant coal resources. But because the maximum water allocations from the Yellow River based on the Yellow River Water Allocation Scheme (established as a result of flow stoppages on the Yellow River) were already being used, however, the Yellow River Conservancy Commission (YRCC) did not permit new water withdrawals needed for electrical power generation. This situation is a sign of the urgent need to secure water resources in the upper and middle reaches of the Yellow River if the West-to-East Electricity Transmission Project is to succeed.

For this purpose, there was a trial run of the Yellow River Water Rights Transfer Management Implementation Regulation in 2004, as a new measure to deal with the above situation. The term "water rights" here refers to the right to withdraw water from the Yellow River, and "water rights transfer" means the transfer of water withdrawal rights from the Yellow River.[5] The power generation sector in Inner Mongolia then sought to obtain water rights from the agricultural sector in an effort to develop the energy sector. The method of transferring water rights here was that the power generation sector invested to promote water conservation projects in the agricultural sector, and the resulting surplus agricultural water was used to generate electricity. This is seen as one effective approach for water resource allocation when there are constraints on the water supply.

Many studies have already examined water resource management for the Yellow River.[6] Higashi (2007) examined effective measures for water resource allocation under resource constraints, for each sector, in the Wei River basin (largest tributary of the Yellow River).[7] Zhang (2006), meanwhile, evaluated the economic benefits that can be obtained by transferring water rights from the agricultural sector to the industrial sector, in Inner Mongolia and Ninxia Autonomous Region.[8] No research to date, however, appears to have comprehensively examined effective water and energy resource allocation based on water rights transfer systems. Furthermore, water rights transfers in China today are permitted only within a given province, and few studies have discussed any expanded scope or range of water rights transfers. Transfers of water and energy resources are tending to cover an increasingly vast area in China today (through projects such as the North Water Transfer Project and the West-to-East Electricity Transmission Project), so it would also be worthwhile to examine and consider the resulting regional impacts of scenarios that include water rights transfers *between* provinces.

In this context, the current study focuses on water rights transfers between the power generation sector and the agricultural sector in Inner Mongolia, and aims to assess the potential for regional development by utilizing water rights transfers. More specifically, we begin by estimating the transferable water volume from the agricultural sector in the target region. Next, we evaluate the effective allocation of water resources and energy to the power generation sector and the industrial sector, using two cases: (1) implementation only within Inner Mongolia, and (2) implementation in both Inner Mongolia and the city of Beijing based on existing policies.[9] In addition, comparing these two cases, we clarify the economic benefits that would arise if water rights transfers covered a broader region than current water rights transfer systems.

## 2. Regional development trends and water resource management in China

### (1) Regional development strategy[9]

China's regional development strategy before 1978 was based on the "theory of balanced development," but after the beginning of reform and openness policies at the end of 1978, actual practice shifted toward "unbalanced development." Deng Xiaoping's "theory of allowing individuals to grow rich first" provides evidence of this change.

The regional development strategy in the Seventh Five-Year Plan, adopted in 1985, draws from the orientation toward the non-balanced development theory: "First, accelerate development in the eastern coastal region, and at the same time shift the centers of development for energy and raw materials to the central region. Work on infrastructure development for large-scale developments in the twenty-first century in the western region." Later, in 1988, when a "coastal region priority development strategy" calling for the promotion of manufactured goods exports, powered by coastal local enterprises, became the official national policy, the unbalanced development theory began to look even more unbalanced.

After the beginning of the 1990s, research into regional issues became a popular topic, amid growing regional disparities and growing dissatisfaction from inland regions. In this context, the "regionally coordinated development strategy" appeared, calling for "adequately exploiting regional comparative advantages while also giving priority to inefficiency and considering equity." This approach was based on the idea of maintaining rapid growth in the coastal regions while also promoting development inland. It was reinforced by the Western Development strategy that was hammered out as a new national strategy in 1999.

Western Development was a centerpiece of China's Tenth Five-Year Plan, which adopted four major projects: the West-to-East natural gas transportation project, the West-to-East electricity transmission project, the South-to-North water diversion project, and the Xizang railroad.

(2) Water resource management

As China promotes large-scale regional development strategies today, policies for securing water resources are becoming increasingly important. China's Ministry of Water Resources is using two strategies: large scale water resource developments such as the South-to-North water diversion project, and the promotion of water conservation. The Water Law, enacted in 1988, is a typical example of the promotion of water conservation. Article 7 promotes water conservation, and Article 32 law stipulates the establishment of water withdrawal permit systems for organizations that withdraw water directly from rivers. In recent years, there have been attempts to strengthen regulations for water conservation: for example, in 1999, implementation for the Yellow River Water Volume Integrated Regulation System began in order to strengthen water resources management on the Yellow River; and in 2002 the water law was amended to clarify in Article 8 the fact that water conservation is an obligation of industries and individuals. Below, we provide an overview of water withdrawal permit regulations and the Yellow River Water Volume Integrated Regulation system.

a) Water withdrawal permit regulations

In the Water Law of 1988, Paragraph 1 of Article 3 states that water resources belong to the state government; Paragraph 3 of the same article describes the separation of water resource rights of ownership and rights of use. Article 32 provides for water withdrawal permit regulations, targeting bodies that draw water directly from rivers. In addition, recognizing the State Council's 1993 enactment of the Water Withdrawal Permit Regulation Implementation Law, the Ministry of Water Resources issued the Notification of Authority of the YRCC for Water Withdrawal Permit Control as a notification relating to issuing bodies of water withdrawal permits for the Yellow River basin, stipulating that the Yellow River Conservancy Commission (YRCC) was to exercise its authority for implementation and supervision of the water withdrawal permit regulations for the Yellow River basin, on behalf of the said Ministry. In addition, in October of the same year, the YRCC enacted the Yellow River Water Withdrawal Permit Implementation Rules, which contain detailed provisions relating to application procedures for water withdrawal permits, decision-making authority for permits, water withdrawal permit registration, and so on. In this case, the basis for the water withdrawal permit regulations is the Yellow River Water Allocation Scheme. It establishes the maximum limits of water allocations for each province and autonomous region.

b) Yellow River Water Volume Integrated Regulation System

The Yellow River Water Volume Regulation coordinates the Yellow River's water resources temporally and spatially, using the function of dams to control water volume. Under this system, this Yellow River Water Volume Regulation is extremely important for the effective utilization of the Yellow River's water resources, because the water resource distribution of the Yellow River is non-uniform. The YRCC executes the Yellow River Water Volume Regulation by exercising integrated control of dams on the main course of the Yellow River.

3. Water rights transfer systems and their significance

In China, water conservation policies have already been promoted for some time, as in the amended Water Law (2002), which states that "Water conservation is the obligation of industries and individuals." Based on this system, the level of water conservation increased in the industrial sector, although in the agricultural sector no major improvement was observed, with irrigation efficiency holding steady at about 40 percent. This lack of improvement originated in a structural problem, as very few channels existed for investment in water conservation in the agricultural sector, so the introduction of water-efficient irrigation depended on the scarce financial resources of governments (Figure 1).[10] Because agricultural water accounts for over 70 percent of water-use volumes in China overall, the promotion of water conservation in this sector is a critical issue to address if China is to deal with its water resource problems.

In this context, the trial run of the Yellow River Water Rights Transfer Management Implementation Regulation began in 2004. Water rights transfers mentioned here mean transferring the right to withdraw water from the Yellow River. Yellow River water rights transfers are only possible within a province or autonomous region.[5] At present, about 30 construction projects are underway in Inner Mongolia that involve water rights transfers by the power generation and agricultural sectors.[5]

Figure 2 shows the predicted results of the introduction of a water rights transfer system. The figure shows an example of water rights transfers between the industrial sector and the agricultural sector. Compared with Figure 1, in the case of utilizing water rights transfer system, Figure 2 suggests that a positive feedback cycle will emerge: corporations can obtain abundant water resources from the agricultural sector by investing in efficient irrigation, improved productivity in industry will boost government tax revenues and bolster its financial resources, and the respective governments will enhance water conservation investments in the domestic and agricultural sectors.

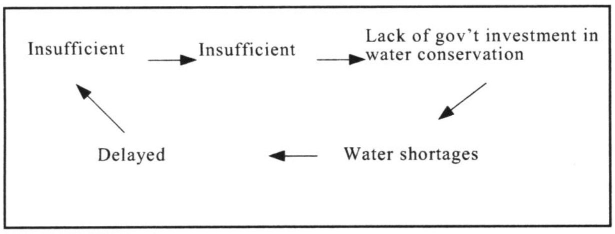


**Figure 1. Example of typical issues of water resources management**

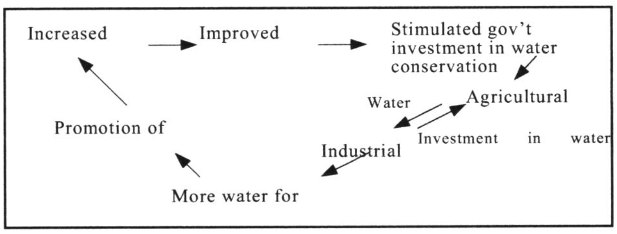


**Figure 2. Potential for regional development through water rights transfers**

4. Potential for regional development through water rights transfers

(1) Target region

Figure 3 shows the location of the Inner Mongolia Autonomous Region and the distribution of irrigation districts within the region.

Inner Mongolia has about 30 percent of China's entire coal reserves, giving this region great potential for coal-fired power generation.

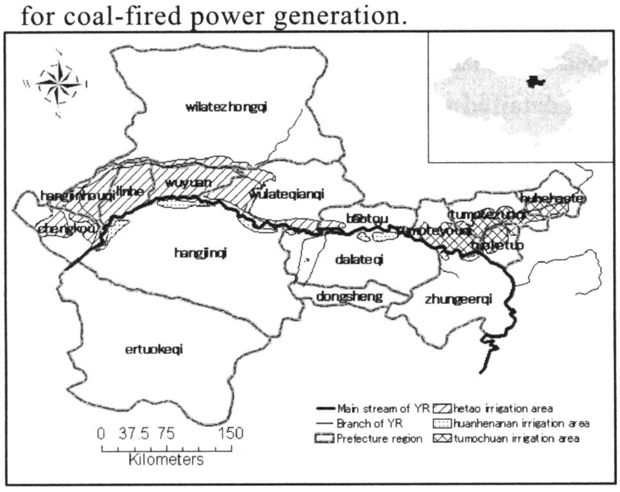


**Figure 3. Location of major irrigation districts in Inner Mongolia**

**Source: Prepared by authors from Yellow River basin maps[11]**

**Table 1. Basic data on major irrigation districts in Inner Mongolia**

| Irrigation District | County | Cultivated area<br>10,000 ha | Effective irrigation area<br>10,000 ha | Cultivated area share of effective irrigation<br>% |
|---|---|---|---|---|
| Hetao | Weikou County, Hangjin Back Banner, Linhe City, Wuyuan County, Wulate Front Banner, Wulate Middle Banner, Baotou City suburbs | 51.6 | 57.64 | 100% |
| Yellow River South Bank | Hangjin Banner, Dalad Banner, Jungar Banner | 3.3 | 4.62 | 100% |
| Tumochuan | Hohot City, Baotou City, Tumote Right Banner, Tumote Left Banner, Tuoketuo County | 27.94 | 9.47 | 33.89% |

**Source: Prepared by authors from references[12]**

About half of Inner Mongolia's coal deposits are in Erdos City.[13] Agricultural water accounts for about 90 percent of all water use in Inner Mongolia, so the water-saving potential in the agricultural sector is huge.[5] Thus, Inner Mongolia would appear to have good prospects for effective water rights transfers between the power generation sector and agricultural sector.

Table 1 shows an outline of the major irrigation districts in Inner Mongolia (Hetao Irrigation District, Yellow River South Bank Irrigation District, and Tumochuan Irrigation District). "Effective irrigation" area here refers to the area of level cultivated land with irrigation facilities and equipment installed, with adequate water resources, and with the potential to conduct normal irrigation during average years.[14]

(2) Calculation of transferable water volume

a) Annual transferable water volume in the agricultural sector

The current study follows the approach taken by Wang (2006)[15] to define the annual transferable water volume in the agricultural sector (TW) as difference between the original amount of allocated water (AW) and the annual volume of agricultural water after implementing water conservation measures (GIW) (Equation 1). Equation 2 can be deduced from Equation 1, because GIW can be derived from the relationship between the net amount of water required for irrigation (NIW), the irrigation water utilization efficiency ratio (***η***), and the irrigation shortfall coefficient (***β***). The ratio ***η*** is determined by the efficiency of facilities, and is the product of the canal irrigation water use efficiency ratio and field irrigation water use efficiency ratio. ***β*** is the irrigation shortfall coefficient. In areas with tight water supplies, farmers use less than the optimal water required for a given crop. In such cases, the irrigation shortfall coefficient is defined as the ratio of actual irrigation water volume and the optimal water demand volume.

Equations in this study use regular (non-italicized) letters to indicate variables that represent multiple meanings (volume) with multiple letters, and italics to indicate where one letter represents one thing (volume). All of the subscripts have been written without italics.

$$\mathrm{TW} = \mathrm{AW} - \mathrm{GIW} \tag{1}$$

$$\mathrm{TW} = \mathrm{AW} - \beta\frac{\mathrm{NIW}}{\eta} \tag{2}$$

**TW: Total transferable water volume GIW: Gross irrigation demand volume NIW: Net irrigation demand volume**

**AW: Water allocated by water rights *η*: Irrigation water utilization coefficient *β*: Irrigation shortfall coefficient**

b) Derivation of net amount of water required for irrigation (NIW)

NIW is derived from Equation 3, which was developed by Duan Ai Wang (2002),[16] Fu Guo Bin (2001),[17] and Liu Yu (2005),[18] but this methodology requires detailed soil data.

$$\mathrm{NIW} = \sum_{\mathrm{i}}(\mathrm{ET_i} - \mathrm{PE} - G_{\mathrm{i}} - \mathrm{ASW_i})\mathrm{ISA_i} \tag{3}$$

**$\mathrm{ISA_i}$ : Irrigable area for crop i PE : Effective precipitation volume**

**$\mathrm{ET_i}$ : Water demand volume required for evapotranspiration for crop i $G_{\mathrm{i}}$: Effective volume of groundwater supplement for crop i $\mathrm{ASW_i}$: Change of effective water storage volume during growing period for crop i**

Because we could not obtain adequate soil information for Inner Mongolia, we decided to express this value by the difference between the potential evapotranspiration amount of crops that have NIW and effective rainfall volume, based on the approach in CROPWAT by Smith (1992).[19] As an additional point, in Inner Mongolia it is common practice to irrigate pasture land, and to irrigate during the autumn season.[20] With this in mind, NIW can be derived as shown in Equation 4.

Autumn irrigation is conducted from the end of September through the end of October after crops have been harvested. The moisture from irrigation freezes during the winter along with the soil, and is held there until it melts and is released in the spring during sowing season when water is scarce; this system could be considered to be an irrigation method unique to semi-arid regions.

$$\mathrm{NIW} = \sum_{i}\left(\mathrm{ET}_i - \mathrm{PE}\right)\mathrm{ISA}_i + \omega * \mathrm{IA} \tag{4}$$

**IA: Effective irrigated area** **$\omega$: Units for autumn irrigation ($m^3$/day/ha)**

Effective rainfall is the amount of precipitation that falls on cultivated land during the period of irrigation and can be used for crop growing.[21] Effective rainfall is calculated using Equation 5, as defined by the Food and Agriculture Organization (FAO).[19]

$$\begin{aligned} &\mathrm{PE}=P(4.17-0.2P)/4.17 && P < 8.3\mathrm{mm/d} \\ &\mathrm{PE}=4.17+0.1P && P \geq 8.3\mathrm{mm/d} \end{aligned} \tag{5}$$

***P*: Precipitation**

c) Allocated water are based on water rights (AW)

Table 2 shows volumes of YRCC-approved water withdrawals from the main course of the Yellow River for major irrigation districts in Inner Mongolia (Hetao Irrigation District, Yellow River South Bank Irrigation District, and Tumochuan Irrigation District).

**Table 2. Approved water withdrawals from the main course of the Yellow River for major irrigation districts in Inner Mongolia**

| Associated irrigation district | Water withdrawal permit no. | Water withdrawal department name | Water withdrawal facility name | Name of water source | Approved water withdrawal (10,000 m3) |
|---|---|---|---|---|---|
| Yellow River South Bank Irrigation District | Withdrawal (State, Yellow) [2000] No. 14001 | Inner Mongolia Yellow River Construction Administration Bureau | South Shore Main Canal Water Gate | Yellow River main course | 41,000 |
| Hetao Irrigation District | Withdrawal (State, Yellow) [2000] No. 14002 | Inner Mongolia Yellow River Construction Administration Bureau | Shenwu Main Canal Water Gate | Yellow River main course | 58,340 |
| | Withdrawal (State, Yellow) [2000] No. 14003 | Inner Mongolia Yellow River Construction Administration Bureau | Beizong Main Canal Water Gate | Yellow River main course | 440,000 |
| Tumochuan Irrigation District | Withdrawal (State, Yellow) [2000] No. 14007 | Inner Mongolia Chengkou Irrigation Administration Bureau | Chenhkou Pump Site | Yellow River main course | 28,000 |
| | Withdrawal (State, Yellow) [2000] No. 14008 | Tumete Right Banner Union | Union Canal Sub-Pump Site | Yellow River main course | 8,000 |
| | Withdrawal (State, Yellow) [2000] No. 14009 | Tuoketuo Yellow River Irrigation Main Company | Madihao Pump Site | Yellow River main course | 8,400 |

**Source: Prepared by the authors from literature.[22]**

For the Tumochuan Irrigation District, because actual water withdrawal data is available for sources other than the main course of the Yellow River, we calculate the volume of water withdrawals here from the main course of the Yellow River, following the approach taken by Wang (2006).[15] When calculating AW, we utilize the value of water withdrawal permits in 2000,[22] before the launch of the water rights transfer system. This calculation results in the following withdrawal volumes from initial (2000) water rights for the three irrigation districts: 4,983 million $m^3$ (Hetao), 410 million $m^3$ (Yellow River South Bank), and 690 million $m^3$ (Tumochuan).

1. Irrigable cultivation area, by zone and by crop

The land use classifications for major irrigation districts in Inner Mongolia are shown in Figure 4. Using provincial boundaries we classify the irrigation districts into 15 zones. The cultivated land of Baotou City is separated into the Hetao and the Tumochuan irrigation districts. Next, the irrigated areas are calculated by zone and by crop, as shown in Equation 6.

$$ISA_{mij} = \left(\frac{SA_{ij}}{SA_j}\right) * \left(\frac{ICA_m}{CA_m}\right) * \left(\frac{CA_{mj}}{CA_j}\right) * SA_j \tag{6}$$

**$ISA_{mij}$: Irrigable area, by zone and by crop** **SAij: Seeded area of crop i in province j**

**ICAm: Effective irrigation area of cultivated land in irrigation district m**

**CAm: Cultivated area in irrigation district m** **CAmj: Cultivated area in each zone**

**CAj: Cultivated area in province j** **SAj: Total seeded area in province j**

The methodology is explained below in more detail.

・Step 1: Calculate cultivated area in each county using the land-use classification map for the year 2000 (Table 3). CAj in the table is the cultivated area in the entire county, and CAmj is the cultivated area associated with each major irrigation district within the cultivated area in each county, in other words, the cultivated area for each zone.

・Step 2: Using the results of Step 1 and the total crop area in each county SAj, calculate crop area in each zone (CAmj / CAj) * SAj.

・Step 3: To calculate the irrigable area in each zone, multiply the crop area in each zone as calculated in Step 2 by the ratio of effective irrigated area of cultivated land in each irrigation district (ICAm / CAm).

・Step 4: Calculate the irrigable area for each zone and each crop ISAmij, from the ratio of crop area for each crop (SAij/ SAj) and the irrigable area in each zone as calculated in Step 2 (Table 4).

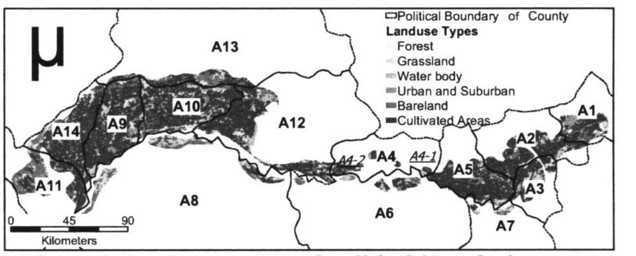


**Figure 4. Land use types and political boundaries or counties of major irrigation districts in Inner Mongolia (2000)**

**Table 3. Basic data on zones of major irrigation districts in Inner Mongolia**

| Irrigation District | County | Zone | CAj (ha) | CAmj (ha) | CAmj / CAj (%) |
|---|---|---|---|---|---|
| Tumochuan | Hohot City | A1 | 53,391.9 | 41,462.2 | 77.66 |
| | Tumote Left Banner | A2 | 103,846.5 | 88,690.9 | 85.41 |
| | Tuoketuo County | A3 | 66,261.7 | 36,959.6 | 55.78 |
| | Baotou City B | A4-1 | 59,152.4 | 8,437.2 | 14.26 |
| | Tumote Right Banner | A5 | 101,628.1 | 101,611.2 | 99.98 |
| Yellow River South Bank | Dalad Banner | A6 | 103,342.9 | 10,360.4 | 10.03 |
| | Jungar Banner | A7 | 46,618.6 | 2,958.7 | 6.35 |
| | Hangjin Banner | A8 | 78,009.7 | 17,067.8 | 21.88 |
| Hetao | Linhe City | A9 | 118,821.8 | 118,821.8 | 100 |
| | Wuyuan County | A10 | 117,517.8 | 117,517.8 | 100 |
| | Weikou County | A11 | 60,743.3 | 45,439.4 | 74.81 |
| | Wulate Front Banner | A12 | 160,515.0 | 114,375.8 | 71.26 |
| | Wulate Middle Banner | A13 | 90,951.8 | 39,674.2 | 43.62 |
| | Hangjin Back Banner | A14 | 137,107.9 | 137,107.9 | 100 |
| | Baotou City A | A4-2 | 59,152.4 | 8,502.6 | 14.37 |

**Table 4. Irrigable area by zone and by crop in Inner Mongolia (2000)**

| County | Zone | Wheat (ha) | Mais (ha) | Cotton (ha) | Beans (ha) | Rice (ha) | Yams (ha) | Oily vegetables (ha) | Hemp (ha) | Vegetables/sugar (ha) | Fruit (ha) | Pasture (ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hohot City | A1 | 3254.53 | 2889.54 | 0.00 | 958.11 | 0.00 | 1134.52 | 1256.19 | 0.00 | 1572.52 | 907.32 | 3292.85 |
| Tumote Left Banner | A2 | 5052.07 | 7744.05 | 0.00 | 516.27 | 0.00 | 1880.70 | 3503.26 | 36.88 | 1106.29 | 291.32 | 1594.67 |
| Tuoketuo County | A3 | 940.96 | 3277.78 | 0.00 | 509.47 | 0.00 | 0.00 | 1614.19 | 0.00 | 579.65 | 221.46 | 5809.31 |
| Baotou City B | A4-1 | 176.79 | 146.02 | 0.00 | 31.05 | 3.64 | 0.00 | 73.85 | 0.00 | 219.87 | 37.62 | 0.10 |
| Tumote Right Banner | A5 | 7849.26 | 8898.13 | 0.00 | 289.82 | 0.00 | 1635.41 | 7497.34 | 0.00 | 3053.45 | 443.35 | 6638.11 |
| Dalad Banner | A6 | 1905.17 | 3439.89 | 0.00 | 203.07 | 0.00 | 717.52 | 1767.33 | 16.00 | 770.44 | 100.06 | 2635.83 |
| Jungar Banner | A7 | 153.48 | 742.93 | 0.00 | 332.25 | 0.00 | 618.97 | 692.34 | 0.00 | 121.43 | 527.81 | 1400.02 |
| Hangjin Banner | A8 | 1770.69 | 3556.31 | 0.00 | 268.96 | 0.00 | 1191.66 | 2286.20 | 0.00 | 556.61 | 580.52 | 796.58 |
| Linhe City | A9 | 40787.41 | 14409.61 | 0.00 | 280.50 | 0.00 | 550.62 | 11718.85 | 0.00 | 10586.44 | 8960.56 | 7477.45 |
| Wuyuan County | A10 | 44820.95 | 12272.54 | 0.00 | 325.72 | 0.00 | 639.80 | 16390.53 | 0.00 | 8189.45 | 4681.01 | 2134.31 |
| Weikou County | A11 | 6574.77 | 3477.71 | 0.00 | 51.91 | 0.00 | 25.95 | 2655.86 | 0.00 | 2993.25 | 1576.21 | 519.32 |
| Wulate Front Banner | A12 | 32992.26 | 11399.26 | 0.00 | 478.66 | 230.47 | 1870.33 | 9458.02 | 177.28 | 6266.93 | 889.07 | 10497.14 |
| Wulate Middle Banner | A13 | 8966.53 | 2050.79 | 0.00 | 39.88 | 0.00 | 1145.03 | 2831.23 | 0.00 | 472.82 | 34.18 | 1582.59 |
| Hangjin Back Banner | A14 | 29868.40 | 12205.08 | 0.00 | 0.00 | 0.00 | 157.15 | 8014.49 | 0.00 | 6945.90 | 6859.99 | 3176.70 |
| Baotou City A | A4-2 | 529.80 | 437.59 | 0.00 | 93.05 | 10.90 | 179.39 | 221.31 | 0.00 | 658.89 | 112.75 | 159.49 |

e) Determination of other parameters

- For precipitation, we use the average values from seven weather monitoring stations in Inner Mongolia for the years 1971 through 2000.
- For water demand by each crop $ET_i$, because insufficient data was available from weather monitoring stations, we utilize values for each crop in Inner Mongolia, calculated using the Penman-Monteith

equation, based on existing literature.[24, 25]

- We assume no changes in crop-specific ET and precipitation for future planning years.
- The irrigation shortfall coefficient is set as 0.8 based on Fu Guo Bin (2003).[26]
- The irrigation water utilization ratio for the year 2000 is set as 0.336 for the Hetao Irrigation District,[24] and 0.24 for the Yellow River South Bank Irrigation District,[5] based on existing literature. Because no information was available for the Tumochuan Irrigation District, here we assume the value 0.336, the same as in the Hetao Irrigation District.
- For the field irrigation water use efficiency after implementation of water conservation measures, we use the value 0.9, based on Chinese water conservation technology standards.[27]
- Based on testing in the South Bank Irrigation District in Inner Mongolia, we use 0.7 as the canal irrigation water use efficiency ratio after water conservation measures were implemented.[5]
- We assume that future crop patterns will be the same as in the year 2000.

f) Results of estimates of annual transferable water volume in the agricultural sector

Figure 5 shows the calculation results of the annual transferable water volume of the agricultural sector. The table shows that water conservation measures, if implemented, would results in a transferable water volume of 2,571 million $m^3$ per year in the target region.

**Table 5. Transferable water volume (100 million m3)**

| Irrigation district | Water rights (volume) | Water demand (2000) | Future planned annual water demand | Transferable water volume |
|---|---|---|---|---|
| Tumochuan | 6.90 | 7.76 | 4.51 | 2.39 |
| Yellow River South Bank | 4.10 | 4.07 | 1.94 | 2.16 |
| Hetao | 49.83 | 49.26 | 28.67 | 21.16 |
| Total | 60.83 | 61.08 | 35.12 | 25.71 |

(3) Case study of regional development using water rights transfers

Below we compare the economic impacts of two cases for water rights transfers: transfers conducted within one single province (Case 1), as is the present case; and transfers conducted between provinces (Case 2), with a view to the future expansion of the scope of water resource and energy transfers in China. Case 1 focuses on Inner Mongolia alone, while Case 2 considers a water rights transfer system covering Inner Mongolia and the city of Beijing. Figures 5 and 6 show the general concepts of water resource and energy allocation.

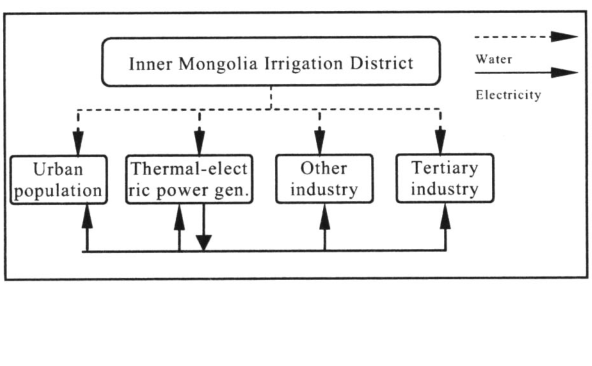


Figure 5. Allocation system within one region

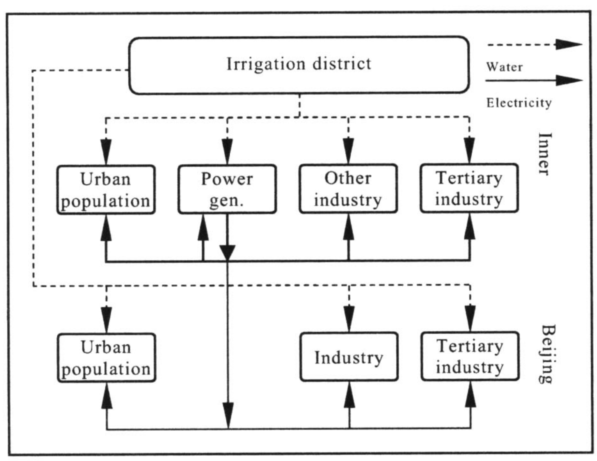


Figure 6. Allocation system between two regions

(4) Analytical methods

We apply the Leontief production function to represent the relationships among industry k (excludes electricity generation industry), electricity generation industry e, and service industry s, and increased value added $\Delta V$ for each industry, as well as labor $\Delta L$, water resources $\Delta W$, and electricity inputs $\Delta E$. We use the upper limits of increases of labor, water resources, and electricity generation as constraining factors (Equations 7 to 12). The increase in electricity generation is determined endogenously from the relationship with water resource allocation to the electricity generation industry, as shown in Equation 13.

$$\Delta V_{\mathrm{k}} = \min\left\{\frac{\Delta L_{\mathrm{k}}}{l_{\mathrm{k}}}, \frac{\Delta W_{\mathrm{k}}}{w_{\mathrm{k}}}, \frac{\Delta E_{\mathrm{k}}}{e_{\mathrm{k}}}\right\} \quad (7)$$

$$\Delta V_{\mathrm{e}} = \min\left\{\frac{\Delta L_{\mathrm{e}}}{l_{\mathrm{e}}}, \frac{\Delta W_{\mathrm{e}}}{w_{\mathrm{e}}}, \frac{\Delta E_{\mathrm{e}}}{e_{\mathrm{e}}}\right\} \quad (8)$$

$$\Delta V_{\mathrm{s}} = \min\left\{\frac{\Delta L_{\mathrm{s}}}{l_{\mathrm{s}}}, \frac{\Delta W_{\mathrm{s}}}{w_{\mathrm{s}}}, \frac{\Delta E_{\mathrm{s}}}{e_{\mathrm{s}}}\right\} \quad (9)$$

Constraining factors

$$\Delta L_{\mathrm{k}} + \Delta L_{\mathrm{e}} + \Delta L_{\mathrm{s}} = \Delta L_{\mathrm{total}} \quad (10)$$

$$\Delta W_{\mathrm{k}} + \Delta W_{\mathrm{e}} + \Delta W_{\mathrm{s}} + \Delta L * p = \Delta W_{\mathrm{total}} \quad (11)$$

$$\Delta E_{\mathrm{k}} + \Delta E_{\mathrm{e}} + \Delta E_{\mathrm{s}} + \Delta L * q = \Delta E_{\mathrm{total}} \quad (12)$$

$$\Delta E_{\mathrm{total}} = \frac{\Delta W_{\mathrm{e}}}{\alpha}(1-\delta) \quad (13)$$

**$\Delta V$: Increased value added  $\Delta L$: Increased labor inputs  $\Delta W$: Increased water inputs  $\Delta$: electricity inputs**

**$\Delta W_{total}$: Potential increase in water resources  $\Delta E_{total}$: Potential increase in electricity  $\Delta L_{otal}$: Potential increase in labor**

**$l$: Labor input per unit of value added  $w$: Water input per unit of value added  $e$: Electricity input per unit of value added**

**$p$: Water use per capita  $q$: Electricity use per capita  $\alpha$: Water demand per unit of electricity generation  δ: Power transmission loss ratio  k: Industry (excluding electricity generation)  e: Electricity generation industry  s: Service industry**

The increase in labor is determined endogenously based on the existing urban plans of each region.[28, 29] The upper limits of future population increases for Inner Mongolia and Beijing are calculated (at 13.6 million, and 18.0 million persons, respectively) from the differences between the respective urban populations in the year 2000 and the upper limits for Inner Mongolia and Beijing according to their urban plans. The increase in water resources (in other words, the transferable water volume), is, as previously calculated, 2,571 $m^3$ million for Inner Mongolia. It is assumed that Beijing's increased water demand for industrial development and domestic uses will be met by Inner Mongolia.

Data for the year 2000 are used for resource inputs per unit of value added, and for average resource consumption per capita (Table 6).[30, 31, 32, 33, 34, 35]

**Table 6. Basic units for analysis (2000)**

| | | Beijing | Inner Mongolia |
|---|---|---|---|
| Annual domestic electricity use per capita (urban) | kWh/person | 549.90 | 155.20 |
| Annual domestic water consumption per capita (urban) | $m^3$/person | 127.44 | 37.08 |
| Industrial water demand (excluding power gen. industry) per unit of value added | $m^3$/10,000 yuan | 114.43 | 153.58 |
| Industrial electricity use (excluding power gen. industry) per unit of value added | kWh/10,000 yuan | 1813.96 | 3672.58 |
| Industrial workers (excluding power gen. industry) per unit of value added | persons/10,000 yuan | 0.13 | 0.17 |
| Service industry water demand per unit of value added | $m^3$/10,000 yuan | 10.15 | 2.06 |
| Service industry electricity use per unit of value added | kWh/10,000 yuan | 790.30 | 445.00 |
| Service industry workers per unit of value added | persons/10,000 yuan | 0.24 | 0.65 |
| Electricity generation industry water demand per unit of value added | $m^3$/10,000 yuan | 77.63 | 139.36 |
| Electricity generation electricity use per unit of value added | kWh/10,000 yuan | 2002.28 | 3538.70 |
| Electricity generation workers per unit of value added | persons/10,000 yuan | 0.03 | 0.07 |
| Water demand per unit of value added | $m^3$/10,000 kWh | 28.80 | 28.80 |
| Power transmission loss ratio | % | 6.18 | 5.56 |

**Source: Prepared by authors from literature.[30, 31, 32, 33, 34, 35]**

(5) Results and discussion

The economic impacts of water rights transfers for each case are shown in Figures 7, 8, and 9. The figures show that multiple provinces can have more economic development when multiple provinces participate in a water rights transfer system than when water rights transfers are conducted within one province alone. Thus, in the context of megaprojects such as China's South-to-North water diversion project, and the West-to-East electricity transmission project, an effort to expand the scope of water rights transfers is likely to benefit the economic development of the country overall.

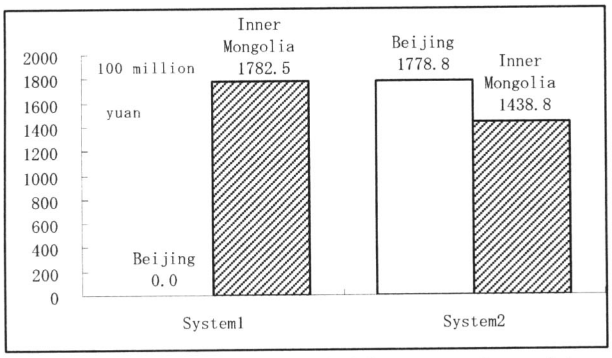


**Figure 7. Comparison of extra value added for one-region and two-region systems**

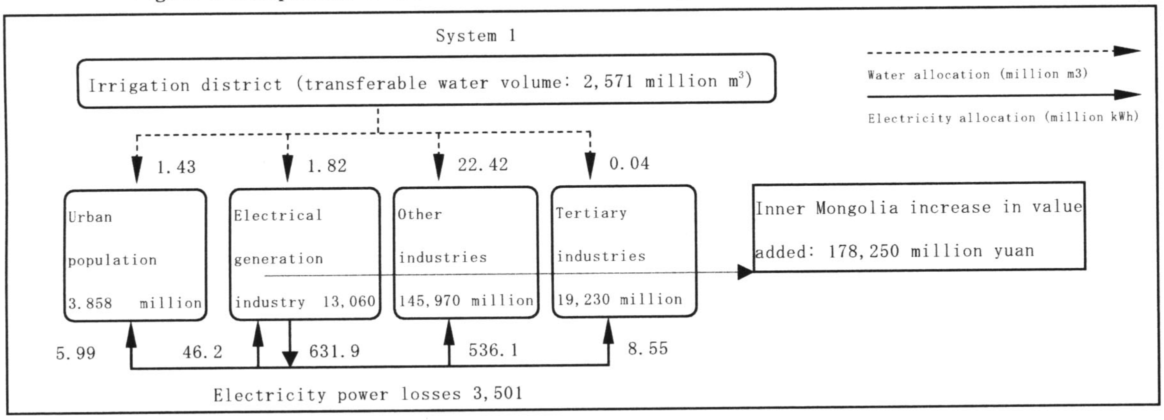


**Figure 8. Resulting allocation with one region**

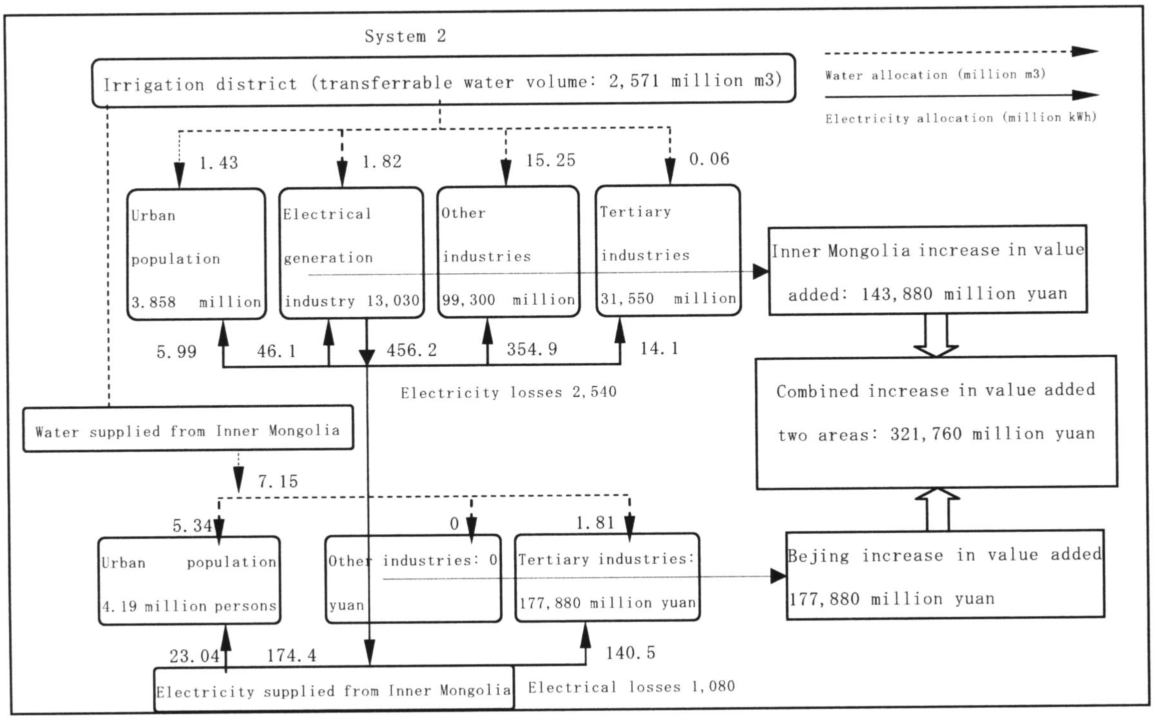


**Figure 9. Resulting allocation with two regions**

5. Conclusion

The current study focuses on water rights transfers between the power generation sector and the agricultural sector in the Inner Mongolia Autonomous Region, and uses two separate cases to assess the potential for regional development by utilizing water rights transfers. Case 1 is based on water rights transfers conducted only within Inner Mongolia, while Case 2 is based on a water rights transfer system between two provinces, using Beijing and Inner Mongolia as an example. This analysis produces an increased economic value-added of 178,250 million yuan per year for Case 1, compared to the remarkable total of 321,760 million yuan for both provinces in Case 2. The findings suggest that when promoting water rights transfer systems in the future, it would be beneficial for the economic development of the entire country if China were to encourage interprovincial transfers.

For future topics, it would be worth developing a detailed water rights transfer system that articulates the rules and other aspects between the various stakeholders involved in the transfers. For example, in the case of water rights transfers between cities, the development of City A, which has obtained water rights, may inhibit the development of City B, which has sold water rights. This could also be a problem between industries and companies. It is also conceivable that the agricultural sector might expand its irrigated area as a result of water rights transfers, but this should be done only after careful consideration of the state of soil salt damage. Meanwhile, in cases in which the industrial sector obtains water rights from the agricultural sector, simply investing in water-conserving irrigation is not the only option; there is also the potential to help create a more stable society, such as by bolstering the safeguard systems in the context of water rights transfers, for example, by preferential hiring of surplus labor from the affected villages. In the future, we also intend to investigate safeguard systems such as these.

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