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RESEARCH ARTICLE

Embodied water analysis for Hebei Province, China by input-output modelling

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Abstract With the accelerating coordinated development of the Beijing-Tianjin-Hebei region, regional economic integration is recognized as a national strategy. As water scarcity places Hebei Province in a dilemma, it is of critical importance for Hebei Province to balance water resources as well as make full use of its unique advantages in the transition to sustainable development. To our knowledge, related embodied water accounting analysis has been conducted for Beijing and Tianjin, while similar works with the focus on Hebei are not found. In this paper, using the most complete and recent statistics available for Hebei Province, the embodied water use in Hebei Province is analyzed in detail. Based on input-output analysis, it presents a complete set of systems accounting framework for water resources. In addition, a database of embodied water intensity is proposed which is applicable to both intermediate inputs and final demand. The result suggests that the total amount of embodied water in final demand is 10.62 billion m^3, of which the water embodied in urban household consumption accounts for more than half. As a net embodied water importer, the water embodied in the commodity trade in Hebei Province is 17.20 billion m^3. The outcome of this work implies that it is particularly urgent to adjust industrial structure and trade policies for water conservation, to upgrade technology and to improve water utilization. As a result, to relieve water shortages in Hebei Province, it is of crucial importance to regulate the balance of water use within the province, thus balancing water distribution in the various industrial sectors.

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1 Introduction

Water is considered as one of the scarcest natural resources in China, and certainly in Hebei Province. Situated in a vulnerable climate zone, Hebei Province has witnessed increasing aridification. In recent years, the water resources in Hebei Province total an average of 20.5 billion cubic meters, only 0.7% of the country's total. With regard to the per capita water resources, the amount is merely one-seventh of the national average, which makes Hebei Province one of several provinces that are most deficient of water resources.

With the accelerating coordinated development of the Beijing-Tianjin-Hebei region, the regional economic integration is recognized as a national strategy (Wang et al., 2015c). With this background, water scarcity has placed Hebei Province in a dilemma but has also endowed Hebei Province with unprecedented historical opportunities. It is of critical importance for Hebei Province to balance water resources as well as to make full use of its unique advantages in the transition to sustainable development.

Water resources management is confronted with severe challenges. In recent years, the booming economy has triggered critical concerns, including over-exploitation of underground water and water resources pollution (Lambooy, 2011). The above-mentioned problems are visually perceived. In fact, as water resources are consumed in the processes of commodities production, virtual streams of water resources are flowing in the network via product exchanges. (Shao et al., 2013; Han et al., 2014a). Hence, through goods trade, water resources as well as energy and environmental emissions are transferred in an invisible way (Chen and Li, 2015; Xia et al., 2015). From the policy-makers' perspective, both the direct and indirect water usages need to be taken into consideration with the acceleration of commodity trade (Shao and Chen, 2013; Han et al., 2015).

To account for water resources usage associated with commodity trade, different studies have been conducted (Odum and Odum, 2003; Chen and Chen, 2010; Chapagain and Hoekstra, 2011; Chen et al., 2011; Zhang et al., 2011; Shao and Chen, 2013). Allen first introduced "virtual water", which is defined as the water resources embedded in the product (Allan, 1996). Afterwards, virtual water embodied in commodity trade has been a hot field for academic studies (Wichelns, 2001; Kumar and Singh, 2005; Han et al., 2014b). The introduction of the virtual water concept has deepened people's understanding of the connection between productions and services. By referring to the definition of ecological footprint, Arjen Y. Hoekstra first raised the concept of water footprint based on the theory of virtual water (Hoekstra, 2003). The water footprint is defined as the summation of the water consumed in the whole supply chain (Ma et al., 2006). The water footprint theory has been widely applied to different products and economies, including agricultural products, livestock and poultry products (Mekonnen and Hoekstra, 2010, 2011), biomass fuels (Winnie et al., 2009), wind power and hydropower projects (Li et al., 2012; Mekonnen and Hoekstra, 2012; Pang et al., 2015; Wang et al., 2015a), etc.

At present, two methods are generally employed to account for water resources, namely process analysis (Stelling and Duinmeijer, 2003; Wu et al., 2016b) and input-output analysis (Zhang et al., 2014a). Process analysis is suitable for micro projects with specific analysis (Wang and Chen, 2015, 2016; Wang et al., 2015b; Wei et al., 2016) , while the latter is more likely to be applied in macro economies. Embodied water theory, combined with the input-output method, can effectively avoid any truncation error remaining in the previous researches and ensure the accuracy of marginal water exploitation quantity (Leontief, 1936; Klaassen, 1973).

Based on Odum's theory of embodied energy (Odum, 1971, 1996; Odum et al., 2000a, b), Chen and his colleagues raised the concept of embodied ecological elements, which is defined as the total amount of ecological elements that are required to manufacture a product or service (Shao et al., 2014). A unified accounting framework has been established which provides a new perspective to understand the relationship between ecological environment and social economy. It has been widely applied for environmental evaluation for various ecological systems such as traditional power plants (Wu et al., 2016a), new energy engineering (Zhang and Chen, 2010), sewage treatment engineering (Shao et al., 2014), and construction and installation engineering (Wu et al., 2014, 2015; Han et al., 2016)

The economic input-output model that was established by W. Leontief in the 1930s has been widely used for almost a century. With the development of research, Chen and his colleagues put forward the method of systems input-output analysis, which is combined with ecology thoughts and balances the relationship between input and output of ecological factors. It was increasingly applied in system accounting and analysis for different economies (Chen and Chen, 2011b; Chen et al., 2013), various embodied ecological endowments (Chen and Chen, 2007a, b), construction engineering (Chen and Han, 2015a, b), artificial wetlands, and renewable energy projects (Zhang et al., 2014b, c, 2015).

As one of the embodied ecological elements, embodied water helps us to analyze the aggregate water that is directly and indirectly invested in the whole life chain of different products and services (Chen et al., 2012). By imitating the concept of energy conversion rate, embodied water intensity formulates the total water resources (direct and indirect) required to yield per unit of product or service (Chen and Chen, 2010, 2011a; Zhou et al., 2010; Chen and Chen, 2013). To our knowledge, however, no relevant work has been carried out on the urban scale to investigate the Hebei economy from the perspective of embodied water.

By combining embodied water theory and input-output analysis, this study undertakes a systems accounting for embodied water in Hebei Province. First, the amounts of water resources are introduced to improve the existing economic input-output table. Then, by establishing the ecological input-output balance equations, the indices of embodied water intensities are calculated. Finally, by analyzing the results, the embodied water flows in the network are illustrated. The outcome will be fully supportive for relevant authorities to enact trade regulations and adjust industrial structure for rational water resources utilization.

2 Method and data sources

2.1 Algorithm

By introducing water resource flows and integrating them with economic flows, the systems input-output tables are structured, as shown in Table 1 with Q_1, Q_2, and Q_3 respectively standing for sector trading matrix, final use, and initial investment, and Q_0 representing the direct investment in water resources. According to the systems input-output table and physical balance, the input-output physical balance of water resources balance i is illustrated in Fig. 1 (Chen and Chen, 2010).

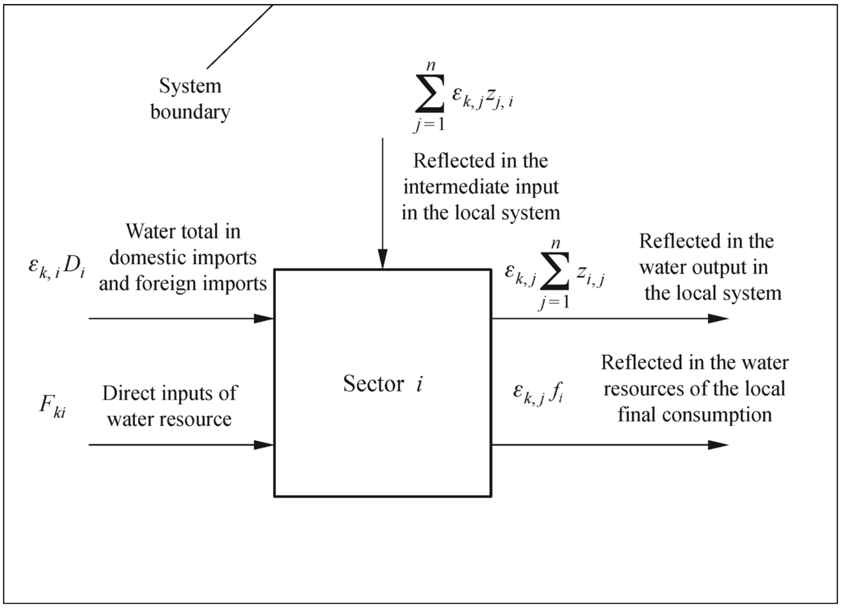

Fig. 1 Embodied water flows for Sector i (k^{th} water resource for example).

Table 1 Basic structure of systems input-output table

Input			Output									
			Intermediate use				Final demand					
			Sector 1	Sector 2	…	Sector n	Household consumption		Government consumption	Gross fixed capital formation	Changes in inventories	Outflows
							Rural	Urban				
Intermediate inputs	Sector 1			Q_1					Q_2			
	Sector 2											
	…											
	Sector n											
Value added	Wages, taxes, surplus, etc			Q_3								
Net environmental inputs	Water	Agricultural production		Q_0								
		Industrial production										
		Biological protection										
		Household use										

According to Fig. 1, the physical balance of water resources is expressed as

$$F_{k,i} + \sum_{j=1}^{n} \varepsilon_{k,j} z_{j,i} = \varepsilon_{k,i} \left(\sum_{j=1}^{n} z_{i,j} + f_i - D_i \right), \quad (1)$$

where $F_{k,i}$ is the amount of k^{th} water resources in Sector i; $z_{j,i}$ is the economic flow from Sector j to Sector i; $z_{i,j}$ is the economic flow from Sector i to Sector j; f_i is the final demand of Sector i; D_i is the outflows of Sector i; $\varepsilon_{k,i}$ and $\varepsilon_{k,j}$ respectively stand for the embodied water intensity of the water resources k of Sector i and j.

Subsequently, Eq. (1) can be further expressed as

$$F_{k,i} + \sum_{j=1}^{n} \varepsilon_{k,j} z_{j,i} = \varepsilon_{k,i} x_i, \quad (2)$$

$$x_i = \sum_{j=1}^{n} z_{i,j} + f_i - D_i, \quad (3)$$

in which x_i is the total economic output of Sector i.

Assuming that this is an ecological system that contains i kinds of sectors and k kinds of water resources, Eq. (2) can be expressed in matrix from as

$$\boldsymbol{F} + \boldsymbol{\varepsilon Z} = \boldsymbol{\varepsilon X}, \tag{4}$$

in which, $\boldsymbol{F} = [F_{k,i}]_{m\times n}$, $\boldsymbol{\varepsilon} = [\varepsilon_{k,i}]_{m\times n}$, $\boldsymbol{Z} = [z_{i,j}]_{n\times n}$, and diagonal matrix $\boldsymbol{X} = [x_{i,j}]_{n\times n}$, where $i,j \in (1,2,...n)$, $x_{i,j} = x_i(i = j)$, and $x_{i,j} = 0(i \neq j)$.

Hence the embodied water intensity matrix $\boldsymbol{\varepsilon}$ is obtained as:

$$\boldsymbol{\varepsilon} = \boldsymbol{F}(\boldsymbol{X} - \boldsymbol{Z})^{-1}, \tag{5}$$

in which $\boldsymbol{F}$ is a properly given direct water use matrix, $\boldsymbol{Z}$ is an intermediate input matrix , and $\boldsymbol{X}$ is a total output matrix. It is assumed that embodied water intensity in domestic imports and foreign imports is equal to intensity in the province.

The intensity obtained principally applies to all the economic flows in systems input-output analysis, including both final demand and intermediate economic activities. $\boldsymbol{\varepsilon}$ is the amount of water resources that are directly and indirectly consumed to manufacture per monetary unit of product. It can reflect the inherent relationship between money value and water resources use.

2.2 Data sources

To maintain data consistency, the direct external water resources data are derived from the China Statistical Yearbook (CCSY, 2008). Water usage is categorized as agricultural water, industrial water, municipal ecological protection, and municipal household water, the amounts of which are 15.16 billion m^3, 2.50 billion m^3, 0.20 billion m^3, and 2.39 billion m^3, respectively. It is assumed that agricultural water is directly extracted by cultivators to irrigate farms, while water used for industrial production, municipal ecological protection, and household use is extracted and pretreated by water plants. In this paper, water exploitation for agricultural production is attributed to agriculture, animal husbandry, and fisheries (Sector 1). Water exploitation for ecological conservation and household water is attributed to the Water Production and Supply Industry (Sector 25). Industrial water use is allocated to the several industrial Sectors according to their output values. Green and grey water are not considered here, which means that the environmental pollution brought by vegetation growth is not taken into account.

This study intends to analyze and discuss water resource use in Hebei's economic activities based on the Hebei 2007 input-output table. Issued by the local Statistics Bureau, the input-output table reflects the systems structure and industrial interaction of the Hebei economy (HSY, 2008). This table is the most detailed official input-output table for Hebei Province. Based on economic activities, the National Bureau of Statistics divides the table into 42 departments with a detailed list of the economic sectors listed in Appendix A. Industry is classified into primary industry, second industry, and tertiary industry. Sector 1 belongs to the primary industry; Sector 2–25 belong to the second industry; Sector 26–42 belong to the tertiary industry.

3 Results

3.1 Embodied water intensity

The embodied water intensities of the 42 sectors of Hebei Province are calculated and presented in Fig. 2 with detailed data presented in Appendix C. From Fig. 2, it can be seen that the three sectors with the highest embodied water intensities turn out to be the Water Production and Supply Industry (Sector 25) with a value of 11,226.02 $m^3/(10^4$ CNY), Agriculture (Sector 1) with a value of 617.08 $m^3/(10^4$ CNY), and the Food Processing, Food Production, Beverage Production, Tobacco Processing (Sector 6) with a value of 304.86 $m^3/(10^4$ CNY). For Sector 25 and Sector 1, the high embodied water intensity is due to the fact that the water resources that are directly exploited by the social economy are concentrated in these two sectors. Water Production and Supply Industry delivers a vast majority water for household use and municipal ecological protection, while Agriculture Animal Husbandry and Fishery supplies the water for agriculture production. For the sectors of Food Production, Beverage Production, and Tobacco Processing, the embodied water mainly originates from agricultural water. The main reason is that a large number of agricultural products are expended in related processes, thus resulting in a huge usage of agricultural water in the supply chain.

The sectors that follow are the Textile Industry (Sector 7), Garments and Other Fiber Products, Leather, Furs, Down and Related Products (Sector 8), and Hotels, Catering Service (Sector 31). Agricultural water is responsible for the majority of the embodied water of these sectors, while these sectors do not directly exploit agriculture water. The result demonstrates that agricultural water remains the largest source for water resources. It should be noted that these sectors are closely correlated with agriculture, most of which feed on agricultural products as raw materials. Sector 7 and Sector 8 belong to Textile and Garment industry, which claims that large amounts of water embodied in this sector. Apart from Hotels, Catering Service, the remaining sectors in the third industry are accompanied by less embodied water intensities. It can be seen from Sector 2 that most embodied water resources in the field of energy engineering come

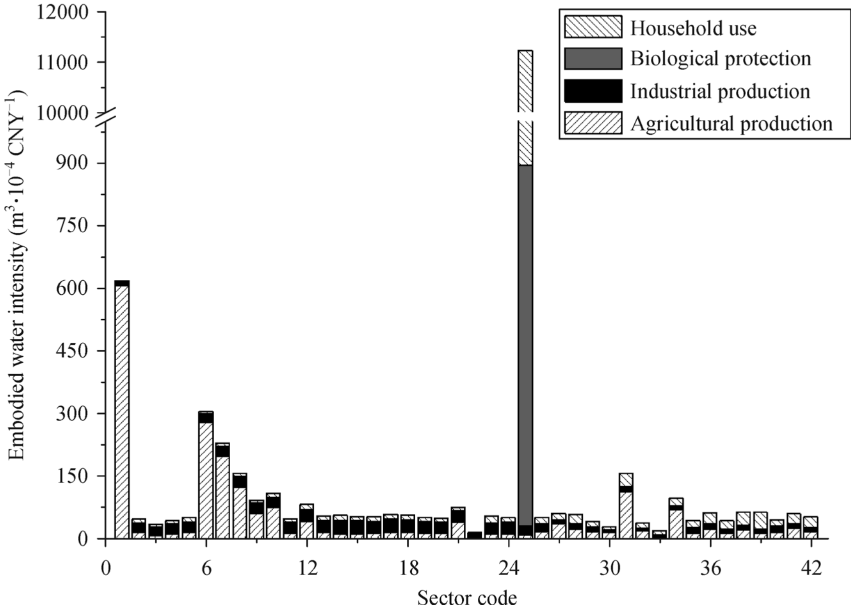

Fig. 2 Embodied water intensity of 42 Sectors.

from industrial water, but there is low intensity of water use in such industry.

The embodied water intensities for the world, China, and Beijing's economies have all been calculated and analyzed in the literature. For the world, the agricultural sector reflects the maximum intensity, mainly from ground water. The second is the electricity, gas, and water production and supply industry, of which industrial water occupies the major share. It can be seen that the development of the world economy depends mainly on both the agriculture and energy industries. For China, the water production and supply industry accounted for maximum intensity, in which the residential water intensity far outweighs the other departments. Thus, it can be seen that China as the most populous country must solve the problem of residential water for its stable national economy. As for Beijing, the capital of China, the embodied water intensity is similar to the national pattern. However, the condition in Hebei Province is slightly different from Beijing and the national situation. The largest share is attributed to residents, while the ecological water-use occupies the remainder. Meanwhile, the industrial water is mainly exported to Beijing and other parts of the country. Therefore, large water resources are required for Hebei in order to protect the ecological environment in economic development.

3.2 Embodied water in final demand

For the overall consideration of domestic and foreign economic trade in Hebei Province, final demand could be sorted into six categories, namely rural household consumption, urban household consumption, government consumption, gross fixed capital formation, changes in inventories, and outflows. The water embodied in final demand is presented in Appendix C. The value of changes in inventories for embodied water in agricultural production turns out to be negative. This suggests that water usage for agricultural production in this year occupies part of water resources inventories of former years, which is not taken into consideration in Fig. 4 and Fig. 5. Among the five categories, embodied water in outflows is the biggest component (26.8 billion m^3), accounting for 69% of the total. Water embodied in urban household consumption (5.67 billion m^3) takes the second place, sharing 15% of the total. With regard to embodied water in rural household consumption (2.02 billion m^3), a portion of 5% is observed. So why are there different amounts and percentages? Is one supposed to be rural household consumption? According to data from the Hebei Statistical Yearbook (HSY, 2008), the urban population (27.95 million people) takes up two-thirds of the rural population (41.48 million people) in 2007. However, embodied water by urban household consumption is three times that of rural household consumption. This demonstrates an extremely unbalanced situation between the living conditions in rural and urban areas. For a rational utilization of water resources, there is an urgent need to invigorate new rural construction, accelerate rural urbanization, and encourage a new lifestyle for water conservation.

As illustrated in Fig. 3, the top four sectors in the final use of embodied water turn out to be Agriculture

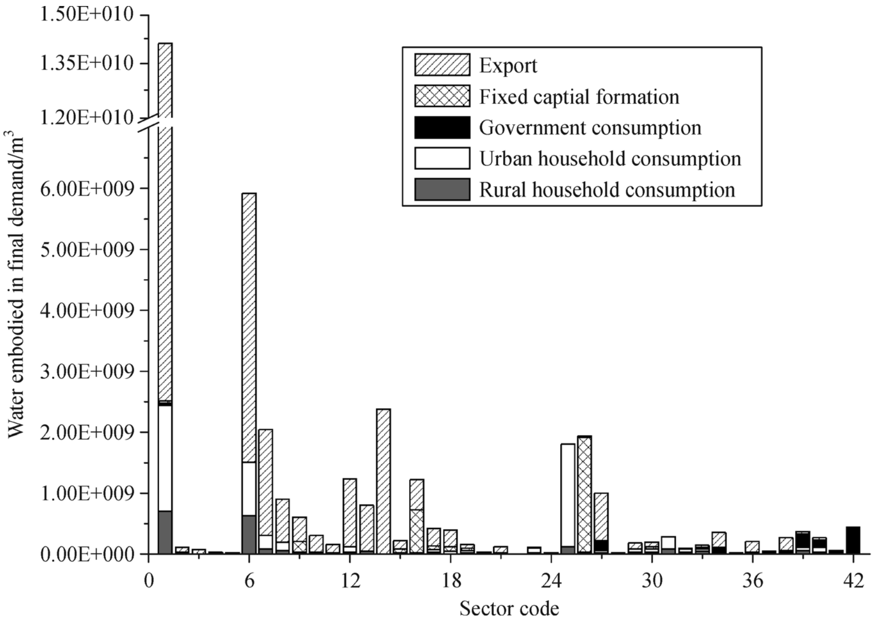

Fig. 3 Water embodied in final demand by sector.

(Sector 1), Food Processing, Food Production, Beverage Production, Tobacco Processing (Sector 6), Smelting and Pressing of Ferrous and Nonferrous Metals (Sector 14), and the Textile Industry (Sector 7). The embodied water of the four sectors by outflows occupies a great proportion, especially in Agriculture Animal Husbandry and Fishery. The major portion of water embodied in agricultural production is used for exports. For Smelting and Pressing of Ferrous and Nonferrous Metals industry, all the embodied water is used for exports.

The sectors ranking in the fifth and sixth place are Construction Industry (Sector 26) and Water Production and Supply Industry (Sector 25). The amounts of embodied water in these two sectors are about the same. All of the embodied water in Sector 26 is for fixed capital formation while the majority of embodied water in Sector 25 is for urban household consumption. From Sector 23, the embodied water coming from energy engineering finally ends up in urban resident consumption.

By comparing the situations in Sector 1, 6, and 25, water use in rural household consumption basically comes from the sectors of Agriculture and Food Processing, Food Production, Beverage Production, and Tobacco Processing, which just account for a meager portion. This suggests that the Water Production and Supply sector mainly supplies water for urban household consumption, while water for rural household could only be obtained via direct exploitation or food production. This implies a different household consumption structure between urban residents and rural residents. Therefore, the water conservation policies will be differentiated for urban and rural residents.

As seen in Fig. 4, the second industries utilize the majority of embodied water, followed by the primary industry. With regard to the tertiary industries, they occupy the smallest portion. Within the second industries, 70% of the embodied water is used for exports, and 17% is for urban household consumption, while increases in inventories mainly originate from the secondary industries. Within the primary industry, 73% of the embodied water is for exports, while that used for urban household consumption and rural household consumption respectively take up 11% and 5%. As for the tertiary industries, government consumption is used in the tertiary industries with a share of 19%, 34% is used for fixed capital formation, and 31% is for exports. Only a small portion is used for urban household consumption and rural household consumption.

3.3 Embodied water in trade

In this work, the difference between domestic and international trade is not distinguished. The “inflow” and “outflow” items are recognized as the summation of domestic and international trade, which in this study are respectively referred to as “imports” and “exports”.

Figure 5 (a) illustrates the embodied water avoided by imports in Hebei Province. As illustrated in the figure, the amount of water embodied in imports is far less than that in exports. Agriculture (Sector 1), Food Processing, Food Production, Beverage Production, Tobacco Processing (Sector 6), and the Water Production and Supply Industry (Sector 25) turn out to be the largest three sectors in imports of embodied water. The amount of the embodied

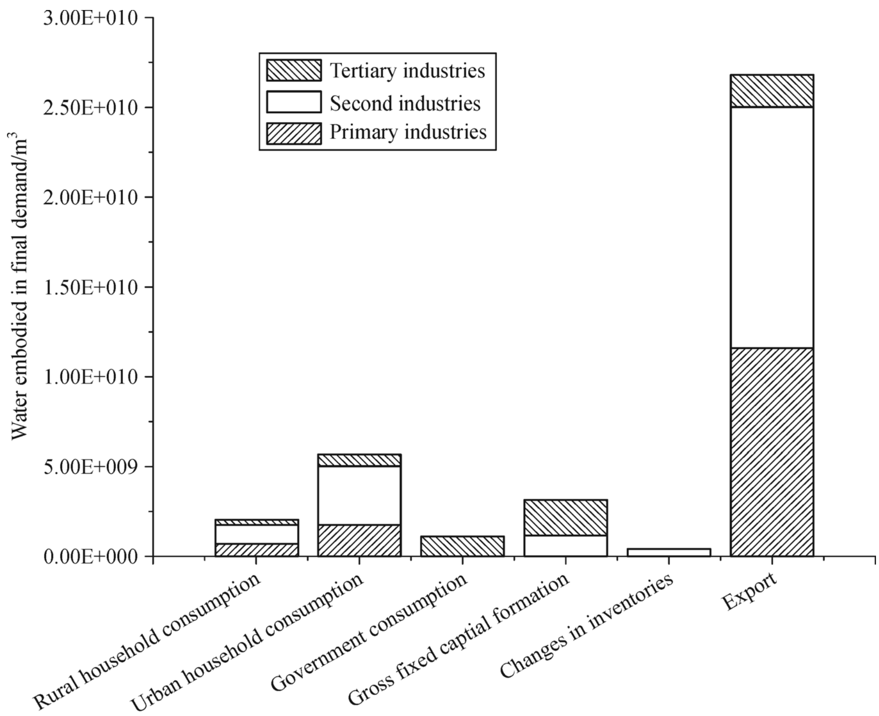

Fig. 4 Embodied water in final demand by industry.

water in imports has respectively reached 4.64×10^9 m^3, 1.76×10^9 m^3, and 1.17×10^9 m^3, which occupy 27.3%, 10.2%, and 6.8% of the total embodied water imports in Hebei.

From the perspective of industry, primary and second industries are responsible for the majority of embodied water in imports, while the portion of embodied water in tertiary industries is very small. The total amount of the embodied water import in primary industries reaches 4.64×10^9 m^3, taking up 27.3% of the total amount, while that in second industries reaches 9.73×10^9, sharing 57% of the total.

Figure 5 (b) illustrates the water embodied in exports in Hebei Province. Agriculture (Sector 1), Food Processing, Food Production, Beverage Production, Tobacco Processing (Sector 6), and Smelting and Pressing of Ferrous and Nonferrous Metals (Sector 14) appear to be the largest three sectors in exports of embodied water. The amounts have reached 1.16×10^{10} m^3, 4.42×10^9 m^3, and 2.38×10^9 m^3, respectively, sharing 43.3%, 16.5%, and 8.9% of the total embodied water exports of Hebei Province.

From the perspective of industry, primary and second industries are responsible for the majority of embodied water exports, while that in the tertiary industries occupies only a small share. The total amount of the embodied water export in primary industries reaches 1.16×10^{10} m^3, taking up 43.3% of the total amount, while that in second industries reaches 1.343×10^{10}, sharing 50% of the total.

3.4 Embodied water balance

Figure 6 reflects the situation of embodied water in trade balance. Hebei Province is shown to be a net exporter of embodied water. The amount of embodied water associated with commodity trade is 9.63×10^9 m^3. With regard to the amount of embodied water exports, it reaches 2.68×10^{10} m^3, far exceeding that of embodied water imports (1.72×10^{10} m^3). Among the 42 sectors, 24 sectors show a virtual water surplus, while the other 18 sectors are have virtual water deficits. Sector 1 (Agriculture Animal Husbandry and Fishery) appears to have the largest trade surplus, with the amount of embodied water exports totaling up to 6.96×10^9 m^3. Sector 6 (Food Processing, Food Production, Beverage Production, Tobacco Processing) ranks second in net export of embodied water, with an amount of 2.66×10^9 m^3 , and is followed by Sector 14 (Smelting and Pressing of Ferrous and Nonferrous Metals) with an amount of 1.67×10^9 m^3. The sectors with the largest amount of embodied water imports are Sector 25 (Water Production and Supply Industry) and Sector 26 (Construction), which are respectively 1.17×10^9 m^3 and 9.11×10^8 m^3.

The results suggest that the embodied water exports in Hebei Province are generally related to food, in which Sector 6 is directly linked to food. Embodied water exports that are correlated with agriculture concentrate on agricultural machinery, chemical fertilizer, and seeds. Many enterprises for steel processing are located in

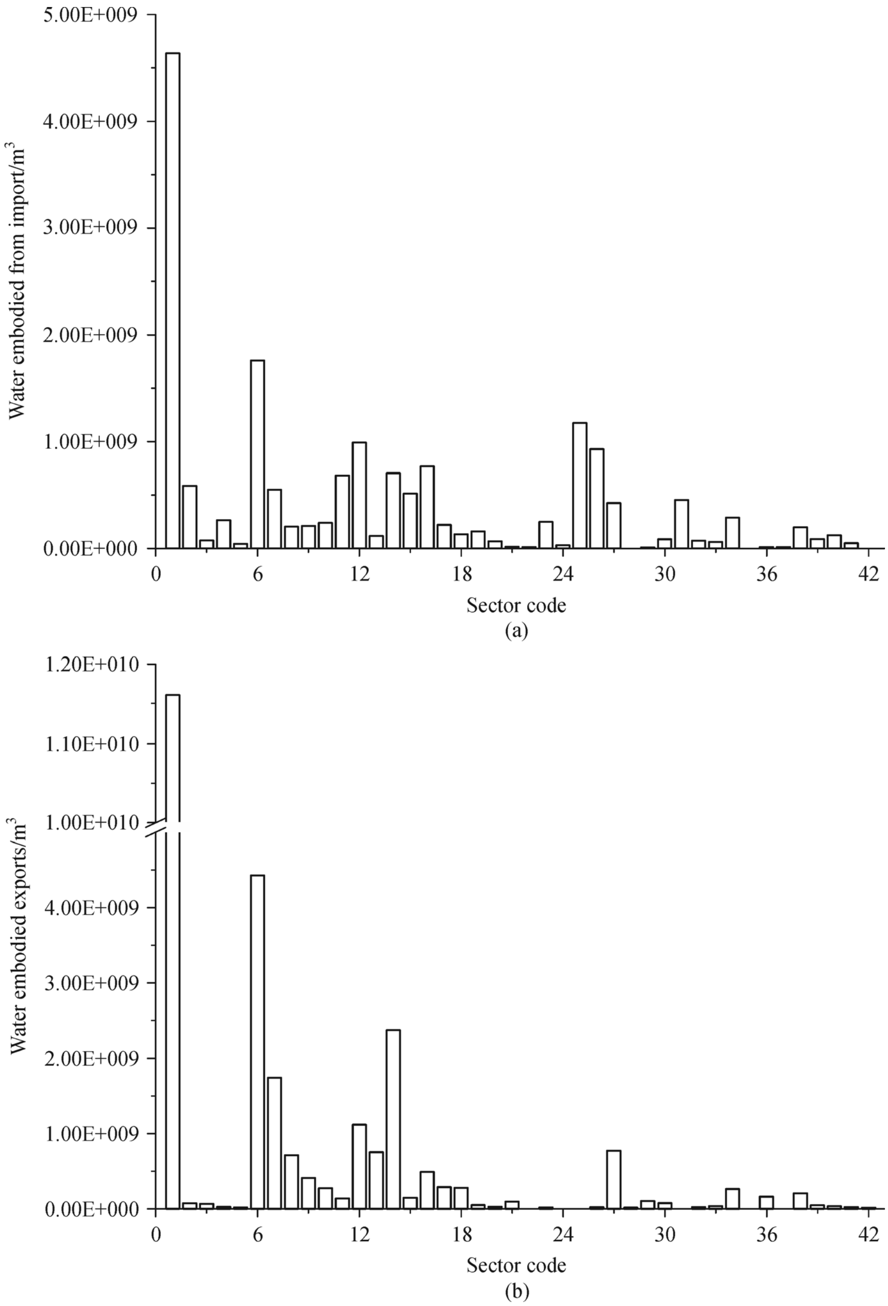

Fig. 5 Water embodied in trade by sector. (a) Water avoided by imports. (b) Water embodied in exports.

Hebei Province and the steel is mainly for export. Therefore, the embodied water export for Smelting and Processing of ferrous and Nonferrous Metals sector is expected with a trade surplus. Hebei Province is seriously lacking in water resources mainly caused by embodied water exports. The primary concern resides with water for household consumption, hence Sector 25 (Water Production and Supply Industry) is followed by the largest amount of embodied water import.

4 Discussion

Although Hebei Province has a scarcity of water resources, the annual export of embodied water is huge. Water resources in Hebei Province are expected to not only satisfy the demand of domestic social economy, but to also partially meet the water requirements of Beijing and Shanghai. Despite the implementation of several projects including "South-to-north water transfer" and "Water

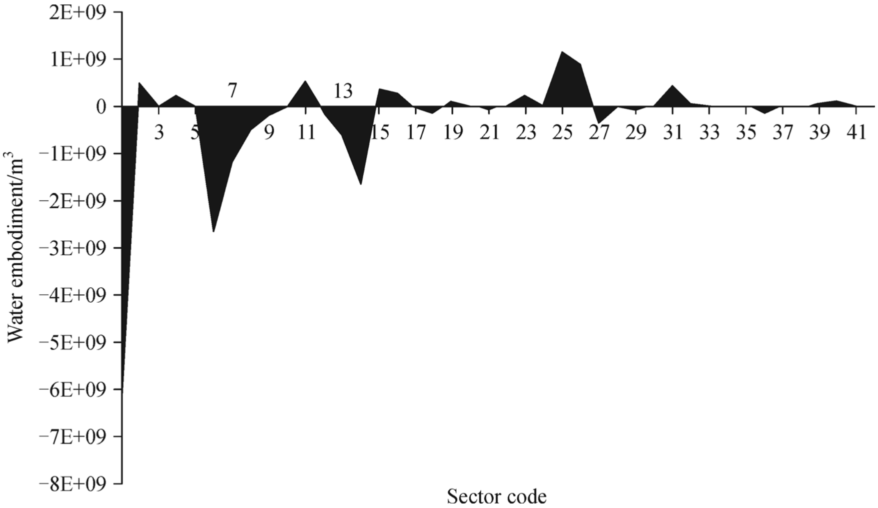

Fig. 6 Embodied water in trade balance.

diversion from the Yellow River", another 2.7 billion m^3 water is required to accomplish the objectives that are raised in the Twelfth Five-Year Plan. As seen in the result, the total amount of embodied water export is calculated to be 26.8 billion m^3, which is far greater than that of embodied water import (12.7 billion m^3). In this context, Hebei Province is confronted with big challenges to cope with water conservation and industrial structure transformation.

From the embodied water end use of subsectors, it can be seen that the largest consumption and export volume are associated with sections including farming, forestry, livestock, and fisheries. Food and tobacco processing exports also occupy a large proportion. According to the analysis of water industry classification and investment, the embodied water exports of the primary and the second industry are greater than that of the tertiary. The results of the trade of the embodied water suggest that it is a more effective way for Hebei to introduce water intensive products from other provinces so as to alleviate the pressure and reduce the negative impact to local environment.

At present, a primary concern resides with the protection of the ecological system in Hebei Province. Water shortages could be at some degree relieved by carrying out the water transfer projects. However, this may also cause damage to the ecological environment. As revealed in this work, it could be an effective way to introduce water-intensive products from other provinces. This could not only help ease the water resources pressure in Hebei Province but also lessen negative environmental impacts.

Under the condition of regional integration, all resources can be flowing freely and be analyzed by administrative divisions for improving the efficiency and capacity of resource utilization. Faced with the common problem "water", the embodied water occupies an enormous portion, and at the same time, Beijing-Tianjin-Hebei can make use of regional merits and construct a scientific and rational embodied water flow system from the perspective of an overall system.

5 Conclusions

The study analyzed the embodied water for Hebei Province and proposed a theoretical framework based on input-output analysis. The scale and distribution of embodied water in Hebei Province is quantitively analyzed, and the database of embodied water intensity for economic sectors in Hebei Province is established. The database could be applicable to calculating the embodied water of final demand and in dealing with the embodied water use in intermediate economic activities. In this work, the embodied water in Hebei Province is analyzed in detail. The result implies that the secondary industries occupy the largest portion in final use of embodied water, of which 70% is used for exports. The primary industries come second in final use of embodied water with 73% for exports. The final use of embodied water of the tertiary industries is far less than that of the primary and second industries, thus unveiling its superiority in water conservation. However, the savings of embodied water from the tertiary industries are unable to regulate the water use in the primary and second industries. As a result, to relieve water shortages in Hebei Province, it is of crucial importance to regulate the balance of payment in Hebei Province, thus balancing water distribution in the various industrial sectors.

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Appendixes

Appendix A

Sectors from Hebei's economic input-output table in 2007

Code	Sector	Code	Sector
01	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy (Agriculture)	22	Waste
02	Coal Mining and Dressing	23	Electric Power/Steam and Hot Water Production and Supply
03	Petroleum and Natural Gas Extraction	24	Gas Production and Supply Industry
04	Ferrous and Nonferrous Metals Mining and Dressing	25	Water Production and Supply Industry
05	Nonmetal and Other Minerals Mining and Dressing	26	Construction Industry
06	Food Processing, Food Production, Beverage Production, Tobacco Processing	27	Transport and Storage
07	Textile Industry	28	Post
08	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	29	Information Transmission, Computer services and Software
09	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	30	Wholesale, Retail Trade
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	31	Hotels, Catering Service
11	Petroleum Processing and Coking, Gas Production and Supply	32	Financial Industry
12	Chemical Products Related Industry	33	Real Estate
13	Nonmetal Mineral Products	34	Leasing and Commercial Services
14	Smelting and Pressing of Ferrous and Nonferrous Metals	35	Research and Experimental Development
15	Metal Products	36	Polytechnic Services
16	Ordinary Machinery, Equipment for Special Purpose	37	Water conservancy, Environment and Public Facilities Management
17	Transportation Equipment	38	Service to Households and Other Service
18	Electric Equipment and Machinery	39	Education
19	Electronic and Telecommunications Equipment	40	Health, Social Security and Social Welfare
20	Instruments, Meters Cultural and Office Machinery	41	Culture, Sports and Entertainment
21	Manufacture of Artwork and Other Manufactures	42	Public Management and Social Organization

Appendix B

Embodied water intensities by 42 Sector (unit: m^3/(1E + 04 CNY))

Code	Sector	Agricultural production	Industrial production	Biological protection	Household use	Total
01	Farming, Forestry, Animal Husbandry, Fishery and Water Conservancy (Agriculture)	608.01	57.52	0.31	3.74	669.58
02	Coal Mining and Dressing	14.75	171.33	0.73	8.71	195.52
03	Petroleum and Natural Gas Extraction	7.29	134.60	0.54	6.44	148.87
04	Ferrous and Nonferrous Metals Mining and Dressing	10.98	94.10	0.66	7.84	113.58
05	Nonmetal and Other Minerals Mining and Dressing	13.43	146.31	0.98	11.68	172.40
06	Food Processing, Food Production, Beverage Production, Tobacco Processing	278.36	224.73	0.55	6.54	510.18
07	Textile Industry	197.36	236.20	0.72	8.64	442.92

(*Continued*)

Code	Sector	Agricultural production	Industrial production	Biological protection	Household use	Total
08	Garments and Other Fiber Products, Leather, Furs, Down and Related Products	123.09	248.71	0.62	7.38	379.80
09	Timber Processing, Bamboo, Cane, Palm and Straw Products, Furniture Manufacturing	58.90	233.87	0.51	6.10	299.38
10	Papermaking and Paper Products, Printing and Record Medium Reproduction, Cultural, Educational and Sports Articles	72.68	185.71	0.71	8.50	267.60
11	Petroleum Processing and Coking, Gas Production and Supply	11.68	282.91	0.64	7.65	302.88
12	Chemical Products Related Industry	39.49	222.16	1.12	13.42	276.19
13	Nonmetal Mineral Products	14.46	254.34	0.91	10.87	280.58
14	Smelting and Pressing of Ferrous and Nonferrous Metals	11.24	233.94	1.04	12.48	258.70
15	Metal Products	11.44	230.75	0.82	9.84	252.85
16	Ordinary Machinery, Equipment for Special Purpose	11.98	351.63	0.87	10.43	374.91
17	Transportation Equipment	13.16	346.14	0.85	10.17	370.32
18	Electric Equipment and Machinery	13.24	291.47	0.87	10.39	315.97
19	Electronic and Telecommunications Equipment	12.64	485.89	0.76	9.10	508.39
20	Instruments, Meters Cultural and Office Machinery	12.52	374.12	0.78	9.37	396.79
21	Manufacture of Artwork and Other Manufactures	38.87	242.51	0.75	9.02	291.15
22	Waste	0.87	26.27	0.06	0.68	27.88
23	Electric Power/Steam and Hot Water Production and Supply	11.02	123.85	1.43	17.12	153.42
24	Gas Production and Supply Industry	11.51	266.70	0.99	11.88	291.08
25	Water Production and Supply Industry	9.23	163.06	864.71	10333.28	11370.28
26	Construction Industry	16.72	143.27	1.21	14.46	175.66
27	Transport and Storage	34.19	80.59	1.24	14.83	130.85
28	Post	21.00	111.91	1.81	21.68	156.40
29	Information Transmission, Computer services and Software	15.83	123.12	1.12	13.43	153.50
30	Wholesale, Retail Trade	14.32	37.23	0.66	7.94	60.15
31	Hotels, Catering Service	111.68	84.77	2.74	32.71	231.90
32	Financial Industry	16.78	51.72	1.04	12.39	81.93
33	Real Estate	5.19	28.97	0.80	9.51	44.47
34	Leasing and Commercial Services	67.69	63.67	1.56	18.69	151.61
35	Research and Experimental Development	12.19	119.39	1.46	17.48	150.52
36	Polytechnic Services	20.60	123.62	2.25	26.84	173.31
37	Water conservancy, Environment and Public Facilities Management	12.58	73.40	1.76	21.09	108.83
38	Service to Households and Other Service	19.21	80.98	2.63	31.40	134.22

(*Continued*)

Code	Sector	Agricultural production	Industrial production	Biological protection	Household use	Total
39	Education	11.64	68.04	3.30	39.44	122.42
40	Health, Social Security and Social Welfare	14.24	151.46	1.14	13.68	180.52
41	Culture, Sports and Entertainment	22.79	78.67	2.00	23.94	127.40
42	Public Management and Social Organization	16.51	58.36	2.13	25.42	102.42

Appendix C

Embodied water by final demand (unit: m^3)

Source	Final demand						
	Final consumption			The total amount of capital formation		Outflows	Total
	Rural household consumption	Urban household consumption	Government consumption	Gross fixed capital formation	Changes in inventories		
Agricultural production	1.54E + 09	3.25E + 09	4.13E + 08	1.05E + 09	−1.54E + 09	2.05E + 10	
Industrial production	1.87E + 08	3.84E + 08	1.68E + 08	1.23E + 09	1.79E + 08	4.08E + 09	
Biological protection	2.25E + 07	1.57E + 08	4.01E + 07	6.62E + 07	4.33E + 06	1.73E + 08	
Household use	2.69E + 08	1.87E + 09	4.79E + 08	7.91E + 08	5.17E + 07	2.07E + 09	
Total	2.02E + 09	5.67E + 09	1.10E + 09	3.13E + 09	−1.30E + 09	2.68E + 10	3.74E + 10

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