Water resource accounting and statistical analysis of water use in Beijing

Yachun GAO[1], Minxue GAO[2], Xiaozhen WEI[3], Yan PING[4]

Abstract: Beijing is a city which is seriously short of water. The rapid growth of population together with the increasing competition for water between agriculture, industrial and urban use results in unprecedented pressures on water resources in Beijing. In order to ensure the sustainable development of Beijing, we must implement strict water resource management and increase water use efficiency substantially.

To use water resources efficiently in Beijing, we needed to analysis the water using data of Beijing in detail. The purpose of this paper is to provide decision making basis for management of water resource. In this paper, we uses the data provided by Beijing Water authority and Beijing Statistical Bureau, together with the actual situation of water in Beijing, makes quantitative analysis of water resource of Beijing. This paper establishes water accounting framework by combining the idea of water resources accounting and input-output accounting to make input-output analysis for water resources.

In order to establish the water input-output table, we need to compile the physical quantity use table of water resources by means of water using data and the characteristics of water resources in Beijing. Combing the water use data and input-output table, we can construct the water input-output table. Then, based on the water input-output table, we can analyze the water use in Beijing.

Key words: water resource accounting, input-output analysis, water use coefficient

[1] Yachun GAO, PhD student, school of statistics in Renmin University of China, mainly engaged in environment accounting.
[2] Minxue GAO, professor, school of statistics in Renmin University of China, mainly engaged in national economic accounting and environment accounting.
[3] Xiaozhen WEI, Deputy Chief of Beijing Statistical Bureau.
[4] Yan PING, Deputy Director of Beijing Statistical Bureau.

1. Introduction

Water is very important for development; it is not only the important elements for ecosystem integrity, but also plays an important role in grain cultivation, energy production, many industrial goods and services production, but as the population growth and the competition for freshwater between agriculture, urban and industry become more and more intense, many areas appear “water crisis”, seriously hindered the economic and social development. The water resources in Beijing are very shortage, the water resource per capital is only 202 cubic meters in 2008, according to the United Nations for extreme water shortage alarm standards of 500 cubic meters per capital, the water shortage problem in Beijing has been very serious. Extreme lack of water resources together with the rapid growth of population and economic, the interactions of these two aspects are unfavorable for the sustainable development. In order to ensure the sustainable development for Beijing, one method is to increase the water supply (such as South-to-North Water Diversion Project or the Yellow River water diversion to Beijing); another method is to control the population and city size. But in the long term, diversion water form other areas in large scales is not a long term solution for Beijing, it can only solve the immediate need, but also influence the water supply of other areas, control the population and city size are also very difficult to achieve for Beijing in a short term. Therefore, in order to achieve the sustainable development for Beijing, we need to rely on the most stringent water management system, starting form the water resource management, improve water use efficiency.

In order to improve water use efficiency, strengthening water resource management, we need to analysis the water use data of Beijing in detail. By means of the data provided by Beijing Water Authority and Beijing Statistical Bureau, together with the water resource and water use conditions of Beijing, this paper compiled water resource use table according to water resource accounting principle, and based on household production and consumption accounting principle, this paper improved the traditional input-output table, then use water resource input-output model analyze the relationship between input and output in the water resource using process.

2. Analysis of water resource and water use in Beijing

The figure 1 is rainfall precipitation changes in every-5-year from 1986-2008. From this figure we can see the rainfall precipitation showing a decline trend on the whole, especially during 2001-2005, the rainfall precipitation is the least.

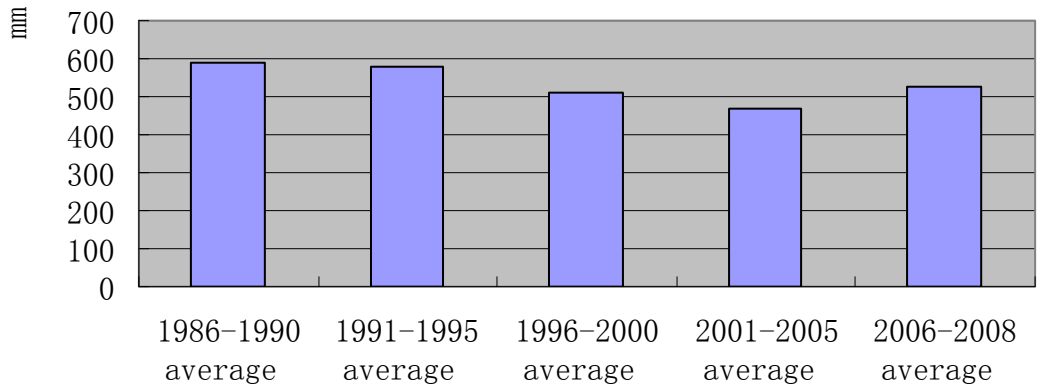

Figure 1: rainfall precipitation changes in every-5-year

Figure 2 reflects the surface water resource changes during 1986-2008, we can see surface water also showing a decline trend; especially in 1999, surface water is the least.

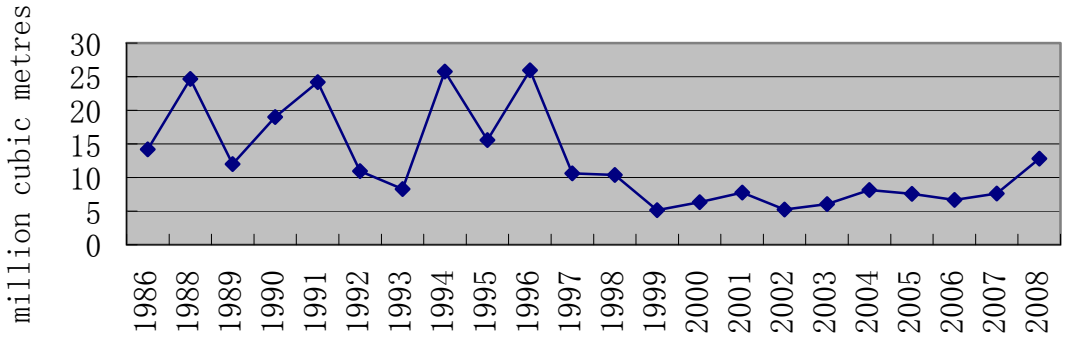

Figure 2: surface water resource changes during 1986-2008

Figure 3 reflects the groundwater situation, we can see the descend speed of the average depth of groundwater was accelerating; that is to say the situation of groundwater was deteriorating.

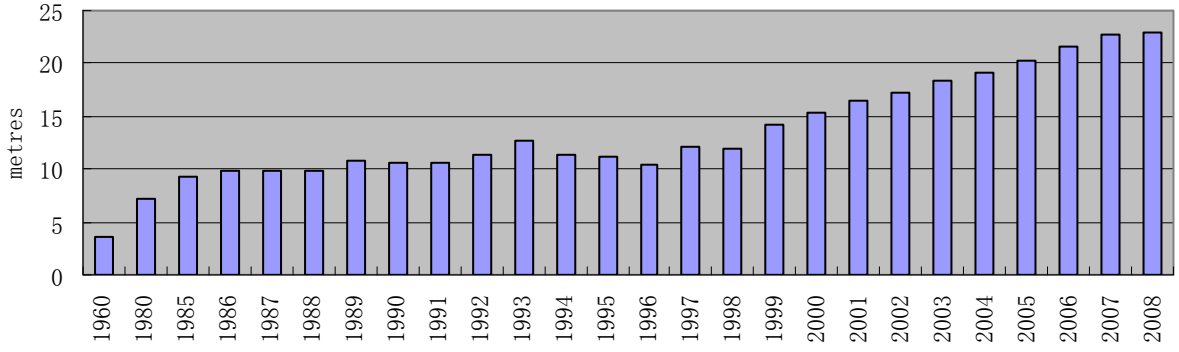

Figure 3: average depth of groundwater in Beijing from 1960-2008

Figure 4 was total water resource changes in every-5-year from 1986-2008, we can see the total water resource was also declined.

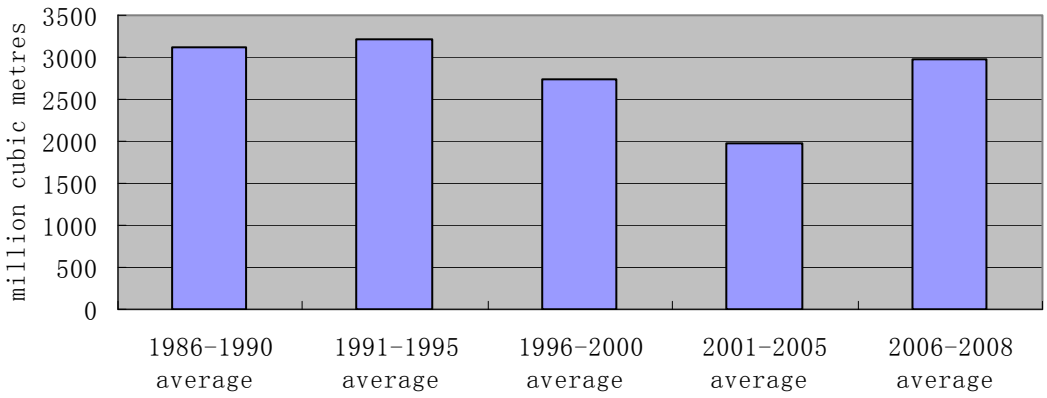

Figure 4: total water resources changes in every-5-year from 1986 to 2008

However, as the water resource supply seriously shortage, the population and the economic growth very fast, from figure 5 and figure 6 we can see, from 1986-2008 the constant price GDP and the population in Beijing increase substantially.

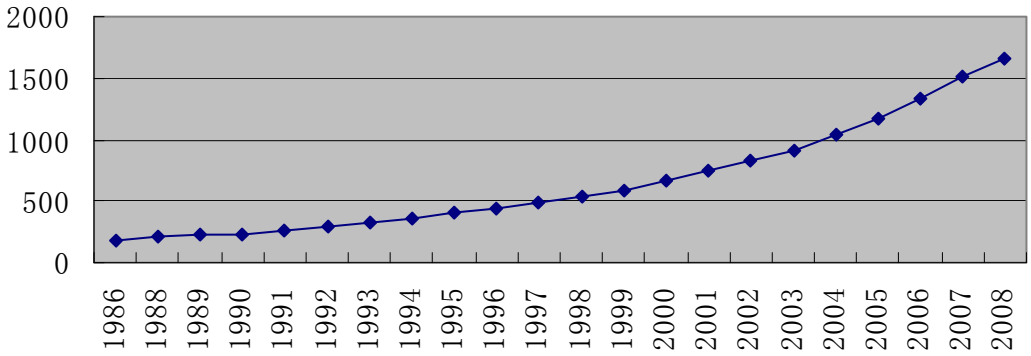

Figure 5: constant price GDP in Beijing from 1986 to 2008（1980=100）

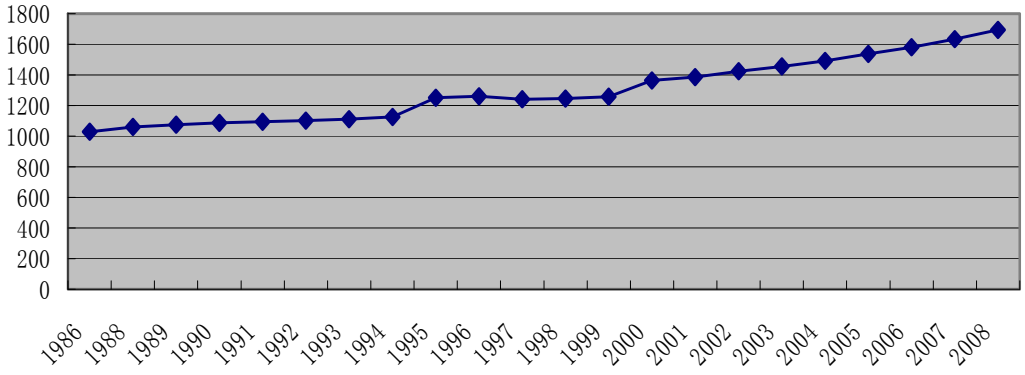

Figure 6: resident population in Beijing from1989 to 2008

Figure 7 and 8showing that although the water resource supply was seriously shortage, and the expansion of economic activity and population, there is a clearly decline of total water use in Beijing, which is the result of substantial decline of water use per GDP.

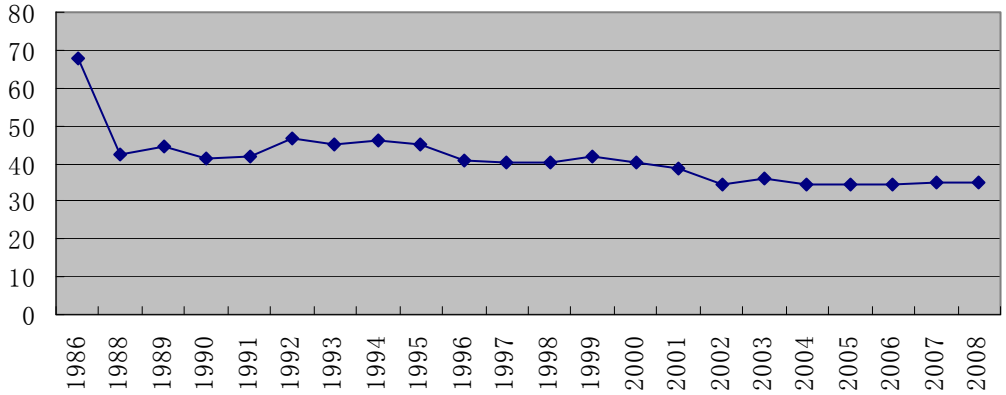

Figure 7: total water use in Beijing from 1986 to 2008

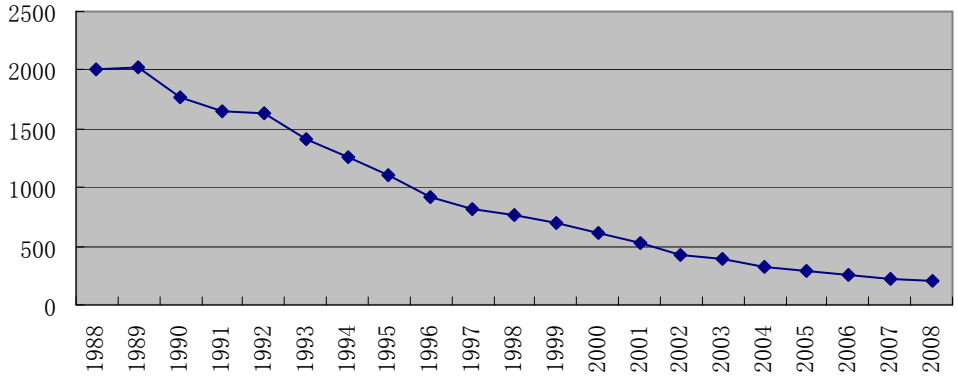

Figure 8: water use per GDP in Beijing from 1988 to 2008

From above analysis, we can conclude that Beijing had made remarkable achievements in water saving and water use efficiency improving.

3. Improving of traditional input-output analysis

Improving the input-output analysis need take two steps, the first step is compiling a water resource use accounting table. The second step is incorporating the household sector into input-output analytical framework.

3.1 compiling of water resource use accounting table of Beijing in 2007

By learning the theory and method of water resource accounting in international literature, combined the water resource accounting and input-output accounting, this paper put forward water resource accounting and analytical framework based on input-output accounting, provide the theoretical foundation for water resource

input-output analysis.

Table1 is the simplified form of water use accounting table of 2007, in the horizontal, we divide water users into primary industry, secondary industry, tertiary industry and household, all together 43 sectors. In vertical, we divide the source of water into directly obtained from the environment and from other economies. Among them, from the environment divide into surface water and ground water, from other economies divide into running water, sewage treatment back to the dosage and waste water. We set the running water supply item is to avoid repetition calculate, that is surface water, groundwater and running water repetition calculate. In the total use, we will subtract the item. The waste water is mainly supplied to sewage disposal and recycling industry. The last row is fresh water use, it equals surface water, groundwater, running water then subtract running water supply.

Table 1: water resource use table of Beijing in 2007 (physical unit)

		Primary industry	Secondary industry					Tertiary industry			household			Total water use
		agriculture	Coal mining and washing industry	…	Industrial sub-total	building industry	Secondary industry total	Transportation and warehousing	…	Tertiary industry total	urban household	Rural household	household total	
Directly obtained from the environment	Surface water													
	groundwater													
	total													
Obtained from other economies	Running water													
	Running water supply													
	Sewage treatment back to the dosage													

	Waste water
	total
	Total water use
	In which：fresh water use

We can put the total water use data in the input-output table below, then construct water use input-output table.

Table 2: water use input-output table

output / Input		Intermediate uses			Final uses			Import	gross output
		Agriculture	…	Public administration and social organizations	Final consumption	capital formation	Export		
Intermediate input	Agriculture ⋮ administration and social organizations	I x_{ij}			II Y_i				X_i
	Total								
Value added	Compensation of employees Other net taxes on production Consumption of fixed capital Operating surplus	III N_{ij}							
	Total								
grossl inputs		X_j							
Water use									

According to the water use table, we can analyze the water use data, From figure 9 we can see, in the total water use, agriculture is the largest water user , household water use is the second largest.

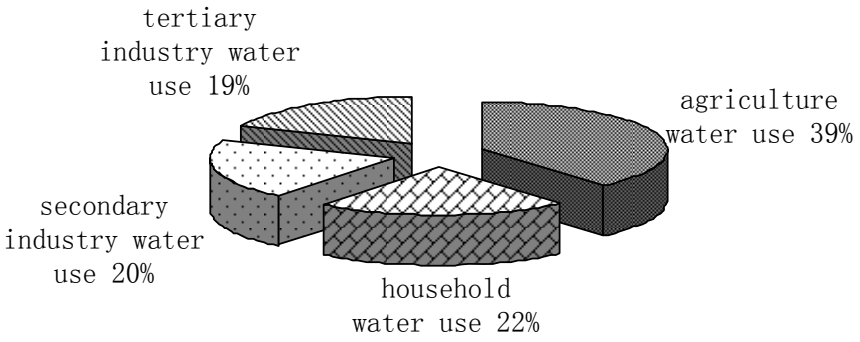

Figure 9: total water use Constitute structure

3.2 incorporating household sector into input-output analytical framework

Taking into account the household water use accounts for so large a proportion, we should incorporate household sector into input-output analytical framework. I researched the compilation method of household production account, household satellite account, and household production and consumption accounting theory, first defined production boundary, here we view household as producers. Then we use household survey data of Beijing, calculated the household immediate consumption, and fixed capital consumption, value of labor input.

Table 3: Scope of the household production

<table>
<tr><td></td><td colspan="4">Household production boundary</td></tr>
<tr><td colspan="2">SNA production</td><td colspan="2">Non-SNA production</td></tr>
<tr><td rowspan="2">Market production</td><td colspan="3">Household production for own use</td><td rowspan="2">Volunteer production</td></tr>
<tr><td>Housing services produced by owner occupiers</td><td>Own account production (goods), in particular, own account construction of dwellings</td><td>Other services produced for own use</td></tr>
</table>

Table 3 is the household production boundary, it include SNA production and non-SNA production, so we need extract housing service produced by owner

occupiers and own account production from SNA account, that is from input-output table, put it in a separate household column and we also need to calculate other service produced for own use and volunteer production put into household column.

We calculate data and extract data put into the household column, the household row data are all zero, this is because the output of household sector are all used for final consumption, the calculate value of labor input set in the compensations of employees, and the fixed capital consumption set this place. Gross output of household equals to final consumption.

Table 4: improved water use input-output table

Output / Input		Intermediate uses			Final uses			import	Gross output
		Agriculture	…	Household	Final consumption	Capital formation	export		
Intermediate inputs	Agriculture								
	⋮								
	Household								
	Total								
Value added	Compensation of employees								
	Other net taxes on production								
	Consumption of fixed capital								
	Operating surplus								
	Total								
Gross inputs									
Water use									

4. Water resource input-output for each sector in Beijing

4.1 Method of input-output analysis of water resource

Input-output mathematical model is:

$$X = (I - A)^{-1} Y$$

Introduce sector j water quota (direct water use coefficient) w, and then total

water consumption can be represented by:

$$W = wX = w\left(I - A\right)^{-1} Y$$

(1) Calculation method for water use coefficient

① Direct water use coefficient

The direct water use coefficient w_j formula is:

$$w_j = \frac{W_j}{X_j}$$

W_j is the water consumption for sector j, X_j is the total output for sector j.

②Total water use coefficient

$$\overline{w} = w(I - \hat{a}A)^{-1}$$

$\hat{a}$ is a diagonal matrix， the diagonal elements is $1 - \frac{import}{tatal\ output + import}$

③value-added water use coefficient

$$w_j^N = \frac{W_j}{N_j}$$

W_j is water use of sector j， N_j is represented the value added of sector j.

④Water use multiplier

$$MW_j = \frac{\overline{w}_j}{w_j}$$

The row vector is expressed as $MW = (MW_1, MW_2, ..., MW_n)$.

(2)Water use level evaluation standard

①Relative water use coefficient

$$Rw_j^X = \frac{w_j^X}{w_o^X}$$

$$Rw_j^N = \frac{w_j^N}{w_o^N}$$

Rw_j^X and Rw_j^N are respectively represent relative water use coefficient for total output and value-added of sector j.

$$w_o^X = \frac{\sum_{j=1}^{n} W_j}{\sum_{j=1}^{n} X_j}, \quad w_o^N = \frac{\sum_{j=1}^{n} W_j}{\sum_{j=1}^{n} N_j}$$

②Relative water use multiplier

$$RMW_j = \frac{MW_j'}{\left(\sum_{j=1}^{n} MW_j' \Big/ n\right)}$$

MW_j is water use multiplier of sector j.

③Relative water structure coefficients

$$RS_j = \frac{W_j / W_0}{\sum_{j=1}^{n} \left(W_j / W_0\right) / n}$$

W_0 is the total water use for all sectors, $W_0 = \sum_{j=1}^{n} W_j$ 。

(2)Water use level evaluation standards

A. water use level—high： $Rw_j^N \geq 1$ or $RS_j \geq 1$；

B. water use level—low： $Rw_j^N \prec 1$ or $RS_j \prec 1$

C. potential water use level—high： $RMW_j \geq 1$

D. potential water use level—low： $RMW_j \prec 1$

4.2 Empirical Analysis

According to the water use coefficient formula listed in above, we calculated 43 sectors water use coefficient.

Table 5: water use coefficient for each sector of Beijing in 2007

	Direct water use coefficient	Value-added water use coefficient	Total water use coefficient	Indirect water use	Water use multiplier
agriculture	455.46	1220.97	554.12	98.66	1.22
coal mining and washing industry	2.17	10.79	7.46	5.29	3.44
oil and natural gas mining industry	0.23	0.44	3.13	2.90	13.61
metal mining industry	40.80	76.05	47.06	6.26	1.15

non-metal ore and other mineral mining industry	19.25	74.43	28.04	8.79	1.46
food manufacturing and tobacco processing	9.01	38.91	88.30	79.29	9.80
textile industry	6.30	21.01	23.87	17.57	3.79
textile clothing, shoes and hats, leather, fur feather and its products industry	2.80	7.33	7.67	4.87	2.74
wood processing and furniture manufacturing industry	2.47	13.10	13.28	10.81	5.38
paper printing , cultural and educational sporting goods manufacturers	4.69	18.37	13.01	8.32	2.77
oil processing and coking and nuclear fuel processing industry	10.38	197.88	14.16	3.78	1.36
chemical industry	5.83	16.32	22.43	16.60	3.85
non-metallic mineral products industry	8.19	41.38	15.83	7.64	1.93
metal smelting and rolling processing industry	22.61	121.62	30.71	8.10	1.36
fabricated metal products industry	2.05	11.42	10.68	8.63	5.21
general specialized equipment manufacturing industry	1.74	6.13	8.45	6.71	4.86
transportation equipment manufacturing industry	1.66	8.37	6.84	5.18	4.12
electrical machinery and equipment manufacturing industry	1.01	4.25	7.07	6.06	7.00

communication equipment computer and other electronic equipment manufacturing industry	0.70	5.00	4.88	4.18	6.97
instrumentation and cultural office use machinery manufacturing	0.71	2.66	4.98	4.27	7.01
art ware and other manufacturing industries	3.01	15.67	11.14	8.13	3.70
scrap waste	1.23	5.85	8.10	6.87	6.59
electric heating power production and supply of industry	22.71	80.65	53.15	30.44	2.34
gas production and supply industry	4.70	5.89	7.55	2.85	1.61
the production and supply of water possession	754.90	2693.62	768.33	13.43	1.02
building industry	3.79	15.42	12.14	8.35	3.20
transportation and warehousing	2.21	5.70	7.92	5.71	3.58
postal service	2.36	4.19	7.41	5.05	3.14
information transmission computer, services and software	0.27	0.69	3.84	3.57	14.22
wholesale and retail	1.62	2.85	6.45	4.83	3.98
accommodation and catering	11.41	25.01	41.24	29.83	3.61
financial industry	0.41	0.59	4.23	3.82	10.34
real estate industry	7.09	10.16	13.08	5.99	1.84
lease and business services	2.12	6.33	12.99	10.87	6.13
research and experimental development industry	3.25	10.52	15.86	12.61	4.88
comprehensive technical services	0.68	2.41	7.32	6.64	10.76

water conservancy environment and public facilities management	71.48	159.15	97.46	25.98	1.36
residents service and other services	2.75	8.96	15.44	12.69	5.61
education	17.64	33.04	30.92	13.28	1.75
health social security and social welfare	4.27	13.28	13.37	9.10	3.13
culture, sports and entertainment	5.07	12.44	14.09	9.02	2.78
public administration and social organizations	5.61	11.76	14.81	9.20	2.64
Household sector	54.76	84.95	91.75	36.99	1.67

From table 5, we can see: agriculture, electric heating power production and supply, etc. those sectors direct water use coefficient and value-added water use coefficient are high.

Agriculture, food manufacturing and tobacco processing, electric heating power production and supply, Accommodation and catering, etc. those sectors indirect water use are high.

Agriculture, food manufacturing and tobacco processing, electric heating power production and supply, accommodation and catering, etc. those sectors total water use coefficient are high.

Table 6: water use level for each sector of Beijing in 2007

	Rw_j^N	RS_j	RMW_j	Water use level	Potential water use level
agriculture	37.499	15.371	0.278	high	low
coal mining and washing industry	0.331	0.033	0.783	low	low
oil and natural gas mining industry	0.014	0.001	3.098	low	high
metal mining industry	2.336	0.050	0.262	high	low
non-metal ore and other mineral mining industry	2.286	0.009	0.332	high	low

food manufacturing and tobacco processing	1.195	0.591	2.231	high	high
textile industry	0.645	0.057	0.863	low	low
textile clothing, shoes and hats, leather, fur feather and its products industry	0.225	0.041	0.624	low	low
wood processing and furniture manufacturing industry	0.402	0.021	1.225	low	high
paper printing , cultural and educational sporting goods manufacturers	0.564	0.120	0.631	low	low
oil processing and coking and nuclear fuel processing industry	6.077	0.481	0.310	high	low
chemical industry	0.501	0.683	0.876	low	low
non-metallic mineral products industry	1.271	0.292	0.439	high	low
metal smelting and rolling processing industry	3.735	1.487	0.310	high	low
fabricated metal products industry	0.351	0.056	1.186	low	high
general specialized equipment manufacturing industry	0.188	0.185	1.106	low	high
transportation equipment manufacturing industry	0.257	0.208	0.938	low	low
electrical machinery and equipment manufacturing industry	0.131	0.041	1.593	low	high
communication	0.154	0.213	1.587	low	high

equipment computer and other electronic equipment manufacturing industry					
instrumentation and cultural office use machinery manufacturing	0.082	0.019	1.596	low	high
art ware and other manufacturing industries	0.481	0.020	0.842	low	low
scrap waste	0.180	0.001	1.500	low	high
electric heating power production and supply of industry	2.477	2.514	0.533	high	low
gas production and supply industry	0.181	0.015	0.366	low	low
the production and supply of water possession	82.728	3.188	0.232	high	low
building industry	0.474	1.005	0.728	high	low
transportation and warehousing	0.175	0.391	0.815	low	low
postal service	0.129	0.023	0.715	low	low
information transmission computer, services and software	0.021	0.080	3.237	low	high
wholesale and retail	0.088	0.313	0.906	low	low
accommodation and catering	0.768	1.001	0.822	high	low
financial industry	0.018	0.096	2.354	low	high
real estate industry	0.312	1.048	0.419	high	low
lease and business services	0.194	0.346	1.395	low	high
research and experimental development industry	0.323	0.220	1.111	low	high
comprehensive technical services	0.074	0.144	2.449	low	high
water conservancy	4.888	1.341	0.310	high	low

environment and public facilities management					
residents service and other services	0.275	0.062	1.277	low	high
education	1.015	1.348	0.398	high	low
health social security and social welfare	0.408	0.328	0.712	low	low
culture, sports and entertainment	0.382	0.350	0.633	low	low
public administration and social organizations	0.361	0.491	0.601	low	low
Household sector	2.609	8.837	0.380	high	low

According to the above calculation, we can divide 43 sectors into several types, in the row; we divided into three categories.

Table 7: divide 43 sectors into several types

	water use(high)	water use(low) potential water use (low)	water use(low) potential water use (high)
Value added (high)	real estate industry, building industry, education, accommodation and catering, electric heating power production and supply of industry, household	Wholesale and retail, transportation and warehousing, chemical industry, public administration and social organizations	Financial industry, information transmission computer services and software, Comprehensive technical services, Lease and business services, Communication equipment computer and other electronic equipment manufacturing industry
Value added	Food manufacturing and	Culture, sports and entertainment,	General specialized equipment

(medium)	tobacco processing, agriculture, metal smelting and rolling processing industry, water conservancy environment and public facilities management, non-metallic mineral products industry	Transportation equipment manufacturing industry, Health social security and social welfare, Paper printing , cultural and educational sporting goods manufacturers	manufacturing industry, Research and experimental development industry, electrical machinery and equipment manufacturing industry, Residents service and other services, instrumentation and cultural office use machinery manufacturing
Value added (low)	The production and supply of water possession, oil processing and coking and nuclear fuel processing industry, metal mining industry, Non-metal ore and other mineral mining industry	Textile clothing, shoes and hats, leather, fur feather and its products industry, postal service, coal mining and washing industry, textile industry, gas production and supply industry, art ware and other manufacturing industries	Fabricated metal products industry, oil and natural gas mining industry, wood processing and furniture manufacturing industry, Scrap waste

5. Conclusions and suggestions

5.1 Conclusions

The main conclusions drawing from descriptive statistical analysis are: the average precipitation, surface water resource and total water volume during 1986 to 2008 was in decline, the situation of underground water were deteriorating, which results in serious shortage of water resources supply. However, with the expansion of urban economic activity and population, there is a clear decline trend for total water consumption of Beijing, which is the result of substantial decline of economic output

per unit and water consumption per capital. It shows that remarkable achievements have been made in water saving and water use efficiency improving in Beijing.

Based on the water resource input-output table, through the analysis of each sector's efficiency of water use in Beijing, we can divide various economic sectors into four categories: the first category is these sectors that economic contributions were high, but their water use levels were also high. Real estate, construction, education, accommodation and catering industry, electricity and heat production and supply belonged to this category, their economic scales were important to the economic development in Beijing, but their water use levels were high. In the future, during the water resources management process, we should pay attention to these sectors. The second category is these sectors that economic contributions were high, water use levels were low. Wholesale and retail trade, transportation and warehousing sector, public sector management and social organization belonged to these types. These sector's economic scales were important to Beijing, and water levels were very low, these sectors development won't pose pressure on water resource. In the future, these sectors should be encouraged. The third category is those sectors that economic contributions were high, and their potential water use levels were also high. Financial industry, information transmission and computer services and software, comprehensive technical services, leasing and business services, communications equipment, computers and other electronic equipment manufacturing belonged to this type, their economic development were very important to Beijing, but their development will lead to water consumption increase rapidly in economic system. Therefore, in the process of pursuit economic development, we should pay attention to reducing their water use. The fourth category is those sectors that economic contributions were small, but water use levels were very high. Agriculture sector belonged to this type; it was the most typical sector. In the future, its water use efficiency need to improve and its water use level need to reduce. In addition, household sector belongs to high water use sector, its water use efficiency need to improve, and use water in a saving way.

5.2 Suggestions

To ensure the sustainable development of water resources in Beijing, we should pay attention to the following aspects in the process of improving the situation of water resources:

Firstly, we should strengthen the integrated water resources management, and

establish water-saving economic system. Secondly, we need to improve the industrial technology level, improve water-saving industrial structure, and reduce the water consumption of existing industrial. Thirdly, the water use efficiency of agricultural still need to be improved, we should promote water-saving agriculture, strengthen basic work of agriculture water-saving, achieve water-saving irrigation for all farmland, focus on the promotion of slight spraying, drip irrigation and other high efficient water-saving irrigation technique.

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