Integrated Water Resources Carrying Capacity in Tongzhou District, Beijing City

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Abstract: Tongzhou District has been put forward as the new developing centre of Beijing City. But the serious water deficiency and pollution restricted the local sustainable development. In this paper, an integrated water resource carrying capacity (IWRCC) model was developed under the sustainable development principle and the "natural–social" water cycle to quantify IWRCC of Tongzhou District. Three scenarios were designed to increase IWRCC and results showed that there was a great gap between IWRCC and the development plan in Tongzhou District. Water shortage restricted urbanization and sustainability seriously and transferring water from other regions besides promoting water saving and controlling pollution in the region would be the most feasible solution for Tongzhou District to mitigate the water shortage stress.

Key words: integrated water resource carrying capacity (IWRCC); gray association analysis; sustainability; Tongzhou District

1 Introduction

Water shortage is one of the major factors restraining social economy development in many areas in China, especially in the urbanizing areas. With the rapid economic increase, urban area expanded rapidly since 1980s in China. By the end of 2005, the urbanized level has reached 43%, and it will be over 50% in 2020 (Wang et al. 2006). But the Ministry of Water Resources P. R. China’s statistical data demonstrated that, in 669 cities these are 400 cities lack of water, 110 of which are lack of water seriously at present.

The concept of carrying capacity comes from ecology (Park et al. 1921). Since 1980s, WRCC has become a hot topic in China. Two different viewpoints have been developed, i.e., one focuses on the degree that the water resources can carry the soc-economy and eco-environment (Gao et al. 2006; Fu et al. 1999; Hui et al. 2001; Cheng 2002; Xia et al. 2004). The degree was usually a non-dimensional quantity, which could be obtained by contrasting the complete indices that affect WRCC with the basic criterion of carrying capacity. The other puts more emphasis on the soc-economic scale that the water resources can carry (e.g. Shi et al. 1992; Kessler 1994; Xia et al. 2002; Wang et al. 2003; del Monte-Luna et al. 2004). The scale was usually obtained by analyzing the harmonious development of society, economy, ecology and environment, and distributing the production-living-ecological water rationally. Although the comprehension of WRCC is different, the ultimate goals are to guide the water resources allocation of the region, and solve the balance of water supply and demand and sustainable development of social economy. In this paper, the water resources carrying capacity prefers to the second definition.

Beijing is a serious water shortage area. Currently, the per capita water resource is less than 300 m$^3$, which is lower than the international safety line, i.e. 1000 m$^3$ (Xu 2000). The contradictory between water supply and demand is extremely incisive. Groundwater was overdraft and polluted seriously. The eco-environment is in poor condition. Along with the rapid development, what’s the IWRCC in Beijing? It is urgent to be answered for policy makers and water resources managers. In this paper, the objectives are: (i) to develop an IWRCC model for urbanizing areas; (ii) to quantify the current IWRCC for typical District of Beijing and provide some countermeasures; and (iii) to supply the significant
consultations for some important events happened in Beijing during “the 12th Five-Year Plan” (2010–2015), such as the constitution of Beijing city development plan, the implement of agricultural water-saving strategy in the suburb, and so on.

2 The study area
Tongzhou District (39°36’–40°02’ N, 116°32’–116°56’ E) is one satellite town of Beijing, located in the southeast of Beijing (Fig.1). The total area is 907 km². There are 13 rivers in the district, which belong to the canal water system and the Chaobai River water systems, respectively.

This district is the warm temperate zone, the average annual air temperature is 11.7℃, the annual mean relative humidity is 56.8%. The annual mean precipitation is 591mm and the evaporation is 1164mm. The precipitation changes obviously every year and mainly in July to Sept, normally, which accounts for 83% of the annual precipitation.

Up to 2004, the total population of Tongzhou District was 620,000, the urbanization level has reached 41%, and agricultural areas were 36671 hectare. The gross value of agricultural output and industrial output were $396 million and $2578 million respectively, the gross domestic product (GDP) was $1569 million. The sewage treatment rate was 58%. The current industrial structure is 10:48:42 (primary industry: secondary industry: tertiary industry).

In the district, most of the surface water is the reusable water discharged from Beijing and the rivers were polluted seriously. The groundwater was overdraft severely. By 2004, it has fallen to 7.61m from 2.80m at the end of 1980, and serious overdraft area occupies 29% of the entire area.

Currently, Tongzhou District is put forward as the new developing centre of Beijing City. “Two axes, two belts, multi-centers” the new development pattern will impel the suburb’s urbanization process, and accelerate the social economy development of the suburb. The water resource deficiency, water pollution and groundwater overdraft restricted the sustainable development of this district, and made the contradiction more prominent between supply and demand of water resources. Thus the IWRCC of Tongzhou District was expected to answer urgently which would be helpful to establish the scientific development plan and direct the development of Tongzhou District, as well as Beijing City.

3 IWRCC model of Tongzhou District
IWRCC of Tongzhou District was considered as the greatest scale of social economy that total water resources of Tongzhou District could support during urbanization expediting, under the sustainable development principle, on the premise of maintaining ecological and environmental benign development, depending on temporal technology and economy level of development. The IWRCC model was introduced in detail in Xia et al. (2006) and the maximal population was selected as the objective function (Zuo et al. 2005). The resolution process of this model was shown in Fig. 2.

4 Results
4.1 The total water resource quantity of Tongzhou District
Tongzhou’s available water resources include runoff, reusable water and groundwater. The annual mean runoff is about 73 million m³, and the exploitation rate is only about 4%. The reusable water exploitation rate is only about 6%, and is about 50 million m³. Groundwater resources are about 213 million m³. To sum up, the annual mean available water resources is 267 million m³.

4.2 The synthetic analysis index system
The development of soc-economy $S(T)$, water resources $W(T)$ and eco-environment $E(T)$ are assessed by the index system. The standard is divided to five levels (Table 1). For example, the world water resources research institute proposes that there are four grades for the average per person water resources quantity. <1000 m³ means serious lack of water; 1000–5000 m³, means lack of water; 5000–10 000 m³, means no lack of water; > 10 000 m³ means abundance of water. In the world, there is another standard which fixes 1700 m³ as the warning line of the annual average water resources per person (Xu 2000). According to the standard above, the average water resources per person in Tongzhou District is that: 10 000
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4.3 IWRCC in different development scenarios

In this research, the base year, the short-term and long-term of development period of Tongzhou District were set as 2005, 2010 and 2020, respectively. Considering it is no water input in the near future, three scenarios have been drawn based on the current water resources.

Scenario one: The water ration is the same as 2005 without regard to saving water.

Scenario two: Reducing water ration of production and increasing the sewage treatment rate. Referring to the water ration of developed countries, there are some potentials only in water saving irrigation currently. Supposing: in 2010, water ration of industrial output holds the line viz. 7800 m$^3$ million dollar$^{-1}$, and water ration of agricultural irrigation falls to 3765 m$^3$ ha$^{-1}$, the sewage treatment rate achieves 90%; In 2020, water ration of industrial output falls to 4680 m$^3$ million dollar$^{-1}$, water ration of agricultural irrigation falls to 3300 m$^3$ ha$^{-1}$, water saving agriculture comes into reality in the entire district, and the sewage treatment rate achieves 100%.

Scenario three: Raising the urbanization level and promoting the industrial structure. According to “The Eleventh Five-Year Plan” (2006 – 2010), the industrial structures will be 7:42:51, and the urbanization level will be 70%. In 2010, the proportion will be 4:37:59, and the urbanization level will be 80%.

All the parameters needed in typical years are shown in Table 2, and IWRCC of Tongzhou District in 2005, 2010 and 2020 are gotten by the model (Table 3).

5 Discussion

5.1 The development of society economy, water resource and ecological environment

By forecasting, up to 2020, the population will be nearly twice larger than 2005s and GDP in the District will reach 12.8 billion dollars. S(T) increases from 0.62 to 0.80. It shows that the soc-economy development of Tongzhou District will be in a high speed development phase and the social economy will increase on a large scale during 2010–2020.

The rapid development of soc-economy results in water shortage, water pollution and the continuous decline of groundwater table in Tongzhou District unavoidably. Water demand including water consumption
of production, living and eco-environment restoration is far larger than water supply. The water resources condition is always overloaded. The water resources carrying degree (I) is larger than 1.0 every year, and W(T) is only 0.25 in 2005, and will drop to 0.18 in 2020.

Because of all the serious eco-environment problems mentioned above, the eco-environment development quality E(T) will be low, only 0.23 in 2005. Furthermore, all of E(T) are less than 0.6 by far. That is to say, the eco-environment is very fragile and the social economy...
development in Tongzhou District will sacrifice the ecological water use. In order to restore the water eco-environment, the water requirements will account for a high percentage of water demand during the Eleventh Five-Year Plan. In 2005, the ecological water use is nearly 260 million m$^3$.

In conclusion, DD(T) keeps in an extremely low level, which is only 0.33 in 2005, 0.35 in 2010, and 0.39 in 2020. Obviously, the development of Tongzhou District is not harmonious. The socio-economy development keeps in a high speed while the eco-environment development and the water resources condition are very weak (Table 4).

### 5.2 WRCC in different development scenarios

In Table 3, the first scenario is the baseline of the IWRCC in the future. In the near future, there is a large gap between IWRCC and the plan. Water shortage has become a bottleneck restricting social economy development, urbanization process and the eco-environment protection in Tongzhou District.

The second scenario searches into the influence of saving water and increasing the sewage treatment rate upon IWRCC, and the third scenario considers the influence of urbanization process and the industrial structure adjustment upon IWRCC.

Comparing the IWRCC in different scenarios, the implement of water saving strategy (scenario two), adjusting the urbanization level, the industrial structure and enhancing the sewage treatment rate (scenario three), can both relieve the water crisis and raise IWRCC to a certain extent. Relatively speaking, the increased scale of WRCC in scenario three is higher and the sustainable development degree is superior. In other words, the influence of urbanization process is more remarkable to IWRCC in Tongzhou District.

Both of the IWRCC in scenario two and three cannot reach the plan either. To solve water resources shortage and realize the sustainable development, it is crying for seeking new water sources or transferring water from other regions besides water saving, controlling pollution in the district.

### Acknowledgements

This study was supported by The Knowledge Innovation Key Project of the Chinese Academy of Sciences (Kzcx2-yw-126). Thanks to Prof. ZUO Qiting from Zhengzhou University for his valuable comments and suggestions which significantly improve the quality of the paper.

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北京市通州区水资源综合承载力

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摘要: 目前, 通州区已被定为北京市的新的发展中心, 但水资源短缺和污染已经严重限制了当地的可持续发展。本文以可持续发展为原则, 基于“自然—社会”水循环, 提出了通州区水资源综合承载力量化模型。根据通州区的未来发展规划, 设计了3种情景来提高该地区的水资源综合承载力。研究表明水资源短缺严重制约了通州区的城市化进程和可持续发展, 外调水、本地区节水和控制污染是解决通州区水资源短缺的有效途径。

关键词: 水资源综合承载力; 灰关联分析; 可持续发展; 通州区