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Water Use Disparity in China-An Overview and Revision

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Abstract. The accuracy of water use statistics has attracted more attention especially after the publication of "Three Red Lines" policy in China. Based on data from China Water Resources Bulletin (CWRB) and China Census for Water (CCW), the authors analyzed water use disparitiesby integrating multiple approaches and identified causes for disparities in industrial and agricultural water uses. We presenteda set of modified water uses data from 1997 to 2015, which might be more realistic and hopefully will provide more accurate base data for future water resources management.

1. Introduction

Water use data is key to successful water resources planning and management since it provides guidelines for implementing regional and nation-wide water conservancy planning, water resources management and project justifications [1, 2].Water resources managers and researchers believe that the cost of a data collection system is just 1/40 of its benefit. However, whatever the source, data error always existsandsome extent of error is always permitted [3, 4].The real problem is more complex and uncertain data continue to emerge. The uncertainty of data themselves, inappropriate measurement, reporting bias and other factors may cause the released final data deviate from the true value [5, 6].

The authenticity of Chinese official statistics was questioned by many researchers in the 1990s [7], including economic data [3, 8, 9], energy data [10], traffic data [11], irrigation area data [5, 12], poverty index [13], especially GDP data [3, 9, 14, 15]. In general researchers concluded that the economic statistical data in that time was not reliable and some data might probably be fabricated [8]. The irrigation area data at the end of twentieth Century also was influenced by professional levels of local statisticians, subjective tendency or administrative changes [5, 12].

The accuracy of water use data are being questioned by some experts or professionals inside Ministry of Water Resources (MWR) since the publication of CWRB from 1997. As Jia [4] indicated that industrial water use data in some counties fluctuate extensively within a few years and water use data changes closely corresponding to personnel changes in water resources bulletin compilation system. It shows that data from the CWRB is easily affected by personal subjective tendency, which in turn means the data does not have sound objective foundation. What's more, water use data gap from the same province can be over 30% for the sake of different reporting purposes. Especially for those provinces along with the Yellow River basin, they often underreport water consumption in order to obtain construction permission for new water projects.

In recognition of the importance of accuracy of water use statistics and lack of previous studies, the authors extended previous qualitative research into quantitative analysis by fully utilizing different sets of water use data developed in recent years. Data inconsistency and its reasons are identified and quantified by using comparative method, Delphi expert survey method and comprehensive diagnosis method. We also made corrections to the water use data at both the national and provincial levels accordingly based on the analysis.

2. Data and Methodology

2.1. Data Sources
There is no continuous statistical water use data before the 1980s. The investigation and assessment of water use were carried out in the process of special water resources assessment and planning work. China Water Resources Bulletin (CWRB) is the authoritative water data source released by the MWR Since 1997. The CWRB data mainly derived from provincial WRB data, which is calculated by quota method based on typical investigation.

In order to fully understand the basic situation of water resources in China, the first national census for water was conducted during the period of 2010 through 2012. The main contents of the census include basic conditions of rivers and lakes, basic conditions of water infrastructures, economics and social issues related water use, management and protection of rivers and lakes, soil and water conservation, and the capacity building of the water sectors. The census were made at the county level administrative unit as the basic working unit by following "the principle of localization", and applied multiple methods of survey such as comprehensive survey, sampling survey, typical survey and key project survey. The basic data derived from investigation respondents were directly handed in through the network, and received simultaneously at provincial authority, river basin authority and the MWR, which could not be modified unless through a formal request and authorization.

Statistical caliber for two data sets is a little bit different. In CWRB livestock water use is classified as part of the rural living water use, while in CCW livestock water use is included in agricultural water use. When comparing these data sets, researchers should take into account caliber conversion of livestock water use, ensuring that comparative analysis was conducted on the same data caliber.

2.2. Methodology
Delphi expert survey method refers to a systematic, interactive forecasting approach relying on the opinions of a panel of experts on a specific issue or project through written questionnaire, based on the principle that decisions from a structured group of individuals are more accurate than those from unstructured groups [16]. The method was first used by Norman Dalkey and Olaf Helmer [17] in science and technology forecasting. When historical data is insufficient, it is possible to use questionnaire survey to a group of experts for consultation. After two or more rounds of questionnaire, opinions of experts tend to converge towards the "correct" answer, which will be the expected forecast. The success of this method depends on the design of questionnaire and proficiency of the selected experts.

Delphi expert survey method takes the following steps: ①determine issue(s) to be advised by the selected experts. ②collect background information and data. ③ Design investigation questionnaire. ④ select a panel of preliminary advisory experts. ⑤initiate contact and send invitation letter and resume to experts. ⑥determine a final list of experts. ⑦ Deliver consultation questionnaire and instruction material. ⑧make statistical analysis of the experts' opinions based on the received feedback. ⑨modify the consultation table and move into the next round. ⑩according to different situation, make further consultation and determine results based on preset criteria.

Delphi expert survey method can make probability estimation about non-technical and quantitative factors. But the method is not stable since the final results are based on statistics of experts' opinions. One of the major weakness of this method is intuition and coordination of different experts are not always consistent and converging (Bowles, 1999).

2.3. Trend deviation method
Trend deviation method refers to a method that revises series data by multiplying trend valuebetweentwo adjacent census years and original trend deviation. The core of this method is to effectively estimate a trend value. We use a power function to estimate the trend value of the series data. For data of two adjacent census years, we can construct the following trend value:

$$T_t^{'} = A_0^{'}(1+r^{'})^T \ , \ r^{'} = \sqrt[T]{A_T^{'}/A_0^{'}} - 1 \tag{1}$$

Where the r' is average annual growth rate between two adjacent census years; the T_t' is trend value; the A_0' is reference value of last census year; the A_T' is reference value of this census year.

Similarly, the annual trend value can be constructed:

$$T_t = A_0^{'}(1+r)^T \ , \ r = \sqrt[T]{A_T/A_0^{'}} - 1 \tag{2}$$

Where the T_t is annual trend value.
Then, the trend deviation value can be obtained:

$$D_t = A_t/T_t \ t = 0,1,2,\cdots, \ T \tag{3}$$

Where the D_t is trend deviation value.
At lastthe revised data can be estimated by connecting original annual series data with the census data:

$$A_t^{''} = T_t^{'} D_t \ t = 0,1,2,\cdots, \ T \tag{4}$$

Where the $A_t^{''}$ is revised data.

3. Results and Discussions

Data errors in China's water use were evaluated based on the disparity between CWRB and CCW datasets. Significant disparity shows that error does exist. Total water use volume from CCW is 621.3billion m3, which is about 10.6 billion m3more than CWRB and the relative error is 1.7%. Agricultural water use from CCW is 31.4 billion m3 morethan CWRB and the relative error is 8.4%.However, both industrial and eco-environmental water use from CCW is less than that of CWRB, of which industrial water use from CCW is 25.9 billion m3 smaller than CWRB and the relative error is 17.7%.

Table 1. Statistics of the disparity of water use data for different categories Unit: 10^9 m^3

Industry	CWRB	CCW	Absolute Error	Relative Error (%)
Total Water Use	610.7	621.3	10.6	1.7
Agricultural Water Use	374.4	405.8	31.4	8.4
Industrial Water Use	146.2	120.3	-25.9	-17.7
Domestic water use	79.0	84.6	5.6	7.1
Eco-environmental Water Use	11.2	10.6	-0.6	-4.9

Data errors in water use are also different for different industries. Larger data errors were observed in industrial and agricultural water uses. Therefore we focus on assessment of the disparity for agricultural and industrial water use data. Data errors in water use varied greatly for one province to another. The lowest relative error is less than 1%, while the highest relative error exceeds 20%.

Methods, measurements, calibers and statistical personnel are different for developing these two data sets. Recognizing existing data errors and objectively analyzing quality of these two data sets will help us better understand realistic situation of water use in China.

3.1. Delphi survey results

Delphi expert survey method was applied to analyze the data discrepancy. We designed a questionnaire on China water use statistics. The main contents contain water metering situation in different industry, data comparison between CWRB and CCW, staff ability, data rationality, etc. A total of 21 answers were received. Some experts were senior advisors for the MWR, while other experts were familiar with local water use statistics. Many experts participated in compilation of national or provincial WRB. One of the senior experts, who were the former official of MWR, was responsible for the compilation of early CWRB.

Table 2. Statistics of experts'responses to the survey

Category (%)	0-25	25-50	50-75	75-100
The WRB data based on investigation	4	9	8	0
The CCW data based on investigation	2	10	8	1
The proportion of replicated statistical personnel	8	9	3	1
Urban living water use measurement coverage	0	1	14	6
Rural living water use measurement coverage	5	12	3	1
Northern industrial water use measurement coverage	2	1	10	8
Southern industrial water use measurement coverage	0	10	7	4
Northern agricultural water use measurement coverage	3	9	9	0
Southern agricultural water use measurement coverage	8	7	6	0

3.2. Industrial water use

Industrial water use from CWRB is about 25.9 billion m3 or 17.7% higher than CCW. We analyze causes for such disparity from the following aspects. Firstly, the authority of the CCW data is higher than that of CWRB. CCWhas a higher monitoring coverage than that of CWRB. Therefore it can be concluded that reliability of CCW data is higher than that of CWRB.

Secondly, we analyzed industrial water use in different period. (1) For the period from 2003 to 2007, CWRB data showed a linear upward trend with a very high growth rate. Most respondents (Table 3) agreed that local governmental agencies tended to report higher water use quantity in order to obtain higher water indices since the National Integrated Water Resources Planning effort was intended to set up water allocation for each provinces during this period. (2) For the period from 2007 to 2009, CWRB data showed a downward trend. According to the China Statistical Yearbook, energy (electricity) consumption from 2007 to 2009 showed a downward trend because of economic crisis. Industrial water trend was consistent with energy consumption during this period. The reported water use data is reliable. (3) After 2010 data showed a rising trend again. Economic situation was improved in 2010, but the growth rate of industrial water use was too large. This is corresponding to "the most strict water resources management regulation" issued by the Central Government of China in 2009, which required each province to establish the total water use cap. Experts agreed that water planners in some areas might prefer to have a higher water use data as their water use cap indicators.

Thirdly, a further analysis on provincial data shows that CWRB data from the areas with poor metering facilities tend to be exaggerated. We collected the data from the released provincial census bulletin and made a comparison with water resources bulletin data. The results showed that industrial water use errors varied greatly among provinces. The minimum relative error is less than 1%, while the maximum relative error is over 60%.

Provinces with little data disparity in industrial water use include Beijing, Shanghai, Tianjin, Shanxi, Hebei, Liaoning, Jiangsu, Zhejiang, Henan and Ningxia, which are located in the coastal zone and the northern area with water shortage. In these areas water metering facilities coverage was better than other parts of China, which ensured high statistical accuracy. In addition, water balance test had been carrying out in those areas since 1980s, which further warranted the reliability of industrial water use data. At the same time water metering system was improved gradually through water balance test within enterprise.

Water balance test also helped to enhance scientific management of enterprise water use and created water-saving benefits. Water use archives were also established which laid a sound foundation for managing water use scientifically.

For the areas with larger data disparities data errors result from poor water metering facilities coverage, in these provinces and water statistical accuracy was not guaranteed. In the early time industrial water use data was not verified with water balance test. Most industrial water use data was obtained by estimate according to industrial production and water use quota since enterprises lack metering systems. Furthermore, the reporting staff's estimate could not reflect the actual situation of enterprises' water use due to lack of experience in statistics and the data processing. For example, in the early 1990s, a group of experts went to Baoding city, Hebei Province, to investigate a textile factory's water consumption. They found that the original water use reported by local staff was about 30 times larger than that estimated by experts due to local staff's lack of understanding of the actual water use. The data for the later years was adjusted with previous data based on a certain growth rate, and in turn inherited errors from the previous data.

In conclusion, industrial water use from CWRB are larger than those from CCW and its growth rate was also too fast. Therefore the industrial water use data from CCW is more reliable.

3.3. Agricultural water use

Agricultural water use of 2011 from CWRB is about 374.4 billion m3, which is 31.4 billion m3 smaller than that of CCW and the relative error is 8.4%. Most provinces' CWRB data is smaller than CCW except Beijing, Hebei and Qinghai. The relative error of Guangdong, Hunan, Gansu, Inner Mongolia, Henan, Fujian, Guangxi and Tianjin is relatively large. The maximum relative error was observed in Jiangxi Province, with the relative error of 30%.

Table 3. Results of regression analysis of agricultural water uses in the selected provinces

Province	Multiple Regression Equation	R^2
Guangdong	$y = -901.5851 - 0.00007x_1 + 0.2348x_2 + 0.2634x_3$	0.98
Henan	$y = 4939.6852 - 0.0691x_1 + 0.0145x_2 - 2.4161x_3$	0.88
Fujian	$y = 3038.7700 - 0.0010x_1 + 0.0359x_2 - 1.4866x_3$	0.73
Heilongjiang	$y = 2081.0297 - 0.0154x_1 + 0.0344x_2 - 0.9929x_3$	0.97
Hebei	$y = 3595.0184 - 0.0523x_1 + 0.0056x_2 - 1.7221x_3$	0.94
Hunan	$y = 7820.6356 - 0.0104x_1 - 3.7921x_3$	0.95
Inner Mongolia	$y = 4493.9593 - 0.0402x_1 - 2.1639x_3$	0.88
Anhui	$y = -2878.3712 - 0.0054x_1 + 0.0367x_2 + 1.3880x_3$	0.90
Shandong	$y = 4497.9029 - 0.0548x_1 + 0.0113x_2 - 2.1776x_3$	0.95

Note: the dependent variable y represents agricultural water use (109m3), the independent variable x_1 represents precipitation (mm), x_2 represents actual irrigation area (104 Mu), x_3 and represents time (year).

Which agricultural water use data is more reliable, CRWB or CCW? The answer is CWRB data, which is contrary with industrial water use data. The reasons for such difference were summarized as following.

Firstly, most experts participated in the questionnaire survey believe that CCW data is overestimated. Experts agree that agricultural water use should decline in recent years through increasing water-saving irrigation area and improving irrigation water utilization coefficient. But the CCW data is larger than CWRB, which is not consistent with the expected trend.

Secondly, monitoring coverage for agriculture water use is the lowest in comparison with other industries. It is difficulty to carry out the survey for agricultural water use. The credibility of CCW results is relatively low due to lack of experience of the survey personnel. Once water census data was

stored in the web report system it is very difficult to correct any data errors because of restricted approval rules in modifying data. So some recognized data errors remains in the data set.

Thirdly, CCW agricultural water use data is susceptible to subjective factors. Each province strives for more water use index and tends to report higher water use values because of the most strict water resources management policy. As the CWRB data is continuous and serves as a base for local water saving, it is difficult to over-report agricultural water use data. However, CCW is a completely new survey and its agricultural water use data is lack of historic measurement for comparison or verification, which provides opportunity for reporting higher water use values subjectively.

Fourthly, CWRB agricultural water use data showed a good correlation with major factors for agricultural water uses, such as precipitation and irrigation acreage, proving its reliability. We chose some provinces with large data errors in agricultural water use and made a regression analysis among irrigation water use, precipitation and irrigation area (Table 5). Except Jiangxi and Fujian Provinces, other provinces showed very high correlation coefficients.

Agricultural water use data from CCW deviate farther alone in comparison with other data such as data from Chinese water resources integrated planning (WRIP) and Chinese mid-long term water supply and demand programming (WSDP) as shown in Figure 3, which further proves its potential inaccuracy.

In sum we believe that agricultural water use data from CWRB follows a good pattern and relatively reliable, while data from CCW was exaggerated.

3.4. Corrected Data Set

Based on foregoing analysis, we concluded that industrial water use data of CCW and agricultural water use of CWRB is more reliable. For the domestic and eco-environmental water use data either data set can be used since their relative error is very small.

In order to asses Chinese water use situation objectively, we made further modification of water use data for different sectors. Domestic living water use data is modified by using trend deviation method. Industrial water use data for the year 2003-2015 is modified by using linear trend extrapolation method based on 1997-2002 CWRB data and 2011 CCW data. Agricultural water use data from CWRB is adopted. Eco-environmental water use for 2011 is directly taken from CCW, while for other years taken from CWRB.

3.5. Discussion

Over-reporting tendency does exist in both CCW and CRWB data sets. Industrial water use was over-reported in CRWB, while agricultural water use data was over-reported in CCW. Such error is attributed to the deviation of the reported data trend from expert judgment that agricultural water use would not increase, while industrial and domestic water use would continue to increase in recent years. Both CWRB and CCW tend to over-report industrial water use, industrial water use data in CCW were difficulty to forge since they were collected from enterprises one by one. Agricultural water use can be easily over-reported since its monitoring coverage rate is relatively low.
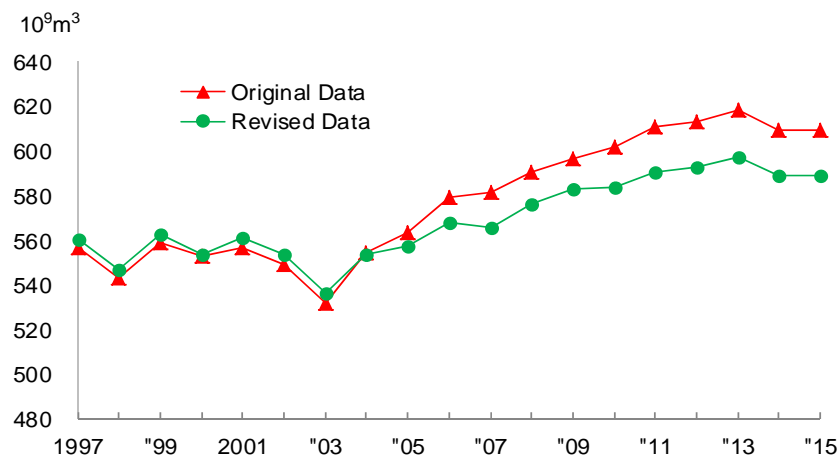
Figure 1. Revised water use data in China from 1997 to 2015

Disparity in China's water use data is big enough to make the "Three Red Lines" green. The relative error for the total water use data between the CCW and CRWB can reach 1.74%.It can even reach 20% in some provinces. However, according to the requirements of the "Three Red Lines" policy, industrial water use per unit added value needs to decrease by 30% in 5 years. Disparity in water use statistics can make the error of this index over 50%, resulting in meaningless of such assessments. Constructing a high-coverage monitoring system for water uses is necessary. It not only is needed for the implement of "Three Red Lines" policy, but also fulfills the requirement for water rights allocation and improvement of water use efficiency.

3.6. Conclusions

Water use statistics in China has significant disparities. The total amount of water use from CCW was approximately 10.6 billion m3 greater than that of CWRB and the relative error was 1.7%. The relative errorsfor industrial and agricultural water uses were much greater, 17.7%, 8.4%, respectively. China's water statistics also showed a strong regional disparity. Because of mismatching of water and land resources, water use measurement systemsin water scarce regions were different from water rich regions. Overall coverage rate of metering in northern and coastal area was relatively high, while water metering infrastructure in the south area was weak.

China's water statistics disparities differed in different industrial sectors, resulting from varied metering capabilities. Urban living water use was the best metered because of metering in water treatment plants. Industrial water use had the middle coverage of monitoring. Agriculture water use was poorest metered. Those led to water use data disparities among different industry sectors, especially in industrial and agricultural water uses.

There are both objective and subjective reasons for water use statistics disparity. The main objective reasons were the weak measurement establishment and low metering rate. The subjective reasons lied in that local governments tended to report more water use in order to rival for more water use rights. Based on the rationality analysis about the CCW and CWRB data, we proposed a new data set for China's water uses for different sectors. We hope this set of data will have less error in comparison with true values. While many experts and scholars studied the reliability of economic statistic data and irrigated area data of China, little research was found about the statistical error of water use data of China. This paper made a preliminary analysis of the disparity and its reasons. In view of significance and complexity of water use statistics in China, the authors have attempted to do a preliminary analysis. We expect to attract more attention concerning accuracy and reliability of water use statistics.

Acknowledgments

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