International Comparison of Water Resources Utilization Efficiency in the Silk Road Economic Belt

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Abstract. In order to get knowledge of the standard of water utilization of the Silk Road Economic Belt from international point of view, the paper analyzes the annual variation of water resources utilization in the Silk Road Economic Belt, and compares with other typical countries. The study shows that Water resources utilization efficiency has been greatly improved in recent 20 years and the water consumption per USD 10000 of GDP has been declined 87.97%. the improvement of industrial water consumption efficiency is the key driving factors for substantial decrease in water consumption.The comparison of water utilization and human development shows that the higher HDI the country is, the more efficient water utilization the country has. the water consumption per USD 10000 of GDP in country with HDI > 0.9 is 194 m³, being 8.5% of that in country with HDI from 0.5 to 0.6. On the premise of maintaining the stable economic and social development of the Silk Road Economic Belt, the realization of the control target of total water consumption must depend on the strict control over the disorderly expansion of irrigated area, the change in the mode of economic growth, the implementation of the development strategy for new industrialization and urbanization, vigorous development of the processing industry with low water consumption as well as the high-tech and high value-added industry. Only in this way, the control target of total water consumption can be realized in the process of completing the industrialization task.

1. Introduction
In 2013, President Xi Jinping proposed the strategic concept of “the Silk Road Economic Belt” and “the 21st Century Maritime Silk Road” (hereinafter referred to as the “Belt and Road”), In 2015, the connotation and arrangement of “Belt and Road” is elaborated in the Vision and Actions on Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road, the provinces, which the Silk Road Economic Belt involves in, are defined in the document. They include 6 provinces in north-western region, that is, Xinjiang, Gansu, Ningxia, Qinghai, Shaanxi and Inner Mongolia, 3 provinces in northeast region, namely, Liaoning, Jilin and Heilongjiang, and 3 provinces in southwest regions, i.e., Guangxi, Yunnan and Tibet, and Chongqing City. The Silk Road Economic Belt covers an area of 6.8547 million km² which takes up 71.4% of China’s land area. In2015, the population in the economic belt was 363 million, accounting for 26.71% of China’s total population, the total water consumption was 225.93 billion m³, taking up 37.02% of China’s total water consumption, the GDP was 2.45 trillion dollars, 23.67% of China’s GDP. The Silk Road Economic Belt is mainly located in the inland regions with vulnerable ecology, arid climate and limited clean water resource. In the regions the per capita water resource is scarce, so the severe problem of water resource becomes one of the important resource factors restricting the strategic arrangement of the Belt and Road[1]. At present, China is implementing the
strictest water resources management system, the control over the increase in the total quantity of water consumed is first upgraded to national strategic level, the total water consumption indicators and water consumption efficiency indicators are integrated into the national economic and social development plan. According to the target of total quantity control of water consumed of each province that is stipulated in the Implementation of the Strictest Water Resources Management System Assessment Methods, the target of total water consumption control of the 13 provinces involving the Silk Road Economic Belt will be 240.291 billion m³ by 2020, while the total amount of water consumed was 225.93 billion m³ in 2015. So the problem to be solved urgently at present is how to achieve the control target of total water consumption in the premise of the steady growth of economy and social economy in the Belt. For this reason, we need to define the level which the development and utilization of water resources the Silk Road Economic Belt lie in among the countries in the world and make reference to the change course of water use efficiency and total water consumption in developed countries. However, it is difficult to comprehensively reflect the status quo of water resource utilization in the world for a long time as a result of lack of effective data support and fragmentary tracking system, we don’t exactly know the current situation of development and utilization of water resources for the other countries, especially developed countries and don’t position China’s water resources and its utilization level in the world. In previous studies, Jia Jinsheng [2] and Ma Jing [3] have conducted international tracking and comparison of the utilization efficiency of water resources in China. In order to provide an objective basis for the implementation of the strictest water resources system and adherence to the “three red lines”, it is necessary to verify the status quo of water resource utilization of countries along the Silk Road Economic Belt, keep abreast of the present situation and development course of water utilization and the utilization efficiency of water resources in major foreign countries, continuously track and compare with the developed countries, make clear the development of utilization level of water resources of the countries along the Silk Road Economic Belt from the international perspective, and internationally compare and analyse the utilization of water resources in the Chinese regions in the Silk Road Economic Belt.

2. Changes in water consumption and utilization efficiency of water resources in the Silk Road Economic Belt

2.1. Water consumption
Since 1997, the water consumption in the Silk Road Economic Belt has grown steadily to 225.93 billion m³ in 2015 from 1972.264 billion m³ in 1997. Only during successive droughts 2000 to 2003, water consumption dropped slightly. The agricultural water grew slowly to 177.53 billion m³ in 2015 from 155.324 billion m³ in 1997, or 14.3% per cent. Industrial water grew slowly before 2011 and declined significantly after 2011. In 2015, only domestic water grew faster, the total water consumption increased to 225.93 billion m³ in 2015 from 206.16 billion m³ in 2005. In terms of water utilization structure, in 1997, the proportion of agricultural water, industrial water and domestic water was 78.74%, 14.12%, 7.14%, respectively. Since then, with the application of water-saving technology and the adjustment of industrial structure, the proportion of agricultural water basically stay at 78%, the proportion of industrial water is decreasing while the proportion of domestic water is increasing continuously. It is predictable that with the continuous development of the Silk Road Economic Belt and further advancement of urbanization, the domestic water and industrial water will continue to increase in our country, while agricultural water will continue to develop steadily with the continuous promotion of water-saving irrigation technology, thus the proportion of agricultural water will decline while the domestic and industrial water will be risen.
Fig. 1. Variation of water use of the Silk Road Economic Belt from 1997 to 2015.

Fig. 2. Variation of water use efficiency of the Silk Road Economic Belt from 1997 to 2015.

2.2. Water consumption efficiency

Water consumption per USD 10000 of GDP and water consumption per USD 10000 of industrial added value are usually adopted to evaluate the comprehensive water consumption efficiency in a country in the world. The paper shows statistical analysis of comprehensive water consumption efficiency and industrial water consumption efficiency in the Silk Road Economic Belt from 1997 to 2015 (Fig. 2), in which GDP data is based on current price of USD from WDI database in World Bank\cite{4}, water consumption data is from China Water Resources Bulletin since 1997\cite{5-23}. It is observed from the calculation that water consumption efficiency has greatly increased in recent 20 years, with water consumption per USD 10000 of GDP decreased from 7655m³ in 1997 to 920m³ in 2015, has decreased by 87.97% and water consumption per USD 10000 of industrial added value decreased from 2480m³ in 1997 to 224m³ in 2015, has decreased by 90.97%. Compared with 402 m³ in 2010, the water consumption has decreased by 44.34%, which has achieved the control target of water utilization efficiency of the provinces along the Silk Road Economic Belt which is set in Strictest Water Resources Management System Assessment Methods.

In order to analysis the key driving factors of the above indicator decrease, a complete decomposition model of water consumption per USD 10000 of GDP between 1997 and 2015 was built\cite{24,25}. The equation of the contribution rate which the change of water consumption per USD 10000 of industrial added value made by industrial structures change ($\gamma_{str}$) and by water efficiency improvement ($\gamma_{eff}$) is as follows.

$$\gamma_{str} = \frac{\sum [w_i^n(y^n_i - y^0_i) + \frac{1}{2}(w_i^n - w_i^0)(y^n_i - y^0_i)]}{\sum_i w_i^n y_i^n - \sum_i w_i^0 y_i^0}$$

$$\gamma_{eff} = \frac{\sum [y^0_i(w_i^n - w_i^0) + \frac{1}{2}(w_i^n - w_i^0)(y^n_i - y^0_i)]}{\sum_i w_i^n y_i^n - \sum_i w_i^0 y_i^0}$$

It is observed from table 1 that from 1997 to 2015, the improvement of industrial water consumption efficiency and structural adjustment are the key driving factors for substantial decrease in water consumption in the Silk Road Economic Belt, with higher rate of contribution by improvement of industrial water consumption efficiency and rate of contribution after 2010 having been higher than 70%. Contribution of improvement in industrial water use efficiency is due mainly to industry and agriculture:
the rate of contribution made by industry maintained at about 18% after 2006 and the rate of contribution made by agriculture increased year after year, which is up to 49% in 2015; given the worsening situation of shortage in water resource in China, improvement in water resources utilization efficiency has been upgraded to national strategy, the total water consumption and water resource utilization efficiency have been used as restrictive index incorporated in national economic and social development program, embodying the position and function of water resource in national macro control. Several measures including legislation, policy guidance and economic leverage shall be taken to improve water resource utilization efficiency. The contribution made by industrial restructuring to decrease water consumption per USD 10000 of GDP is mainly embodied in adjustment of agricultural structure. The rate of contribution made by change of percentage of industry and other industrial structures is insignificant, the reason for which is that agricultural water consumption in the Silk Road Economic Belt has been large in percentage; its water consumption per USD 10000 of GDP is much higher than water consumption of industry and other industries. From 1997 to 2015, the agricultural structure changed substantially in percentage, decreasing from 18.3% in 1997 to 8.9% in 2015.

| year     | \( \gamma_{str} \) | Industry | Agriculture | Other industrial structures | \( \gamma_{eff} \) | Industry | Agriculture | Other industrial structures |
|----------|----------------------|----------|-------------|-----------------------------|---------------------|----------|-------------|-----------------------------|
| 1997-1998 | 17.65%               | -1.13%   | 19.13%      | -0.35%                      | 82.35%              | 18.68%   | 57.81%      | 5.87%                       |
| 1998-1999 | 71.70%               | -2.24%   | 76.57%      | -2.63%                      | 28.30%              | 22.00%   | -1.16%      | 7.46%                       |
| 1999-2000 | 74.53%               | -3.57%   | 79.87%      | -1.77%                      | 25.47%              | 25.62%   | -0.34%      | 7.19%                       |
| 2000-2001 | 62.01%               | -1.72%   | 65.92%      | -2.19%                      | 37.99%              | 18.22%   | 12.20%      | 7.57%                       |
| 2001-2002 | 43.79%               | -1.27%   | 46.59%      | -1.53%                      | 56.21%              | 18.54%   | 30.74%      | 6.93%                       |
| 2002-2003 | 41.21%               | -1.69%   | 44.11%      | -1.21%                      | 58.79%              | 18.68%   | 36.37%      | 3.75%                       |
| 2003-2004 | 32.47%               | -2.07%   | 34.92%      | -0.37%                      | 67.53%              | 18.29%   | 43.46%      | 5.77%                       |
| 2004-2005 | 33.23%               | -0.95%   | 35.48%      | -1.30%                      | 66.77%              | 16.63%   | 45.00%      | 5.14%                       |
| 2005-2006 | 34.78%               | -1.55%   | 37.24%      | -0.91%                      | 65.22%              | 16.56%   | 43.21%      | 5.46%                       |
| 2006-2007 | 31.67%               | -1.75%   | 34.04%      | -0.62%                      | 68.33%              | 16.40%   | 46.48%      | 5.44%                       |
| 2007-2008 | 30.09%               | -2.09%   | 32.46%      | -0.29%                      | 69.91%              | 16.48%   | 48.09%      | 5.34%                       |
| 2008-2009 | 28.25%               | -1.65%   | 30.40%      | -0.51%                      | 71.75%              | 15.99%   | 49.75%      | 6.01%                       |
| 2009-2010 | 30.32%               | -1.98%   | 32.68%      | -0.38%                      | 69.68%              | 16.17%   | 47.60%      | 5.92%                       |
| 2010-2011 | 28.77%               | -2.03%   | 31.06%      | -0.26%                      | 71.23%              | 16.25%   | 48.83%      | 6.15%                       |
| 2011-2012 | 27.96%               | -1.63%   | 30.05%      | -0.45%                      | 72.04%              | 16.17%   | 48.91%      | 6.96%                       |
| 2012-2013 | 26.59%               | -1.37%   | 28.53%      | -0.56%                      | 73.41%              | 15.92%   | 50.39%      | 7.10%                       |
| 2013-2014 | 27.97%               | -0.85%   | 29.78%      | -0.96%                      | 72.03%              | 15.48%   | 49.03%      | 7.53%                       |
| 2014-2015 | 27.73%               | -0.20%   | 29.31%      | -1.38%                      | 72.27%              | 14.98%   | 49.46%      | 7.83%                       |

3. International comparisons
Broadly speaking, the countries along the Silk Road Economic Belt mainly involve 51 countries, including 18 Asian and European countries such as China, India and Russia, 5 Central Asian countries like Kazakhstan and Uzbekistan and 28 European Union countries. All the countries cover an area of 45.678 million km², accounting for 31.72% of the global area, their population reached 4.047 billion in 2015, 55.45% of the global population, and their total water consumption was 2.26 trillion m³ of in 2015, 56.78% of total global water consumption, and their GDP was 32.87 trillion dollars in 2015, 44.89% of global GDP. Among the countries, the total water consumption of China, India and Pakistan exceeded 100 billion m³, the total water consumption of Russia, Iran, Iraq and Uzbekistan ranged from 50 billion m³ to 100 billion m³, the total water consumption of 15 countries, that is Italy, Germany, Spain, Bangladesh, Myanmar, France, Turkmenistan, Kazakhstan, Afghanistan, Ukraine, Azerbaijan, Poland,
Tajikistan, Portugal and the Netherlands, varied from 10 billion m³ to 50 billion m³, while the total water consumption of other 29 countries like the United Kingdom, Greece and Sweden was less than 10 billion m³.

The paper collects and analyzes water consumption, water consumption structure, water consumption efficiency and industrial structure in more than 100 countries and regions in the world based on statistics, in which, global water resources quantity and water consumption data are difficult to obtain, the paper adopts the prevailing and latest data from (FAO) AQUASTAT database[26], the database is upgraded every five years. China and the US adopt the most authoritative official data related to water resources in their countries respectively [27]. Data about added values in GDP and tertiary industries in other countries are from WDI database in World Bank.

3.1. International comparisons in water consumption
Among the countries along the Silk Road Economic Belt, the total water consumption of China, India and Pakistan exceeded 100 billion m³, the total water consumption of Russia, Iran, Iraq and Uzbekistan ranged from 50 billion m³ to 100 billion m³, the total water consumption of 15 countries, that is Italy, Germany, Spain, Bangladesh, Myanmar, France, Turkmenistan, Kazakhstan, Afghanistan, Ukraine, Azerbaijan, Poland, Tajikistan, Portugal and the Netherlands, varied from 10 billion m³ to 50 billion m³, while the total water consumption of other 29 countries like the United Kingdom, Greece and Sweden was less than 10 billion m³.

Fig. 3 water consumption of the countries along the Silk Road Economic Belt

Fig. 4. Water consumption per GDP of 10 thousand dollars

Fig. 5. Water consumption per GDP of 10 thousand dollars of industrial added value
3.2. International comparisons in water consumption efficiency

3.2.1. Water utilization efficiency of countries along the Silk Road Economic Belt. This paper compares the water utilization efficiency of 51 countries along the Silk Road Economic Belt in broad sense (Fig. 4), the data show that the water consumption per USD 10000 of GDP of 25 EU developed countries such as the United Kingdom, Ireland, Denmark and Sweden was less than 300 m³ in 2015, that of 6 countries (that is, Russia, Greece, Spain, Hungary, Romania and Mongolia) ranged from 300 m³ to 500 m³ in 2015, that of 3 countries (i.e., China, Portugal and Estonia) varied from 500 m³ to 1,000 m³, that of 10 countries like Kazakhstan, India and Iran fluctuated between 1,000 m³ and 5,000 m³, that of Central Asian countries such as Pakistan, Turkmenistan, Uzbekistan and Burma ranged from 5,000 m³ to 10,000 m³ and that of 3 countries (namely, Afghanistan, Kyrgyzstan and the Republic of Tajikistan) exceeded 10,000 m³. By contrast, there is still a big gap in the water utilization level per USD 10000 of GDP between the countries along the Silk Road Economic Belt and developed countries like EU countries, while the water utilization efficiency of the countries along the Silk Road Economic Belt is higher than most developing countries in Central Asia and Western Asia.

For industrial water consumption, the water consumption per USD 10000 of industrial added value of 10 EU developed countries such as the United Kingdom, Ireland and Denmark was less than 100 m³ in 2015, that of 14 countries such as China, India, Spain, Greece ranged from 100 m³ to 300 m³ in 2015, that of 8 countries such as Italy, Portuguese, Germany ranged from 300 m³ to 500 m³, that of 10 countries like Russia, France, Netherlands fluctuated between 500 m³ and 1,000 m³, that of 9 countries like Kazakhstan, Turkmenistan exceeded 1,000 m³.

3.2.2. Water use efficiency in countries at different development levels. In order to determine water resource utilization level of the Silk Road Economic Belt based on international perspective, the paper introduced Human Development Index (HDI) to analyze the difference of water resource utilization efficiency between the Silk Road Economic Belt and other countries in different development level. The closer the HDI nearer to 1 indicates the higher of human development level. The paper divides statistical water consumption efficiency in more than 100 countries and regions according to HDI level, obtained water consumption efficiency of countries in different development level in 2015 (Table 2).

| HDI       | water consumption per USD 10000 of GDP (m³) | water consumption per USD 10000 of industrial added value (m³) | water consumption per capita (m³) | water consumption structure (%) |
|-----------|-------------------------------------------|---------------------------------------------------------------|---------------------------------|--------------------------------|
| >0.9      | 194                                       | 386                                                          | 917                             | Agriculture | 39.1 | 45.3 | 15.6 |
| 0.8~0.9   | 286                                       | 438                                                          | 590                             | industry    | 46.1 | 37.7 | 16.2 |
| 0.7~0.8   | 663                                       | 305                                                          | 505                             | other       | 70.1 | 16.4 | 13.5 |
| 0.6~0.7   | 2596                                      | 442                                                          | 615                             | industrial structures | 86.8 | 5.4 | 7.8 |
| 0.5~0.6   | 2278                                      | 222                                                          | 336                             | Agriculture | 89.6 | 2.1 | 8.3 |
| China (0.738) | 541                                       | 295                                                          | 436                             | industry    | 64.4 | 22.3 | 13.3 |
| Silk Road | 920                                       | 224                                                          | 622                             | other       | 78.6 | 10.8 | 10.6 |

Development and utilization of water resource in a country is not only influenced by climate and living habit but also closely associated with development stage and development level of economy and society, country with higher development level of society and economy is superior to the country with
lower development level of society and economy, in terms of index, including water consumption structure and water consumption efficiency to evaluate water resource development and utilization level. Table 3 shows that with the increase of HDI, water consumption per USD 10000 of GDP and water consumption per USD 10000 of industrial added value are on the decrease and water consumption per capita is on the increase. For three major industries, lower percentage in agriculture shall result in lower percentage in agricultural water consumption in water consumption structure, in which, water consumption per USD 10000 of GDP is the most obvious. Water consumption per USD 10000 of GDP in country with HDI > 0.9 is 194m³, being 8.5% of that in country with HDI from 0.5 to 0.6.

water consumption per USD 10000 of GDP of the Silk Road Economic Belt was 920m³, higher than those countries with HDI from 0.7 to 0.8, much lower than those countries with HDI from 0.6 to 0.7, water consumption per USD 10000 of industrial added value was 224m³, industrial water consumption efficiency is superior to those countries with HDI from 0.7 to 0.8; Water consumption per capita was 622m³, higher than those countries with HDI from 0.7 to 0.8; agricultural water consumption percentage was 78.6%, superior to those countries with HDI from 0.6 to 0.7. In a word, water resources utilization efficiency in the Silk Road Economic Belt is superior to those countries with HDI from 0.6 to 0.7.

4. Conclusion
By tracing the development and utilization of water resources in different countries, this paper clearly positions the exploitation and utilization of water resources in the Silk Road Economic Belt. In recent years, the utilization efficiency of water resources in the Silk Road Economic Belt has been significantly improved, which is better than that of countries whose HDI varies from 0.6 to 0.7. But compared with developed countries, a big gap still exists. The experience of the developed countries tells us that the adjustment of the industrial structure which results from the development of national economic and social development is the driving force for the fact that the total water consumption tends to be stable. If one country has higher social and economic development level, its indexes that are used to measure the development and utilization level of water resources are better than those of the country with low development level. On the premise of maintaining the stable economic and social development of the Silk Road Economic Belt, the realization of the control target of total water consumption must depend on the strict control over the disorderly expansion of irrigated area, the change in the mode of economic growth, the implementation of the development strategy for new industrialization and urbanization, vigorous development of the processing industry with low water consumption as well as the high-tech and high value-added industry. Only in this way, the control target of total water consumption can be realized in the process of completing the industrialization task.

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