

# Research on the Utilization Efficiency of Agricultural Water Resources in Tianjin based on DEA Model

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**Abstract.** Improving the efficiency of agricultural water resources is an important measure to enhance the comprehensive strength of agriculture and build a water-saving society. In this context, this paper takes the efficiency of agricultural water resources utilization in Tianjin based on DEA model from 2008 to 2017 as the research object, and uses the input index of agricultural water consumption, annual precipitation, effective irrigation area, irrigation water consumption, agricultural labor force required under the unit effective irrigation area, and the total power of agricultural machinery required under the effective irrigation area of the unit. The output index of total agricultural output value and unilateral aquatic quantity are selected. The results show that Tianjin needs to reduce the proportion of agricultural water use according to local conditions, speed up the application and transformation of agricultural water-saving achievements, and increase the proportion of technology input to replace labor input, so as to further improve the efficiency of agricultural water resources utilization.

## Introduction

Tianjin is one of the most water-scarce cities, with a per capita water resource of 83.6 cubic meters per person, only 1/15 of the national average. Therefore, Tianjin has always attached great importance to the conservation and utilization of water resources, especially to improve the efficiency of agricultural water resources, has carried out a pilot project for comprehensive reform of agricultural water prices, strengthen agricultural water conservation, vigorously promote efficient water-saving irrigation technology, improve the grass-roots agricultural water-saving technology extension service system. Successively implemented the Opinions on the Implementation of the Comprehensive Reform of Agricultural Water Price in Tianjin and the "Two-Control Action Plan for the Total and Intensity of Water Resources Consumption in Tianjin City 13th Five-Year Plan", forming a more perfect system of agricultural water use. By constructing the index system and using the DEA model, this paper evaluates the efficiency of agricultural water resources utilization in Tianjin from 2008 to 2017, and helps us to analyze the comprehensive situation of agricultural water resources utilization in Tianjin, so as to improve the efficiency of agricultural water resources utilization.

## Variable Selection and Data Description

In this paper, according to the principles of system, authenticity, dynamics, scientificity, operability, etc., according to the DEA model and the characteristics of the utilization of agricultural water resources in Tianjin in the last ten years, the agricultural water consumption, annual precipitation, irrigation water consumption, effective irrigation area, the labor force required under the unit effective irrigation area, The total power of agricultural machinery required under the effective irrigation area of units is used as input index, and the output index of single-sided water production and agricultural output value is taken as the output index, and the efficiency of agricultural water resources utilization in Tianjin from 2008 to 2017 is analyzed.

### Empirical Analysis

First of all, using the CCR model, by calculating the values of each input and output indicator, we get the relaxation variable values ( $S_j^-, S_r^+$ ) of the agricultural water resources utilization efficiency value ( $S_j^-, S_r^+$ ) of the years in Tianjin from 2008 to 2017. The specific value is shown in Table 1. Secondly, by replacing each input-output data into the BCC model, the net technical efficiency value of the utilization efficiency of agricultural water resources in Tianjin has been obtained in the last ten years. Finally, through the analysis of specific data, we can get the technical efficiency value, pure technical efficiency value and scale efficiency value of agricultural water resources utilization in Tianjin from 2008 to 2017, the specific value is shown in Table 2.

### Technical Efficiency Analysis

Table 1. CCR model solution results

DMU/Year	$\theta$	$S_1^-$	$S_2^-$	$S_3^-$	$S_4^-$	$S_5^-$	$S_6^-$	$S_7^+$	$S_2^+$
2008	0.8034	0.7315	102.807	6.40E-02	0.1556	0.4117	0	0	0
2009	0.808	1.3576	127.646	0.2129	0.1729	0.396	0	0	0
2010	1	0	0	0	0	0	0	0	0
2011	0.9883	0.7809	226.005	0.95702	0	0.6057	8.0554	0.1437	0
2012	1	0	0	0	0	0	0	0	0
2013	0.9789	1.7589	0	0.47644	0	3.6867	25.652	0	0
2014	1	0	0	0	0	0	0	0	0
2015	0.892	1.2656	91.8292	0	0	0.2677	8.5061	0	0
2016	0.9011	1.4799	69.1798	6.91E-02	0	1.4575	0	0	0
2017	1	0	0	0	0	0	0	0	0

As can be seen from Table 1, the most efficient years for the utilization of agricultural water resources in Tianjin in the past decade are 2010, 2012, 2014 and 2017. The efficiency value of agricultural water resources utilization in these four years is 1, and the relaxation variables  $S_j^-, S_r^+$  are all 0, which shows that Tianjin has reached the best state of agricultural water resources input and output in these four years. The utilization efficiency value of 2008, 2009, 2011, 2013, 2015 and 2016 was lower than 1, indicating that the six years were not effective for DEA, but the efficiency value was relatively high, indicating that the efficiency of agricultural water resources in Tianjin was still at a high level, and the relaxation variable  $S_j^-, S_r^+$  is not 0, indicating that Tianjin in these six years there is excess input and insufficient output phenomenon.

## Analysis of Pure Technology Efficiency and Scale Efficiency

Table 2. Measurement seamounts of agricultural water resources utilization efficiency in Tianjin, 2008-2017

Year	$\theta$	$\sigma$	s	returns to scale
2008	0.8034	0.9546	0.8416	-
2009	0.808	0.9543	0.8467	-
2010	1	1	1	-
2011	0.9883	1	0.9883	Increase
2012	1	1	1	-
2013	0.9789	1	0.9789	Increase
2014	1	1	1	-
2015	0.892	1	0.892	Increase
2016	0.9011	1	0.9011	Increase
2017	1	1	1	-

According to the calculation results of Table 2, it can be seen that in the year of effective technical efficiency, the value of pure technical efficiency and scale efficiency are 1, respectively, the best state of pure technical efficiency and scale efficiency. In years where technical efficiency is ineffective, the four years of 2011, 2013, 2015 and 2016 are purely technically valid, while the remaining invalid years have pure technical efficiency values of less than 1, and pure technical efficiency is invalid. It shows that the utilization of agricultural water resources in Tianjin has not reached the best state in these years, and the input value needs to be further improved so as to achieve the best output state. From the scale efficiency point of view, the value of technical efficiency is 1, the scale efficiency is effective, the value of technical efficiency is not 1, the scale efficiency is not effective. The ineffectiveness of DEA in 2011, 2013, 2015 and 2016 and the increasing scale gains suggest that these years will require continued expansion in production and increased input of resources to yield more output.

## Modified Target Factor Analysis

Table 3. Invalid year dea projection results

Variable	2008	2009	2011	2013	2015	2016
X <sub>1</sub> improved value	-3.1	-3.82	-0.92	-2.02	-2.6	-2.67
X <sub>1</sub> Improve the proportion	25.72%	29.77%	7.93%	16.56%	21.07%	22.17%
X <sub>2</sub> improved value	-211.33	-240.21	-233.25	-8.98	-152.73	-133.89
X <sub>2</sub> Improve the proportion	38.28%	40.97%	37.53%	2.11%	27.09%	20.46%
X <sub>3</sub> improved value	-1.92	-2.058	-1.07	-0.66	-0.88	-0.92
X <sub>3</sub> Improve the proportion	20.33%	21.42%	10.64%	7.56%	10.8%	10.7%
X <sub>4</sub> improved value	-7	-6.85	-0.39	-0.65	-3.34	-3.03
X <sub>4</sub> Improve the proportion	20.1%	19.7%	1.17%	2.11%	10.8%	9.89%
X <sub>5</sub> improved value	-6.9	-6.73	-0.98	-4.4	-3.72	-4.62
X <sub>5</sub> Improve the proportion	20.9%	20.4%	3.06%	12.95%	11.64%	14.44%
X <sub>6</sub> improved value	-50.55	-49.3	-11.08	-31.33	-37.19	-22.74
X <sub>6</sub> Improve the proportion	19.66%	19.2%	4.27%	11.64%	14%	9.89%
Y <sub>1</sub> improved value	0	0	+0.1437	0	0	0
Y <sub>1</sub> Improve the proportion	0	0	2.5%	0	0	0
Y <sub>2</sub> improved value	0	0	0	0	0	0
Y <sub>2</sub> Improve the proportion	0	0	0	0	0	0

From the table, we can see that in 2008 the agricultural water consumption redundancy of 310 million cubic meters, in 2009 agricultural water redundancy of 382 million cubic meters, in 2011 agricultural water redundancy of 0.92 million cubic meters, in 2013 redundancy of 202 million cubic meters, in 2015 redundancy of 260 million cubic meters, 267 million cubic meters of redundancy in 2016, indicating that agricultural water use in 2008, 2009, 2011, 2013, 2015 and 2016 was too large and needed to be adjusted, with adjustments of 25.72%, 29.77%, 7.93%, 16.56%, 21.07 percent and 22.17 percent. Also in this 6 years, annual precipitation, irrigation water consumption, effective irrigation area, agricultural labor, agricultural machinery power is also too much investment, resulting in waste of water resources, human resources. In 2011, the output of single-sided water production was insufficient, and crop yields needed to be further increased by 2.5%. The remaining years in the single water output and agricultural output value DEA projection of 0, indicating that Tianjin square water production and agricultural output value is more reasonable.

### Summary and Suggestion

(1) Through the analysis of the CCR model of agricultural water resources utilization in Tianjin from 2008 to 2017, the efficiency of agricultural water resources utilization in Tianjin reached more than 80%, except in 2008 and 2009 for about 80%, the rest of the years reached more than 90%, the overall level is more ideal. However, the DEA's effective years account for only 40 per cent, and in ineffective years, there is a shortage of inputs and insufficient output, indicating that agricultural water resources are inefficient in these years. Therefore, in order to further improve the efficiency of agricultural water resources, it is necessary to continuously improve the input of technology instead of labor input, so as to achieve the best output state, so as to improve efficiency.

(2) The evaluation results show that in the input factors, the proportion of agricultural water input is large, there is a problem of excess input, so the proportion of agricultural water needs to be further reduced. On the one hand, on the basis of overall planning, we should establish a long-term mechanism for water-saving utilization of agriculture in Tianjin, such as vigorously implementing preferential policies such as agricultural water-saving subsidies, promoting the process of reforming the comprehensive water price of agriculture, and promoting the awareness of water-saving irrigation among all kinds of agricultural production and operation subjects through publicity and education. On the other hand, Tianjin should formulate water-saving irrigation schemes according to the actual conditions of each agricultural area. In addition, the irrigation water consumption rate of farmland in Tianjin reached 87.5%. The gap between the application of irrigation pipeline, irrigation and drip irrigation in the whole city is still quite large compared with that of developed countries, so we should speed up the transformation of water-saving irrigation application results, improve the utilization rate of water resources, and thus improve the yield of crops.

(3) Through the analysis of the evaluation results of economies of scale, Tianjin city should reduce the proportion of input of agricultural water elements, but also reduce the proportion of input of labor force and other factors. On the one hand, to improve basic education and vocational training in rural areas, to improve the rural education infrastructure, and to continuously improve the quality of the agricultural labor force by strengthening the training of new types of vocational farmers and rural practical personnel, and on the other hand, to reduce the proportion of labor input; In order to reduce the input of agricultural labor, and constantly improve the contribution rate of technological progress in agricultural water resources, so as to improve the efficiency of agricultural water resources.

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