Research Progress on Water-use Efficiency Evaluation Based on CiteSpace

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ABSTRACT

Based on 1084 international water efficiency research literature collected from the core collection of Web of Science from 2007 to 2022, CiteSpace software was used to visualize and analyze the research institutions, teams, and keywords published in the literature, systematically sorting out the hotspots and evolution of international water efficiency research, and revealing the progress of international water efficiency evaluation research. Research has shown that the evaluation of water-use efficiency essentially takes water resources and related capital and labor as input indicators, and corresponding economic, ecological, and social benefits as output indicators, and constructs a suitability indicator system based on regional or industry characteristics. Based on the characteristics of traditional DEA models and their extended models, the authors select models that match the research object, purpose, and content for water efficiency evaluation, and determine the direction for future improvement of water efficiency in the region or industry. In this evaluation process, it is necessary to clarify the impact of factors such as economic development, social benefits, and ecological protection on water-use efficiency based on regional economic and social characteristics or industry water use structure, improve the efficient, intensive, and economical utilization capacity of water resources, and achieve coordinated development of water resources, economy, society, and environment. In the future, there is an urgent need to deeply implement the concept of green development, explore suitable water resource utilization models for different regions and industries, construct targeted evaluation index systems and operable evaluation models based on this, and improve the research on water-use efficiency evaluation methods.

Keywords: *Water-use efficiency, Evaluation, Indicators, Model, Knowledge graph.*

1. INTRODUCTION

Water resources, as a fundamental element of the resource system, are an important resource for human survival and development. In the context of the prominent contradiction between water supply and demand, improving water-use efficiency is a key way to solve the problem of water resource shortage. From 2007 to 2022, there has been an increasing number of literature on water-use efficiency research internationally, but few scholars have used visual analysis tools to systematically and thoroughly report on water-use efficiency research, scientifically and reasonably sorting out the progress of water-use efficiency evaluation. Therefore, this article uses the Web of Science Core Collection (WOS) as the platform, and takes water-use efficiency research literature published by SSCI, SCI as the research object. 1084 English literature are obtained, and with the help of CiteSpace software, visualization analysis of international water-use efficiency research is carried out. The research results of water-use efficiency evaluation are systematically summarized, providing reference for further improving the theoretical research and practical exploration of water-use efficiency evaluation.

2. RESEARCH METHODS AND DATA RESOURCES

CiteSpace is visual analysis software for mapping knowledge maps, which mainly reveals the knowledge base and research frontiers in scientific research field through citation analysis and co-occurrence analysis [1]. Based on CiteSpace, through data mining, graphs are drawn for key information such as research institutions and teams, keywords, etc. [2], visualizing the hotspots and trends in international water-use efficiency research from 2007 to 2022. WOS conducted SSCI and SCI literature searches with the theme "water-use efficiency" and obtained 1084 English literature. After appropriately deleting irrelevant literature, the authors import the English literature into CiteSpace 6.1R3 to complete data preparation. In CiteSpace 6.1R3 software, the time slice is first set to 1 year, followed by selecting institutions and authors for knowledge graph co-occurrence analysis. Then, the time slice is set to 4 years, and keywords are selected for knowledge graph co-occurrence analysis to reveal the progress of water-use efficiency research.

3. VISUAL ANALYSIS OF WATER-USE EFFICIENCY RESEARCH

According to the changes in the number of WOS publications in the international water-use efficiency study from 2007 to 2022, it can be seen that from 2007 to 2016, the annual number of WOS publications was in a slow growth period. But since 2017, the annual publication volume of WOS has rapidly increased and reached its peak in 2021. The number of WOS publications has decreased in 2022 (see "Figure 1").

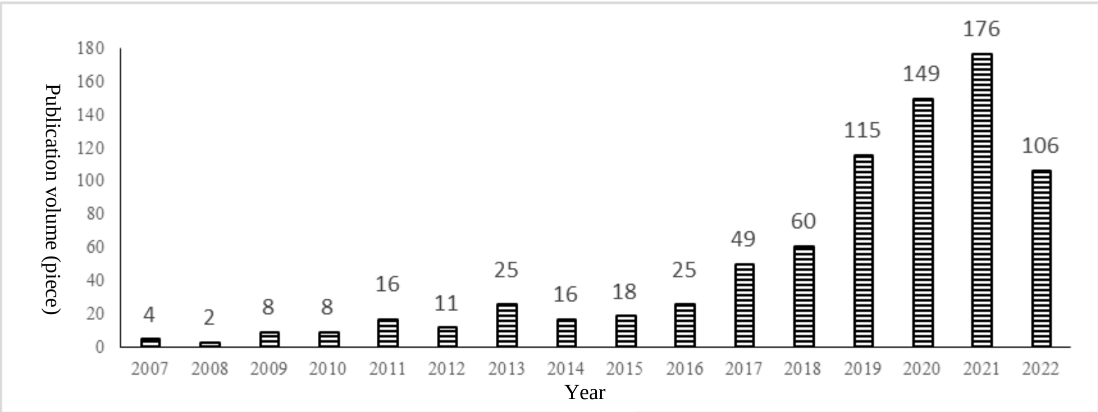

Figure 1 Annual publication volume of water efficiency research from 2007 to 2022.

3.1 Research Institutions and Teams

An in-depth analysis of publication trends in the literature can provide more accurate data support and reference for research institutions and teamwork network analysis.

3.1.1 Research Institutions

For research on water-use efficiency, WOS is dominated by universities and research institutes in China, the United States and Pakistan, mainly including: Chinese Academy of Social Sciences(China), University of Chinese Academy of Social Sciences (China), China Agricultural University(China), Hohai University(China), Northwest A&F University (China), Beijing Normal University (China), Stanford University (USA), Chinese Academy of Agricultural Sciences (China), University of Agriculture Faisalabad (Pakistan), Sichuan University (China). At the same time, with these universities and research institutes as the center, a research group with intensive internal cooperation has been formed, such as the research group with the Chinese Academy of Social Sciences as the center (see "Figure 2").

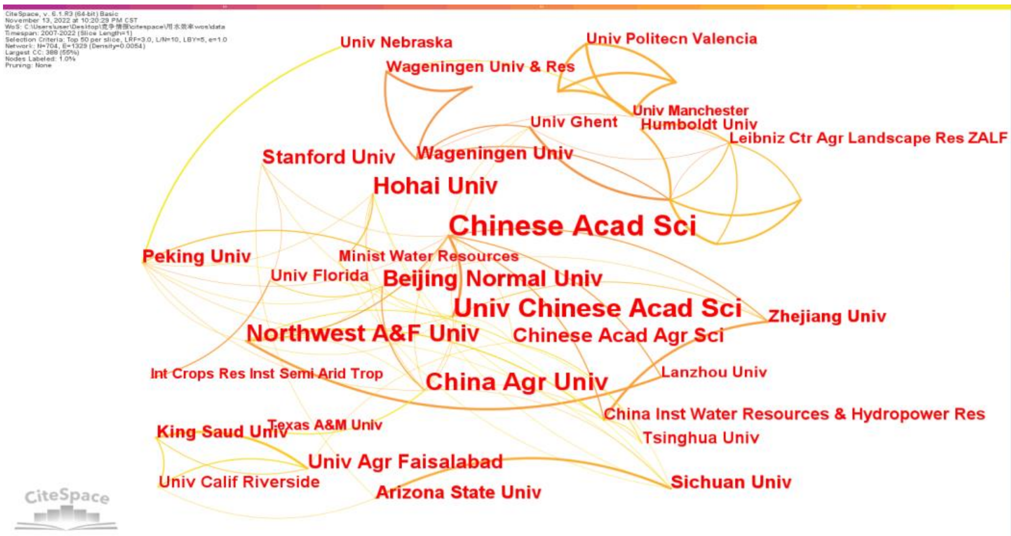

Figure 2 Co-occurrence map of WOS research institutions for water-use efficiency research from 2007 to 2022.

Meanwhile, through the comparison of the number of publications by universities and research institutes of WOS (see "Table 1"), it can be seen that WOS's colleges and universities have stronger research capabilities and are more competitive.

Table 1. Comparison of WOS research institutions' publications on water-use efficiency research from 2007 to 2022

Ranking	Research institution	Number of articles published
1	Chinese Academy of Social Sciences	98
2	University of Chinese Academy of Social Sciences	65
3	China Agricultural University	43
4	Hohai University	40
5	Northwest A&F University	40
6	Beijing Normal University	38
7	Stanford University	20
8	Chinese Academy of Agricultural Sciences	20
9	University of Agriculture Faisalabad	19
10	Sichuan University	16

3.1.2 Research Teams

By analyzing the number of articles published by authors and the frequency of citations in their literature, leading figures and high-yield authors in the research field can be identified. Based on collaborative network co citation visualization, a relatively stable research team has been formed in the field of water-use efficiency research. The research teams with a high volume of WOS publications include the WU PUTE team, CHIU YUNG-HO team, LUO GEPING team, AJAMI NEWSHAK team, and SHI MINJUN team (see "Figure 3"). The size of the nodes in the figure is directly proportional to the frequency of the author's appearance, and the number of lines and the thickness of the connecting lines between the nodes reflect the cooperation and closeness between the authors. [3]

Figure 3 Co-occurrence of WOS research team for water-use efficiency research from 2007 to 2022.

3.2 *Keywords*

By organizing the frequency of keyword occurrences in different time periods (see "Table 2"), the evolution of water-use efficiency research can be further revealed.

Table 2. WOS key keywords sorting by time domain frequency

Time slice	Key keywords	Frequency
2007-2009	Water-use efficiency	283
	Management	208
	Climate change	202
	Yield	98
	Consumption	98
	Model	93
	Irrigation	89
	Agriculture	78
	Water scarcity	40
2010-2012	Water use	101
	Data envelopment analysis	49
	Demand	47
	Maize	40
	Scarcity	38
	Crop	37
	Temperature	29
	Basin	16
	Emission	15
2013-2015	Productivity	110
	Use efficiency	75
	Performance	74
	Water footprint	56
	River basin	36
	Lifecycle assessment	27
	Greenhouse gas emission	18

Time slice	Key keywords	Frequency
2016-2018	Deficit irrigation	25
	Decomposition	15
	Cropping system	11
	Drought stress	9
	Water resource	9
	CO_2 emission	5
	Conservation agriculture	5
	Implementation	5
2019-2022	Drip irrigation	33
	Green	18
	Strategy	13
	Decomposition analysis	9
	Fruit quality	8
	Industry	7
	Urban	7
	Risk	6
	Mechanism	6
	Groundwater depletion	6

"Table 2" shows that from 2007 to 2009, WOS focused on water management, the relationship between climate change and agricultural water use, and the relationship between agricultural irrigation output and water consumption. From 2010 to 2012, WOS focused on the application of DEA models, water demand, food production, and research on water pollution emission control. From 2013 to 2015, WOS focused on productivity, water footprint, life cycle assessment and climate change research. From 2016 to 2018, WOS focused on research on agricultural water-saving irrigation, water and drought pressures, and carbon emissions. From 2019 to 2022, WOS will focus on farmland drip irrigation, green development, water crisis and model mechanism research. Overall, WOS focuses on agricultural irrigation and sustainable development of the ecological environment.

4. PROGRESS IN WATER-USE EFFICIENCY EVALUATION

According to literature review in "Figure 3", it can be seen that the academic community mainly constructs corresponding evaluation index systems and models from the perspective of input-output, and conducts research on water-use efficiency evaluation. Among them, the design of evaluation index has certain differences due to different research objects and purposes, and the construction of evaluation models focuses on using DEA models.

4.1 Evaluation Index System

Based on the input-output perspective, many scholars mainly select water consumption, fixed assets investment and employed population as input indicators and GDP as output indicators when building the water-use efficiency evaluation index system. On this basis, scholars have systematically designed evaluation index for regional water-use efficiency based on national and regional conditions. At the same time, based on the characteristics of industry water use, a systematic design was carried out for the evaluation indicators of industry water-use efficiency.

4.1.1 Evaluation Index for Regional Water-use Efficiency

Based on the national and regional conditions, the design of regional water-use efficiency evaluation index mainly involves three levels: national, basin, and regional. From the design of national water-use efficiency evaluation index, Deng et al. [6] selected labor force, capital investment, and total water use as input indicators, GDP as expected output indicators, and sewage discharge as non-expected output indicators to evaluate the water-use efficiency of 31 provinces and regions in China from 2004 to 2013; Zhang et al. [7], based on the induction of the selection characteristics of non-expected output indicators, selected comprehensive environmental factors as the negative output indicators, and explored the effectiveness of China's environmental regulations in improving water-use efficiency.

From the design of evaluation indicators for water-use efficiency in river basins, Le et al. [8] divided the input-output system into two stages and evaluated the water resource utilization efficiency of the Dongnai River Basin in Vietnam. The first stage takes water resources as direct input, generating intermediate output, which is the final output of the economic and social subsystems in the second stage.

From the design of evaluation index for regional water-use efficiency, Kamal et al. [9] selected water purchase cost, energy cost, worker wages, repair and maintenance costs as input indicators, and total income as output indicators to compare the urban water supply situation and water-use efficiency between the Gaza Strip and developed Western countries from 1999 to 2002; SUN et al. [10] established 16 input indicators and 14 output indicators to comprehensively evaluate the water resource utilization efficiency of Jilin Province from 2004 to 2017. They used principal component analysis to reduce the input indicators to 3 principal components and the output indicators to 2 principal components; Hu et al. [11] selected capital stock, labor force, domestic water consumption, and production water consumption as input indicators, and GDP as output indicators to evaluate the total factor water-use efficiency in the eastern, central, and western regions of China.

In summary, scholars have constructed corresponding water-use efficiency evaluation index based on differences in knowledge background. On the one hand, it is to incorporate domestic water, production water, and ecological water into the comprehensive indicator framework system, with a focus on considering the social or economic environmental benefits of water resources. On the other hand, it is to establish corresponding indicator systems for the stage differences of water resource systems, and consider the selection of unexpected indicators based on different research purposes. Overall, scholars have taken into account three aspects when selecting investment indicators: capital, labor, and water resources. When selecting output indicators, regional GDP indicators are used as representatives.

4.1.2 Industry Water-use Efficiency Evaluation Index

According to the characteristics of industrial water use, the design of industrial water-use efficiency evaluation index mainly involves agriculture, industry, city and ecology. From the design of evaluation index for agricultural water-use efficiency, Manjunatha et al. [12] studied the agricultural irrigation efficiency of groundwater in India using agricultural water consumption, irrigation area, labor input, machine power, and fertilization as input indicators, and agricultural total output value as output indicators; Yilmaz et al. [13] used water supply and irrigation area as input indicators and gross agricultural output value as output indicators to evaluate the water-use efficiency of agricultural irrigation in Türkiye's Buyuk Mendere basin to find effective irrigation areas; Zhao et al. [14] evaluated the agricultural water-use efficiency in the urbanization process of the middle and lower reaches of the Yellow River Basin using the employment population in the primary industry, agricultural water consumption, and grain planting area as input indicators, and grain production as output indicators.

From the perspective of industrial water-use efficiency evaluation index design, Zhao et al. [14] evaluated the industrial water-use efficiency in the process of urbanization in the middle and lower reaches of the Yellow River basin with the secondary industry employment population, industrial water use, fixed assets investment as input indicators and the secondary industry GDP as output indicators; Liu et al. [15] constructed an input index system from two aspects: input indicators related to water resources and input indicators not related to water resources, and evaluated the industrial water-use efficiency of Chinese mainland with industrial added value as the expected output index, and the total amount of wastewater directly discharged into the environment and the total amount of wastewater directly discharged into the sewage treatment plant as the non-expected output index.

From the design of evaluation index for urban and ecological water-use efficiency, Tupper et al. [16] selected labor cost, operating cost, and capital cost as input indicators, and used water production and sewage treatment volume as output indicators to evaluate the water-use efficiency of Brazilian water companies; Byrnes et al. [17] considered the characteristics of Victoria and New South Wales and selected input indicators excluding labor and fixed assets. The complaint index and total drinking water volume were used as output indicators to measure the water supply efficiency of water companies; Liu et al. [18] selected three input indicators based on the three basic categories of capital investment, labor force, and water consumption, and selected 11 output indicators from aspects such as water conservancy infrastructure, soil and water conservation, water pollution prevention and control, improvement of ecological environment, and economic benefits to comprehensively evaluate the ecological efficiency of China's water system.

In summary, there are significant differences in the design of water-use efficiency evaluation index among different industries. The input indicators highlight the water use characteristics of different industries, and the output indicators are represented by the total economic output value or economic added value of the industry. At the same time, some scholars have conducted research on the evaluation of water-use efficiency in agriculture, industry, and daily life, incorporating ecological benefits in the form of unexpected outputs into the scope of indicator selection.

4.2 Evaluation Methods

According to the literature review, since DEA model evaluates the effectiveness of the same type of decision-making units based on multi indicator inputs and multi indicator outputs, it has the advantages of not dealing with the impact of random errors, not considering the production function relationship between inputs and outputs, and so on, scholars mainly use DEA model and its expansion model to carry out water-use efficiency evaluation research.

4.2.1 Evaluation Method for Regional Water-use Efficiency Based on DEA Model

Based on the national and regional conditions, the construction of a regional water-use efficiency evaluation method based on the DEA model mainly involves three levels: national, watershed, and regional. From the perspective of the construction of national water-use efficiency evaluation methods, Cetrulo et al. [19] incorporated the differences in water resource utilization, i.e. water inequality, into the DEA model and used a relaxed DEA directional distance function model to evaluate the water use performance of developing countries. The results showed that the sustainability of water resource utilization in developing countries was relatively low.

From the perspective of constructing evaluation methods for watershed water-use efficiency, Le et al. [8] used a two-stage DEA method to evaluate the water resource utilization efficiency of the Dongnai River Basin in Vietnam. The results showed that this method helps decision-makers make correct decisions for water resource management and improving water-use efficiency.

From the perspective of constructing regional water-use efficiency evaluation methods, Byrnes et al. [17] used the DEA model to measure the relative technical efficiency of water resources in New South Wales and Victoria, and the results showed that water use restriction policies suppressed water-use efficiency; Amar et al. [20] used DEA cross efficiency method to evaluate the comprehensive water quality of 47 dams in northern Algeria. This method can comprehensively evaluate the water quality, thus improving the robustness of the calculation of comprehensive water quality index.

In conclusion, most scholars mainly choose to expand DEA model or mixed DEA model when evaluating regional water-use efficiency, and analyze panel data in combination with EBM model [21], panel Tobit model [22], MPI model [23], SBM model [24] and other models. In addition, when studying the basin water-use efficiency, scholars often use multi-stage DEA models to better distinguish the water-use efficiency of different systems within the basin.

4.2.2 Evaluation Method for Industry Water-use Efficiency Based on DEA Model

According to the characteristics of industrial water use, the design of industrial water-use efficiency evaluation method mainly involves agriculture, industry, city and ecology. From the perspective of constructing evaluation methods for agricultural water-use efficiency, Veettil et al. [24] adopted a stochastic DEA model to analyze the relationship between farm output and irrigation water input under the new pricing system. The results showed that rising water prices would not reduce water-use efficiency but would reduce water demand.

From the perspective of constructing evaluation methods for industrial water-use efficiency, Liu et al. [15] used an improved SBM-DEA model to study the industrial water-use efficiency in China, incorporating marginal water use costs and marginal wastewater treatment costs into the model calculation variables. The study found that industrial water-use efficiency can be further improved by adjusting the water use structure and wastewater discharge structure.

From the perspective of constructing evaluation methods for urban and ecological water-use efficiency, Storto et al. [25] used a parallel network DEA model to measure urban water supply efficiency in Italy. The parallel network DEA solves the shortcomings of traditional DEA models and can comprehensively summarize the water-use efficiency of different service nature tools in the industry; Maria et al. [26] used the stochastic non parametric envelope Stoned method combining DEA and stochastic frontier analysis (SFA) to measure the water-use efficiency and pollution discharge efficiency of Chilean water enterprises. The results showed that environmental variables may have a higher impact on cost improvement and efficiency reduction of public water companies than private water enterprises.

In summary, the traditional DEA model has strong applicability in some studies. Most scholars use the CCR model in conjunction with the BCC model to calculate the technical efficiency, pure technical efficiency, and scale efficiency of each decision-making unit, thereby better exploring the key factors affecting water-use efficiency. At the same time, due to the differences in the water use structure of industries, scholars have combined different models with DEA models, such as rough set theory (RST), grey system correlation test method, Tobit model, DELPH method, expert consultation method, and principal component analysis method, to calculate the rationality or hierarchical induction of evaluation index selection.

5. CONCLUSION

Through visual analysis of water-use efficiency research, the following conclusions have been drawn: firstly, the research institution and team have clarified the distribution of core research forces in this field. The core institutions of WOS are concentrated in colleges and universities, and the core author team is mainly concentrated in China. Secondly, the keywords clarify the research hotspots of water-use efficiency. From a time perspective, WOS has always focused on agricultural irrigation and sustainable development of the ecological environment. Thirdly, the evolution of water-use efficiency research was reviewed, with a focus on exploring the evaluation index system of water-use efficiency based on input-output perspectives. The traditional DEA model and its extension model were developed, providing reference for subsequent scholars' research.

According to literature review, there are still some shortcomings in this field of research. Firstly, it is mainly focused on the agriculture and irrigation fields, with a focus on the relationship between agricultural water resource utilization and the environment, as well as industrial water-use efficiency. There are few literature focusing on the evaluation of water-use efficiency in the service industry. Secondly, when constructing evaluation index systems and selection models based on input-output perspectives, some scholars did not closely combine regional or industry characteristics and chose basic indicators and models, resulting in research conclusions that were not targeted. However, there are relatively few evaluation index for the domestic and ecological water-use efficiency in existing literature, and few scholars have focused on conducting in-depth research on the domestic and ecological water-use efficiency. Therefore, research in this field still needs to be deepened: on the one hand, it is necessary to focus on optimizing and upgrading the industrial structure, and study the balance of water-use efficiency in the primary, secondary, and tertiary industries; on the other hand, it is also necessary to focus on the interaction between water resource utilization and environmental and social benefits, and further improve the evaluation index system and methods for social and environmental water-use efficiency; In addition, when evaluating the water-use efficiency of specific regions or industries, the researchers should not be limited to the basic indicator system. There is a necessity to select targeted evaluation index systems and evaluation models matching the indicator system based on regional characteristics, industry characteristics and data availability.

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REFERENCES

[1] Chaomei C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature [J]. Journal of the American Society for Information Science and Technology, 2005, 57(3): 359-377.

[2] Chaomei C. Searching for intellectual turning points: progressive knowledge domain visualization [J]. Proceedings of the National Academy of Sciences of the United States of America, 2004, 101 Suppl 1:3-10.

[3] Chaomei C, Fidelia I, Jianhua H. The structure and dynamics of cocitation clusters: A multiple - perspective cocitation analysis [J]. Journal of the American Society for Information Science and Technology, 2010, 61(7): 1386-1409.

[4] Zhao Rongying, Xu Limin, The Knowledge Map of the Evolution and Research Frontiers of the Bibliometrics [J]. Journal of Library Science in China, 2010, 36(05): 60-68. (in Chinese)

[5] Chen Yue, Chen Chaomei, Liu Zeyuan, etc., The methodology function of Cite Space mapping knowledge domains [J]. Studies in Science of Science, 2015, 33(02): 242-253. (in Chinese)

[6] Deng G, Li L, Song Y. Provincial water use efficiency measurement and factor analysis in China: Based on SBM-DEA model [J]. Ecological Indicators, 2016, 69: 12-18.

[7] Zhang C, Liu H, Bressers H T A, et al. Productivity growth and environmental regulations - accounting for undesirable outputs: Analysis of China's thirty provincial regions using the Malmquist–Luenberger index [J]. Ecological Economics, 2011, 70(12): 2369-2379.

[8] Le N T, Thinh N A, Ha N T V, et al. Measuring water resource use efficiency of the Dong Nai River Basin (Vietnam): an application of the two-stage data envelopment analysis (DEA) [J]. Environment, Development and Sustainability, 2022, 24(10): 12427-12445.

[9] Kamal A, H F E, Andrew K, et al. Governance of water supply systems in the Palestinian Territories: A data envelopment analysis approach to the management of water resources [J]. Journal of environmental management, 2008, 87(1): 80-94.

[10] SUN B, YANG X. Analysis of Water Resources Utilization Efficiency in Jilin Province Based on DEA Method [J]. DEStech Transactions on Computer Science and Engineering, 2019.

[11] Hu J, Wang S, Yeh F. Total-factor water efficiency of regions in China [J]. Resources Policy, 2006, 31(4): 217-230.

[12] Manjunatha A V, Speelman S, Chandrakanth M G, et al. Impact of groundwater markets in India on water use efficiency: A data envelopment analysis approach [J]. Journal of Environmental Management, 2011, 92(11): 2924-2929.

[13] Yilmaz B, Yurdusev M A, Harmancioglu N B. The Assessment of Irrigation Efficiency in Buyuk Menderes Basin [J]. Water Resources Management, 2009, 23(6): 1081-1095.

[14] Zhao J, Wang Y, Zhang X, et al. Industrial and Agricultural Water Use Efficiency and Influencing Factors in the Process of Urbanization in the Middle and Lower Reaches of the Yellow River Basin, China [J]. Land, 2022, 11(8): 1248.

[15] Liu K, Yang G, Yang D. Investigating industrial water-use efficiency in China's mainland: An improved SBM-DEA model [J]. Journal of Environmental Management, 2020, 270: 110859.

[16] Tupper H C, Resende M. Efficiency and regulatory issues in the Brazilian water and sewage sector: an empirical study [J]. Utilities Policy, 2003, 12(1): 29-40.

[17] Byrnes, J., Crase, et al. The relative economic efficiency of urban water utilities in regional New South Wales and Victoria [J]. Resource and energy economics, 2010, 32(3): 439-455.

[18] Liu Y, Sun C, Xu S. Eco-Efficiency Assessment of Water Systems in China [J]. Water Resources Management, 2013, 27(14): 4927-4939.

[19] Cetrulo T B, Ferreira D F C, Marques R C, et al. Water utilities performance analysis in developing countries: On an adequate model for universal access [J]. Journal of

Environmental Management, 2020, 268(C): 110662.

[20] Amar O, Amin S A, Sara Z, et al. A DEA cross-efficiency inclusive methodology for assessing water quality: A Composite Water Quality Index [J]. Journal of Hydrology, 2022, 612(PA).

[21] Song M, Wang R, Zeng X. Water resources utilization efficiency and influence factors under environmental restrictions [J]. Journal of Cleaner Production, 2018, 184: 611-621.

[22] Guofeng W, Jiancheng C, Feng W, et al. An integrated analysis of agricultural water-use efficiency: A case study in the Heihe River Basin in Northwest China [J]. Physics and Chemistry of the Earth, 2015, 89-90.

[23] Shi T, Zhang X, Du H, et al. Urban water resource utilization efficiency in China [J]. Chinese Geographical Science, 2015, 25(6): 684-697.

[24] Veettil P C, Speelman S, Huylenbroeck G. Estimating the Impact of Water Pricing on Water Use Efficiency in Semi-arid Cropping System: An Application of Probabilistically Constrained Nonparametric Efficiency Analysis [J]. Water Resources Management, 2013, 27(1): 55-73.

[25] Storto C L. Measuring the efficiency of the urban integrated water service by parallel network DEA: The case of Italy [J]. Journal of Cleaner Production, 2020, 276: 123170.

[26] Maria M, Alexandros M. Benchmarking the efficiency of water and sewerage companies: Application of the stochastic non-parametric envelopment of data (stoned) method [J]. Expert Systems with Applications, 2021, 186: 155711.