Official Journal of the World Water Council
Water Policy

Water Policy Vol 24 No 12, 1859 doi: 10.2166/wp.2022.108

A quantitative evaluation of water resource management policies in China based on the PMC index model

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ABSTRACT

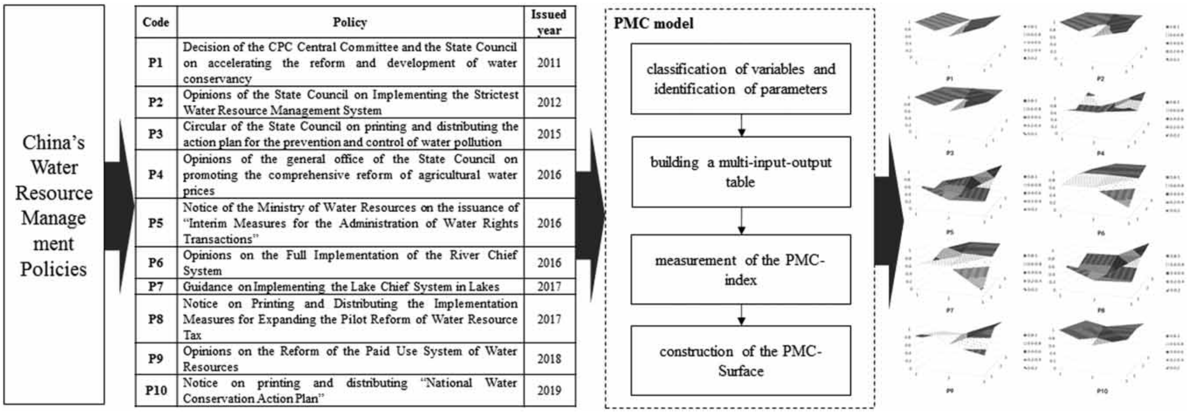
Water policies play a critical role in good water governance and sustainable water development. The evaluation of water policies helps improve the quality of water policy systems and water governance. This study quantitatively evaluated water resource management policies through the policy modeling consistency (PMC) index model and a text-mining method based on national water resource management policy texts produced from 2011 to 2019. This study constructed an evaluation index system based on the water resource management policy's high-frequency words, including 9 first-level variables and 43 second-level variables; furthermore, it compared and analyzed key water resource policies based on the PMC index and PMC surface. The results showed that China's water resource management policies are generally applicable, but it needs to be improved. China's water resource management policies are reasonable in terms of policy nature, policy function, policy priority, and function level, and need to be further improved in terms of policy prescriptions, incentive constraints, policy fields, policy evaluations, and policy priorities. This study thus provided a scientific basis for the optimization of water resource management policies and water governance capacities in China.

Key words: China, PMC index, Policy evaluation, Water governance, Water policy, Water resource management

HIGHLIGHTS

- The key water resource management policies in China have been evaluated through the hybrid method that includes PMC model, text mining, and content analysis.
- An evaluation index system has been constructed based on the high-frequency words of policy texts, including 9 first-level variables and 43 second-level variables.
- This study compared and analyzed key water resource policies based on the PMC index and PMC surface.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Water resources are basic natural resources and important drivers of urbanization, economic growth, and sustainable development. Water security, water governance, and sustainable water governance are important challenges for China and the world (Empinotti *et al.*, 2019). The economic growth and urban development in China are hampered by poor allocation, limited water sources and huge populations, uneven spatial and temporal distributions of water resources, and serious water pollution (Wang *et al.*, 2018). Water policies play a critical role in good water governance and sustainable water development. Countries worldwide have formulated many policies for promoting good water governance (OECD, 2011).

China's water resource management policy has been undergoing constant reformation as water issues have changed (Shen, 2014). In recent decades, the Chinese government has issued many important water resource management policies to strengthen the effective and rational utilization of water resources (Wang *et al.*, 2020a, 2020b). Water resource management policies have focused on water conservancy supervision, public water services, and water resource protection (Dou, 2016). Some popular topics regarding water resource management policies and water governance in China in the current study are as follows. The first is the overall development-related evaluation of water resource management systems and policies (Liu & Speed, 2009; Zhang, 2019). Second, the current study also focused on water resource allocation, water rights (Jia *et al.*, 2016; Dou & Wang, 2017), water system reform (Shen & Wu, 2017; Qian *et al.*, 2020), water economics (Wang *et al.*, 2010a, 2010b; Qin *et al.*, 2012), and comparative studies of water resource management policies (Mushtaq *et al.*, 2008). The third issue involved evaluations of policy implementation effects; this mostly focused on empirical research regarding the river and lake chief system (Wang & Chen, 2020) and river basin management (Chang *et al.*, 2020; He, 2021). The evaluation of water resource management policies helps improve the quality of water policy systems and governance.

Policy evaluation refers to certain functional activities including comprehensively testing, evaluating, judging, and summarizing the entire policy system and stages by using feasible evaluation criteria to improve the effects of policy formulation, decision-making, and implementation (Magro & Wilson, 2019; Mergoni & De Witte, 2022). Problems and risks can be avoided through policy evaluation and analysis. This important part of the policy process guarantees the healthy operation of public policy (Aranguren *et al.*, 2017). Since the 1970s, policy evaluation has gradually become a mainstream issue (Adelle & Weiland, 2012). Currently, policy evaluation research has grown very extensively to involve fields such as industrial policy (Logar, 2010; York & Zhang, 2010), transport policy (Hsieh, 2020), science and technology policy (Martin, 2016; Zhang *et al*., 2017), social security (Claes *et al*., 2017), ecological environment (Mirzaei *et al*., 2019; Jiang *et al*., 2021), financial policy (Mertens *et al*., 2021), health policy (Collins, 2005), and poverty alleviation policy (Meng, 2013). Over the past decade, the practice of policy effect evaluation has mainly focused on empirical studies and has adopted various econometric methods for conducting policy post-evaluation. The PMC index model is one of the novel and popular quantitative policy evaluation methods.

The PMC index model was first proposed by Ruiz Estrada *et al.* (2008) for evaluating policy consistency. The core of this model is the link between the existence and development of things (Ruiz Estrada *et al*., 2008). It holds that policy evaluation models should consider variables broadly; that is, there is no limit to the number of secondary variables (Kuang *et al*., 2020). This model has been widely used for conducting policy evaluations, such as care insurance policy (Peng *et al*., 2020), industry policy (Li *et al*., 2021), green development policy (Dai *et al*., 2021), waste separation management policy (Liu & Liu, 2022), and disaster relief policy (Li & Guo, 2022). However, there are few studies on the application of PMC model in water policy evaluation.

The existing water policy evaluation studies have been mainly qualitative, focusing on macro-level and theoretical analyses. In addition, water resource management policy evaluations in China have mainly focused on the impact of a single policy on industrial development, regional development, and basin development. Few studies have focused on the quantitative evaluation of water resource management policies.

Therefore, one key topic of water resource management policy evaluation is assessing whether the water resource management policy is continuous, scientific, and targeted. Does policy implementation achieve the expected goal? Is the policy process manageable and rational? To address this topic, this study attempts to quantitatively evaluate water resource management policies in China and analyze potential directions for improving water resource management policies by using multiple indexes and dimensions. This study adopts an integrated approach including text mining, content analysis, and the construction of the PMC index model; furthermore, it selects 10 representative water resource management policies issued from 2011 to 2019 as the research object. The contribution of this study is twofold. On the one hand, this study contributes toward enriching the global knowledge body of water policy evaluation. On the other hand, this study provides a concrete and operational basis for improving water resource management policies in China.

The remainder of this paper is organized as follows. The next section reviews the theoretical background of this study; it is followed by a section describing the study's utilized methods and materials. The fourth section provides descriptive analyses and discusses the study's empirical results. The final section concludes this paper.

2. METHODS AND MATERIALS

There are four basic steps in the application of the PMC index model: classification of variables and identification of parameters, building a multi-input–output table, measurement of the PMC index, and construction of the PMC surface (Ruiz Estrada *et al.* 2008).

2.1. Classification of variables and identification of parameters

To evaluate the water resource management policy in a targeted manner, this research uses the POST-CM6 software in order to perform word segmentation, analyze word frequency statistics, and perform invalid verb elimination on 20 selected national water resource management policies from 2000 to 2019 to obtain effective high-frequency words (Table 1).

Using the summary of high-frequency words in water resource-related policies and the combinations of the characteristics of water resource management policies and the PMC index model, this study constructed a

Table 1 | High-frequency words.

No.	Keyword	Word frequency	No.	Keyword	Word frequency
1	Environment	465	16	People's Government	197
2	Department	454	17	Reform	184
3	Water resource	448	18	Administration	164
4	Protect	381	19	Utilize	161
5	Water conservation	368	20	Discharge	160
6	Administration	367	21	Plan	156
7	Water use	336	22	Standard	154
8	Executive director	326	23	Ecology	153
9	Facilities	281	24	Prevention and cure	151
10	Handle	275	25	Region	151
11	Sewage	274	26	Lake	149
12	Water intake	267	27	Agriculture	145
13	Development	208	28	Water supply	144
14	Water pollution	207	29	Measures	144
15	Drainage	206	30	Mechanism	133

secondary variable and the evaluation index system. The index system included secondary variables, including 9 primary variables and 43 secondary variables. The primary variables were policy nature (X1), policy prescription (X2), incentive constraint (X3), policy field (X4), policy evaluation (X5), policy function (X6), policy priority (X7), function level (X8), and policy openness (X9), as shown in Table 2. In the process of setting up the index system, policy nature (X1) examines whether the relevant policy has the functions of predictability, description, supervision, planning, guidance, and support in order to govern and protect water resources. Policy prescription (X2) examines the timeliness characteristics of the policy in terms of water governance, which are divided into long, medium, and short terms. The incentive constraint (X3) examines the rationality of government incentive constraint measures for all levels, enterprises, and the general public during policy implementation, including subsidies, government investment, technical talent support, incentives for administrative examination and approval, rewards, fee penalties, and financial subsidies. The policy field (X4) examines the scope of possible action at the following levels: economy, ecological environment, technology, and social governance. Policy evaluation (X5) evaluates resource management policy based on four aspects: clear goals, detailed planning, scientific programs, and sustainable development. Policy function (X6) determines the function based on the reality of the water resource management policy, including water-saving management and control, ecological protection, resource allocation, normative guidance, and institutional constraints. Policy priority (X7) covers water-saving, water resource taxes and fees, ecological governance, industrial water use, assessment, supervision, and management, technical support, partitioning of multiple subjects, and construction of water conservancy facilities. The function level (X8) examines the scope of policy implementation, which is classified based on countries, regions, industries, enterprises, and the general public. Policy openness (X9) inspects whether the policy is open without a subordinate variable. This study adopted the binary system. When the policy conformed to the secondary variable, the value was considered as 1. When the policy did not match the secondary variable, the value was considered 0. Policy openness (X9) had two secondary variables. When the policy was open, the value was considered as 1. When the policy was not open, the value was considered 0.

Table 2 | The variables and coding for the water resource management policy PMC model[a].

Primary variables	Code	Secondary variables	Code	Secondary variables
X_1 policy nature	$X_{1:1}$	Prediction	$X_{1:2}$	Description
	$X_{1:3}$	Regulation	$X_{1:4}$	Planning
	$X_{1:5}$	Guidance	$X_{1:6}$	Support
X_2 policy prescription[b]	$X_{2:1}$	Long term	$X_{2:2}$	Medium term
	$X_{2:3}$	Short term		
X_3 incentive constraint	$X_{3:1}$	Subsidy	$X_{3:2}$	Government investment
	$X_{3:3}$	Technical talent support	$X_{3:4}$	Constraint of administrative examination and approval
	$X_{3:5}$	Reward	$X_{3:6}$	Fee penalty
	$X_{3:7}$	Regulation	$X_{3:8}$	Financial subsidy
X_4 policy field	$X_{4:1}$	Economy[c]	$X_{4:2}$	Ecological environment
	$X_{4:3}$	Technology	$X_{4:4}$	Social governance
X_5 policy evaluation	$X_{5:1}$	Clear goal	$X_{5:2}$	Detailed planning
	$X_{5:3}$	Scientific program	$X_{5:4}$	Sustainable development
X_6 policy function	$X_{6:1}$	Water-saving management and control	$X_{6:2}$	Ecological protection
	$X_{6:3}$	Resource allocation	$X_{6:4}$	Normative guidance
	$X_{6:5}$	Institutional constraint		
X_7 policy priority	$X_{7:1}$	Water-saving	$X_{7:2}$	Water resource taxes and fees
	$X_{7:3}$	Ecological governance	$X_{7:4}$	Industrial water use
	$X_{7:5}$	Assessment and supervision and management	$X_{7:6}$	Technical support
	$X_{7:7}$	Participation of multiple subjects	$X_{7:8}$	Construction of water conservancy facilities
X_8 function level	$X_{8:1}$	Nation	$X_{8:2}$	Area
	$X_{8:3}$	Industry	$X_{8:4}$	Enterprise
	$X_{8:5}$	Society		
X_9 policy openness				

[a]The variable was selected based on the Ruiz Estrada *et al*. (2008) and high-frequency words in water resource management policy.
[b]The policy timeliness of secondary variables are as follows: X2: 1 long-term > 10 years, X2: 2 medium-term > 5 years, X2: 3 short-term < 3 years.
[c]The economic field in the policy field refers to economic and financial activities, such as flood insurance, water conservancy-related credit capital investment, bond issuance, financial leasing, and other specific economic activities.

2.2. Building a multi-input–output table

The multi-input–output table can store large amounts of data to measure any single variable and build a scientifically sound data-analysis framework. Building a multi-input–output table is the basis for calculating the primary variables, which include multiple primary and subordinate secondary variables. Each primary variable contained multiple secondary variables without limits. However, each secondary variable had the same importance and was assigned an equal weight in no particular order. This study's established multi-input–output table is shown in Table 2.

2.3. Measurement of the PMC index

A typical PMC index measurement involves the following four steps. First, the secondary variables established in the PMC index model of the water resource management policy are inserted into the multi-input–output table. To ensure the objectivity of text quantification, the secondary variable is assigned according to text mining, as shown in Equations (1) and (2), which obeys the distribution of [0,1]. However, the primary variable value of the water resource management policy is calculated according to Equation (3). Finally, the policy primary index values are summed to obtain the PMC index, as shown in Equation (4).

$$X \sim N[0, 1] \tag{1}$$

$$X = \{XR{:}[0 \sim 1]\} \tag{2}$$

$$X_t\left(\sum_{j=1}^{n} \frac{X_{tj}}{T(X_{tj})}\right) \quad t = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, \ldots\ldots, \infty \tag{3}$$

$t =$ primary variable; $j =$ secondary variable;

$$\mathrm{PMC} = \begin{pmatrix} X_1\left(\sum_{i=1}^{6} \frac{X_{1i}}{6}\right) + X_2\left(\sum_{j=1}^{3} \frac{X_{2j}}{3}\right) + X_3\left(\sum_{K=1}^{8} \frac{X_{3k}}{8}\right) \\ + X_4\left(\sum_{l=1}^{4} \frac{X_{4l}}{4}\right) + X_5\left(\sum_{m=1}^{4} \frac{X_{5m}}{4}\right) + X_6\left(\sum_{n=1}^{5} \frac{X_{6n}}{5}\right) \\ + X_7\left(\sum_{o=1}^{8} \frac{X_{7o}}{8}\right) + X_8\left(\sum_{P=1}^{5} \frac{X_{8p}}{5}\right) + X_9 \end{pmatrix} \tag{4}$$

2.4. Construction of the PMC surface

The PMC surface displays the PMC index in the form of an image. The policy quantitative evaluation results can be intuitively displayed in detail by displaying the advantages and disadvantages of each policy indicator in a multi-dimensional coordinate system. The construction of the PMC matrix forms the basis of the formation of the PMC surface. This matrix contains all the set primary variables. This study focused on nine primary variables, which formed a third-order square matrix that satisfied the symmetry of the matrix and the balance of the PMC surface. The PMC matrix values were derived using Equation (5).

$$\text{PMC surface} = \begin{pmatrix} X_1 & X_2 & X_3 \\ X_4 & X_5 & X_6 \\ X_7 & X_8 & X_9 \end{pmatrix} \tag{5}$$

2.5. Data sources

It can be said that China's water resource management policy has gone through the following stages. The first stage, the natural water use stage, mainly involved dealing with drought and flooding disasters. During the decentralized management stage, which was adopted from the mid-1900s to the 1980s, water resource management underwent a development stage involving water supply-oriented management. From the 1980s to the end of the 1990s, water resource management underwent a stage of rapid development, focusing on the water management route and the water resource sustainable development route. From the beginning of the 21st century to the present period, water resource management has been undergoing a formative stage, which promotes harmony between people and water. It was during this stage that the 'Three Red Lines,' the construction of a water-saving society, and the construction of the national water network were proposed. The No. 1 Central Document for 2011 proposed that the reform and development of water conservancy should be accelerated. Therefore, 2011 was selected as the time node, and the key water resource management policies of 2011–2019 were selected as the research objects. The specific directories are listed in Table 3.

Table 3 | Summary of key water resource management policies from 2011 to 2019.

Code	Name of policy	Issued year
P1	*Decision of the CPC Central Committee and the State Council on accelerating the reform and development of water conservancy*	2011
P2	*Opinions of the State Council on Implementing the Strictest Water Resource Management System*	2012
P3	*Circular of the State Council on printing and distributing the action plan for the prevention and control of water pollution*	2015
P4	*Opinions of the general office of the State Council on promoting the comprehensive reform of agricultural water prices*	2016
P5	*Notice of the Ministry of Water Resources on the issuance of 'Interim Measures for the Administration of Water Rights Transactions'*	2016
P6	*Opinions on the Full Implementation of the River Chief System*	2016
P7	*Guidance on Implementing the Lake Chief System in Lakes*	2017
P8	*Notice on Printing and Distributing the Implementation Measures for Expanding the Pilot Reform of Water Resource Tax*	2017
P9	*Opinions on the Reform of the Paid Use System of Water Resources*	2018
P10	*Notice on printing and distributing 'National Water Conservation Action Plan'*	2019

3. RESULTS AND DISCUSSION

3.1. The PMC index for water resource management policies

The PMC index for the water resource management policy was calculated as shown in Table 4. Ten water resource management policies were selected in a chronological order. The PMC index provides a further understanding of policy evaluation trends, as shown in Figure 1. To facilitate the analysis of the graph, the sink index

Table 4 | PMC indexes of various water resource management policies.

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Mean
X1 policy nature	1	1	1	0.67	0.67	0.67	0.67	0.67	0.83	1	0.82
X2 policy prescription	0.67	0.67	1	0.67	0.33	0.67	0.67	0.33	0.67	0.67	0.64
X3 incentive constraint	1	0.88	1	0.88	0.38	0.25	0.13	0.38	0.5	0.88	0.63
X4 policy field	1	1	1	0.5	0.25	0.75	0.5	0.25	0.75	1	0.7
X5 policy evaluation	0.75	0.75	0.75	0.5	0.25	0.75	0.75	0.25	0.75	1	0.65
X6 policy function	1	1	1	0.6	0.8	0.8	0.8	0.8	1	1	0.88
X7 policy priority	1	1	1	0.88	0.38	0.75	0.75	0.63	0.63	1	0.8
X8 function level	0.8	1	1	0.6	0.6	1	1	0.6	0.6	0.8	0.8
X9 policy openness	1	1	1	1	1	1	1	1	1	1	1
Score	8.22	8.3	8.75	6.3	4.66	6.64	6.27	4.91	6.73	8.35	6.88
Sink index	1.78	1.7	1.25	3.7	5.34	3.36	3.73	5.09	3.27	1.65	–
Rank	4	3	1	7	10	6	8	9	5	2	–

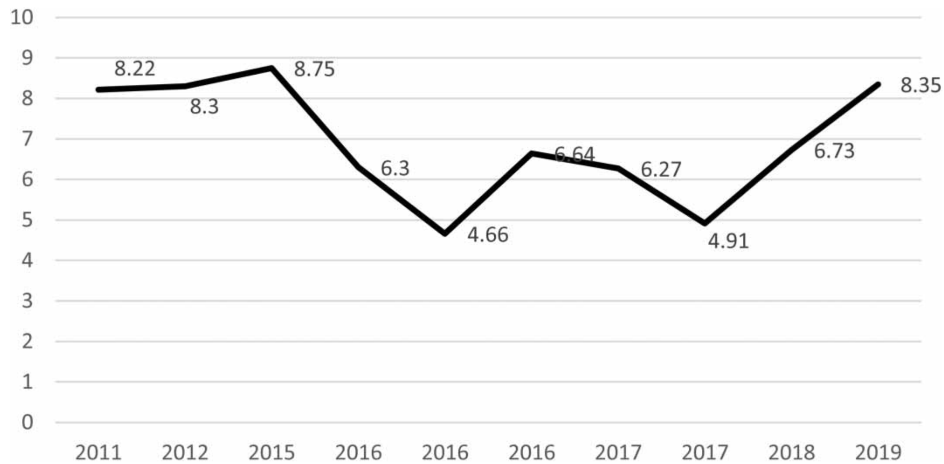


Fig. 1 | The PMC score for 10 water resource management policies from 2011 to 2019.

concept was used to describe the degree of difference between a policy and an 'ideal policy.' This study used the ratio of the PMC index scores and the sink index scores to calculate the sink degree of the 10 policies. The specific sink degrees are shown in Figure 2.

As shown in Figure 1, the PMC scores of the 10 water resource management policies from 2011 to 2019 generally showed a trend of first decreasing and then increasing. In 2011, the state accelerated the development and reform of water conservation policies. The PMC indices of policies P1, P2, and P3 are 8.22, 8.3, and 8.75, respectively, which reflect the comprehensiveness and completeness of the policies. In 2016, three special water conservancy development policies were issued in response to certain problems in the water resource

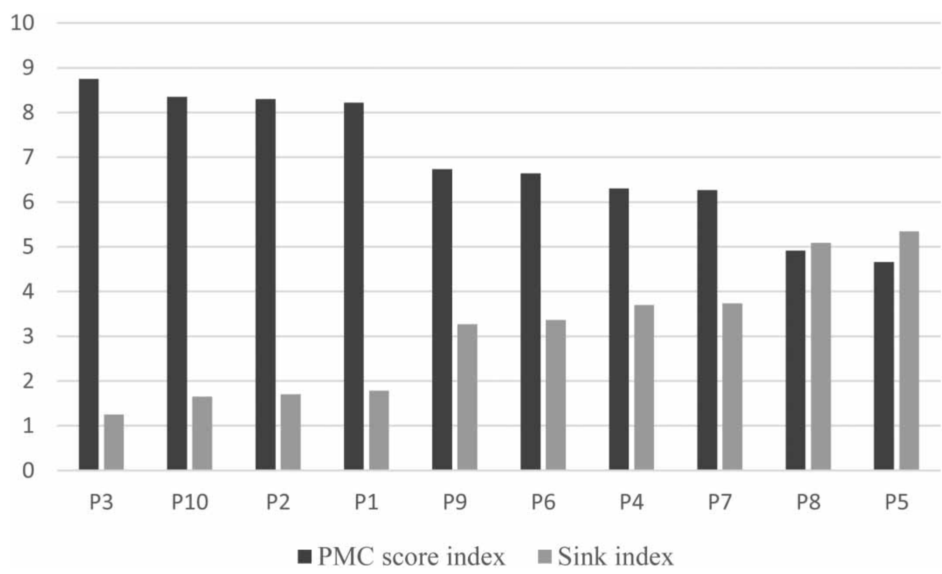


Fig. 2 | The PMC index and the sink index of 10 water resource management policies.

management process. The PMC score showed a downward trend, reflecting the updating and improvement of the policy implementation process. Since 2017, the PMC policy score has shown a steady upward trend.

Ten water resource management policies established from 2011 to 2019 were graded based on policy scoring criteria proposed by Ruiz Estrada *et al.* (2008). Because nine primary variables were established in this study, the optimal policy included nine points. The policy scoring criteria were adjusted slightly. The policy scoring standard proposed by Ruiz Estrada was divided into four categories: perfect (10–9), excellent (8.99–7), acceptable (6.99–5), and poor (4.99–0). This study classified the scores for the water resource management policies into three grades: excellent [9–8], good [7.99–6], and acceptable [5.99–4]. These results are presented in Table 5. Four water resource management policies (40%) reached the 'excellent' level: P1, P2, P3, and P10. The water resource management policies at the 'good level' included P4, P6, P7, and P9, accounting for 40%. P3 had the highest score, thus indicating that this policy had the strongest rationality and completeness. The lowest score was achieved by P5, but this was still at an acceptable level.

3.2. The PMC surface scores of water resource management policies

The PMC index has a strong advantage in that the constructed PMC surface can evaluate and judge policies' advantages and disadvantages using various perspectives. Figure 3 shows the PMC surfaces for various water resource management policies. The relevant policy's perfection degree is evaluated based on the visualization effect of the PMC surface. By evaluating the sink index of the water resource management policy and comparing the scores of each primary variable with its average value, the differences between each water resource management system and the 'ideal policy' can be analyzed; this, in turn, can be further used to judge any policy weaknesses.

The policy's primary variable score was compared with its mean. After removing P4, P5, and P7, the remaining policy scores for the X5 policy evaluation were found to be above average. For X2 policy prescriptions, policies P1, P2, P3, P4, P6, P7, P9, and P10 all had above average scores, thus accounting for 80%. Therefore, the water resource management policy involves sustainable development, which is more suitable for long-term development. For the X8 function level, the policy scores for P1, P2, P3, P6, P7, and P10 were all higher than the average, accounting for 60%. In the X4 policy field, policies P1, P2, P3, P6, P9, and P10 all had above average scores. Additionally, policies P1, P2, P3, and P10 had a score of 1. In the X6 policy function, policies P1, P2, P3, P9, and P10 (accounting for 50%) had a score of 1, which is higher than the average. In the X7 policy priority, the scores of policies P1, P2, P3, P4, and P10 were all higher than the average score, accounting for 50%; this reflects the importance of policy function and policy prioritization in the process of water governance. The policy scores in this dimension were relatively different, and this indicated that some policies still had a relatively large room for improvement. Because the water resource management policies have all been publicly released, the scores of policy openness (X9) were all full marks. To sum up, policy nature (X1), incentive constraint

Table 5 | Classification of water resource management policies.

Policy	PMC index	Level	Policy	PMC index	Level
P1	8.22	Excellent	P6	6.64	Good
P2	8.3	Excellent	P7	6.27	Good
P3	8.75	Excellent	P8	4.91	Acceptable
P4	6.3	Good	P9	6.73	Good
P5	4.66	Acceptable	P10	8.35	Excellent

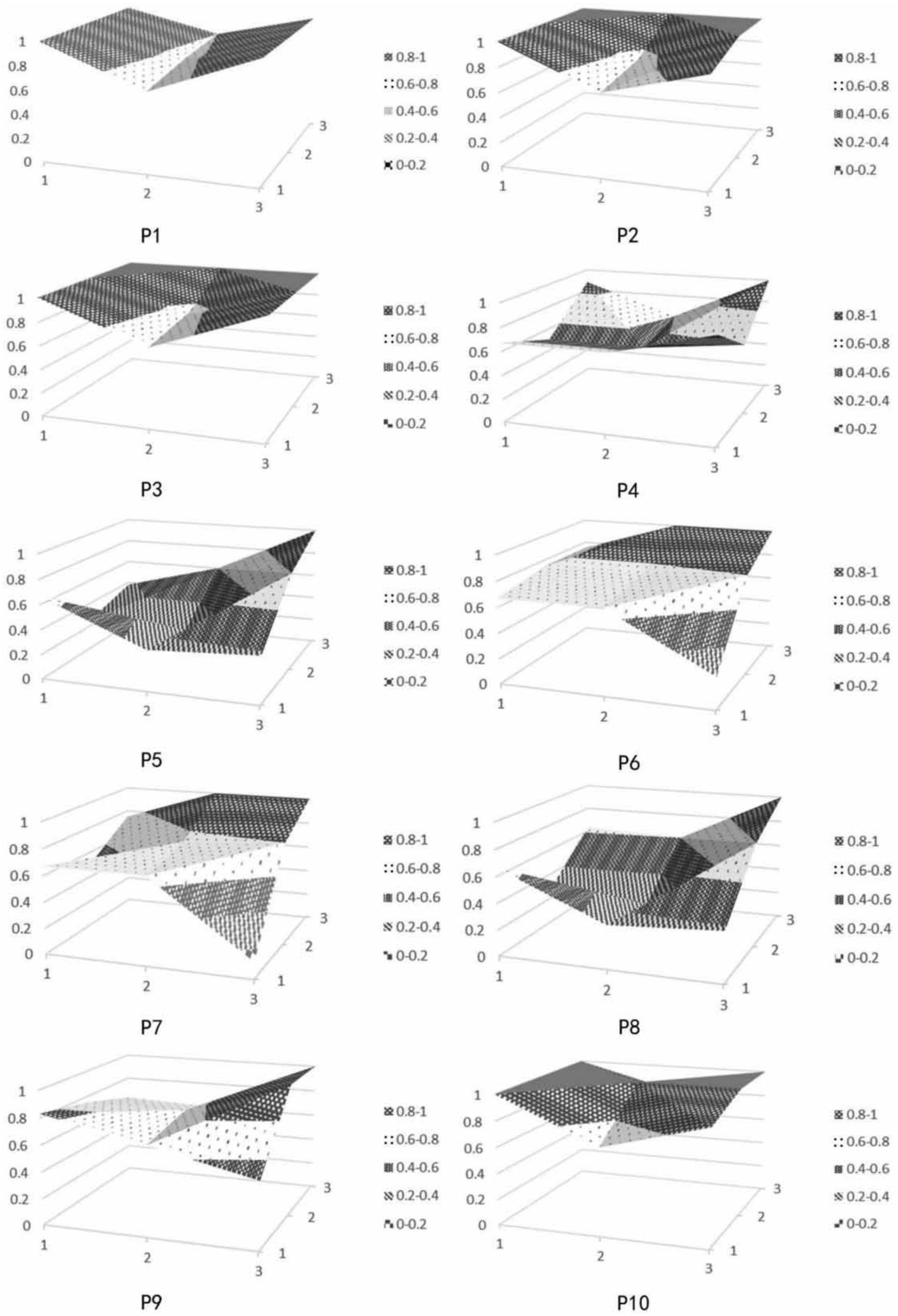


Fig. 3 | PMC surface of water resource management policies.

(X3), policy function (X6), policy priority (X7) – four primary variables – had five policies whose scores were lower than the average value; this indicated that, for this dimension policy, the difference was large. The average values of policy nature (X1), policy function (X6), policy priority (X7), and function level (X8) were 0.82, 0.88, 0.8, and 0.8, respectively, with a relatively high PMC score, thus indicating that the formulation of China's water resource management policy has focused more on indicators such as X1, X6, X7, and X8.

Based on the sink index scores of each policy in Table 4, the sink degree was divided into three levels: a high sink degree index [6, 4.1], an acceptable sink degree index [4, 2.5], and a low sink degree index [2.4, 0.1]. Among them, P5 and P7 had a high sink degree index, while P4, P6, P7, and P9 had an acceptable sink degree index, and P1, P2, P3, and P10 had a low sink degree index. Figure 2 shows that the PMC and sink degree indices are inversely proportional. The larger the PMC index, the weaker the sink degree. The sink degrees of the 10 water resource management policies were ranked as P5–P8–P7–P4–P6–P9–P1–P2–P10–P3 from strong to weak. Based on the sink degree, the PMC surface clearly showed the sink trend for each variable of the water resource management policy and intuitively reflected the weak link of the primary variable. Among the 10 water resource management policies, P5 had the strongest sink degree, with a sink index of 5.34. Compared with the ideal policy, the sink degree index of P5 with regard to policy prescription (X2), incentive constraint (X3), policy field (X4), policy evaluation (X5), and policy priority (X7) was all higher than 0.5; this is an unacceptable sink index. The relevant details are shown in Figure 4.

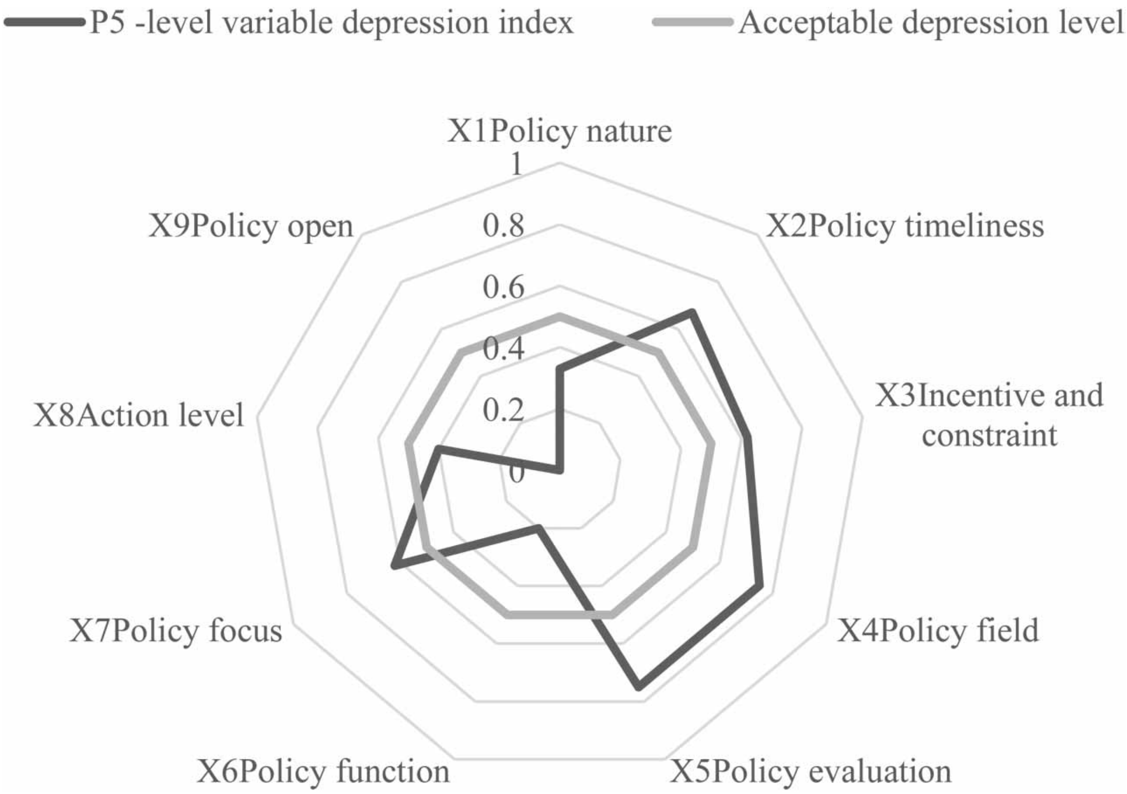


Fig. 4 | Sink degree index of the P5 primary variable.

3.3. Comparative analysis of water resource policies

For a clearer policy comparison, this study selected policies P3 and P5 with the highest and lowest PMC index scores, respectively. P3 is the *Circular of the State Council on printing and distributing the Action Plan for the Prevention and Control of Water Pollution* issued in 2015, and P5 is the *Notice of the Ministry of Water Resources on the issuance of 'Interim Measures for the Administration of Water Rights Transactions'* in 2016. Using the PMC index of the water resource management policy, this study obtained the score comparison map of P3 and P5 (Figure 5). The scores of policy P5 were found to be lower than P3 and the mean score. The differences in scores for policy function and function level were relatively small, and the scores for policy openness were consistent. Therefore, X1 policy nature, X2 policy prescription, X3 incentive constraint, X4 policy field, X5 policy evaluation, and X7 policy priority were selected for analysis. Table 6 shows the multi-input–output tables for P3 and P5. Specific segmentation data can provide a more intuitive and accurate understanding of the differences between policies.

In terms of the X1 policy nature of the policy text, P5 had a score of 0.67, compared to the full score of P3. P5 had serious deficiencies in (X1:1) predictability and (X1:4) planning. Policy P5 was a provisional regulation regarding water rights trading, which did not have long-term target planning and forecasting for performance results compared with Policy P3. The main content of P5 aimed to improve the water rights system, implement water rights trading, cultivate the water rights trading market, and strengthen administrative supervision. Simply put, P5 focused on the confirmation and transaction of water rights, and it did not clearly state any future goals or outcomes. Policy P3 was concerned with water pollution prevention and control. Based on text analysis, it could be said that P3 was a comprehensive and forward-looking guiding policy. In terms of predictability and planning, P3 clearly proposed performance standards for ensuring water environment quality, including 30 index values, such as urban sewage treatment phased targets, water consumption per 10,000 yuan of GDP (m^3), and water-saving irrigation area (100 million mu).

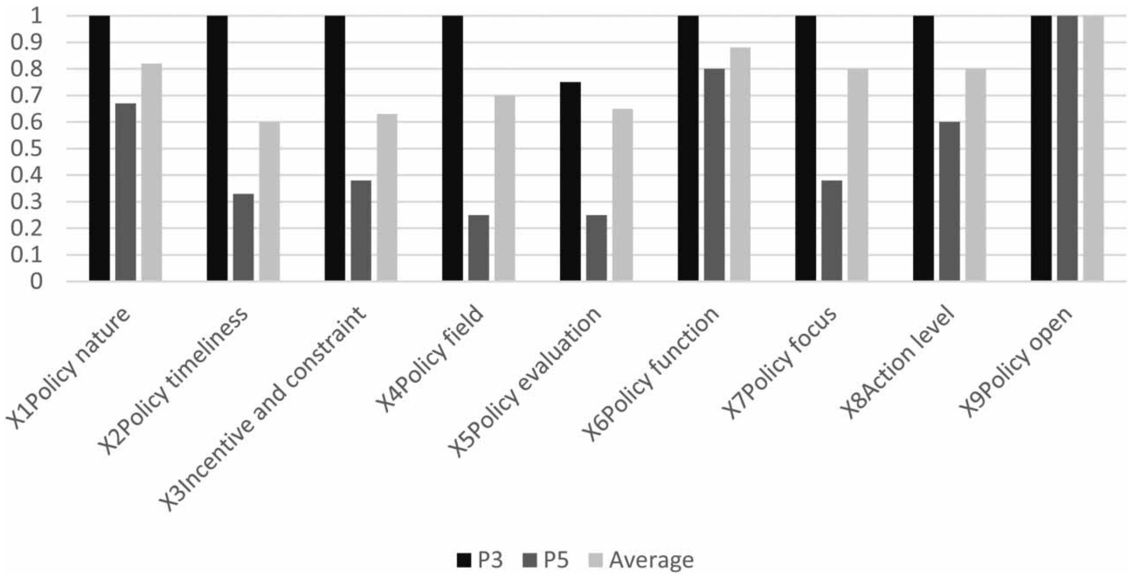


Fig. 5 | Comparison of the scores of P3 and P5.

Table 6 | Multi-input–output of P3 and P5.

X1	X1:1	X1:2	X1:3	X1:4	X1:5	X1:6		
P3	1	1	1	1	1	1		
P5	0	1	1	0	1	1		
X2	X2:1	X2:2	X2:3					
P3	1	1	1					
P5	0	0	1					
X3	X3:1	X3:2	X3:3	X3:4	X3:5	X3:6	X3:7	X3:8
P3	1	1	1	1	1	1	1	1
P5	0	0	0	1	0	1	1	0
X4	X4:1	X4:2	X4:3	X4:4				
P3	1	1	1	1				
P5	0	0	0	1				
X5	X5:1	X5:2	X5:3	X5:4				
P3	1	0	1	1				
P5	0	0	1	0				
X6	X6:1	X6:2	X6:3	X6:4	X6:5			
P3	1	1	1	1	1			
P5	1	0	1	1	1			
X7	X7:1	X7:2	X7:3	X7:4	X7:5	X7:6	X7:7	X7:8
P3	1	1	1	1	1	1	1	1
P5	1	0	0	1	1	0	0	0
X8	X8:1	X8:2	X8:3	X8:4	X8:5			
P3	1	1	1	1	1			
P5	1	0	1	1	0			

For each of the scores in the X2 policy prescription, P5 scored lower than P3 in both X2:1 long term and X2:2 medium term. As a provisional regulation for water rights trading, the policy effectiveness of P5 had limitations. For instance, it did not clearly state medium- and long-term development plans and lacked sustainability. In contrast, Policy P3 was detailed with regard to the long, medium, and short terms. The short-term goal was to control the leakage rate of the national public water supply system pipe network and reduce it to within 12% by 2017. The medium-term goal was to achieve a national water-saving irrigation area of approximately 700 million mu by 2020. The long-term goal was to achieve more than 75% of relevant water quality requirements in key river basins by 2030.

In terms of the X3 incentive constraint, P5 had a score of 0.38, whereas P3 had a full score. P5 had no provisions for X3:1 subsidy, X3:2 government investment, X3:3 talent technology, X3:5 reward, and X3:8 financial subsidy, which only involved X3:4 administrative examinations and approvals, X3:6 fee penalties, and X3:7 regulations. The means adopted by P3 were more diversified, including administrative control, legal constraints, and economic regulation (e.g., government investment, subsidies, talent technical support, rewards, and financial subsidies). In terms of the X4 policy field, P3 involved the economic field, ecological environment, technology, and social governance, whereas P5 only involved social governance.

For X7 policy priority, Table 6 shows that there were five items with P5 scores lower than P3, including X7:2 water resource taxes and fees, X7:3 ecological governance, X7:6 technical support, X7:7 participation of multiple subjects, and X7:8 foundation facility. P5 was a highly targeted policy that only involved the special issue of water rights trading; this subject was narrower than those discussed by Policy P3. As a comprehensive policy, P3 covered a wider and more detailed area. Using water resource taxes and fees as an example, P3 stipulated and improved urban sewage treatment fees and sewage charges, charging policies, and management methods for the collection of water resource fees. Furthermore, P3 repeatedly mentioned ecological governance and the promotion of demonstration and applicable technologies while emphasizing the co-governance of multiple subjects in order to give full play to the market role in resource allocation and to mobilize the enthusiasm of enterprises and the public.

3.4. Further discussion

The aforementioned findings show that China's water policy formulation is, first, generally reasonable and satisfies the criteria for policy completeness, innovation, rationality, and sustainable development. The other eight key water policies chosen are good and excellent, in addition to *Notice of the Ministry of Water Resources on the issuance of 'Interim Measures for the Administration of Water Rights Transactions'* and *Notice on Printing and Distributing the Implementation Measures for Expanding the Pilot Reform of Water Resource Tax*. However, the sink index of the water policies indicates that China's water resource management policy still needs to be improved. Second, several market-oriented policies connected to the management of water resources, such as institutional reforms of water rights transactions, water resource tax, paid use of water resources, and scored poorly. Furthermore, in addition to openness, each water policy is deficient in terms of other indexes. However, the appraisal of many metrics varies substantially between various water policies. The difference is dynamic and diverse. Policies for managing water resources are influenced by various values, goals, and resources at different times. At the same time, it demonstrates the primary goals and areas of attention of water resource management policies are continuously changing, growing, and improving through time. The analysis of two typical water resource management policies – water pollution control and water rights transactions – in comparison reveals that, on the one hand, sustainable development has a significant influence on these policies, and the government places more emphasis on the creation and implementation of water pollution control policies related to environmental sustainability. On the other hand, water resource management policies ought to have clear goals, long-term planning, and quantifiable requirements.

The scientific and rational water policy is being optimized as China's water governance capacity and governance system are being enhanced, which could be one of the causes of this phenomenon. Second, water resources play a significant role in limiting China's urbanization and economic growth. As a result, over the past 10 years, the Chinese government has given the management of water resources and the development of water policies an increasing amount of attention. Moreover, China has long relied on an administrative system to manage its water resources, making the need for a market-oriented reform even more pressing. However, implementing a market-oriented reform has been incredibly challenging, and regulations connected to it still require improvement. At last, the optimization of China's water resource management policy must focus on the aspects of policy nature, incentive constraints, policy functions, and policy priorities. The order of importance was policy nature – incentive constraints – policy functions – policy priorities. However, this order is not absolute and should be adjusted according to the background related to the time, practical needs, and regional characteristics.

4. CONCLUSION

Through content analysis, text mining, and the PMC index model of water policies, this study quantitatively evaluated 10 national-level water resource management policies from 2011 to 2019. First, it constructed secondary variables for policy analysis and evaluation, including 9 primary indexes and 43 secondary indexes, which were used for accurately analyzing the strengths and weaknesses of policy links. The water resource management policy was quantitatively analyzed by plotting the PMC surface and sink degrees. The following conclusions were drawn: first, the PMC scores of the 10 water resource management policies generally showed a trend of first decreasing and then increasing. Among them, policies P1, P2, P3, and P10 had excellent grades; policies P4, P6, P7, and P9 had good grades; and P5 and P8 had acceptable grades. Therefore, China's water resource management policy was found to have general applicability, with a relatively large room for improvement. Second, the PMC index of the 10 policies had obvious advantages with regard to indicators such as policy nature, policy function, policy priority, and function level. However, it was relatively weak with regard to indicators such as policy prescriptions, incentive constraints, policy fields, and policy evaluations. Third, the gap between P5 and the ideal policy was the largest with regard to the sink degree index of the primary variable. Its sink degree index was 5.34, which was at a high sink level. The policy scores were higher in the PMC index of policy nature, policy function, and function level but lower in the PMC indices of policy prescriptions, incentive constraints, policy fields, policy evaluations, and policy priorities. The improvement of this policy should be based on the actual situation, with the abovementioned four dimensions as key breakthroughs. Finally, the sink degree of the 10 policies was ranked as P5–P8–P7–P4–P6–P9–P1–P2–P10–P3 from strong to weak. These results were consistent with those of the PMC surface. Therefore, it is necessary to improve the weak links of the primary variables.

This research could not only enrich the global knowledge body of water governance but also provide a scientific basis for the optimization of water resource management policies in China. However, this study had some limitations. For instance, the selection, extension, and completeness of the selected variables required further improvement. Furthermore, the universality and diversity of the PMC index should be investigated in order to further expand the application scope of the PMC model.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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First received 19 May 2022; accepted in revised form 14 November 2022. Available online 23 November 2022