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Policy Optimization for Hainan Tropical Rainforest National Park Based on Quantitative Comparison of Regional Policies of Free Trade Port Areas

*Hong Wang and Yaxue Zeng**

School of Tourism, Hainan University, Haikou, China

Hainan Tropical Rainforest National Park, as one of the first national parks established in China, should make full use of the gold brand of "Hainan Free Trade Port" and "National Park," rely on the advantages and potential of system integration and innovation, draw on the experience of national parks in mature free trade ports (FTPs), and build a perfect national park policy system. This study introduces the PMC index model, constructs a national park policy evaluation index system, and conducts a systematic comparative analysis of 14 representative national park policies in Hainan rainforest, Hong Kong, and Singapore. The study finds that the policy of Hainan Tropical Rainforest National Park is not effective enough, the policy in social and cultural fields is relatively lacking, the policy content needs to be further strengthened, and the policy functions need to be improved, *etc*., and puts forward corresponding suggestions for optimization.

Keywords: Hainan tropical rainforest national park, National park policies, Free trade port areas, PMC index model, Quantitative comparison of policies

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***Correspondence:**
Yaxue Zeng
zengyaxue1996@163.com

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INTRODUCTION

National parks are widely recognized around the world as an effective way of ecological environment protection and resources utilization (Tang, 2020). The world's first national park: Yellowstone National Park in the United States has a history of more than 140 years (Ferretti-Gallon et al., 2021). In comparison, the development of national parks in China started relatively late. In 2013, the establishment of a national park system was first proposed (Liu et al., 2020), which initiated the exploration of the construction of national parks with Chinese characteristics. The tropical rain forest in Hainan is the most concentrated, best-preserved, primitive tropical rain forest with the largest contiguous area in China, which is a typical representation with global significance. In 2018, at the 30th anniversary of the establishment of special economic zone in Hainan, China proposed that Hainan should take active steps to advance the work of building the national pilot zone, to construct national parks especially the tropical rainforest park. In 2019, Hainan Tropical Rainforest National Park launched a pilot program. After 2 years of construction and development, on 12 October 2021, China announced the official establishment of China's first national parks at the 15th Conference of the Parties to the Convention on Biological Diversity, and Hainan's tropical rainforest was among them, which marked a new starting point for the construction of Hainan's ecological civilization.

Hainan Tropical Rain Forest National Park has been highly regarded by the government and academia from its inception to its official establishment. Hainan gibbon is the most concerned

flagship species. Scholars pay attention to the protection of gibbon from many aspects, such as how to protect habitat and food supply (Du et al., 2020; Fan et al., 2021); As an important embodiment of the social value of national parks, scholars have studied the spatial relationship between land use types and ecosystem service value, ecosystem management and other contents (Zhai et al., 2018; Li et al., 2022); As a national park with the shortest time from pilot to formal, the successful experience of Hainan tropical rain forest is worth discussing. Therefore, some scholars summarized the construction experience during the pilot period from the aspects of management systems, ecological protection and natural resource heritage management (Zong, 2020). Generally speaking, the existing researches have keenly explored the protection of species, the exertion of ecosystem service value and management systems in the development of tropical rain forest in Hainan, but have not focused on the policy system.The role of the government in the rapid development of Hainan's tropical rainforest is directly presented in the form of policies. Both the research and development and application of technology as well as the innovation of management system need to be guided and standardized by laws and regulations, normative documents and other policies. It is worth noting that Hainan tropical rain forest is the only national park in China set up under the background of the construction of free trade port. China clearly demands that the construction of Hainan free trade port should aim at the highest level of openness in the world, and strive to achieve a major breakthrough in policy and institutional system.As mature free trade ports, Hong Kong and Singapore have a long history of National Park Development and achieved remarkable results.Therefore, this study chose the national park policies of Hong Kong and Singapore to compare with Hainan tropical rain forest national park policies.

Specifically, Singapore passed the "Parks and Trees Act" and the "National Parks Act" in 1975 and 1990, respectively, to legislate for the protection of natural resources and to establish the legal status of the management of the National Parks Board. Subsequently, a series of policies on biodiversity development, greening, and overall planning have been issued. As a result, national parks are regarded as economic, social and environmental assets, which help to enhance national identity, beautify the image of destinations, improve people's health and welfare, and promote the country's sustainable development and prosperity (Henderson, 2013). To avoid the impact of rapid urban development on agriculture, Hong Kong introduced the Western concept of national parks in the 1970s. However, due to area limitations, it developed into a country park. In 1976, Hong Kong promulgated the Country Parks Ordinance, which established a good legal environment for the development of country parks. Subsequent planning policies and biodiversity conservation policies have accelerated the development of country parks. So far, 24 country parks have been built in Hong Kong, which are good places for recreation, leisure and scientific research for people from all walks of life in Hong Kong (Chan et al., 2018), and are becoming a new landscape for Hong Kong's tourism industry. After more than 50 years of development, the rich experience accumulated by Singapore and Hong Kong in policy formulation is worth learning from Hainan.

In view of this, this study attempts to use the policy modeling consistency (PMC) index model to systematically compare and evaluate the national park policies of Hainan, Singapore, and Hong Kong through the construction of the national park policy evaluation framework, with a view to providing methodological reference for the formulation and optimization of policies for Hainan Tropical Rainforest National Park in the context of the construction of the free trade port areas.

Literature Review

National Park Policy

The National Park policy mainly refers to the corresponding administrative management, policy guidance and organizational guarantee issued by the government for the management of natural and cultural resources, biodiversity protection, community development and other contents. The existing researches focus on the National Park policy could be divided into the following three categories. First, the formulation of National Park policy. Walpole et al. took Komodo National Park in Indonesia as an example to study how nature reserves should price tourism policies. The research showed that moderate and layered increase in admission fees should be considered in policy-making process, which may improve tourists' willingness to pay (Walpole et al., 2001); Kubo et al. (2019) pointed out that when formulating policies for the protection and governance of national parks, the strategic combination of policy tools could improve the effectiveness of policies; Bright et al. (1993) pointed out that in the formulation of National Park combustion control policy, managers needed to strengthen communication with the public and promote public participation in policy formulation. Second, the implementation of the National Park policy. Tan et al. (2021) proved that the joint implementation of concession policy and forest land transfer policy in Nanshan National Park could increase the total income of farmers; Peng et al. (2020) creatively studied the impact of the implementation of two important management strategies of ecosystem service payment and relocation on wetland ecosystem. Third, the problems of the National Park policy. Ahebwa et al. studied the income sharing policy of the National Park in Bwindi, Uganda. The study found that the problems of inequality and benefit dispersion needed to be solved in the income sharing policy (Ahebwa et al., 2012); Phuc (2009) took the protection policy of Ba Vi National Park as an example and pointed out that the main reason for the failure of the protection policy was to emphasize biodiversity protection at the expense of local livelihoods. It could be seen that the existing research focused on the formulation, implementation and role of a single National Park policy. Therefore, the purpose and guidance of National Park policy research was strong, which was to promote the ecological protection and economic development of national parks. However, the existing researches were still lack of systematic and structured evaluation of National Park policy. Policy evaluation was an important part in the process of policy development. It played an irreplaceable role in correcting the defects of existing policies and ensuring the realization of policy objectives.

Policy Evaluation Methods

Policy evaluation aims to systematically analyze the effect and value of the entire policy system through scientific evaluation criteria and methods, so as to provide a basis for decision-making for the formulation of new policies. The current academic research on policy evaluation is generally classified into two categories: qualitative and quantitative research. Qualitative research mainly includes text mining method (Kang et al., 2021), qualitative comparative analysis (Warren et al., 2013), and expert survey method (Jennings, 2020), *etc*.; and quantitative research mainly involves the introduction of mathematics, fuzzy mathematics, operational research, econometrics, *etc*., resulting in fuzzy comprehensive evaluation (Li et al., 2018), data envelopment method (Mohd Chachuli et al., 2021), difference-in-differences model (Lin et al., 2021) and other quantitative evaluation methods. In addition, with the development of computers, software such as STATA and R have provided powerful tools for the estimation and inspection of policy evaluations, and enhanced the scientificity and rationality of the evaluation results. Although all of the above evaluation methods have their own advantages, the reality that China's national parks are developed in a short time and the quantity of policy texts is small makes it difficult to adapt to evaluation methods that require a large sample size and data quality. The Policy Modeling Consistency Index was proposed by Estrada based on the Omnia-Mobilis hypothesis. It overcomes the more stringent requirements of existing methods in terms of sample size and data quality, and develops an overall comprehensive evaluation of the policy text by considering all possible and relevant variables (Ruiz Estrada, 2010). This method combines text mining with mathematical tools to find out the features of the policy evaluation system of national parks by text mining, and makes calculation with rigorous mathematical methods, thereby improving the scientific nature of policy evaluation. In addition, PMC index and PMC surface diagram can visualize the calculation results, and then clearly and intuitively see the advantages and disadvantages of each policy text (Ruiz Estrada, 2011). At present, academia has carried out research on land policy, energy policy, artificial intelligence policy and other fields based on the PMC index model. The details are as follows. Kuang, B et al. established the cultivated land protection policy evaluation system by using the PMC index model to evaluate China's eight policies. The research found that efforts should be strengthened to optimize the structure of agrarian policy tools, the coordination of policy issuing institutions and the completeness of policy content (Kuang et al., 2020). Yang, T et al. used the PMC index model to analyze 11 policy texts of China's new energy vehicle industry by examining the scores of indicators at various levels in order to identify policy shortcomings and make corresponding suggestions for optimization (Yang et al., 2021); Mao Zijun et al. conducted a comparative analysis of AI policies in five countries, including China, the United States, and Japan combined with policy tools-innovation value chain and PMC index model, to provide reference for the subsequent formulation and improvement of China's AI policies (Mao and Hong, 2020).

Hainan Tropical Rainforest National Park was born, constructed and grown under the background of the Free Trade Port. Since its establishment as a pilot, the government has issued a series of policies to guide the development of Hainan Tropical Rainforest National Park. It is urgent to evaluate the existing policies and continuously optimize and improve the relevant policy system to effectively serve the construction of Hainan Tropical Rainforest National Park. As mature free trade ports in the world, Hong Kong and Singapore have advanced practical experience in the formulation and implementation of national park policies, which are worth of Hainan to learn from Hainan. Based on the PMC index model, this paper has a strong theoretical and empirical basis for comparative research on the national park policies of Hainan, Hong Kong, and Singapore.

MATERIALS AND METHODS

Sample Selection

The research object of this paper is the national park policies of Hainan, Singapore and Hong Kong. The policies for Hainan National Park are mainly derived from the National Forestry and Grassland Administration, the Standing Committee of the Hainan Provincial People's Congress, the Department of Natural Resources and Planning of Hainan Province, *etc*.; Singapore's national park policies are mainly derived from the Singapore Regulations Online website (https://sso.agc.gov.sg/), the official website of the National Parks Bureau (https://www.nparks.gov.sg/), *etc*.; Hong Kong's national park policies are mainly derived from the electronic version of the Hong Kong Laws website (https://www.elegislation.gov.hk/), the official website of the Planning Department of the Government of Hong Kong Special Administrative Region (https://www.pland.gov.hk/pland_en/tech_doc/hkpsg/index.html), and the official website of the Environment Bureau of the Government of Hong Kong Special Administrative Region (https://www.enb.gov.hk/en/top.html) *etc*. This study follows the following principles in document filtering: 1) Policy documents are from public documents officially released by the government; 2) The time is from the establishment of national parks in three regions to now; 3) The contents of policies related to national parks are clear and direct; 4) The selected policy documents are the most representative and significant policies in the National Park policy system of Hainan, Hong Kong and Singapore; 5) The general or rough contents related to national parks in the policy text shall be eliminated. Finally, 14 representative policy texts are selected for analysis. The policy name, issuing organization, and release time are shown in **Table 1**:

Construction of the PMC Index Model

As a policy measurement model, the PMC index model is used to construct variables with the same weight, which can not only analyze the overall internal consistency of a certain policy, but also intuitively reflect the advantages and disadvantages of any specific policy, so as to scientifically quantify policies. The construction and analysis of the PMC

TABLE 1 | Samples of national park policies in Hainan, Hong Kong, and Singapore.

No.	Name of policy	Issuing organizations	Release time
1	Pilot Scheme of Hainan Tropical Rainforest National Park System	National Park Administration	2019
2	Rules of Hainan Tropical Rainforest National Park (Trial)	Standing Committee of Hainan Provincial People's Congress	2020
3	Franchise Management Measures for Hainan Tropical Rainforest National Park	Standing Committee of Hainan Provincial People's Congress	2020
4	Guiding Opinions on the Implementation of Land Ownership Replacement for Ecological Relocation of Hainan Tropical Rainforest National Park	Department of Natural Resources and Planning of Hainan Province	2020
5	Measures for the Management of Natural Resources Assets of Hainan Tropical Rainforest National Park (trial)	Department of Natural Resources and Planning of Hainan Province	2020
6	Planning of Hainan Tropical Rainforest National Park (2019–2025)	National Forestry and Grassland Administration	2020
7	Country Parks Ordinance	Legislative Council of the Hong Kong Special Administrative Region of the People's Republic of the China	1976
8	Hong Kong Planning Standards and Guidelines	Planning Department The Government of the Hong Kong Special Administrative Region	2019 (revised edition)
9	Hong Kong Biodiversity Strategy and Action Plan (2016–2021)	Environment Bureau The Government of the Hong Kong Special Administrative Region	2016
10	Parks And Trees Act	Legislation Division of the Attorney-General's Chambers of Singapore	2006 (revised edition)
11	National Parks Board Act	Legislation Division of The Attorney-General's Chambers of Singapore	2012 (revised edition)
12	Singapore's National Biodiversity Strategy and Action Plan	National Parks Board of Singapore	2009
13	Singapore Index on Cities' Biodiversity	National Parks Board of Singapore	2010
14	Singapore Green Plan 2030	Ministry of Education Ministry of National Development Ministry of Sustainability and the Environment Ministry of Transport Ministry of Trade and Industry	2021

index model is divided into the following four steps: one is variable classification and parameter confirmation; the second is the establishment of multi-input–output table; the third is the calculation of the PMC index; and the fourth is the construction of a PMC surface chart. Since this study is a comparison of the national park policy systems in Hainan, Hong Kong, and Singapore, rather than a comparison of individual policies, the calculation of the mean values of the first-level indicators of national park policies in the three regions is added after the calculation of the individual policy PMC index is completed.

Variable Classification and Confirmation

After selecting the policy texts, this study makes a preliminary analysis of the selected 14 National Park policy texts by using the text mining software ROSTCM 6.0. High-frequency word statistics and high-frequency word meaning network so as to provide the basis for the index evaluation system and quantitative evaluation of National Park policy below.

High frequency word statistics. 1) Import 14 policy texts into the software for word segmentation. 2) The high-frequency words of the policy text after word segmentation are counted to filter out the words that are not related to the characteristics of the National Park. 3) Select the top 40 high-frequency words from high to low, as shown in **Table 2**.

High frequency word meaning network. Based on the word frequency analysis, and then according to the high-frequency word co-occurrence matrix, we have drawn a semantic network diagram of the high-frequency words of national park policy, as shown in **Figure 1**. In the semantic network diagram, high-frequency words are represented in the form of nodes. If a node has more connections with other nodes, its centrality is stronger, indicating that the node is more important.

The semantic network diagram can visualize the relationship between high-frequency words. By combing the relationship between high-frequency words, it can lay a foundation for the following construction of the evaluation variables of National Park policy indicators. As shown in the figure, the keywords "National Park," "ecology," "protection" and "nature" have high centrality. As the central theme of policy design, "National Park" has the highest frequency and the widest radiation, so it is placed in the center of the figure. In addition, other words such as "resources," "institution," "country" and "value" appear less frequently and are marginalized, but these words can not be ignored, which indicated that the national park policy focused on the development of diversification. Specifically, the links between high-frequency words such as "natural resources," "facilities,"

TABLE 2 | Statistics of high frequency words in National Park policy.

Serial number	High-frequency words	Frequency	Serial number	High-frequency words	Frequency
1	national park	1034	21	social	174
2	protection	997	22	natural resources	172
3	ecology	741	23	countries	171
4	tropical rainforest	593	24	education	165
5	nature	555	25	engineering	163
6	development	445	26	science	158
7	Hainan	429	27	biology	154
8	biodiversity	407	28	value	154
9	government	394	29	assessment	148
10	facilities	394	30	Singapore	143
11	park	385	31	assets	141
12	environment	345	32	participation	139
13	recreation	287	33	franchise	139
14	construction	278	34	standard	138
15	region	253	35	animal	122
16	resources	224	36	regulations	122
17	community	198	37	economic	116
18	building	194	38	data	114
19	impact	179	39	public	112
20	establishment	179	40	green	106

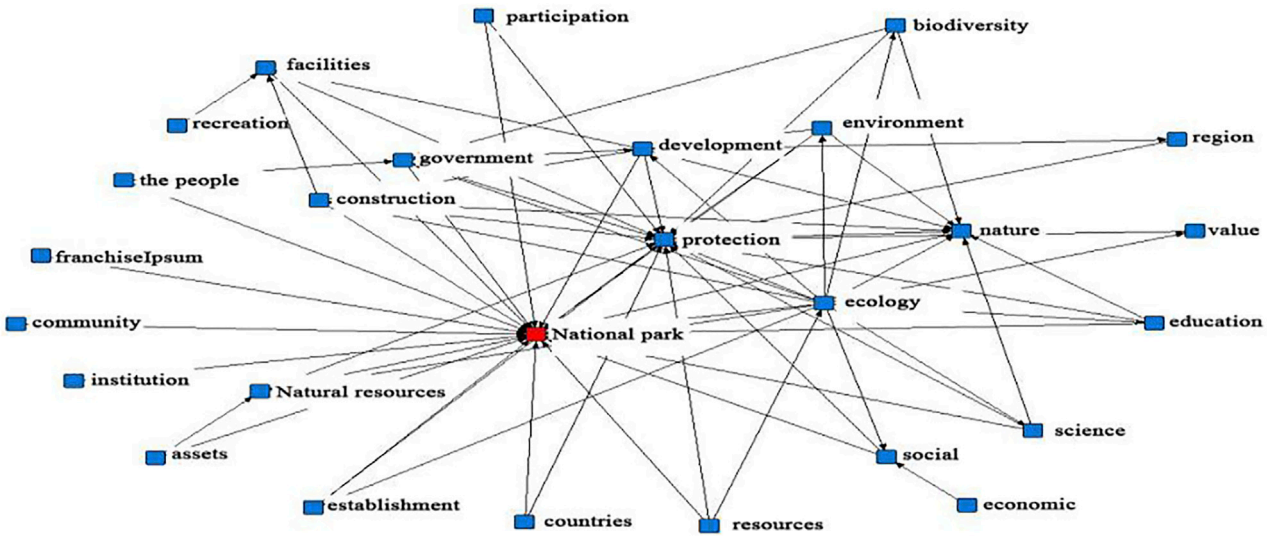

FIGURE 1 | Network diagram of the semantics of high-frequency words.

"franchise" and "biodiversity" reflect the contents covered by the National Park policy; The relationship between high-frequency words such as "society," "economy" and "environment" mainly reflects the fields involved in National Park policy; The relationship between high-frequency words such as "education," "science," "ecology" and "protection" can be summarized as the function of National Park policy.

The setting of index evaluation variables is directly related to the and effectiveness of the policy evaluation results. The setting of variables should follow the "Omnia Mobilis" hypothesis as much as possible to ensure the systematicness and comprehensiveness of the evaluation variables as much as possible. Based on Estrada's criteria for setting variables and the existing literature on the setting of policy evaluation indicators, we set up the primary variables such as policy nature (X_1), timeliness of policy (X_2), policy effectiveness (X_3), policy evaluation (X6) and policy perspective (X_7). According to the statistics of high-frequency words of policy text and the network semantic map, the section adjusted and set the primary variables policy domain (X_4), policy content (X_5), functions of policy (X_8) and policy benefit goal (X_9), and set its secondary variables combined with the characteristics of policy text in three regions and relevant research referring to existing literature. Finally, this paper

TABLE 3 | Variable settings of the quantitative evaluation system of national park policies.

Primary variables	No. of secondary variables	Name of secondary variables	Source or basis
Policy nature X_1	$X_{1:1}$	Forecast	Modified based on Ruiz Estrada (2011)
	$X_{1:2}$	Regulation	
	$X_{1:3}$	Description	
	$X_{1:4}$	Recommendations	
	$X_{1:5}$	Guidance	
Timeliness of policy X_2	$X_{2:1}$	Short term (1–3 years)	Modified based on Kuang et al. (2020)
	$X_{2:2}$	Mid-term (3–5 years)	
	$X_{2:3}$	Long term (more than 5 years)	
Policy effectiveness X_3	$X_{3:1}$	Laws	Modified based on Kuang et al. (2020)
	$X_{3:2}$	Regulations	
	$X_{3:3}$	Rules	
	$X_{3:4}$	Normative documents	
Policy domain X_4	$X_{4:1}$	Economic	Modified based on Ruiz Estrada (2011); High-frequency word statistics; Semantic network diagram
	$X_{4:2}$	Social culture	
	$X_{4:3}$	Environment	
	$X_{4:4}$	Science and technology	
Policy content X_5	$X_{5:1}$	Planning of the park system	Modified based on the work of He Yan and Yin Lina (2015) (He and Yin, 2015); High-frequency word statistics; Semantic network diagram
	$X_{5:2}$	Land Conservation	
	$X_{5:3}$	Natural resource management	
	$X_{5:4}$	Cultural resource management	
	$X_{5:5}$	Interpretation and education	
	$X_{5:6}$	Park Facilities	
	$X_{5:7}$	Commercial tourist services	
	$X_{5:8}$	Biodiversity conservation	
Policy evaluation X_6	$X_{6:1}$	Well-founded	Modified based on Yang et al. (2021)
	$X_{6:2}$	Scientific program	
	$X_{6:3}$	Clear objectives	
	$X_{6:4}$	Detailed planning	
	$X_{6:5}$	Clearly defined rights and responsibilities	
Policy perspective X_7	$X_{7:1}$	Macro	Modified based on the work of Mao and Mei (2020)
	$X_{7:2}$	Micro	
Functions of policy X_8	$X_{8:1}$	Ecological protection	Modified based on the work of Liu Jiajing and Bai Gefeng (2019) (Liu and Bai, 2019); High-frequency word statistics; Semantic network diagram
	$X_{8:2}$	Recreation services	
	$X_{8:3}$	Scientific research	
	$X_{8:4}$	Environmental education	
	$X_{8:5}$	Community development	
Policy benefit goal X_9	$X_{9:1}$	Environmental protection benefits	High-frequency word statistics; Semantic network diagram
	$X_{9:2}$	Conservation of natural and cultural heritages	
	$X_{9:3}$	Public welfare benefits for all	
	$X_{9:4}$	Sustainable development benefits	

TABLE 4 | Multi- input-output indicators of national park policies.

Primary Variables	Secondary Variables
X_1	$X_{1:1}$, $X_{1:2}$, $X_{1:3}$, $X_{1:4}$, $X_{1:5}$
X_2	$X_{2:1}$, $X_{2:2}$, $X_{2:3}$
X_3	$X_{3:1}$, $X_{3:2}$, $X_{3:3}$, $X_{3:4}$
X_4	$X_{4:1}$, $X_{4:2}$, $X_{4:3}$, $X_{4:4}$
X_5	$X_{5:1}$, $X_{5:2}$, $X_{5:3}$, $X_{5:4}$, $X_{5:5}$, $X_{5:6}$, $X_{5:7}$, $X_{5:8}$
X_6	$X_{6:1}$, $X_{6:2}$, $X_{6:3}$, $X_{6:4}$, $X_{6:5}$
X_7	$X_{7:1}$, $X_{7:2}$
X_8	$X_{8:1}$, $X_{8:2}$, $X_{8:3}$, $X_{8:4}$, $X_{8:5}$
X_9	$X_{9:1}$, $X_{9:2}$, $X_{9:3}$, $X_{9:4}$

established the PMC index evaluation system of national park policy, including nine primary variables and 40 secondary variables. The specific variable design is shown in **Table 3**.

Build a Multi-Input–Output Table

The multi-input–output table is essentially a data analysis framework that can measure any single variable by storing a large amount of data, as shown in **Table 4**. These single variables reflect the evolution of a certain policy from a general perspective, and therefore are used to evaluate different types of variables. In the multi-region input–output table, each primary variable has the same weight as that of the secondary variable. The primary variable can be set with multiple secondary variables according to its characteristics, and the importance is in no order. The construction of multi-input-output table is conducive to a comprehensive and systematic measurement of national park policies.

Calculation of PMC Index

The calculation method of PMC can be summarized in the following four steps.

Step 1: Input the constructed primary and secondary indicator variables into a multi-input-output table.

Step 2: Referring to the description of the secondary variables and the content of the policy text to be evaluated, the policy is assigned 1 point for relevant content and 0 points for non-relevant content. The values of the secondary variables obey the [0,1] distribution as shown in (**Eqs 1**, **2**);

Step 3: Calculate the values of the primary variables according to **Eq. 3**;

Step 4: Calculate the PMC index of the policy to be evaluated according to

Eq. 4, i.e., the values of the primary variables are summed up.

The specific calculation formula is shown below.

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

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

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

(where t is a primary variable and j is a secondary variable)

$$PMC = \left\{\begin{array}{l} X_1\left(\sum_{i=1}^{5}\frac{X_{1i}}{5}\right) + X_2\left(\sum_{j=1}^{3}\frac{X_{2j}}{3}\right) + X_3\left(\sum_{k=1}^{4}\frac{X_{3k}}{4}\right) \\ X_4\left(\sum_{t=1}^{4}\frac{X_{4t}}{4}\right) + X_5\left(\sum_{m=1}^{8}\frac{X_{5m}}{8}\right) + X_6\left(\sum_{n=1}^{5}\frac{X_{6n}}{5}\right) \\ X_7\left(\sum_{v=1}^{2}\frac{X_{7v}}{2}\right) + X_8\left(\sum_{p=1}^{5}\frac{X_{8p}}{5}\right) + X_9\left(\sum_{r=1}^{4}\frac{X_{9r}}{4}\right) \end{array}\right\} \tag{4}$$

Nine primary variables are set in this paper, so the PMC index score of national park policies ranges from 0 to 9. Combining the evaluation criteria of Estrada and others, it is specifically divided into the following four levels: A PMC index score of 8–9 is an excellent policy; a PMC index score of 6–7.99 is a good policy; a PMC index score of 4–5.99 is an acceptable policy; and a PMC index score of 0–3.99 is a low policy.

Comparison of the Mean Value of the First-Level Variables of the Policies

By calculating the average of the values of the primary variables, the strengths and weaknesses of the policy system design can be analyzed as a whole. In this study, the PMC indices of Hainan, Hong Kong, and Singapore national park policies were averaged to explore the strengths and weaknesses of the three regions in the design of the national park policy system by comparing the mean values, effectively avoiding the problem of over generalization in the analysis of individual policies.

PMC Surface Construction

The PMC surface can present the PMC index in a visual and graphical format, and intuitively show the strengths and weaknesses of the policy samples in various dimensions. The PMC surface chart is generally a concave and convex three-dimensional chart, with the shades of color representing different levels of scores. The convex part indicates that the evaluation index corresponding to the policy sample has a high score, and the concave part indicates that the evaluation index corresponding to the policy sample has a low score. The establishment of the PMC matrix is a prerequisite for drawing the PMC surface. Considering the perfect symmetry of the PMC surface, a 3*3 matrix is constructed. The specific calculation formula is as follows:

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

RESULTS

Analysis of PMC Index Model Results of National Park Policies in Hainan, Hong Kong and Singapore

According to the calculation steps of the PMC index, this study assigns values to the secondary variables in the index system by text semantic mining. By comparing the previous formulas, the scores of the first-level index and the PMC index are calculated, and the final calculation results are shown in **Table 5**. At the same time, to facilitate the comparison of the advantages and disadvantages of national park policies in the three regions, the mean values of the first-level indicators of national park policies in Hainan, Hong Kong, and Singapore are calculated, as shown in **Table 6**.

Firstly, the average value of the PMC index in the three regions is 6.91, with an overall good performance of the policy level. Among the 14 samples of national park policies in the paper, 12 policies were evaluated with good grades and two with acceptable grades, with no failing policies, indicating that the national park policies in the three regions are reasonable and scientific in their overall planning layout and can provide positive guiding directions for the development of regional national parks in the context of the Free Trade Port Areas. Secondly, according to the PMC index ranking of 14 policy samples, namely, P6>P12>P9>P14>P1>P8>P11>P5 >P10>P2>P13>P7>P3>P4, it can be seen that the national park policies of Singapore and Hong Kong are of higher quality, ranking relatively high, and policies with acceptable level are mainly concentrated in the tropical rain forests of Hainan; thirdly, the average ranking of the PMC index of national park policies in Singapore, Hong Kong, and Hainan shows that Singapore > Hong Kong > Hainan, indicating that Singapore's national park policy is the best among the three regions.

TABLE 5 | PMC Index of national park policies in Hainan, Hong Kong and Singapore.

Policy No.	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	PMC index	Ranking	Policy level
P1	1	1	0.25	0.75	1	0.8	0.5	1	1	7.30	5	Good
P2	0.8	0.33	0.25	0.75	1	1	0.5	1	1	6.63	10	Good
P3	0.6	0.67	0.25	0.5	0.88	1	0.5	0.8	0.5	5.69	13	Acceptable
P4	0.6	1	0.25	0.5	0.38	1	0.5	0.2	1	5.43	14	Acceptable
P5	0.8	0.67	0.25	0.75	0.88	1	0.5	1	1	6.84	8	Good
P6	1	0.67	0.25	1	1	1	1	1	1	7.92	1	Good
P7	0.8	0.67	0.25	0.5	0.75	1	1	0.6	1	6.57	12	Good
P8	0.8	0.67	0.25	0.5	0.88	1	1	1	1	7.09	6	Good
P9	1	0.67	0.25	1	0.75	1	1	1	1	7.67	3	Good
P10	0.8	0.67	0.25	0.5	0.75	1	1	0.8	1	6.77	9	Good
P11	0.8	0.67	0.25	0.5	0.88	1	1	0.8	1	6.89	7	Good
P12	1	1	0.25	1	0.75	0.8	1	1	1	7.80	2	Good
P13	1	0.67	0.25	0.75	0.63	0.8	0.5	1	1	6.59	11	Good
P14	1	0.67	0.25	1	0.88	0.8	1	1	1	7.59	4	Good
Mean	—	—	—	—	—	—	—	—	—	6.91	—	Good

TABLE 6 | Mean values of first-level indicators of national park policies in Hainan, Hong Kong and Singapore.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	PMC mean value
Hainan	0.80	0.72	0.25	0.71	0.85	0.97	0.58	0.83	0.92	6.63
Hong Kong	0.87	0.67	0.25	0.67	0.79	1.00	1.00	0.87	1.00	7.11
Singapore	0.92	0.73	0.25	0.75	0.78	0.88	0.90	0.92	1.00	7.13

TABLE 7 | Hainan Tropical Rainforest National Park policies lack predictive, descriptive strategic design.

			P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
X_7	$X_{7:1}$	Macro	1	0	0	0	0	1	1	1	1	1	1	1	0	1
	$X_{7:2}$	Micro	0	1	1	1	1	1	1	1	1	1	1	1	1	1
Average score of policy perspective					Hainan 0.58					Hong Kong 1				Singapore 0.9		
X_1	$X_{1:1}$	Predict	1	0	0	0	0	1	0	0	1	0	0	1	1	1
	$X_{1:2}$	Regulation	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{1:3}$	Description	1	1	0	0	1	1	1	1	1	1	1	1	1	1
	$X_{1:4}$	Suggestion	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	$X_{1:5}$	Guidance	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Average score of Policy nature					Hainan 0.80					Hong Kong 0.87				Singapore 0.92		

Problems of Hainan Tropical Rainforest National Park Policy

Some Policies of Hainan Tropical Rainforest National Park Lack Predictive, Descriptive Strategic Design

In the comparison of various policy quantitative indicators, Hainan has the largest gap with Hong Kong and Singapore in terms of policy nature (X1) and policy perspective (X7). Specifically, as shown in **Table 7**, In Hainan's policies involving ecological relocation, concessions, and natural resource asset management, there is no description of the underlying concepts and importance of the relevant areas, nor is there any phased setting of goals for the relevant areas of work. Relatively speaking, the policy texts of Hong Kong and Singapore have macro-level designs such as core concept descriptions, forecasts, and strategic goals, in addition to regulations that directly involve specific indicators. Due to the lack of descriptive and predictive macro-strategic design, the incentives and strategic guidance of relevant policies of Hainan National Park are relatively insufficient.

Relatively Low Policy Effectiveness of Hainan Tropical Rainforest National Park

On the variable of policy effectiveness, although the average value of PMC index is the same in the three regions, it can be found from the secondary indicators that the policy of Hainan Tropical Rainforest National Park is mainly composed of regulations and regulatory documents, lacking the support of laws and

TABLE 8 | Relatively low policy effectiveness of Hainan Tropical Rainforest National Park.

X_3		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
$X_{3:1}$	Law	0	0	0	0	0	0	1	0	0	1	1	0	0	0
$X_{3:2}$	Regulation	0	1	1	0	0	0	0	0	0	0	0	0	0	0
$X_{3:3}$	Rules	1	0	0	0	1	0	0	1	0	0	0	0	0	0
$X_{3:4}$	Normative document	0	0	0	1	0	1	0	0	1	0	0	1	1	1
Average score of policy effectiveness				Hainan 0.25					Hong Kong 0.25				Singapore 0.25		

TABLE 9 | Relative lack of policies in the socio-cultural field of Hainan Tropical Rainforest National Park.

X_4		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
$X_{4:1}$	Economy	1	1	1	1	1	1	1	1	1	1	1	1	1	1
$X_{4:2}$	Social culture	0	0	0	0	0	1	0	0	1	0	0	1	1	1
$X_{4:3}$	Environment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
$X_{4:4}$	Technology	1	1	0	0	1	1	0	0	1	0	0	1	0	1
Average score of policy perspective				Hainan 0.71					Hong Kong 0.67				Singapore 0.75		

TABLE 10 | Policy content of Hainan Tropical Rainforest National Park needs further consolidation.

X_5		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
$X_{5:1}$	Park system plan	1	1	1	1	1	1	1	1	1	1	1	1	0	1
$X_{5:2}$	Land conservation	1	1	1	1	1	1	1	1	1	1	1	1	1	1
$X_{5:3}$	Natural resource management	1	1	1	1	1	1	1	1	1	1	1	1	1	1
$X_{5:4}$	Cultural resource management	1	1	1	0	1	1	1	1	0	1	1	0	1	0
$X_{5:5}$	Explanation and education	1	1	1	0	1	1	1	1	1	1	1	1	1	1
$X_{5:6}$	Park facilities	1	1	1	0	1	1	1	1	1	1	1	1	0	1
$X_{5:7}$	Commercial visitor services	1	1	1	0	1	1	0	0	0	0	0	0	0	1
$X_{5:8}$	Biodiversity conservation	1	1	0	0	0	1	0	1	1	0	1	1	1	1
Average score of policy content				Hainan 0.85					Hong Kong 0.79				Singapore 0.78		

regulations, as shown in **Table 8**. In contrast, Singapore and Hong Kong have formulated laws at the beginning of the birth of national parks, providing a good environment for the construction and development of national parks. As the construction of Hainan Free Trade Port continues to advance, the advantages of the system should be given full play to continuously improve the development of laws and regulations to build legal support for the healthy development of Hainan Tropical Rainforest National Park.

Relative Lack of Policies in the Socio-Cultural Field of Hainan Tropical Rainforest National Park

From the comparative analysis of the secondary indicators of policy areas, Hainan Tropical Rainforest National Park policy is more comprehensive in the fields of economy, environment, science and technology, but very little in the field of social-culture, as shown in **Table 9**. In fact, as a human ecological asset, national parks play an irreplaceable role in cultivating national spirit and enhancing people's cultural identity, which is one of the three core functions of national parks. It is the socio-cultural function that Hong Kong and Singapore attach the greatest importance to in the area of national park policy. In Hainan, which is building an ecological demonstration zone, the national park should become an important carrier of China's ecological civilization, but also can become a useful platform for Hainan's special regional culture. The realization of these potentials and functions of the Tropical Rainforest National Park urgently requires the effective improvement of policies in the socio-cultural field of the national park.

Policy Content of Hainan Tropical Rainforest National Park Needs Further Consolidation

In terms of policy content, the average policy PMC index of Hainan Tropical Rainforest National Park ranks first, as shown in **Table 10**. The secondary indicators show that the policy of Hainan Tropical Rainforest National Park covers land protection, natural resource management, and park facilities, *etc*., and is rich and comprehensive in content; however, the flaw lies in the lack of policies for biodiversity protection. Biodiversity protection is the fundamental purpose of China's establishment and construction of national parks. In addition to the black-crowned gibbon, the Hainan tropical rainforest also has

TABLE 11 | Policy functions of Hainan Tropical Rainforest National Park need to be improved.

X_8		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
$X_{8:1}$	Ecological protection	1	1	1	1	1	1	1	1	1	1	1	1	1	1
$X_{8:2}$	Recreation services	1	1	1	0	1	1	1	1	1	1	1	1	1	1
$X_{8:3}$	Scientific research	1	1	0	0	1	1	0	1	1	1	1	1	1	1
$X_{8:4}$	Environmental education	1	1	1	0	1	1	1	1	1	1	1	1	1	1
$X_{8:5}$	Community development	1	1	1	0	1	1	0	1	1	0	0	1	1	1
Average score of policy functions		Hainan 0.83						Hong Kong 0.87				Singapore 0.92			

rare and endangered animals such as Hainan thrush, Hainan elk, and Goniurosaurus bawanglingensis, *etc*., which require a clear, systematic and complete biodiversity protection policy. Singapore and Hong Kong have formulated special protection strategies for biodiversity protection. Hainan should learn from their diverse protection measures and protection practices, and build biodiversity conservation system on the basis of China's biodiversity protection regulations.

Policy Functions of Hainan Tropical Rainforest National Park Need to Be Improved

In terms of policy functions, the policy scores of Hainan National Parks are not far from those of Hong Kong and Singapore, and they are weak in terms of environmental education and community development functions, as shown in **Table 11**.

Environmental education can promote the public's understanding of the value of national parks, closely integrating resources, tourists, communities, and management, and become an important way for the public to participate in the protection of national parks; Hainan National Park provides the public with the opportunity to get close to nature and experience it, but it is far from being a "vivid example for education" for environmental education, one of the reasons being the lack of curriculum design for environmental education. In Hong Kong and Singapore, the design, provision, and opening of environmental education courses for national parks have been included in the policy system, laying a good foundation for public services for ecological environmental protection and the development of the research and travel industry, and it is worth learning from Hainan.

Community development is the core function of national parks to promote sustainable development. Hainan Tropical Rainforest National Park is located in the center of Hainan Province. The surrounding counties and cities such as Baisha, Wuzhishan, and Changjiang have weak economic foundations, and their economic development is relatively backward. Therefore, it is urgent to focus on community development in addition to the design of the franchise system and improve the policy system to ensure the effective implementation of the strategy of "lucid waters and lush mountains are invaluable assets."

Surface Chart Analysis of PMC of National Park Policy

By averaging the PMC index of the primary variables of the national park policies in the three regions (**Table 6**) and constructing a surface plot of the mean values of the PMC indices of the primary variables of national park policies in the three regions, we can visually and three-dimensionally show the overall situation of national park policies in the three regions, and at the same time, we can show the high and low mean values of the primary indicators of national park policies in the three regions, as shown in **Figure 2**, **Figure 3** and **Figure 4**. First of all, judging from the color of the mean surface map of the PMC index of the national park policies in the three regions, blue indicates the highest score area. Obviously, Singapore has the largest proportion of blue in the surface map, followed by Hong Kong, and finally Hainan. This indicates that Singapore has a large share of high mean PMC values for the national park first-level policy indicators. Secondly,

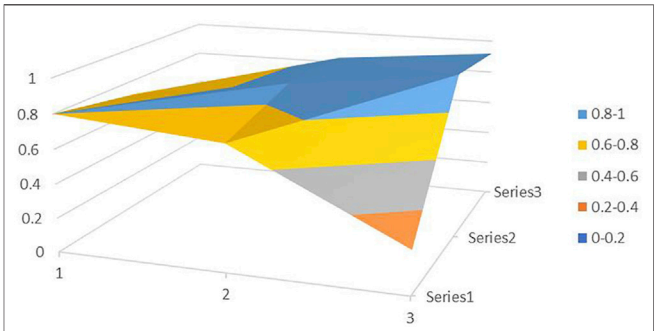

FIGURE 2 | Average PMC Index Surface Chart of First-level Policy Indicators of Hainan Tropical Rainforest National Park.

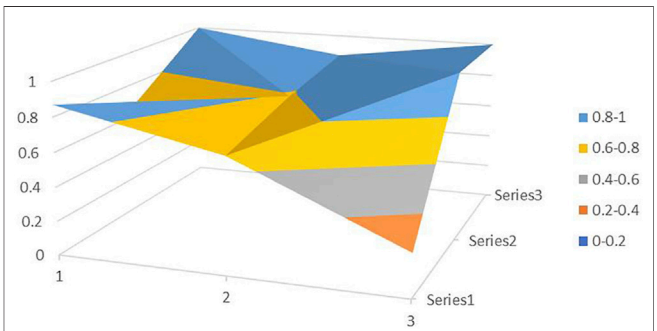

FIGURE 3 | Average PMC Index Surface Chart of Hong Kong's National Park First-level Policy Indicators.

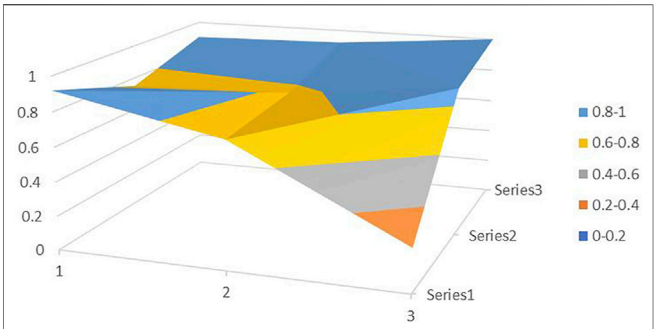

FIGURE 4 | Average PMC Index Surface Chart of Singapore's National Park First-level Policy Indicators.

judging from the unevenness of the PMC mean surface chart of the national park first-level policy indicators in the three regions, concave means low score, and convex means high score. The upper left corner of the Hainan surface chart is obviously concave, which means that the scores of the first-level indicators included in this part are low. The specific reasons for the low scores can be explored from the scores of the second-grade indicators; the upper left corner of the Singapore surface chart is obviously close to a flat surface, which means that the first-level indicators included in this part have a higher score. Finally, by looking at the values of the vertical coordinates corresponding to the nine points on the surface plot, we can determine the high and low values of the variables at the national park policy in the three regions, and then analyze the strengths and weaknesses in the design of the policy system.

Discussion and Suggestions

In 2021, China applied to join the Comprehensive and Progressive Agreement for Trans-Pacific Partnership formally and the whole country is pushing the institutional opening-up of regulation and standard. Hainan, as the provenience with independent legislative power should and can be the frontier in the docking of international regulatory institution system. With this background, this study quantitatively evaluates 14 national park policies in Hainan, Hong Kong and Singapore through PMC index model. According to the research results, Hainan Tropical Rain Forest National Park policy has relative disadvantages in effectiveness level, environmental education function, social and cultural shaping, biodiversity protection. Through analyzing the whole text of the related policies and literature reviewing research, the following suggestions were made.

Add Predictive and Descriptive Contents to Clarify the Objectives of National Park Policies

Policy makers should fully consider the correlation between policy nature, policy timeliness, and policy perspective when making decisions. The design of descriptive and predictive policy texts is a reflection of the macro policy perspective, which can enhance the incentives of related policies; at the same time, when formulating policies, attention should be paid to the policy nature and policy duration in line with the policy, for example, medium and long-term policies need to have the nature of prediction, description, *etc*., to clearly show the stage objectives. In view of this, policymakers of Hainan Tropical Rainforest National Park should strengthen the description of the relevant content and concepts of the national park when designing policies, depict a bright blueprint for the future development of Hainan's tropical rainforests, enhance relevant personnels' understandings of realizing objectives of ecological protection, economic development, spiritual and cultural shaping, thus making the policies encouraging.

Improve the Effectiveness of Policies to Consolidate the Legal Guarantee System for Ecological Conservation of National Parks

Law is the rule with the highest binding effect. The formulation of laws is very necessary to balance the protection and utilization of national parks (Cengiz, 2007). Since the establishment of the national park system in 1916, the U.S. has a long history of legislative management, establishing the Act to Establish the National Park Service, the National Parks Comprehensive Management Act and other basic laws to provide a legal basis for the construction of national parks (Guo, 2020); Singapore and Hong Kong also adopted the national Park laws one after another at the beginning of the creation of national parks, which provided a favorable environment for the development of national parks. This shows that the law plays an important role in the construction of the national park system. Hainan should make full use of the legislative power of the free trade port to innovate the legal system, so that the national park has laws to follow in terms of protection, recreation, health and scientific research. At the same time, it is necessary to strengthen the integration with international law, integrate the content of international law such as the Convention on Biological Diversity into local laws and regulations, make Hainan's local regulations both localized and international, and contribute local wisdom to the exploration and formulation of national park laws and regulations.

Enhance the Complexity of Policy Functions to Optimize the Education and Community Development Functions of National Parks

Strengthen the Policy Function of Environmental Education in Hainan Tropical Rainforest National Park

The experience that environmental education can help the public gain insight into the relationship between development and conservation and promote the growth of environmental knowledge and pro-environmental attitudes has been proven (Hutcheson et al., 2018; Piñeiro-Corbeira et al., 2020). The scores show that Singapore and Hong Kong attach great importance to the function of environmental education in the construction of national parks, as evidenced by the inclusion of biodiversity conservation in the education curriculum of all grades in Singapore, and the assessment of the quality and quantity of nature education specifically for children in the Singapore Urban Biodiversity Index; Assess the quality and quantity of children's nature education; Hong Kong Agriculture, Fisheries and Conservation Department offers a variety of interactive, activity-based programs for kindergartens, primary and

secondary schools to raise students' awareness of biodiversity conservation through experience. Hainan Tropical Rainforest National Park is in a critical period of development. Environmental education can raise public awareness of protection. In addition to learning from the above-mentioned initiatives in Singapore and Hong Kong that emphasize the inclusion of environmental education knowledge in the curriculum, the dissemination of environmental knowledge in outdoor environments can also be adopted. Studies have shown that environmental education, as one of the important dimensions influencing ecotourism practices, can promote the turn of tourists' environmental behavior (Zheng et al., 2021). Therefore, as an effective means of ecological protection, environmental education should be incorporated into the policy system to form a diversified ecological and environmental protection system.

Strengthen Policy Functions in Community Development of Hainan Tropical Rainforest National Park

Community participation provides a strong guarantee for the win-win situation of ecological protection and people's livelihood improvement in national parks. At present, Hainan Tropical Rainforest National Park has issued a policy for ecological relocation, and has achieved good results in practice, but there are few policies for community residents after ecological relocation to participate in the management of the national park. Singapore believes that community participation is the key to Singapore's long-term success in protecting its natural heritage. National Parks Board and NGOs have launched many interesting community activities, such as the Community in Bloom Initiative (Tan and Neo, 2009), which aims to cultivate community spirit and bring together residents of all ages, making Singapore a city of nature. Hong Kong is seeking to protect biodiversity and encourage local communities to actively participate in finding sustainable ways to manage habitats, improving lives and protecting the environment. Therefore, on the basis of handling the relationship between national park land ownership and ecological relocation, Hainan should introduce resources and guide community residents to participate in the ecological management of the national park in a richer form through effective policy design.

Improve National Park Policies in Socio-Cultural Fields to Shape the Cultural Identity

Social culture refers to the promotion of cultural identity of the whole nation by constructing national parks and shaping national symbols. For example, the United States has created national parks as a tool to highlight the uniqueness of the United States and build a national identity, and endow them with lofty spiritual and cultural values (Gao, 2019). In the case of this study, Singapore stated in its policy that "by protecting biodiversity, the public's awareness and interest in natural heritage will be raised, and national pride will be enhanced"; Hong Kong's country park policy states that "human beings benefit from the multiple benefits of biodiversity, not only in physical terms, but also in terms of cultural life (aesthetic and spiritual values, *etc.*) beyond the physical." This fully demonstrates that Singapore and Hong Kong use national parks as a powerful tool to shape their cultural identity. As a beautiful "ecological business card" in Hainan, the tropical rainforest national park has injected strong impetus into tourism development, talent introduction, and cultural output in the context of the construction of the free trade port. Hainan should clearly emphasize social and cultural functions in the national park policy to enhance the public's cultural self-confidence.

Increase the Policy Content of "Biodiversity Protection" to Promote the Sustainable Development of National Parks

Biodiversity is related to human well-being and is an important foundation for human survival and development. At present, the world is facing the threat of biodiversity loss, and the international community generally recognizes the importance of biodiversity conservation. National parks are the cradle of biodiversity conservation (Government Network of State Forestry and Grassland Administration, 2021). Different countries have developed different biodiversity conservation policies based on the characteristics of their national parks, such as policies from the perspective of participants by strengthening effective coordination among government, enterprises, and community residents (McCarthy et al., 2021); integrated policies by establishing linkages between policies in biodiversity conservation-related fields (Zhou and Seethal, 2011); and policies on ecosystem services by exploiting the economic value of biodiversity (Le et al., 2016). Hainan Tropical Rainforest National Park is extremely rich in biodiversity, which is a precious treasure given by nature, and measures should be taken to strictly protect it. In terms of biodiversity conservation in Hong Kong and Singapore, they have formulated special administrative regulations, namely the Biodiversity Strategy and Action Plan for Hong Kong and the Biodiversity Strategy and Action Plan for Singapore. In addition, Singapore has also issued the Urban Biodiversity Index, a quantitative tool used to measure urban biodiversity. To promote the biodiversity conservation of Hainan Tropical Rainforest National Park, Hainan may also learn from the practices of Hong Kong and Singapore to build a systematic and highly operable strategy for the biodiversity conservation of Hainan Tropical Rainforest National Park.

CONCLUSIONS AND IMPLICATIONS

This study introduces the PMC index method to construct a national park policy evaluation index system, and conducts a quantitative comparative analysis of a total of 14 representative policies in the construction and development of Hainan, Singapore, and Hong Kong national parks. Research shows that, first of all, four of the six policies of Hainan Tropical Rainforest National Park are rated as good and two are rated as acceptable, indicating that the overall policy design is reasonable and scientific, but there is still room

for improvement. Secondly, through further comparison and analysis with the policies of Hong Kong and Singapore, we found that the policy of Hainan Tropical Rainforest National Park is in a disadvantageous position in terms of policy nature, policy effectiveness, policy content, policy domain and policy function, *etc*. There are some problems in Hainan, such as insufficient policy effectiveness, relative lack of policies in the social and cultural fields, and further strengthening of policy content. Finally, based on the characteristics of Hainan Tropical Rainforest National Park's own policy and the advantages of the national park policies of Hong Kong and Singapore, suggestions are made for the optimization of Hainan Tropical Rainforest National Park's subsequent policy formulation.

The PMC index model policy evaluation method introduced in this study is relatively rare in national park policy evaluation, and to some extent, it can provide a new research idea and analytical framework for future national park policy evaluation. However, in view of the practical application goals of the research, this paper only analyzes representative policy texts. In future research, it can be improved from the following two aspects: 1) The evaluation indexes of policy tools are introduced, and the policies are classified into supply-type, demand-type, and environment-type for comparison, and the functions of different types of policies are explored. 2) Select all policies related to national parks and conduct a more comprehensive analysis.

DATA AVAILABILITY STATEMENT

The data generated or analyzed during this study are included in this published article.

AUTHOR CONTRIBUTIONS

Conceptualization, HW and YZ; Methodology, HW and YZ; Software, YZ; Validation, HW and YZ; Formal analysis, HW and YZ; Investigation, HW and YZ; Resources, HW and YZ; Data curation, YZ; Writing—original draft preparation, HW and YZ; Writing—review and editing, HW. All authors have read and agreed to the published version of the manuscript.

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