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Original Research

Research on the Boundary Delimitation Method of National Park Based on Cultural Service Protection

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Abstract

China is in the process of establishing and improving the national park system and carrying out pilot projects. With China's vast territory and diverse ecological systems, appropriate delimitation of the boundaries of national parks is a key scientific issue in the construction of the national park system. Guidelines for the establishment of national parks attach great importance to its cultural service functions such as scientific research, education and public recreation. It is of practical significance to consider the cultural service values of ecosystems when exploring the boundary delimitation methods used to delineate national parks. Based on remote sensing images and network big data resources, this paper selects the Guangdong-Hong Kong-Macao Greater Bay Area as the study area and evaluates the value of ecosystem cultural services in this area. From the perspective of cultural service protection, this paper simulates a variety of scenarios and determines the optimal boundaries through comparative analysis, taking the risk of decision-making into consideration. The principal findings are as follows. (1) Cultural service value varies greatly among regions. (2) Considering the risk and balance of decision-making, seven risk coefficients (0, 0.2, 0.4, 0.5, 0.6, 0.8, 1) between 0 and 1 were considered, and this analysis generated seven scenarios for national park boundaries. (3) Scenario 5 is the most favourable, with cultural, recreational, biodiversity, recuperative and aesthetic cultural efficiency values of 1.292, 1.520, 1.469, 1.543 and 1.430 respectively. This study provides a novel approach for the delineation of national park boundaries, and serves as a reference for regional development planning.

Keywords: cultural service, national park, boundary delimitation, Guangdong-Hong Kong-Macao Greater Bay Area

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Introduction

The “Overall Plan for Establishing a National Park System" [1] states: "A national park is a specific land or marine area approved and managed by the state, with clear boundaries, with the main purpose of protecting a large area of nationally representative natural ecosystems and realizing scientific protection and rational utilization of natural resources." This clearly requires national parks to have clear boundaries. However, in the construction and development of national parks in China, there are many types of nature reserves, such as scenic spots, forest parks, world heritage sites, geological parks, water conservancy scenic areas, and wetland parks, etc. [2] These nature reserves face challenges such as overlapping settings, multi-head management, unclear boundaries, and unclear powers and responsibilities [3]. How to integrate the various types of nature reserves, delimit the boundaries of national parks, and protect the most representative natural ecosystems and landscape and cultural heritage resources has become an urgent issue in the construction of the national park system these days [4].

The demarcation of national park boundaries is a critical step in determining the allocation of limited natural landscape resources, and the protection of biodiversity and ecosystem services. The United States, Germany, Britain, Japan and many other countries have formulated national park standards according to their respective national conditions [5-7]. The “Overall Plan for Establishing a National Park System”, sets standards for establishing national parks in China, considering the representativeness of natural ecosystems, the suitability of areas and the feasibility of management. However, there are few specific operational methods mentioned in the domestic and foreign literature on how to reasonably delimit the boundaries of national parks. The relevant studies and arguments on the delimitation protected areas are discussed in the remainder of this paragraph. Wang et al. [8] believed that the scope of national parks is closely related to the formulation of protective measures, the planning of construction projects, the establishment of management systems and the implementation of management strategies. At present, theoretical research on the scopes and boundaries of national parks remains in an early stage. Most scholars discuss the boundaries of national parks from the perspective of demarcation principles, management, and protective structures and functions, and the scope of boundary demarcation is closely related to decision-making attitudes and positioning. Wang Zaifeng et al. [9] believed that the scope of island area protection is related to the natural environmental conditions of islands, protected features, the level of management of protected areas and external risks of protected areas. O'Connor et al. [10] discussed the combination of biological and sociological variables within the framework of "return on investment" to determine protection priority. Schmieller et al. [11] advanced a decision-making method for the designation of priority protected areas within multiple political jurisdictions and took into consideration the reality that the threat situation did not always reflect the actual protection needs and may differ markedly from actual protection priorities. Larsen et al. [12] explicitly discussed the selection of biodiversity and ecosystem services in priority areas and identified the specific regions and service combinations that synergize and reduce tradeoffs by revealing the important synergies and tradeoffs among ecosystem services. Zhang et al. [13] believed that it was difficult to achieve the goal of protecting biodiversity and ecosystems at the same time when designating priority protected areas, because multiple ecosystems need to be considered. He et al. [14] proposed to apply the ecosystem service framework and data to determine the beneficiaries, management issues, and key areas of national parks. Chen Xi et al. [15] put forward the concept of double-layer boundary demarcation of national parks from the perspective of "multi-regulation integration" of land space use control, landscape ecology and community life. Tang Fanglin et al. [16] proposed that the planning and design of Chinese national parks should emphasize the importance of planning and design and the scientific basis and need for planning and design and strengthen scientific decision-making based on survey data, scientific analysis and comparison of multiple schemes in terms of content and depth.

Boundary demarcation is an important means of national park protection and management. It usually refers to delineation of the boundaries of administrative regions and physical geographical boundaries, with the aid of artificial intervention. However, less consideration of the cultural services of ecosystems and human interference factors results in unreasonable and unclear boundary demarcation. The establishment of national parks should attach great importance to their cultural service functions, such as scientific research, education and public recreation [17]. It is of practical significance to consider the cultural service values of ecosystems when exploring the boundary delimitation of national parks [18]. However, few articles focus on the cultural service functions listed above when discussing national parks. The cultural services of ecosystems are the nonmaterial benefits that people receive from ecosystems, such as the aesthetic quality of the landscape, entertainment and learning opportunities, and even healing and spiritual contribution to human wellbeing [19-21]. Cultural services have attracted widespread attention, but they are often missing from the research framework of ecosystem services [22]. In recent years, scholars both domestic and overseas have carried out relevant research on ecosystem cultural service evaluation [23-25]. For example, Alessa et al. and Bagstad et al. applied geographic information systems (GIS) to carry out cultural value research [26, 27]. Hernández-Morcillo et al. [28] have stressed that recreation and leisure are the most important categories of cultural services, and welfare indicators are most commonly used to evaluate education and entertainment services. Brown et al. [29] used the spatial value transfer method (PPGIS) to identify the cultural services of ecosystems and the participatory mapping method to evaluate the benefits of various ecosystem services including cultural services in urban parks. Huosigao and Maqiao et al. [30, 31] used questionnaires and related environmental background information to run the SolVES model to evaluate cultural services in small-scale areas such as ecological parks and forest parks. Research on ecosystem cultural services at home and abroad is mostly concentrated in local areas, while research on broadscale areas such as national parks and nature reserves is very rare.

This research introduces ecosystem cultural services into the study of the national park boundary delimitation method. Considering the decision-making risks and tradeoffs that occur when applying different combinations of factors, a variety of scenarios are simulated, and the optimal boundary is determined through comparative analysis, which provides a new approach for national park boundary delimitation and a reference for regional development planning.

Material and Methods

Overview of the Study Area

The Guangdong-Hong Kong-Macao Greater Bay Area is located in South China (21.57°N~24.39°N, 111.36°E~115.41°E), and is the fourth largest metropolitan bay area in the world after the New York Bay Area, the San Francisco Bay Area and the Tokyo Bay Area, with a total area of 56,000 square kilometres. It consists of the Hong Kong and Macao Special Administrative Region and the cities of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing in Guangdong Province (Fig. 1). It is one of the regions with the highest degree of openness and the strongest economic vitality in China. The Greater Bay Area experiences a subtropical monsoon climate, with abundant rainfall and heat, and its vegetation type is subtropical evergreen broadleaf forest with an average annual temperature of 22.3ºC [32].

Data Sources and Description

This study involved two kinds of data: remote sensing images, which were obtained from Geospatial Data Cloud (http://www.gscloud.cn/), and network big data. The network big data used in this study can be classified into two types. The first type was point-of-interest (POI) data (1), which were downloaded from websites for nature reserves in the Guangdong-Hong Kong-Macao Greater Bay Area through 91 Weitu Enterprise Edition software. After a series of operations, such as duplicate removal, deviation correction and screening, the original data were transformed to interest point data with a series of attributes, including name, classification and coordinate information (Fig. 2). Then, this study established a spatial attribute dataset for nature reserves in the Guangdong-Hong Kong-Macao Greater Bay Area, including nature reserves, scenic spots, forest parks, geological parks, wetland parks and water conservancy scenic areas, through ArcGIS 10.4. The second data type was network text data (2), using a post-game collector to collect evaluation text of POI in nature reserves from websites such as Ctrip and public comments. The network text data served as the basic dataset for assessing the values of ecosystem cultural services in nature reserves.

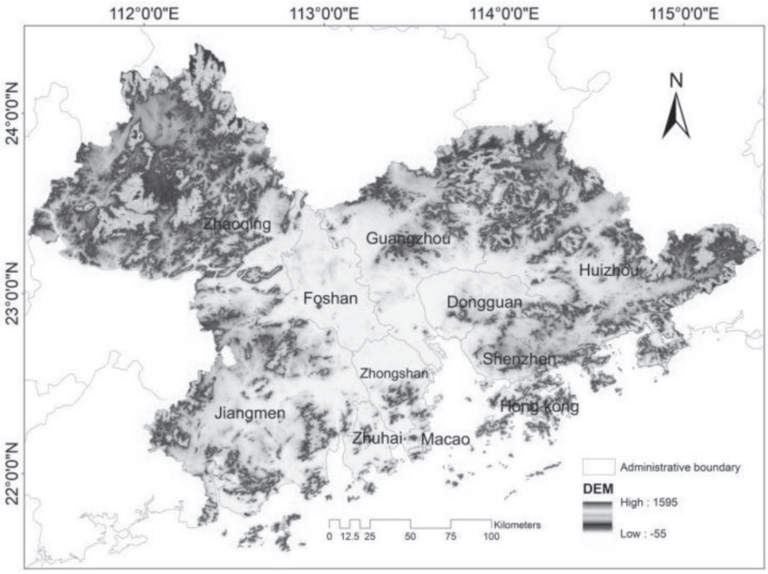

Fig. 1. Location map of the Guangdong-Hong Kong-Macao Greater Bay Area.

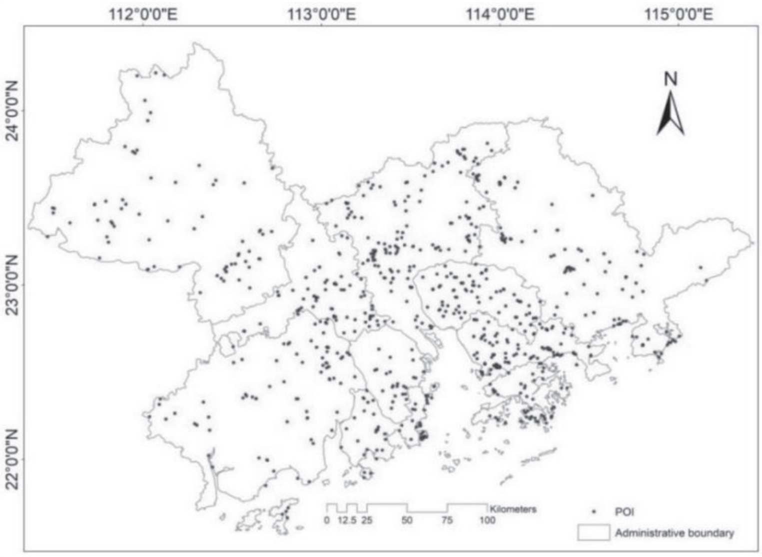

Fig. 2. POI distribution map related to national parks.

Research Method

Empirical Bayesian Kriging (EBK)

Empirical Bayesian Kriging (EBK) is a geostatistical interpolation method that requires little interactive modelling. By estimating the basic semivariogram to explain the introduced errors, the most difficult steps in the process of building an effective kriging model can be automatically executed [33]. This spatial interpolation method is more accurate than other kriging methods in terms of predicting standard error. The ArcMap 10.4 platform was used in this paper to apply the empirical Bayesian kriging method to carry out spatial interpolation, with the spatial resolution set to 1000.

GIS-Based Ordered Weight Averaging (OWA)

Ordered Weighted Averaging (OWA) based on a geographic information system first applies GIS technology to rasterize the existing standard layers and then applies the OWA method to aggregate in a GIS environment. OWA not only considers the weight of the criterion layer but also introduces the ordered weight to overcome the decision error caused by the excessive numerical differences between indicators and results of the subjective Analytical Hierarchy Process (AHP) method to determine the weight of each criterion. In this study, the OWA arithmetic formula was used to assess the values of cultural services [13]:

$$OWA(x_{ij}) = \sum_i^n \omega_i \, s_{ij}, \quad (\omega_i \in [0,1] \text{ and } \sum_i^n \omega_i = 1, \text{ for i and j} = 1,2,3,\ldots,\text{n}) \tag{1}$$

...where x_{ij} refers to a group of attribute values at the ith position on the jth normalized grid map. In this paper, the standardized grid layers included five kinds of ecosystem cultural service values after standardization, namely, aesthetics, culture, entertainment, biodiversity and recuperation value. s_{ij} signifies the five new datasets obtained after x_{ij}, and its corresponding standardized grid values of five ecosystem cultural services are arranged in descending order from large to small, and ω_i is the ordered weight of the five new data sets s_{ij}.

The ordered weights were determined on the basis of the corresponding numerical index values and the understanding of decision risk. Usually, risk factors are used to reflect decision risk. Risk factors are formulated according to the understanding of decision risk caused by the numerical difference between an index factor and the subjective weight in an actual situation, which depends on the decisionmaker's attitude towards risk. The formulas for calculating risk and tradeoffs under different ordered weight choices are as follows [34]:

$$risk = (n-1)^{-1} \sum_i^n (n-i)\, \omega_i \quad (0 \le risk \le 1) \tag{2}$$

$$tradeoff = 1 - \sqrt{\frac{n \sum_i^n (\omega_i - \frac{1}{n})^2}{n-1}} \quad (0 \le tradeoff \le 1) \tag{3}$$

...where n is the total number of all grid atlas points, and ω_i is the weight of the ith point. Theoretically, by changing the risk and tradeoff level within the scope of OWA's decision-making strategy, we can obtain numerous scenarios. The higher the risk value of a scenario is, the higher the risk of losing ecosystem services. The higher the tradeoff value of a scenario, the closer to the average the value from each ecosystem service is in the final OWA result.

Ant Colony Optimization (ACO)

Ant colony optimization (ACO) is a bionic optimization algorithm based on group intelligence, which is a general framework for solving discrete optimization problems. As a heuristic intelligence method, ant colony optimization can update its knowledge base according to environmental changes and the resulting behaviour [35]. It features strong robustness, adaptability and a positive feedback mechanism. This study applied the ACO-CA model in the GeoSOS 1.2.0 surface optimization module to delimit the boundaries of national parks.

Results

Indicator Selection and Cultural Service Evaluation

Indicator Selection

China's national park system is a new type of nature reserve model, emphasizing ecological protection, national natural heritage and public welfare [36]. National parks are designated to protect nationally representative natural ecosystems and feature unique natural landscapes, rich scientific significance and superior natural heritage. Therefore, the national park system serves as an important method of ecological protection and sustainable development [37]. Based on the actual situation of the study area, this paper selected five evaluation indexes related to the protection of cultural services, namely, cultural value, recreation value, biodiversity value, recuperation value, and aesthetic value (see Table 1 for description of value types). The service value level was divided into five levels, i.e., very low, low, typical, high and very high, with values ranging from 1 to 5. The classification of service values was based on evaluation text data from Ctrip, public comments and other websites collected by the post-game collector.

Evaluation of Cultural Service Value

The Empirical Bayesian Kriging method was used to interpolate the values of cultural services. Based on the Arcmap10.4 platform, the spatial resolution was set to 1000. The cultural service value map is shown in Fig. 3. To clarify the value classification and better prepare for the subsequent scenario simulation, this paper applied the natural breakpoint method to redivide the value map into 1-5 levels from low to high based on Fig. 3 (see Fig. 4).

According to Fig. 4, the areas with high cultural value are mainly concentrated in Luofu Mountain Scenic Spot in Huizhou City; the Nanshe Ancient Villages of the Ming and Qing Dynasties in Dongguan City; Baiyun District, Yuexiu District and Haizhu District in Guangzhou City; the areas surrounding Xiqiaoshan National Geopark in Foshan City; Qixingyan Scenic Spot, Jungengshan Scenic Spot, Xinghu Scenic Spot, Dinghushan Scenic Area and Fengkai National Geopark in Zhaoqing City; Kaiping Diaolou Scenic Area; Chikan South Building, Kuifengshan Scenic Area; and Birds' Paradise in Jiangmen. Hotspots of cultural value are compatible with urban areas with profound cultural background and rich historical and cultural heritage.

Areas surrounded by a large number of recreational opportunities show high recreational value. For example, there are a large number of parks, recreational places and facilities in cities, which provide people with public spaces in which to engage in frequent recreational activities. Luofu Mountain Scenic Spot in Huizhou; Qixingyan Scenic Spot, Xinghu Scenic Spot and Dinghu Mountain Scenic Spot in Zhaoqing, Songshan Lake in Dongguan; Window of the World in Shenzhen; East Overseas Chinese Town, big and small Meisha, Canton Tower, Guangzhou Zoo, Yuexiu Park and Baiyun Mountain Scenic Spot in Guangzhou; and country parks in Macao coastal areas are all ideal locations for entertainment. Visitors can easily reach the city centre and experience close contact with nature.

The areas with high biodiversity are mainly concentrated in scenic spots, forest parks and wetland parks in various cities. The areas with high recuperation value and aesthetic value are similar. In addition to the areas mentioned above, the index scores of the scenic coastal areas of Huizhou and Jiangmen are high. High scores indicate that these areas not only feature good scenery but can also relieve mental stress, serving as excellent areas for physical and mental recuperation. When delimiting the boundaries of national parks, greater attention and protection should be provided to areas with high cultural service value.

Table 1. Description of Five Value Types.

Value types	Value description
Cultural value	The cultural background and atmosphere are strong, and people's cultural activities are rich and diverse
Recreational value	The attractive places and rich opportunities provided by ecosystems for human beings to engage in various outdoor recreational activities
Biodiversity	People enjoy a variety of biological resources such as birds, animals, insects, fish, flowers and trees provided by the ecosystem
Recuperation value	Ecological system makes people feel cured and recuperated both mentally and physically
Aesthetic value	People enjoy the beautiful scenery and beautiful scenery provided by the ecosystem

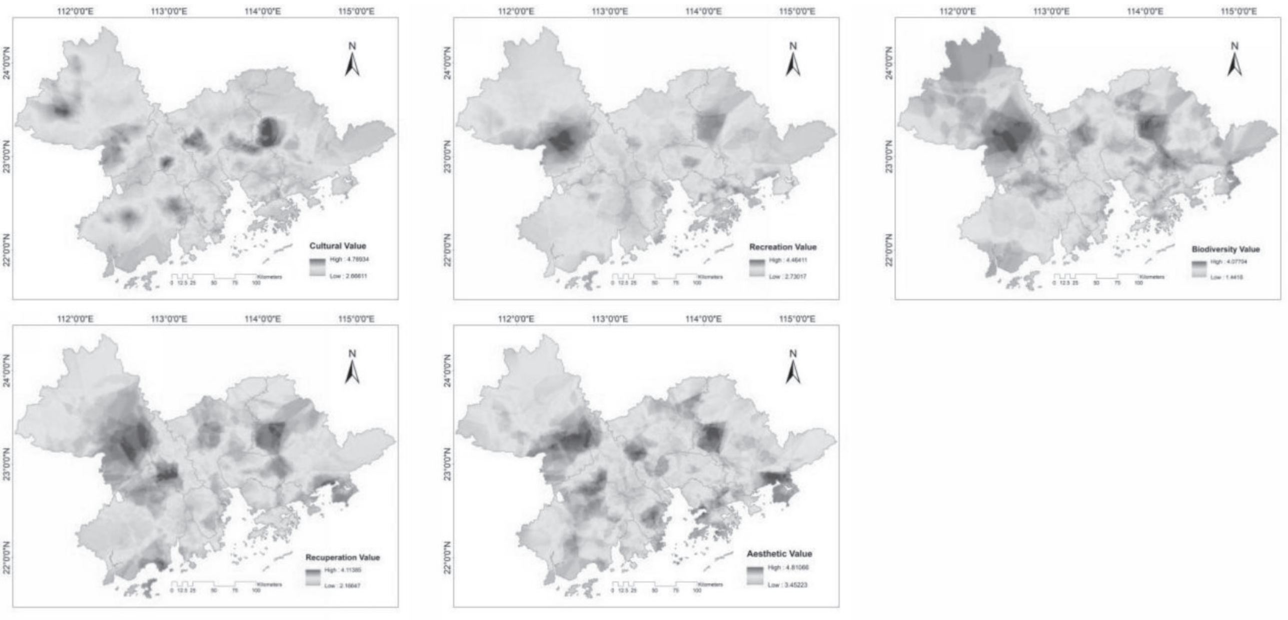

Fig. 3. Cultural service value distribution in the Guangdong-Hong Kong- Macao Greater Bay Area.

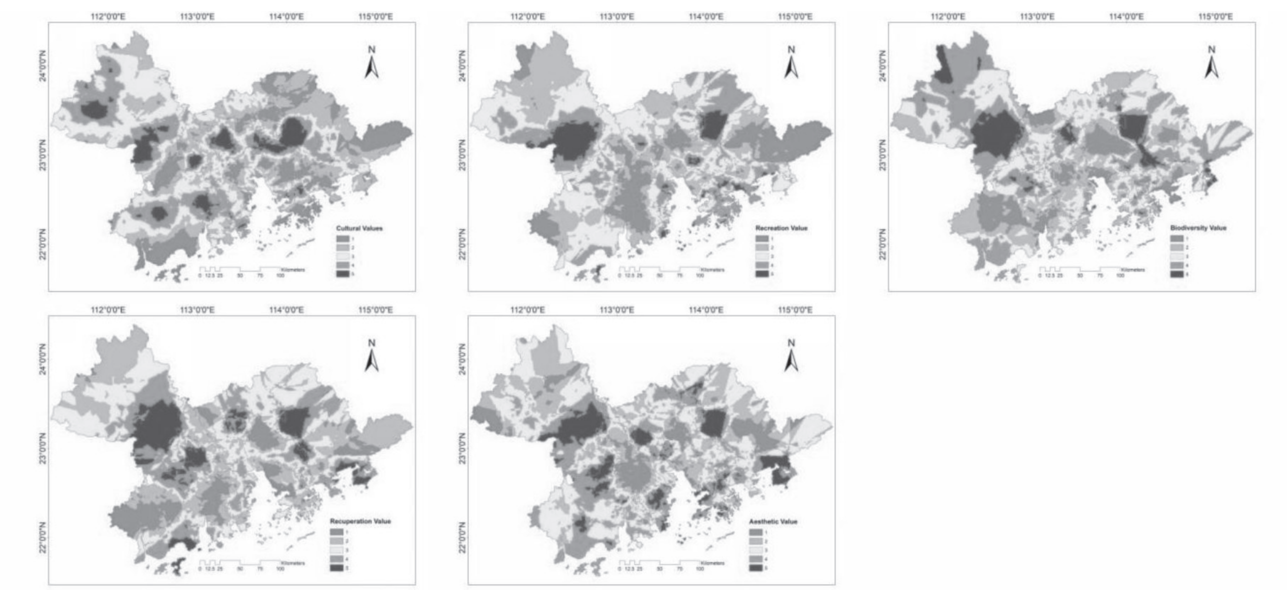

Fig. 4. Re-classification map of cultural service value.

When formulating development and management policies, priority should be afforded to areas with low value.

Scenario Planning Simulation

Determination of Criterion Weights

This paper used Analytic Hierarchy Process (AHP) to determine the criterion weight for each index, which was realized by the weight module in Terrset 18.3. In the module, we first input the standardized grid layer of each index in each level, and then input the evaluation results of consulting landscape planning experts about the importance of pairwise. The output was a judgement matrix, where the weight of cultural value was 0.0771, the weight of entertainment value was 0.0449, the weight of biodiversity was 0.5263, the weight of recuperation value was 0.2306, and the weight of aesthetic value was 0.1212. The consistency ratio was 0.06. The single ranking and total ranking of each level in the evaluation index system passed the consistency test.

Determination of Ordered Weights

To explore the delimitation of national park boundaries based on cultural service protection, this

Table 2. Ordered weight values under different risk scenarios.

Scenario	Risk	ω_1	ω_2	ω_3	ω_4	ω_5
1	0	0	0	0	0	0
2	0.2	0	0.04	0.18	0.32	0.46
3	0.4	0.12	0.16	0.2	0.24	0.28
4	0.5	0.2	0.2	0.2	0.2	0.2
5	0.6	0.28	0.24	0.2	0.16	0.12
6	0.8	0.46	0.32	0.18	0.04	0
7	1	1	0	0	0	0

study established seven weight sets under different risks. To increase the time efficiency, the risk values range from 0 to 1. Six scenarios were set for risk value with an interval of 0.2, and another scenario was also set for the intermediate value of 0.5. Therefore, we were able to secure enough scenarios without unnecessary delays. Using the risk values in the seven scenarios and the mathematical formulas (1), (2) and (3), the ordered weights of the scenarios are shown in Table 2.

Seven Plans Based on Risk Scenarios

After quantifying layers of criteria (aesthetic, cultural, recreational, biodiversity, and therapeutic values), the decisionmaker aggregates criteria and weights using the OWA-GIS method, aggregating elements according to different decision risks in the GIS environment. Based on the MCE module of the Terrset 18.3 platform, this study selected the ordered

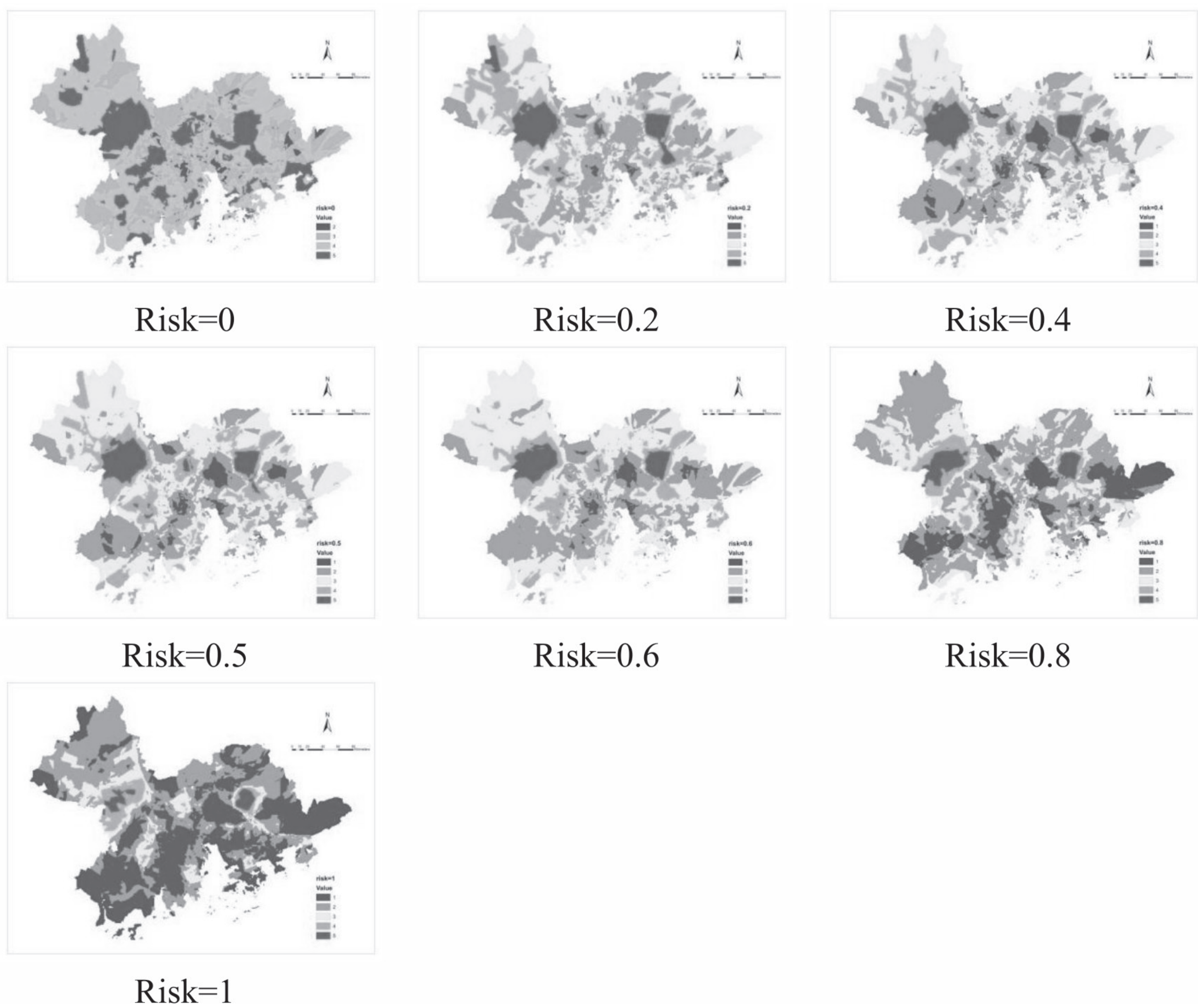

Fig. 5. Evaluation results of cultural service value under different risk scenarios.

weighted average to generate the corresponding OWA-GIS grid map to realize the value assessment of cultural services. Since the determination of the boundaries of national parks in the next step requires raster cell values based on integral values, the OWA-GIS raster map needed to be reclassified. The results are shown in Fig. Considering the actual land-use situation in the Guangdong-Hong Kong-Macao Greater Bay Area, 15% of the total area was determined to be the combined area of national parks, and this area was converted into grid units $(5.64\times10^{8}\times15\%)/(1000\times1000) = 8460$. The ACO-CA module in GeoSOS 1.2.0 was used for optimization. The corresponding ACO parameters were set as follows: information intensity was set to 5, heuristic weight was 2, volatility number was 0.04, volatile prime number was 0.04, information weight was set to 3, suitability factor was 1, compactness factor was 1, ant number was 8460, grid side length was 1000, and the total number of iterations was 300. This algorithm selected the best grid according to the order of raster cell values from high to low while taking the compactness of the national park distribution into account. The simulation result is the scenario plan for the national park boundaries, as shown in Fig. 6.

Comparison and Selection of Plans

Analysis of the Delimitation of National Parks under Various Different Scenarios

Fig. 6 shows that there are obvious differences in the delimitation of national parks under each risk scenario. For example, in the first three scenarios, Zhongshan, Zhuhai and Macao were hardly represented in the boundaries of national parks, while in scenarios 6 and 7, the Jiangmen coastal area was not included in the national park boundaries. Under different risk/tradeoff combinations, due to the differences in location and size of the five kinds of cultural services, the OWA grids differ, and the protection services are different, resulting in different national park areas. In addition, there are some similarities in terms of locations included in national parks designated by each scenario plan, such as Luofu Mountain scenic spot in Huizhou, Dinghu Mountain scenic spot in Zhaoqing, and Qixingyan scenic spot, which are all included in the boundaries of national parks under all seven scenarios.

As shown in Fig. 7, under the seven risk scenarios, the total area of grassland, cultivated land, forest

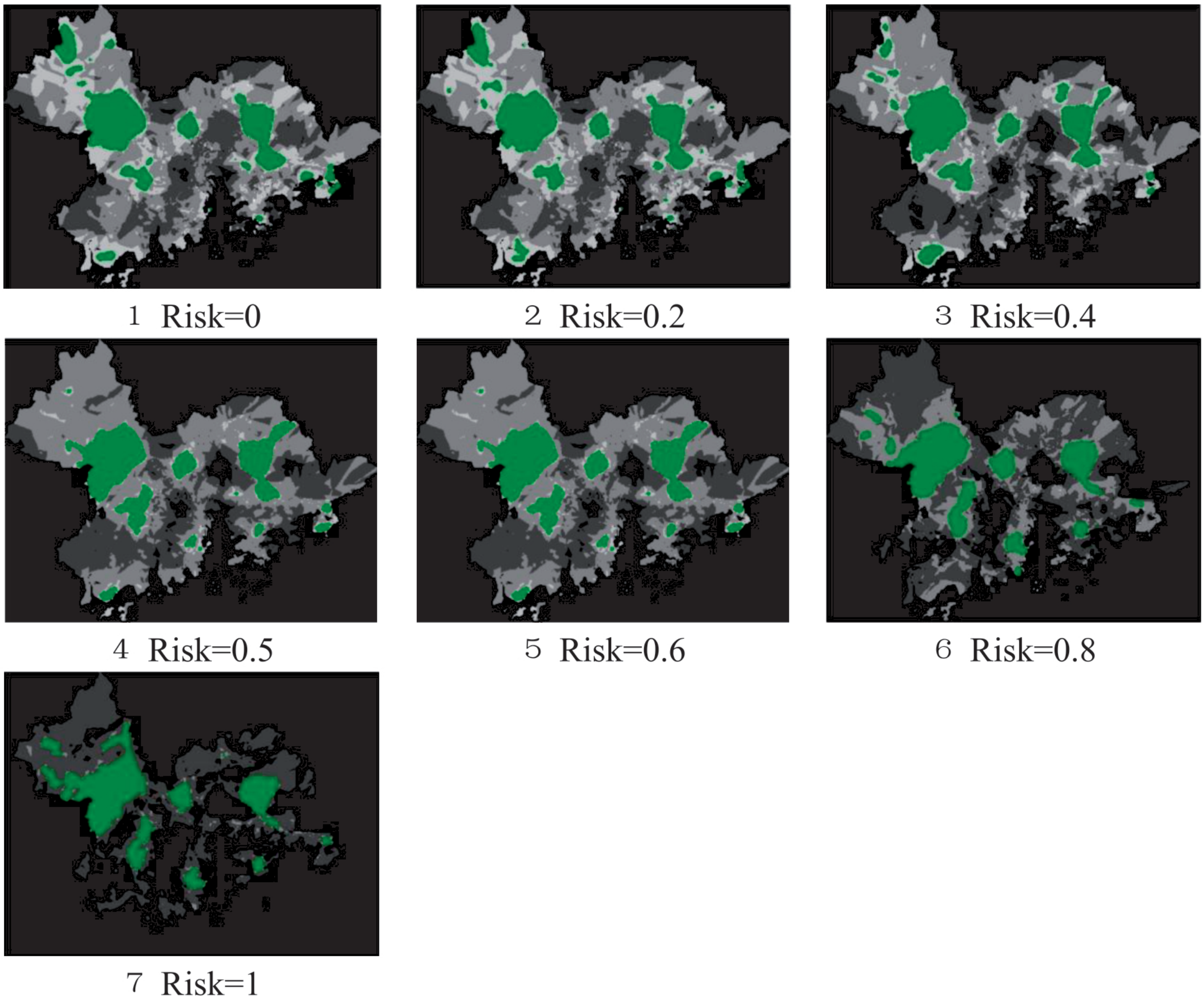

Fig. 6. Plans for demarcation of national park boundaries under different risk. scenarios

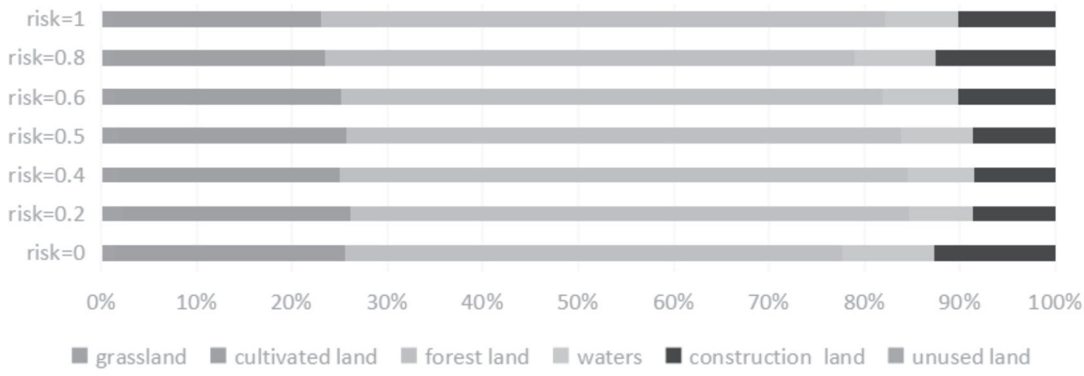

Fig. 7. Proportion of land use area included in the delineation of national parks under scenarios.

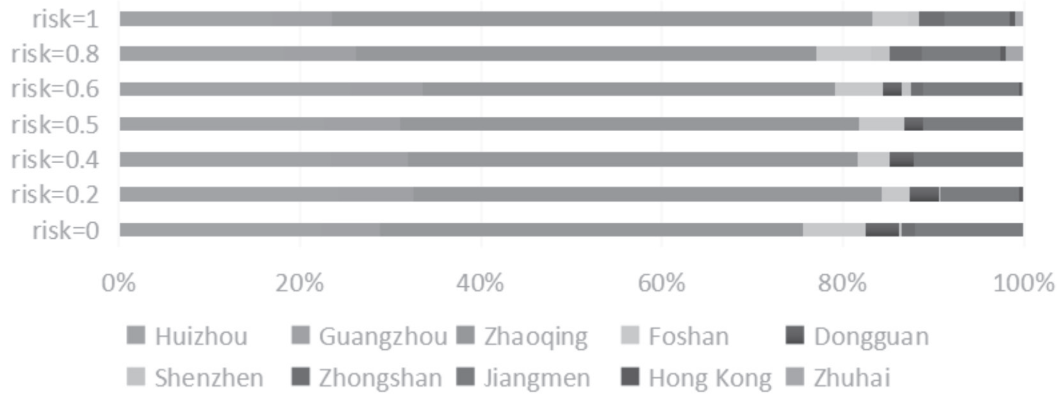

Fig. 8. Proportion of national parks in each city of the Greater Bay Area under scenarios.

land and waters accounted for over 85% of landcover, among which, forest land area accounted for the largest proportion, followed by cultivated land and waters. With increasing risk, the area of land-use types in national parks did not change regularly, mainly because the risk plans in this study were all set based on the protection of cultural services, and indicators such as cultural and aesthetic value were not significantly correlated with land-use type at the spatial scale of 1000 m × 1000 m. Among the seven risk scenarios, the proportion of construction land was significantly greater in Scenario 1 and Scenario 6 (risk = 0 and risk = 0.8) than in other scenarios. Because the primary function of national parks is to protect the authenticity and integrity of important natural ecosystems, the delimitation of national parks is inferior under Scenario 1 and Scenario 6 to that under other scenarios.

Under the seven risk scenarios, the proportion of area that would be devoted to national parks varies greatly among cities in the Guangdong-Hong Kong-Macao Greater Bay Area, with some cities having no land at all included in the boundaries of national parks (Fig. 8). Although national parks are of great significance to the realization of comprehensive functions such as ecosystem protection, scientific research, education and recreation, occupation of too great a proportion of total land area by national park land will greatly impact a city's competitive position and economic development. Therefore, under the premise of protecting a large area of natural ecosystems that is representative of the country, a relatively balanced layout is also conducive to providing educational and recreational opportunities for people in various regions. Therefore, scenarios 1, 5, 6 and 7 (i.e., scenarios with risk values of 0, 0.6, 0.8 and 1) would be conducive to serving a greater number of people.

Analysis of the Efficiency of Cultural Service Protection under Different Risk Scenarios

It is necessary to introduce the index of protection efficiency to evaluate the delimitation of national parks under various risk scenarios. The specific calculation is as follows [38]:

$$E = \frac{\overline{ES_C}}{\overline{ES_O}} \tag{4}$$

...where, E is the conservation efficiency of the specific ecosystem services of a national park, $\overline{\mathrm{ES}_\mathrm{C}}$ is the average value of the specific ecosystem services of a national park, and $\overline{\mathrm{ES}_\mathrm{O}}$ is the average value of the specific ecosystem services of the whole study area.

Table 3. Protection efficiency of the five cultural services under different risk scenarios.

Scenario	Risk value	$E_{Culture}$	$E_{Recreation}$	$E_{Biodiversity}$	$E_{Rehabilitation}$	$E_{Aesthetic}$
1	risk = 0	**1.430**	1.391	1.335	1.399	1.393
2	risk = 0.2	1.240	1.380	**1.504**	1.442	1.337
3	risk = 0.4	1.226	1.437	1.503	1.502	1.366
4	risk = 0.5	1.260	1.453	1.501	1.517	1.375
5	risk = 0.6	1.292	**1.520**	1.469	**1.543**	1.430
6	risk = 0.8	1.422	1.514	1.386	1.473	**1.450**
7	risk = 1	1.410	1.499	1.398	1.478	1.412

Equation (4) was used under each scenario to calculate the cultural service values of five ecosystem services of national parks, including culture, recreation, biodiversity, recuperation and aesthetics, and the average value of the five ecosystem services corresponding to each grid unit was obtained by dividing by the number of grid units in national park land. Next, the average value of the five kinds of ecosystem cultural services in each grid unit in all regions of the Guangdong-Hong Kong-Macao Greater Bay Area was calculated. The protection efficiency of the ecosystem cultural services under each risk scenario plan was obtained by dividing the average value within the national park land designated under each scenario plan by the average value for the Guangdong-Hong Kong-Macao Greater Bay Area. The results are shown in Table 3.

Table 3 shows that the area delineated as national parks under the seven scenario plans exerts a favourable protective effect on the five kinds of ecosystem cultural services. The highest protection efficiency for cultural value is under Scenario 1 (1.430). Scenario 5 exhibits the best protection efficiency for recreation value (1.520). Scenario 2 features the best protection efficiency for biodiversity (1.504). The best protection efficiency for recuperative value is scenario 5 (1.543). Scenario 6 displays the best protection efficiency for aesthetic value (1.430). Scenario 5 has the best conservation efficiency for recreational value and biodiversity.

Determination of the Optimal Plan for Delimitation of National Parks

Based on the analysis of national park delimitation under the above risk scenarios, we believe that Scenarios 1 and 6 are unreasonable from the perspective of land use; Scenarios 1, 5, 6 and 7 are more reasonable from the perspective of balanced provision of educational and recreational opportunities for more people. Through the analysis of the efficiency of cultural services protection under the above risk scenarios, we believe that Scenario 5 achieves the optimal efficiency of recreation value and biodiversity protection. In summary, considering the protection of different ecosystem services, Scenario 5 is the best, which is the designated national park area of the Guangdong-Hong Kong-Macao Greater Bay Area.

Forest land occupies the greatest proportion of the designated area of Guangdong-Hong Kong-Macao Greater Bay Area national parks, with an area of 4795 km^2, accounting for 56.68% of the total area of the national parks. Ranking second, cultivated land covers an area of 1997 km^2, accounting for 23.61% of the total area of the national parks. The proportions of construction land and water area rank third and fourth, respectively, with the construction land area encompassing 858km^2 and the water area 678 km^2, accounting for 10.14% and 8.02% of the total national park area, respectively.

Discussion

The innovation of this topic lies in introducing a method of delimiting the boundaries of national parks from the perspective of ecosystem cultural service protection. In the past, there have been a greater number of studies on the regulating function, supporting function and supplying function of ecosystem services but fewer on the cultural function of ecosystem services [22, 39, 40]. The existing studies only carried out qualitative research on ecosystem services, and there was no specific quantitative research. In terms of research methods, the research on culture has mostly been limited to questionnaire surveys. However, in actual questionnaire surveys, the respondents are often limited, and it is difficult to fully reflect the actual application. Therefore, this study used the combination of POI data and online text data instead of a questionnaire survey. POI data describe the spatial location and attribute characteristics of geographical entities and can generate an intuitive sense of the distribution of geographical features such as scenic spots, protected areas, forest parks, etc. The POI network evaluation performed by web-crawling collectors derives from the observations of all kinds of people from all over the world, and the number of survey samples is sufficient for accurate research.

In terms of scenario setting, the risks and tradeoffs of decision-making are considered. Although more protective scenarios can be obtained by examining a greater number of risk values, setting too many scenarios will increase the time and the difficulty of calculation. Therefore, this study only used seven different decision-making risk coefficients (0, 0.2, 0.4, 0.5, 0.6, 0.8, 1) for scenario simulation. By analyzing the protection efficiency for cultural services within the boundaries delineated in each scenario plan, no plan was found to achieve the best protection of culture, recreation, biodiversity, recuperation and aesthetic value. Therefore, we can only identify a relatively reasonable plan as the optimal plan by comprehensively weighing all the influencing factors. It should be noted that this contribution only discusses the method of delimiting the boundary of national parks from the perspective of cultural service protection. In practical work, additional indicators, such as ecological integrity, water conservation capacity, and soil and water conservation capacity, should be added according to the actual situation so that the establishment of national parks can better protect a greater number of ecosystem services.

The delimitation of national park boundaries requires a comprehensive decision-making process. In addition to considering ecosystem services, the coordination of interests of surrounding communities and the feasibility of planning and management are also factors that cannot be ignored. To alleviate the binary opposition between national parks and surrounding areas and achieve the goal of regional coordination of strict protection of natural resources and sustainable development of the social economy, it may be a more dynamic and adaptable approach to adopt the double-layer boundary demarcation model of "rigid control and flexible management" for national parks in the future, which is the direction of our subsequent research and discussion.

Conclusion

Based on ArcMap 10.4, Terrset 18.3, GeoSOS 1.2.0 and other software platforms; using remote sensing images, network big data and other resources; applying EBK, OWA, ACO and other models and algorithms; and considering the risks and tradeoffs of decision-making; this paper proposes a national park boundary delimitation method based on ecosystem cultural service protection. This study draws the following conclusions.

Evaluation of cultural services in the Guangdong-Hong Kong-Macao Greater Bay Area indicates the distribution is not even, and there are considerable regional differences. Cultural value hotspots are mainly located in areas with profound cultural heritage and rich historical and cultural heritage resources. Recreational value hotspots are areas surrounded by a large number of entertainment opportunities. The areas with high biodiversity are mainly concentrated in scenic spots, forest parks and wetland parks in various cities. The coastal areas of Huizhou and Jiangmen feature high recuperative value and aesthetic value and are excellent sacred spaces for physical and mental recuperation.

Considering the risks and tradeoffs, this paper simulated seven risk scenarios. Based on the assessment of cultural service value, this study used the OWA method in a GIS environment to convert the area of national parks into grid numbers. Next, we used the ACO method to select the areas for national park land with the aim to simulate and generate seven scenarios to determine the optimal distribution of national parks. After comprehensive consideration, Scenario 5 was found to be the most favourable, and its efficiency of cultural, recreational, biodiversity, recuperative and aesthetic value protection was 1.292, 1.520, 1.469, 1.543 and 1.430, respectively. The boundaries of national parks determined in this study are of great significance to the development of the Guangdong-Hong Kong-Macao Greater Bay Area and provide a reference for the development planning of this region.

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Conflict of Interest

The authors declare no conflict of interest.

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