Spatial Differentiation Patterns and Influencing Factors of National Desert (Rocky Desert) Parks: Postprint

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Abstract

Based on directory data of 125 national desert (rock desert) parks published by the National Forestry and Grassland Administration, this study integrates spatial analysis, geographic detector, and geographically weighted regression methods to investigate the spatial differentiation characteristics and influencing factors of national desert (rock desert) parks. The results indicate: (1) Regionally, national desert (rock desert) parks display a 'more in the north, fewer in the south' distribution pattern, with a construction chronology of 'north first, south later'. (2) The nearest neighbor index is 0.537, revealing a significantly clustered distribution, though with notable variations in clustering scale and magnitude. (3) Spatially, they exhibit a 'sparse in the south and dense in the north, with dual cores and one belt' configuration, demonstrating prominent spatial differentiation. (4) Natural geographical factors exhibit stronger explanatory power than human factors regarding spatial differentiation, and interaction effects between natural geography and human factors are significantly stronger than internal interactions within each domain. (5) The influence intensity of six optimal factors on spatial differentiation shows a trend of increasing positive effects and decreasing negative effects from southeast to northwest, with the northwestern region experiencing the strongest combined forces from natural geography and human factors.

Full Text

Spatial Differentiation Patterns and Influencing Factors of National Desert (Rocky Desert) Parks

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Abstract: Based on data from 125 national desert (rocky desert) parks published by the National Forestry and Grassland Administration, this study employs spatial analysis, geographic detector, and geographically weighted regression methods to examine the spatial differentiation characteristics and influencing factors of national desert (rocky desert) parks. The results reveal: (1) The distribution of national desert (rocky desert) parks exhibits a pattern of "more in the north and less in the south" regionally, and a construction sequence of "first in the north, then in the south." (2) The nearest neighbor index of national desert (rocky desert) parks is 0.537, showing significant agglomeration distribution characteristics, though the agglomeration scales and intensities differ markedly. (3) Spatially, national desert (rocky desert) parks display a pattern of "sparse in the south and dense in the north, with dual cores and one belt," with prominent spatial differentiation features. (4) Natural geographic factors demonstrate stronger explanatory power than human factors for the spatial differentiation of national desert (rocky desert) parks, and the interaction effects between natural geography and human factors are significantly stronger than the internal interactions within each category. (5) The six most influential factors show a trend of increasing positive effects and decreasing negative effects from southeast to northwest, with the northwestern region experiencing the strongest combined influence of natural geographic and human factors.

Keywords: spatial differentiation; geographic detector; geographically weighted regression; national desert (rocky desert) park

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China is one of the countries most severely affected by land desertification in the world, with existing desertified land area of 1.72$\times10^{6}$ km^2, accounting for 17.93% of the national territory, and also represents the most ecologically fragile region in China. Desert (rocky desert) areas possess enormous resource advantages and ecological functions, and actively developing distinctive national desert (rocky desert) parks constitutes a beneficial project for humanity. Desert (rocky desert) parks take desert (karst) landscapes as the main body, focus on protecting desert (karst) ecosystems and ecological functions, rationally utilize natural and cultural landscape resources, and conduct ecological protection, vegetation restoration, scientific monitoring, publicity and education, and ecotourism activities in specific areas. The construction of desert (rocky desert) parks holds positive significance for innovating desertification control models and promoting high-quality regional economic development, and bears important contemporary meaning for building a modern society featuring harmonious coexistence between humans and nature.

Both domestic and international communities have paid close attention to desert (rocky desert) park construction. Internationally, the United Nations Convention to Combat Desertification, adopted in Paris on June 17, 1994, promoted global desertification control efforts, with desert (rocky desert) park construction becoming an effective international measure. Foreign scholars have focused on desert (rocky desert) park demand functions, plant communities and environmental relationships, vegetation-environment relationships, grazing impacts on vegetation, and plant community and diversity assessments. Domestically, since 2013 when the concept of "building desert (rocky desert) parks in suitable locations to develop desert landscape tourism" was first proposed, and with the official issuance of the National Desert Park Development Plan (2016-2025) in October 2016, China has established 125 national desert (rocky desert) parks. In June 2019, the state categorized protected areas into three types based on ecological value and protection intensity: national parks, nature reserves, and natural parks, with natural parks including forest, wetland, geological, and desert parks. The 14th Five-Year Plan further proposed building a nature protected area system with national parks as the main body, nature reserves as the foundation, and various natural parks as supplements.

Domestic scholars have extensively researched the spatial distribution patterns of natural parks such as forest parks, wetland parks, and geological parks, though investigations into underlying formation mechanisms remain limited, with analytical tools restricted to overlay analysis and buffer analysis. Regarding desert (rocky desert) parks specifically, scholars have explored development concepts, planning frameworks, construction practices and implications, tourism carrying capacity, and tourism environment evaluation systems. However, existing research has only examined rocky desert park distributions, with insufficient attention paid to the spatial structure of desert parks, and even fewer studies have deeply explored the correlations with influencing factors. Therefore, this paper selects data from 125 national desert (rocky desert) parks published by the National Forestry and Grassland Administration, using prefecture-level cities where these parks are located as the study area. By comprehensively employing spatial analysis, geographic detector, and geographically weighted regression methods, this study examines the spatial differentiation characteristics and influencing factors of national desert (rocky desert) parks, aiming to provide references for rational layout and sustainable development of these parks, offer theoretical guidance for promoting high-quality tourism development in the new era, and contribute Chinese experience and models for global desertification control.

1.1 Study Area

China' s desertified land is mainly distributed in inland basins and plateau regions between 75°-125°E and 35°-50°N, concentrated from the Tarim Basin in the west to the western Songnen Plain in the east, covering arid and semi-arid areas. These regions can actively promote national desert park construction. Southern karst areas are rich in karst landforms and biological landscape resources, allowing for active exploration of national rocky desert park construction. This study selects 125 prefecture-level cities where 125 national desert (rocky desert) parks are located as the research area.

1.2 Data Sources

The national desert (rocky desert) park list data were obtained from the National Forestry and Grassland Administration (http://www.isenlin.cn). Temperature data for explaining natural geographic factors were sourced from the National Meteorological Science Data Center (https://data.cma.cn). Data on sand content, precipitation, vegetation cover index, terrain relief, and elevation were obtained from the Resources and Environmental Sciences Data Center of the Chinese Academy of Sciences (https://www.resdc.cn). Human factor data were derived from the 2021 National Economic and Social Development Statistical Bulletins of each city. Additionally, administrative boundary data for the 125 parks across 12 provinces (autonomous regions) and 125 cities were downloaded from the Ministry of Natural Resources Standard Map Service System (http://bzdt.ch.mnr.gov.cn) with map approval number GS(2019)1823.

1.3 Methods

1.3.1 Nearest Neighbor Index The nearest neighbor index compares the actual mean nearest neighbor distance with the theoretical mean nearest neighbor distance. The calculation method is:

$$N = \frac{\bar{D}_o}{\bar{D}_e}$$

where N is the nearest neighbor index; $\bar{D}_o$ is the mean distance between actual nearest points; and $\bar{D}_e$ is the theoretical mean nearest neighbor distance. When $N > 1$, it indicates uniform distribution; $N < 1$ indicates agglomerated distribution; and $N = 1$ indicates random distribution.

1.3.2 Multi-Distance Spatial Cluster Analysis (Ripley' s K Function) Ripley' s K function, proposed in 1977, analyzes the degree of clustering at different distances for point datasets, reflecting the spatial clustering or dispersion of features. The formula is:

$$K(d) = \frac{A}{n^2} \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(d)$$

where A is the study area; n is the number of national desert (rocky desert) parks; $w_{ij}(d)$ is a dummy variable for the distance between points i and j within distance d, where $w_{ij}(d) = 1$ if $d_{ij} \leq d$ and $w_{ij}(d) = 0$ if $d_{ij} > d$.

To linearize and stabilize variance, Besag proposed the $L(d)$ function transformation:

$$L(d) = \sqrt{\frac{K(d)}{\pi}} - d$$

Monte Carlo simulation is recommended for hypothesis testing of $L(d)$ function estimation, with confidence level set at 99.99%. The functional relationship diagram of $L(d)$ can analyze and test the multi-scale spatial distribution pattern of national desert (rocky desert) parks. If $L(d) > 0$, it indicates spatial clustering; $L(d) < 0$ indicates uniform distribution; and $L(d) = 0$ indicates random distribution.

1.3.3 Kernel Density Estimation Kernel density estimation uses point aggregation degree to describe the probability of geographic events occurring at different spatial locations. The calculation formula is:

$$\hat{f}_h(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right)$$

where K is the kernel function; h is the bandwidth; n is the number of national desert (rocky desert) parks; and $x - X_i$ is the distance from valuation point x to desert (rocky desert) park point X_i.

1.3.4 Geographical Detector Geographical detector is an analytical tool for detecting spatial differentiation patterns and influencing mechanisms. This study employs differentiation detection to measure the explanatory power of factors affecting the spatial differentiation of national desert (rocky desert) parks, and interaction detection to identify the strength of interactions between different factors. Details are provided in reference [23].

1.3.5 Geographically Weighted Regression Geographically weighted regression (GWR), proposed by Brunsdon et al., incorporates spatial heterogeneity and non-stationarity into regression analysis. It introduces spatial weighting to estimate the influence of factors in different regions, effectively capturing the non-stationary impact of various elements on national desert (rocky desert) parks and describing how variable relationships change with space. This study uses the GWR model to detect the local spatial characteristics of factors influencing the spatial differentiation of national desert (rocky desert) parks. The formula is:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) X_{ik} + \varepsilon_i$$

where i is the observation unit; (u_i, v_i) are the geographic coordinates of observation i; parameter β is a function of u_i and v_i, meaning that the estimated parameters for any specific location are obtained through local estimation and vary with geographic location; X_{ik} is the explanatory variable value for city i; $\beta_k(u_i, v_i)$ is the regression parameter for the kth variable; and $\beta_0(u_i, v_i)$ and ε_i are the intercept term and random error term for location i, respectively.

2 Results and Analysis

2.1 Spatial Distribution Differences

From 2013 to 2021, a total of 9 batches were released, establishing 125 national desert (rocky desert) parks. The first national desert park was established at Shapotou in Zhongwei, Ningxia. The distribution shows a clear pattern of "more in the north, less in the south" regionally, with 98 parks in the north (78.40%) and only 27 in the south (21.60%). At the provincial scale, the pattern is "more in the west, less in the east," with Xinjiang alone having 36 parks (28.80%), exceeding the combined total of Inner Mongolia and Hunan (tied for second). Shanxi, Qinghai, and Gansu follow with similar numbers, each accounting for 8.80%-9.60%, while other provinces have smaller proportions not exceeding 4.80%. At the prefecture level, the pattern shows "few clusters, many scattered distributions." Among 125 prefecture-level cities, only a small portion exhibits spatial clustering patterns. Changji Hui Autonomous Prefecture has the most with 6 parks, followed by Datong City with 5, and Bayingolin Mongol Autonomous Prefecture with 4. The majority show scattered patterns, with over half (65) of prefecture-level cities having only 1 park, and no more than 3 parks in 85% of cities. The distribution across national, provincial, and municipal scales demonstrates heavy dependence on natural geographic conditions. Since selection criteria require a minimum area of 200 hm^2 and desertified land generally accounting for 60% of total park area, the vast desert (rocky desert) areas provide natural conditions for park creation. Chronologically, northern desert parks were established before southern rocky desert parks. Ningxia and Xinjiang pioneered national desert park construction in 2013, followed by widespread implementation in Shaanxi, Qinghai, Inner Mongolia, Gansu, and Liaoning, while rocky desert park construction began in 2015 and reached large-scale development in 2017.

2.2 Spatial Distribution Types

Using ArcGIS 10.6 software' s nearest neighbor distance tool to analyze the 125 national desert (rocky desert) parks, the overall and batch-specific average nearest neighbor indices were obtained (Table 1). Except for the first batch which failed significance testing, all remaining batches and the overall dataset passed the 99.99% confidence test ($|\text{Z-score}| > 2.58$, $\text{P-value} < 0.01$), showing either agglomerated or uniform distribution patterns at the national scale with certain spatial regularities. The overall nearest neighbor index for 125 parks is 0.537, indicating significant agglomeration. Batch differences are substantial: Batch 1 shows uniform distribution, Batches 2, 3, 4, 5, 7, 8, and 9 show significant agglomeration, while Batch 6 exhibits absolute random distribution.

2.3 Spatial Agglomeration Characteristics

Ripley’ s K function analysis reveals that Batch 1 shows random distribution at any scale (K value < 0). Batches 2-9 all show significant agglomeration distribution. From the perspective of agglomeration scale, the order is: Batch 3 > Batch 9 > Batch 5 > Batch 4 > Batch 8 > Batch 2 > Batch 7. Batch 3 has the largest scale (100-800 km), showing agglomeration characteristics within 100-800 km, but begins to show random distribution as spatial scale increases. Batch 7 has the smallest scale (100-300 km). From the perspective of agglomeration intensity, the order is: Batch 3 > Batch 5 > Batch 9 > Batch 8 > Batch 4 > Batch 2 > Batch 7, with significant differences—Batch 3 is the largest and Batch 7 the smallest, differing by nearly 3 times. Different batches have different agglomeration regions: Batch 3 is most densely distributed in northern Xinjiang, with block distributions in the Gurbantünggüt and Taklamakan Deserts; Batch 4 forms high-density distribution in the Hunshandake Sandy Land at the junction of Shanxi, Hebei, and Inner Mongolia, with secondary density in northern Xinjiang; Batch 5 forms high-density distribution in the Gurbantünggüt Desert in Xinjiang and the karst valley rocky desertification areas in Hunan, with secondary density in the Mu Us Sandy Land in Inner Mongolia; Batch 6 forms high-density distribution in the peak forest plain rocky desertification area in Hunan, with scattered point distributions in southeastern Yunnan and southwestern Xinjiang; Batch 7 forms high-density core distribution in the Badain Jaran Desert and secondary core distribution areas at the Hunan-Guangxi border. Overall, due to the construction sequence, national desert (rocky desert) parks have experienced three stages: scattered pilot, concentrated construction, and gap-filling improvement. Evolution patterns are constrained by resource endowments and economic development levels, with most provinces showing an evolutionary pattern of strengthening batch by batch. Xinjiang, Inner Mongolia, Gansu, Qinghai, and other northwestern provinces have extensive and concentrated desert areas. Hunan has actively responded to rocky desertification challenges through government attention, financial support, and agricultural-tourism integration, achieving ecological and economic win-win outcomes.

2.4 Density Characteristics

2.4.1 Overall Density Characteristics Kernel density analysis shows that national desert (rocky desert) parks display a pattern of “sparse in the south and dense in the north, with dual cores and one belt.” The dual cores consist of two high-density core areas: one centered on the Gurbantünggüt Desert in Xinjiang’ s arid sandy region, and the other centered on the rocky desertification area of Hunan’ s solutional depression (trough valley). The belt refers to the intermittent arc-shaped desert belt along the east-west direction of the Great Wall, including the semi-arid sandy regions of the Horqin, Hunshandake, and Mu Us Sandy Lands, and the arid sandy regions of the Kubuqi, Ulan Buh, Tengger, and Badain Jaran Deserts, the Hexi Corridor Desert, and the Qaidam Basin Desert. The overall distribution characteristics of national desert parks clearly reflect high dependence on natural geography, while the high-density core area of national rocky desert parks in Hunan is also related to human factors.

2.4.2 Batch-Specific Density Characteristics As shown in Figure 4, kernel density analysis of different batches reveals varying spatial patterns. Batch 1 shows high-density distribution in the Mu Us Sandy Land at the junction of five provinces (Shanxi, Inner Mongolia, Shaanxi, Ningxia, Gansu) and the Qaidam Basin Desert at the Qinghai-Gansu border, with block concentrations in northern and western Xinjiang and at the Inner Mongolia-Liaoning border. Batch 2 forms high-density distribution in the Hunshandake Sandy Land at the Shanxi-Hebei-Inner Mongolia border and secondary density in northern Xinjiang. Batch 3 forms high-density distribution in the Gurbantünggüt Desert in Xinjiang and the karst trough valley and solutional depression rocky desertification areas in Hunan, with secondary density in the Mu Us Sandy Land in Inner Mongolia. Batch 4 forms high-density distribution in the peak forest plain rocky desertification area in Hunan, with scattered distributions at the Yunnan-Guangxi and Hunan-Guangxi borders. Batch 5 forms high-density core distribution in the Badain Jaran Desert and secondary density core areas at the Hunan-Guangxi border. Overall, the evolution trend of batch-specific density changes shows that construction scope expanded from west to east and north to south, with three stages: scattered pilot, concentrated construction, and gap-filling improvement.

2.5 Influencing Factors of Spatial Differentiation

The formation and spatial differentiation characteristics of national desert (rocky desert) parks result from long-term natural evolution and human-land system interactions, reflecting dependence on both natural geographic and human factors. Drawing on existing research regarding influencing factors of natural parks such as wetland parks, forest parks, and geological parks, this study uses 6 factors to represent natural geography (temperature, sand content, precipitation, vegetation cover index, terrain relief, elevation) and 8 factors to represent human aspects (urbanization rate, per capita GDP, tourist arrivals, number of A-level scenic spots, number of star-rated hotels, tourism revenue, number of travel agencies, total highway mileage, number of students in school, and number of patent authorizations). Differentiation and interaction detection were used to analyze the influence intensity of driving factors on spatial distribution, and the six strongest factors were selected for further measurement of their directional effects.

2.5.1 Differentiation Detection Analysis Factor detection results (Table 2) show that all 14 influencing factors passed the 99.99% confidence test ($P < 0.01$), with each factor having some explanatory power (q) for spatial differentiation, though differences are significant. The driving strength ranking is: temperature (X_1) > sand content (X_2) > precipitation (X_3) > star-rated hotels (X_{10}) > tourist arrivals (X_8) > tourism revenue (X_9) > vegetation cover index (X_4) > number of travel agencies (X_{11}) > total highway mileage (X_{12}) > number of students (X_{13}) > patent authorizations (X_{14}) > terrain relief (X_5) > elevation (X_6) > urbanization rate (X_7). The two strongest driving factors are natural geographic factors, indicating that natural geography overall has stronger driving force than human factors.

Natural Geographic Factors: Deserts are natural phenomena on Earth, and natural geographic environments provide fundamental support for the formation and distribution of national desert (rocky desert) parks. Temperature is the most influential factor because national desert (rocky desert) parks are typically located in regions with arid, rainless climates and large temperature variations. Sand content is the second most important factor, as higher sand content leads to faster water infiltration, poorer water retention, and easier desert (rocky desert) formation. Precipitation and vegetation cover index are also strong natural drivers. National desert (rocky desert) parks require adequate precipitation to guarantee ecological and other water demands, while low vegetation coverage is an important cause of desert formation. Both precipitation and vegetation cover index show negative correlations with park distribution overall. Terrain relief and elevation have relatively weak influence on spatial differentiation.

Human Factors: Sandy and rocky desertification areas are not only multi-ethnic inhabited regions and important border defense zones but also crucial energy, metallurgical, and heavy chemical industry bases in China. Developing national desert (rocky desert) parks provides a new path for resolving contradictions between ecological protection and economic development in sandy areas, serving as a guiding driving force for spatial differentiation. Among human factors, star-rated hotels (representing tourism industry potential) and tourist arrivals (representing tourism development level) have the greatest influence. Desert tourism, a product combining unique natural landforms with market economics, has become one of the five major fashionable tourism industries. As desert tourism destinations, the tourism infrastructure and visitor reception capacity of these areas directly determine the number and development potential of local desert (rocky desert) parks. Economic factors also strongly influence spatial differentiation, with higher urbanization rates and per capita GDP being more favorable for park protection and development. Hunan, ranking first in both number and area of national rocky desert parks, also leads in tourism revenue. Although highway mileage, student numbers, and patent authorizations have smaller influence, they remain important. Transportation accessibility directly affects tourist experience, while talent and technological innovation enrich desert tourism product displays.

2.5.2 Interaction Detection Analysis Interaction detection results show all factor pairs exhibit nonlinear enhancement or dual-factor enhancement (Figure 5). The spatial differentiation of national desert (rocky desert) parks is a complex phenomenon resulting from multi-factor coupling and feedback, with combined effects of two factors generally stronger than the sum of individual effects. The top-ranked interaction combinations are: X_1 X_{10}, X_1 X_8, X_2 X_{10}, X_1 X_9, X_2 X_8. Overall, natural geographic factor interactions are significantly stronger than human factor interactions, but natural geography-human interactions are significantly stronger than internal interactions within each category, indicating that park formation results from long-term natural evolution and human-land system interactions. Temperature and star-rated hotels are the strongest individual interaction factors from natural geography and human factors respectively. Desert (rocky desert) formation and evolution are closely related to temperature changes, while star-rated hotel-supported tourism infrastructure greatly enhances visitor experience and promotes sustainable desert tourism development.

2.5.3 Geographically Weighted Regression Results The six strongest influencing factors (X_1, X_2, X_3, X_7, X_8, X_{10}) were fitted using the GWR model to analyze spatial differences in factor effects and intensity. Results show that factor effects on park differentiation exhibit a trend of increasing positive effects and decreasing negative effects from southeast to northwest, with the northwestern region experiencing the strongest natural geographic and human influences.

Natural Geographic Factors: Temperature (X_1) and precipitation (X_3) have negative regression coefficients, exerting significant negative effects on park differentiation, while sand content (X_2) has positive coefficients with significant positive effects. The negative effect of temperature decreases progressively from south to north, being most significant in Altay, Xilingol, Chifeng, Tongliao, and Chengde. The negative effect of precipitation and positive effect of sand content show a "southeast-northwest" increasing trend, with the most significant effects in Xinjiang (except for Kizilsu Kirghiz Autonomous Prefecture, Ili Kazakh Autonomous Prefecture, and Bortala Mongol Autonomous Prefecture).

Human Factors: Urbanization rate (X_7), tourist arrivals (X_8), and star-rated hotels (X_{10}) all have positive regression coefficients, exerting enhanced positive effects on spatial differentiation. Higher urbanization levels mean better infrastructure and greater tourist attraction, with greater tourism development potential. These effects are particularly significant in Xilingol League of the Hunshandake Sandy Land, Alxa League and Zhangye City of the Badain Jaran Desert, Haixi Mongolian and Tibetan Autonomous Prefecture, Huangnan Tibetan Autonomous Prefecture, and Hainan Tibetan Autonomous Prefecture of the Qaidam Basin Desert, as well as Bayingolin Mongol Autonomous Prefecture, Aksu, Kashgar, and Hotan of the Taklamakan Desert, and Changji Hui Autonomous Prefecture of the Gurbantünggüt Desert. Tourist arrivals, as an important indicator of tourism development level, show consistent effect direction and similar spatial scope as urbanization rate but with greater intensity. Star-rated hotels, as important pillars of tourism industry potential and urban image, show lower influence intensity than tourist arrivals, with relatively uniform impact across northwestern cities in Xinjiang, Qinghai, Gansu, and western Inner Mongolia. Overall, human factors, primarily related to tourism industry development level, show obvious enhanced positive effects on spatial differentiation.

3 Discussion

3.1 Conclusions

This study comprehensively employs nearest neighbor index, multi-distance spatial cluster analysis, kernel density estimation, geographic detector, and geographically weighted regression to objectively describe spatial differentiation characteristics and influencing factors of national desert (rocky desert) parks, reaching the following conclusions:

1) National desert (rocky desert) parks show significant regional distribution differences: "more in the north, less in the south" regionally; "more in the west, less in the east" provincially, with Xinjiang having the most and Shaanxi, Guangxi, Guangdong, Sichuan, and Hubei having the fewest; and chronologically, northern desert parks preceded southern rocky desert parks.

2) The 125 parks have a nearest neighbor index of 0.537, showing significant agglomeration. Batch differences are notable: Batch 1 shows uniform distribution, Batches 2, 3, 4, 5, 7, 8, and 9 show significant agglomeration, while Batch 6 shows absolute random distribution. Batch 3 shows an "inverted U-shaped" characteristic in both agglomeration scale and intensity, while Batch 6 shows absolute spatial randomness.

3) Spatially, parks display a "sparse in the south and dense in the north, with dual cores and one belt" pattern. The dual cores include one centered on the Gurbantünggüt Desert in Xinjiang' s arid sandy region and another centered on the rocky desertification area in Hunan's solutional depression (trough valley). The belt refers to the intermittent arc-shaped desert belt along the Great Wall.

4) Natural geographic factors have stronger explanatory power than human factors, though natural geography-human interactions are significantly stronger than internal interactions within each category. Temperature and star-rated hotels are the strongest interaction factors.

5) GWR analysis of the six strongest factors shows that their effects on park distribution exhibit increasing positive effects and decreasing negative effects from southeast to northwest, with the northwestern region experiencing the strongest combined influences. Temperature and precipitation have significant negative effects, sand content has significant positive effects, while urbanization rate, tourist arrivals, and star-rated hotels have enhanced positive effects. Under high-quality tourism development goals, human factors show increasingly significant enhanced positive effects on park spatial distribution.

3.2 Recommendations

National desert (rocky desert) parks are important components of the national park system and crucial carriers for promoting high-quality eco-tourism development. Studying their spatial distribution and formation mechanisms provides scientific reference value for optimizing the spatial structure layout of desert (rocky desert) national park systems.

1) **Optimize layout and promote coordinated development.** The spatial distribution remains agglomerated and uneven, mainly concentrated in arid and semi-arid sandy regions with poor transportation and long distances from cities, while scattered distribution in humid 零星 sandy areas hinders integration and optimization. The state should increase financial investment and policy support, strengthen transportation network infrastructure, and prioritize encouraging development in provinces with zero park distribution (e.g., Jilin, Heilongjiang, Shandong, Henan) and zero-distribution sandy sub-regions (e.g., Huang-Huai Plain, Hulunbuir) to effectively 发挥 the positive roles of parks in improving local ecology, combating desertification, and promoting coordinated regional development.

2) **Classify categories and implement precise policies.** Based on influencing factors, national desert (rocky desert) parks can be categorized into natural landscape-dependent, cultural heritage utilization, sightseeing and entertainment experience, and leisure vacation health types. Natural landscape-dependent models should develop distinctive desert (rocky desert) tourism products based on resource endowments and location advantages. National desert parks should leverage desert resource advantages to create unique brand advantages and optimize tourism product supply structures. National rocky desert parks should fully utilize unique karst tourism resources to build karst tourism brands and display karst natural features. Cultural heritage utilization models should leverage Silk Road ancient city sites like Loulan, Niya, and Milan to develop important archaeological tourism resources. Sightseeing and entertainment experience models should diversify activity programs beyond homogeneous sand sliding and desert off-roading to include extreme sports, parent-child interactions, and wedding photography. Leisure vacation health models should integrate with surrounding tourism resources (urban customs, ethnic cultures, historical sites) to form desert industry clusters and develop resort health tourism products to meet visitors' needs for ecological culture experience, fitness, and outdoor leisure, promoting quality upgrading of desert tourism industries.

3) **Integrate human factors and scientifically select sites.** Current application conditions for national desert (rocky desert) parks focus primarily on basic natural geographic factors like geographic location, area, and water resources. However, human factors show increasingly significant en-

hanced positive effects on spatial differentiation. Future selection should incorporate human factor indicators such as urbanization rate, tourist arrivals, and star-rated hotel numbers as reference standards to ensure optimal application, scientific evaluation, and strict selection, guaranteeing effective park construction.

4) **Prioritize ecology and promote green development.** National desert (rocky desert) parks are mostly located in ecologically fragile areas, and tourism is a typical environment-dependent industry. If desert (rocky desert) ecosystems are damaged, tourism cannot be sustained. Therefore, we must firmly establish the concept that "lucid waters and lush mountains are invaluable assets," follow an ecology-first, green development path, enhance ecological functions, build ecological security barriers, ensure tourism-related industries do not exceed ecological carrying capacity, enable desert (rocky desert) ecosystems to enter virtuous cycles and natural succession, achieve harmonious coexistence between humans and nature, and high-quality advancement of the national park system.

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Note: Figure translations are in progress. See original paper for figures.