DESIGN AND IMPLEMENTATION OF GEOPARK MANAGEMENT SYATEM IN SOUTHWEST CHINA BASED ON GIS

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ABSTRACT:

Geoparks contain various geological relics and peculiar geological landscapes, which have good ornamental value and are non-renewable precious wealth. Today, with the deterioration of the natural environment and the impact of human activities, the geopark has been destroyed to a certain extent, but the current research methods on the geopark are still mostly traditional propaganda methods with a single method. This study takes the geoparks in Southwest China as the research object, establishes a geopark management system, realizes the display, query, statistical rendering, distribution analysis and impact factor analysis of geoparks in the region, not only intuitively reflects the distribution of geoparks, The GIS analysis method is also introduced to explore the regularity of their distribution and the factors affecting the distribution, so as to provide reference for the protection, planning and construction of subsequent geoparks.

1. INTRODUCTION

National Geoparks are regions with unique natural landscapes formed by multiple factors such as time and geographical environment, integrating natural and cultural landscapes. In April 1999, the Department of Earth Sciences of UNESCO formally proposed the establishment of a geopark plan(Ding et al., 2012). The construction of China's geoparks is a new work initiated by the Ministry of Land and Resources in 2000 in response to the UNESCO initiative to establish a "World Geopark Network System". Geoparks are responsible for three tasks(Stoffelen et al., 2019; Zhao and Zhao, 2002): the first is to protect geological relics and protect the natural environment; the second is to popularize earth science knowledge and improve the scientific quality of the public; the third is to carry out tourism activities and promote the sustainable development of local economy and society. However, due to the impact of natural changes and human activities, the destruction of historical relics and natural landscapes in geoparks is becoming more and more serious.

When we study the existing geopark management system designed and developed based on GIS, we find that there are still some places that can be improved. First of all, most of the management systems of geoparks are guided tours of geoparks, including basic functions such as simple display and query, or ecological environment assessment, which are mostly administrative and lack in-depth business logic analysis. Secondly, in terms of theory, most of them are applied analysis of geoparks, such as site selection analysis and accessibility analysis. However, there are few studies on the distribution characteristics of geoparks, and deep-level business management such as time-space mining is lacking, so it is difficult to grasp the distribution rules of geoparks and realize efficient management.

In order to deal with the above challenges, in this study, we used the first batch to the eighth batch of world-class and national-level geopark data in Southwest China, and took the B/S model as the development framework to realize the information of geoparks in Southwest China. A system for displaying, querying, and statistical rendering, distribution analysis, and distribution effects. The main contributions of our research are as follows.

1) Explored the distribution rules of geoparks and the factors affecting the distribution of geoparks, which is convenient for the subsequent planning and layout of geoparks.

2) Integrate the unique spatial analysis results of GIS into the geopark management system to enrich the functions of the system and help decision makers better resource management and protection.

2. RELATED WORK

With the rapid development of the economy, the destruction of the ecological environment has become more and more serious, and people have begun to realize the importance of protecting geological relics. As for the protection of geoparks, the construction of geoparks in foreign countries started earlier, which has reference significance for the development and protection of geoparks in my country. The United States was the first country to protect geological relics by establishing geoparks, and applied GIS to geological park management(Li, 2013). Some

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scholars have designed mobile GIS to help tourists plan their routes and introduce information about the attractions of geoparks. For example, Darsiharjo (Arrasyid et al., 2021) developed a mobile GIS application to provide navigation, display geopark information, and recommend routes for users. Insani N(Insani et al., 2022) used ADDIE (Analysis, Design, Development, Implementation, Evaluation) to develop and evaluate a mobile GIS application that provides navigation and geohazard maps of volcanic eruptions. Some scholars, such as Utama P W (Utama et al., 2019), used spatial analysis methods to assess the suitability of land use in the Batur UNESCO Global Geopark area, and at the same time assessed land use through land capacity classification. In China, most of the geographic information management systems established are based on the perspective of tourism science, conducting ecological environment assessment or guiding geoparks(Chen et al., 2022; Chu and Wu, 2017; Huo and Tian, 2018; Zhang et al., 2019). There are also some scholars who conduct theoretical research on geoparks, including accessibility analysis and site selection analysis of geoparks(He and Liu, 2019; Liang et al., 2021).

Generally speaking, although the protection of geoparks has entered a new stage of development, in terms of systems, most of them focus on simple geoparks and their content display, lack of decision-making and analysis content, and cannot dig out its deep information to achieve comprehensive manage. On the other hand, the management of geoparks is more administrative, with little protection and single means. Most of them are limited to text and picture promotion through websites, and tourism and other methods are used to attract more people to geoparks. There is a lack of in-depth theoretical analysis. Therefore, it is now a key issue to integrate the spatial analysis results of geoparks into the system and display them.

3. STUDY AREA AND DATASET

In this study, Southwest China was selected as the study area. Southwest China is one of the seven natural geographical divisions in China. It borders Central China and South China in the east, and Northwest China in the north. The Southwest region under the natural division mainly includes the Sichuan Basin, the Yunnan-Guizhou Plateau, the southern Qinghai-Tibet Plateau, and the western part of the Guangdong-Guangzhou hills, but there is no clear definition of provinces and cities in the Southwest region(Wang et al., 2022; Wang and Yu, 2013). This study adopts the project area stipulated in the National Key Research Program Project "Climate Change's Influence Laws and Mechanisms on Southwest Ecological Security", which includes the entire territory of Guangxi, Guizhou, Sichuan, Chongqing, and Yunnan provinces as well as Yushu in Qinghai, Lhasa in Tibet, Naqu, Shannan, Lingzhi, Qamdo.

From the perspective of topography, the southwest region is one of the regions with the most complex terrain conditions in China. The terrain descends in a stepwise manner from west to east, and the region spans three steps, including the Qinghai-Tibet Plateau in the first step, the Sichuan Basin in the second step, and the transition zone in the middle and lower reaches of the Yangtze River in the third step(Xiong et al., 2019). Therefore, unique natural landscapes and historical relics can be formed and eventually developed into a geoparks. From the perspective of climate, the climate types in the southwest region range from a warm and humid marine climate to a plateau monsoon climate with four seasons like spring, to a subtropical plateau monsoon humid climate and a plateau climate on the Qinghai-Tibet Plateau, with a large span and uneven distribution of temperature and precipitation, affecting the formation of geoparks(Zeng et al., 2022). From the perspective of water system, the density of river network in Southwest China is high, the structure of water system is complex, and there are many large rivers, with obvious differences among regions. The central and northern areas are dominated by rivers in the Yangtze River Basin, while the southern and western areas are divided into the Pearl River Basin and the Yarlung Zangbo River. In addition, there are many small inland rivers flowing into the lake, which promotes the development of the geoparks.

3.1 Dataset

The geoparks data in this study are all from the world-level and national-level geoparks announced by the State Forestry and Grassland Administration. The dataset includes the data of the first, second, third, fourth, fifth, sixth, seventh, and eighth batches of world-class and national-level geoparks. The fields include the name, batch, time, area, level, and main geological landscape of the geopark. Through the basic information of the geopark, use the Gaode coordinate picking system to collect the longitude and latitude coordinates of each geopark, set it as a field, and save it in the table together with the basic information of the geopark collected in the previous step. Use ArcMap to carry out X and Y coordinates to visualize the geographic location of the geopark, and proofread the points with large errors. The population and GDP data of this study are all from the 2015-2020 statistical yearbooks of the whole country and Southwest regions, and the main rivers are selected for the rivers. The distribution of geoparks in Southwest China is shown in Figure 1.

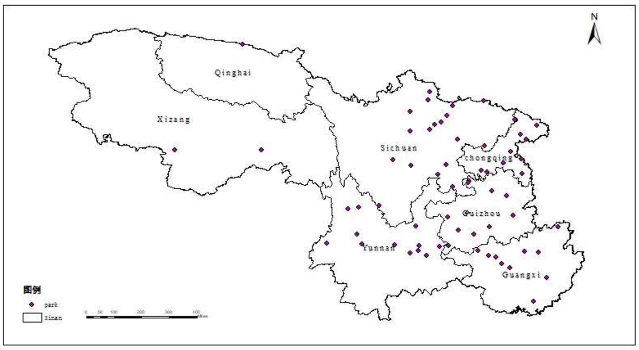

Figure 1. Distribution of Geoparks in Southwest China.

4. METHODS AND SYSTEM DESIGN

4.1 Methods

4.1.1 Kernel Density Analysis

Kernel density analysis is used to describe the spatial density characteristics of geoparks in Southwest China. This method believes that geographical events can occur in all regions of geographic space, but the probability of occurrence in different regions is different. An event has a high probability of occurring in areas where point elements are densely distributed, and a low probability in areas where point elements are sparsely distributed. This method is generally expressed by Rosenblatt-Parzen kernel estimation, and the formula is as follows (Liu et al., 2011; Jing et al., 2020):

$$f_n(x) = \frac{1}{nh} \sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right), \tag{1}$$

where $f_n(x)$ = kernel density estimate
n = number of geopark points

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h = bandwidth
i = the ith geopark point
x - x_i= distance from point to sample park point

4.1.2 Nearest Neighbor Index

The nearest neighbor index method is an important geographical indicator for judging the spatial distribution type (uniform, random, and cohesive) of point elements. From a macro perspective, geoparks in Southwest China can be abstracted into point elements. Based on the comparison of the average observation distance between each geopark point and its actual nearest neighbor. When R>1, it means that the geopark points tend to be evenly distributed, which is a uniform type; when R<1, it means that the geopark points tend to be cohesively distributed, which is a cohesive type; Random distribution, random type. The formula is as follows (Liu et al., 2022):

$$r_E = \frac{1}{2}\sqrt{\frac{n}{A}} = \frac{1}{2}\sqrt{D} \quad , \quad R = \frac{\bar{r}_1}{r_E}, \tag{2}$$

where n = Total number of geopark points
A = area of Southwest
D = density of geopark
R = nearest neighbor index

4.1.3 Buffer analysis

Buffer analysis is one of the important spatial analysis functions in geographic information systems. It takes point, line, and area entities as target elements, constructs buffer polygons within a certain width range around them, and then combines the layer with the target layer Overlay, to analyze the effect on neighboring features. This study plans to construct a river buffer zone, and by overlaying it with the thermal map of the geopark, the number of geoparks covered in the river buffer zone can be obtained based on correlation analysis. With the increase of the distance of the river, the change law of the distribution of the geopark is analyzed, and the relationship between the spatial distribution of the geopark and the distribution of the river is deduced.

4.2 System Design

The system adopts a three-layer architecture based on industry standards, including the presentation layer, analysis layer, and data layer, as shown in Figure 2. The data layer is visualized through the coordinate points of the crawled geopark. The analysis layer includes map services published by GeoServer and models for spatial analysis. The presentation layer is the final module displayed by the system, providing users with intuitive display of geopark information and spatial analysis results.

The functions of each view module of the presentation layer are as follows.

1) Basic tools module. This module mainly shows the first interface of the Southwest Geopark system and the basic interaction of the user with the system, and provides an overall understanding of the distribution of Geoparks in the Southwest region.

2) Query and statistics rendering module. This module supports users to make precise query, fuzzy query, conditional query and spatial query for geoparks, and display the returned results in the result box by highlighting them. It also renders statistics for Southwest Geoparks by level and region, and uses various ways such as charts to display them visually.

3) Distribution analysis module. This module analyzes the spatial aggregation status of geoparks in Southwest China using the kernel density analysis method, and analyzes the spatial distribution status using the mean nearest neighbor analysis method.

4) Influence factor module. The module mainly focuses on three influence factors, rivers, GDP and topography, and explores their influence on the distribution with geoparks through spatial analysis methods.

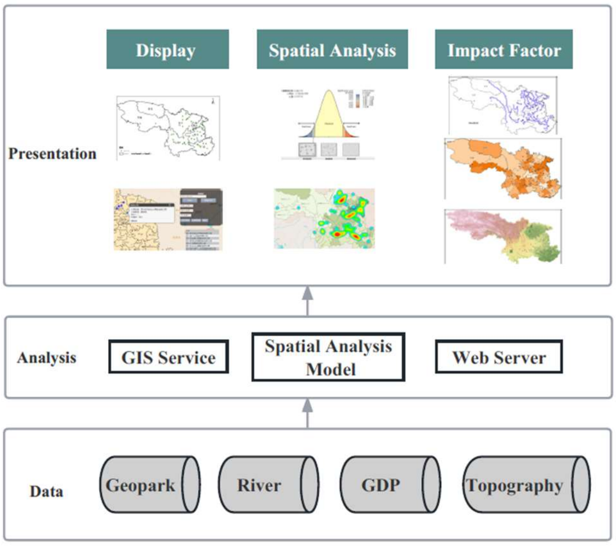

Figure 2. System Architecture.

5. SYSTEM IMPLEMENTATION

By investigating the system requirements and system design, this study implements a geopark management system in the southwest region, and the system interface is shown in Figure 3. A is the basic tool view of the system, B is the query and rendering view of the system, C is the distribution analysis view of the system, and D is the impact factor view of the system.

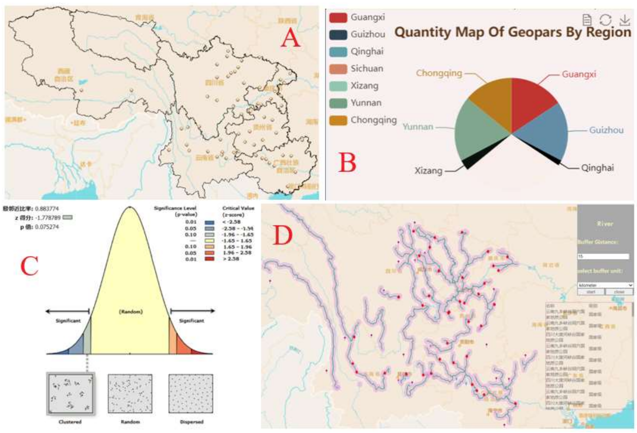

Figure 3. System Implementation.

5.1 Basic Tools Module

Southwest China is a vast area, geoparks are distributed in different areas, and their distribution can be intuitively seen by displaying them. The homepage of the system contains three parts: the title bar, the navigation bar and the main interface. The title bar shows the name of the system in the upper left corner, and the navigation bar shows the main function modules of the system, including four parts: home page, query and statistical rendering, distribution analysis and impact factor. The main interface provides a display of the map and the results after user operation, which includes basic tool modules such as zoom in and out, locating the center point, and after clicking on a geopark, it can display its detailed information, specifically including the name, level, batch and place of the geopark, which provides information for understanding the basic situation of the geopark.

5.2 Query And Statistics Rendering Module

Querying mainly realizes comprehensive querying of geoparks in the southwest region and returns results to users, mainly including: exact query, fuzzy query, conditional query, and spatial query, as shown in Figure 4. Statistical rendering mainly uses ECharts visualization technology to realize mathematical statistics on the number and distribution of geoparks in the southwest region, mainly including statistical rendering by region, as shown in Figure 3B.

The precise query function mainly implements the query according to the precise name of the input geopark. If the query is successful, the query result will be returned and highlighted. The fuzzy query function is to query all geoparks containing these words according to the words entered in the name box, and display them in the result box. You can also click to view the detailed information of geoparks. The conditional query function is to query the level, batch, and city where the user chooses. The level includes world level and national level. Cities include Sichuan, Yunnan, Guangxi, Tibet, Chongqing, Guizhou, and Qinghai. After the query is successful, it will display the number of geoparks that meet the query requirements, and after highlighting, the name of the geopark will be displayed in the result box. The spatial query function mainly allows the user to click on the map area to draw any polygon, select the required geopark, double-click to complete the drawing, highlight the geopark in the frame, and display the result in the result box.

Rendering statistics by region mainly perform unique value rendering according to the different cities to which geoparks belong, and at the same time count the number and proportion of geoparks in each province in the Southwest region. Through statistics and rendering functions, users can have a clear understanding of the number and categories of geoparks in Southwest China.

Figure 4. Query Function. From left to right, from top to bottom, corresponding to exact query, conditional query, fuzzy query and spatial query.

5.3 Distribution Analysis Module

Spatial distribution state analysis used the average nearest neighbor method, the average nearest neighbor tool is released as GP service, the distance method uses ArcGIS comes with EUCLIDEAN_DISTANCE (straight line distance between two points) for the average nearest neighbor operation, and finally jumps to the average nearest neighbor result report, as shown in Figure 3C.

The spatial aggregation analysis uses the kernel density method, which is expressed in the form of a heat map in the figure. By studying the aggregation status of Geopark points, the higher the probability of occurrence in the aggregated places, the darker the color is expressed in the figure; the lower the probability of occurrence in the discrete places, the lighter the color is relatively, as shown in Figure 5.

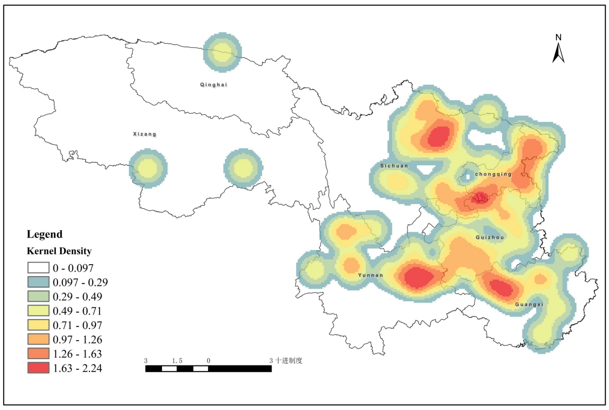

Figure 5. Kernel Density Analysis Results.

5.4 Influence Factor Module

The impact factor module selects three impact factors, river, GDP, and topography, to explore their impact on the distribution of geoparks, thereby obtaining the distribution rules of geoparks for subsequent protection and development.

Rivers are the beginning of human civilization. Through their own flow rate, they erode and accumulate land, forming various geological landscapes. There are many rivers in Southwest China, so it is necessary to study the influence of river factors on the distribution of geoparks. The system selects the main rivers in the southwest region, constructs buffer zones for them, and observes the results of the number of geoparks in the buffer zones, as shown in Figure 3D. GDP is an important indicator of national economic accounting. Generally speaking, the higher the GDP, the richer people's lives, the higher the spiritual needs, and the better the protection and development of natural resources. In the figure, the darker the color, the higher the GDP per capita, and the lighter the color, the lower the GDP per capita, as shown in Figure 6. The formation of geoparks is inseparable from topographic factors. In some areas of the southwest, geological movements may lead to large fluctuations in the topography, creating many unique geological landscapes and slowly forming geoparks. This study analyzes the impact of topography on the distribution of geoparks by overlaying the topography of the southwest region with the distribution layer of geoparks, as shown in Figure 6.

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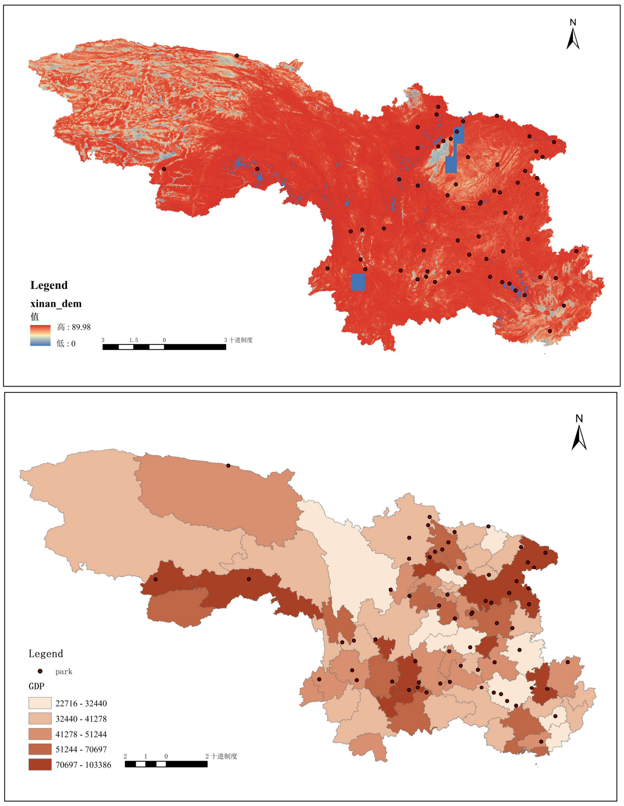

Figure 6. Results Of Topographic (top) And GDP (bottom) Impact Factors.

6. DISCUSSION

Through the display and statistics of the rendering module, it can be seen that among all regions, the number of geoparks in Sichuan Province ranks first, and the number of geological parks in Tibet Autonomous Region and Qinghai Province is relatively small. Since the southwest region in this study only includes some cities in the Tibet Autonomous Region and Qinghai Province, the included cities can gradually increase the number of geoparks.

In the spatial analysis module, the results of the average nearest neighbor method show that the nearest neighbor ratio R of the spatial distribution of geoparks in Southwest China is 0.883774 < 1, which indicates that geoparks tend to be cohesively distributed and cohesive. According to the heat map of the overall spatial distribution of geoparks in Southwest China, it can be seen that the distribution of geoparks in Southwest China forms four extreme core areas, one high density area and three secondary density areas. The four extreme core areas are distributed at the junction of Mianyang and Deyang in Sichuan Province; the junction of Chongqing and Zunyi in Guizhou Province; the junction of Kunming and Qujing in Yunnan Province; and Hexi in Guangxi Zhuang Autonomous Region; one high-density area is distributed in Chongqing; and three sub-density areas are distributed in Lijiang in Yunnan Province; Dali Bai Autonomous Prefecture and Liuzhou City in Yunnan Province. The overall distribution of geoparks in Southwest China and the reasons for this can be summarized as follows:

First, Sichuan Province is known as the "province of a thousand rivers", with many rivers, mainly the Yangtze River system, and abundant water resources create good conditions for the formation of geoparks. Secondly, Chongqing, also known as the "City of Mountains", has a large difference in topography and is the largest economic center in the southwest region. Third, Yunnan Province is a popular cultural and tourism province in the country. The province is divided into two major topographic regions, the east and the west. The east is a part of the Yunnan-Guizhou Plateau, with low and undulating topography, and the west is steep. There are many kinds of geological phenomena, and it is easy to form a geopark. Fourth, the Guangxi Zhuang Autonomous Region is located in the southern Xinjiang of China, with the overall landform of mountainous and hilly basins. The protection of the natural landscape of geoparks is also increasing. Fifth, although the western region, including some cities in Tibet and Qinghai, has complex and diverse terrain, numerous rivers, and a large difference in terrain. However, due to the unique and complex climate and the relatively small number of residents, the concept of establishment and protection of geoparks is gradually improving, and no gathering area has yet been formed.

Through the influence factor module, the analysis shows that the distribution of geoparks is influenced by the river, GDP and topography factors, and is positively correlated with the population and GDP factors, and most of them are located near rivers and in areas with large topographic relief.

Through the development of a GIS-based system, the above modules are effectively integrated, and a comprehensive and intuitive display is given to users. At the same time, various component libraries such as ECharts are introduced to give users a better interactive experience.

7. CONCLUSIONS

Geoparks, as our precious wealth, cannot just stay at the theoretical level. The research object of Geopark Management System in Southwest China designed in this paper is mainly geoparks, and the research area is Southwest China. It is a complete system integrating display, query and analysis. Compared with the traditional geoparks management system, this system provides a new solution for the management of geoparks more effectively. In addition to presenting the geoparks to users more intuitively, it helps to grasp the distribution characteristics of the geoparks. At the same time, it uses the spatial analysis function excavates the distribution rules of geoparks and integrates them into the management system to provide support and decision-making for the development of geoparks in the future.

At the same time, there are some deficiencies in this system. The Geopark Management System in Southwest China is a user-oriented system, but as people's awareness of nature protection gradually increases, the number of geoparks will gradually increase. When building the system, not only the current user interaction, but also consider the problem of massive data in the future.

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