Research of Fractal Dimension Based on Classification of Karst Basin Contours

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Abstract. Karst basin as a relatively independent hydrological and geomorphological system is composed of different sub-units. The ecological environment conditions of each unit have both internal relations and obvious differences, so it is difficult to conduct ecological governance in the same way. By using GIS technology, automatic extraction and multicomponent auxiliary correction were used to determine the basin boundary, fractal theory was adopted to classify the basins, and the characteristics of each type of drainage basins were analyzed in combination with slope, undulation, vegetation cover and land use. The results show that: (1) The problem of boundary inconsistency between above-ground and underground drainage basins in karst basin is solved by using the method of correcting the basin extracted automatically from the surface basin. (2) According to the calculated average fractal dimension of contour line of each river basin, and combined with the geomorphological characteristics of each river basin, the dividing threshold of each river basin was determined, and the fractal dimension value greater than or equal to 1.64 was divided into the first type of river basins. The fractal dimension between 1.64 and 1.74 is the second type of basin. The fractal dimension value greater than or equal to 1.74 is divided into the third type of basin. (3) Three karst basins of different types have different landforms, vegetation cover and land use, which provide theoretical basis and technical support for the control of rock desertification in accordance with local conditions.

Key words: Karst basin; Fractal Dimension; Classification.

1. Introduction

Rocky desertification is a major obstacle to the sustainable development of karst areas [1]. For this reason, the country has carried out a series of projects to control rocky desertification, such as returning farmland to forests, benefiting national science and technology and tackling key problems [2-3]. Many scholars have also tried to study and discuss the restoration and reconstruction measures of karst ecosystem from different perspectives, and concluded many beneficial governance models [4-5]. However, after years of efforts to comprehensively treat rocky desertification, the governance effect is still not ideal, mainly because there is no comprehensive and accurate grasp of the characteristics of the objects of governance.
River basin is a complete natural geographical units. In the basin ecological environment are the result of superposition of nature and human activity effect, the integrated management model in basin as a unit is considered to be the prevention and treatment of soil and water loss [6-7], the most effective way to rocky desertification governance, but basin as a relatively independent karst hydrological landscape system is composed of different secondary units, each unit of the ecological environment condition is an obvious difference, the correlation of both the inner ecological management is difficult to use the same methods.

In view of this, this paper takes Liupanshui city which is the most serious rocky desertification in guizhou and the whole southwest karst region as the research object. The fractal classification of basin in karst area is carried out based on the fractal dimension of contour line. Different karst basin areas have their own characteristics, and different basin areas are classified for later remediation and management. This new classification method, more comprehensive and more comprehensive than conventional quantitative parameters of reaction, the characteristics of the basin can raise questions degree of quantitative analysis of basin and the relation of spatial differentiation of all kinds of basin are discussed and the scale effect, provide data support for further analysis of the basin, also facilitate subsequent karst basin other aspects of the quantitative research, provide the basis for other aspects of quantitative research.

2. Materials and Methods

2.1. Study Area

Liupanshui city is located at 25 ° 19 '44 "N - 26 ° 55' 33" N, 104 ° 18 '20 "E - 105 ° 42' 50" E (Fig. 1), located in Yunnan and Guizhou provinces at the junction, is located in the secondary terraced slopes of Yunnan to Guizhou plateau, total area of 9965 square kilometers, the total population of 3.1 million. Liupanshui is a typical karst landform with a wide distribution area of carbonate rocks. It is one of the most serious rocky desertification areas in Guizhou and even the whole Southwest karst region. The rocky desertification area has reached 2,575 square kilometers, which has seriously threatened the living environment of nearly one million people.

![Figure 1](image)

Figure 1. Study area location in China (a) and topography (b)

2.2. Materials

The data required for this study are shown in Table 1. The vector data contain the administrative border data data. The raster data contain NDVI, DEM, land use.
Table 1. Major data sources

| Data Name                  | Data Source                                      | Data Source Site Link     |
|----------------------------|--------------------------------------------------|---------------------------|
| Liupanshui city Administrative Boundary | State Earth System Science Data Sharing Platform | http://www.geodata.cn/    |
| DEM data                   | Geospatial data cloud                            | http://www.gscloud.cn/    |
| NDVI data                  | Geospatial data cloud                            | http://www.gscloud.cn/    |
| Land use                   | Geospatial data cloud                            | http://www.gscloud.cn/    |

2.3. Methods.

2.3.1. Extracted Basin. The hydrological module in ArcGIS 10.2 is used to extract the basin with 1:500000 Dem data. Firstly, the depression in DEM data is filled, which ensures that the natural drainage system extracted from DEM data is a continuous application of D8 algorithm [8]. The second is to calculate the flow direction. The third calculates the number of grids that flow directly or indirectly to each grid point. The fifth is to determine the main water systems on the surface and underground of the karst basin. The main water systems extracted automatically are modified manually according to topographic data, high-resolution images and hydrogeological survey data. The fifth is to determine the flow direction of the karst carbonate permeable layer in the area where the main flow flows. The correction of the sixth basin requires that some basins that have been automatically extracted should be corrected by using hydrogeological data, combined with high-resolution images, and according to the determined flow direction.

2.3.2. Calculation of fractal dimension. When fractal theory quantitatively characterizes non-smooth, irregular and broken fractal objects, the larger the fractal dimension, the more complex and rough the object [9]. This paper used fractal curve method to calculate fractal dimension [10].

The fractal curve method is that when a fixed ruler \( r \) is used to measure the curve, the product of the measured number \( N(r) \) and the ruler \( r \) can form the total length \( L(r) \) of the curve.

\[
L(r) = N(r) \cdot r \tag{1}
\]

Because of the complex shape of the curve, when measured with different rulers, different lengths of the curve can be obtained. Let the fractal dimension of the curve be \( D \).

\[
N(r) = r^{-D} \cdot M \tag{2}
\]

Where \( M \) is constant. The following equation can be obtained from (1) and (2):

\[
L(r) = r^{1-D} \cdot M \tag{3}
\]

That is the logarithm between the total length of the curve and the measurement scale \( r \) has a linear relationship, and the negative value of the difference between the slope and 1 is the fractal dimension of the curve.
3. Results

3.1. Extracted Basin

Under the unique geological background of karst, the extraction of drainage basin is different from that of non-karst regions, which cannot be simply filled up and judged to flow direction. When the hydrological module arcgis 10.2 is used for drainage basin extraction, images and hydrogeological maps are added as supplementary references to correct the boundary of drainage basins according to the specific conditions of each region. The original extracted basins were 97, and the corrected ones were 80, as shown in Fig. 2. On the basis of the 80 extracted basins, fractal fractal dimension was adopted for classification.

![Initial basin (a) and Repair basin (b) in Study Area](image)

**Figure 2.** Initial basin (a) and Repair basin (b) in Study Area

3.2. Fractal Dimension of Basin Contour Line

**Table 2.** Calculation results of fractal dimension of contour line

| Number | Elevation | Average fractal dimension | Number | Elevation | Average fractal dimension | Number | Elevation | Average fractal dimension |
|--------|-----------|---------------------------|--------|-----------|---------------------------|--------|-----------|---------------------------|
| 1      | 1400-1963 | 1.63                      | 21#    | 1380-1962 | 1.63                      | 41#    | 1384-2778 | 1.67                      |
| 2      | 1163-1980 | 1.56                      | 22#    | 1340-1983 | 1.73                      | 42#    | 840-2850  | 1.69                      |
| 3      | 1540-1940 | 1.55                      | 23#    | 1300-1926 | 1.64                      | 43#    | 720-2025  | 1.69                      |
| 4      | 1560-2140 | 1.73                      | 24#    | 844-2249  | 1.68                      | 44#    | 1220-1726 | 1.69                      |
| 5      | 1280-1976 | 1.62                      | 25#    | 1340-1920 | 1.63                      | 45#    | 1200-1853 | 1.73                      |
| 6      | 1421-2288 | 1.64                      | 26#    | 1480-2143 | 1.64                      | 46#    | 700-2288  | 1.77                      |
| 7      | 1300-2259 | 1.64                      | 27#    | 1480-2149 | 1.65                      | 47#    | 800-2368  | 1.77                      |
| 8      | 2243-2269 | 1.60                      | 28#    | 1520-2669 | 1.65                      | 48#    | 880-2850  | 1.77                      |
| 9      | 1320-2004 | 1.62                      | 29#    | 1796-1812 | 1.67                      | 49#    | 740-2028  | 1.70                      |
| 10     | 270-2296  | 1.76                      | 30#    | 1808-1824 | 1.50                      | 50#    | 761-2469  | 1.77                      |
| 11     | 270-2059  | 1.70                      | 31#    | 1240-2302 | 1.72                      | 51#    | 929-1092  | 1.70                      |
| 12     | 1520-2199 | 1.70                      | 32#    | 1520-2197 | 1.67                      | 52#    | 920-929   | 1.63                      |
| 13     | 1420-2292 | 1.72                      | 33#    | 887-2540  | 1.72                      | 53#    | 900-2300  | 1.72                      |
| 14     | 270-2642  | 1.70                      | 34#    | 1500-2298 | 1.70                      | 54#    | 740-2018  | 1.71                      |
| 15     | 1664-2392 | 1.70                      | 35#    | 1321-2540 | 1.71                      | 55#    | 1180-1994 | 1.59                      |
| 16     | 1400-2338 | 1.76                      | 36#    | 1500-2580 | 1.73                      | 56#    | 1160-1713 | 1.61                      |
| 17     | 2615-2621 | 1.63                      | 37#    | 1381-2538 | 1.72                      | 57#    | 770-2492  | 1.73                      |
| 18     | 1660-2717 | 1.66                      | 38#    | 1480-2457 | 1.70                      | 58#    | 680-2138  | 1.71                      |
| 19     | 1380-2013 | 1.71                      | 39#    | 700-2339  | 1.73                      | 59#    | 1020-2414 | 1.75                      |
| 20     | 1300-2092 | 1.71                      | 40#    | 841-2374  | 1.68                      | 60#    | 800-2495  | 1.73                      |
|        |           |                           |        |           |                           | 61#    | 961-2001  | 1.75                      |
The fractal dimension of basin contour line needs to be clipped into independent units to extract the topographic contour line of each basin. Ten representative contour lines were extracted from each basin topographic contour line, and measured with a length of 0.1, 0.5cm, 1cm, 2cm, 3cm, 4cm, 5cm, 6cm, 7cm, 8cm, 9cm and 10cm interval ruler, respectively. The fractal dimension value of each river basin is calculated by using the fractal dimension formula 1-3 to calculate the fractal dimension value of each river basin's different contour lines, and then the average value is calculated. The statistical results of the fractal dimension value of the river basin are shown in Table 2.

3.3. Karst Basin Classification

For each basin, the average fractal dimension of the contour line expresses the complexity of the topography within the basin, which is too general for the classification of basin. It fails to reflect the geomorphological changes within each basin unit. Therefore, it is necessary to analyze the fractal dimension variation of different elevation contour lines of each basin, so as to grasp the complete geomorphologic variation of basin and find out the differences of various geomorphologic conditions with basin as the unit. By analyzing the fractal dimension values of contour lines at different elevation of each river basin, the bar graph is generally normally distributed. That is the fractal dimension values reach the maximum in the middle of the elevation range of the river basin, and the fractal dimension values of contour lines on both sides gradually decrease. Although it is normally distributed, the shape of this normal distribution pattern changes to each river basin. There are three types in total. The maximum value of the bar graph of the fractal dimension of the contour lines of the second type is slightly to the right, and the relative topographic height difference within the basin is about 1000m. The maximum value of fractal dimension histogram of the third type of contour line is in the middle or slightly left position, and the relative topographic height difference in the basin is above 1000m.

According to the statistics, the average fractal dimension of the first type is below 1.64. The fractal dimension of the catchment in the second type is basically between 1.64 and 1.72. The basins in the third type are all below 1.72.

Based on the above analysis, the 80 basins can be divided into 3 types, as shown in Table 3.

### Table 3. Classification table of karst watershed based on average fractal dimension of contour line

| Type              | Average fractal dimension | Characteristics                                    | Basin sequence number                           |
|-------------------|----------------------------|---------------------------------------------------|-------------------------------------------------|
| The first type of basin | ≤1.64                     | The fractal dimension values of all elevation contour lines. | 1#, 2#, 3#, 5#, 6#, 7#, 8#, 9#, 17#, 21#, 23#, 25#, 26#, 30#, 32#, 52#, 55#, 56#, 62#, 63# |
| The second type of basin | 1.64-1.72                 | The elevation difference of relative topography is small. | 11#, 12#, 13#, 14#, 15#, 18#, 19#, 20#, 24#, 27#, 28#, 31#, 33#, 34#, 35#, 37#, 38#, 40#, 41#, 42#, 43#, 44#, 47#, 49#, 51#, 53#, 54#, 58#, 66#, 68#, 69#, 70#, 71#, 72#, 73#, 76#, 77#, 78#, 79#, 80# |
| The third type of basin | ≥1.72                     | The fractal dimension values of all elevation contour lines. | 4#, 10#, 16#, 22#, 29#, 36#, 39#, 45#, 46#, 48#, 57#, 50#, 59#, 60#, 61#, 64#, 65#, 67#, 74#, 75#, |
|                   |                            | The elevation difference of relative topography in the basin is more than 1000m. |                                                 |


3.4. characteristics of different karst basin types

The superposition analysis of the three types of basin with and without slope, undulation, vegetation cover and land use was conducted, and combined with the image data and the actual survey, it can be found that these three types of basin have the following characteristics.

The first type of basin is relatively flat with the surface undulating and gentle. It is mainly distributed in the mountainous dam area and peak cluster depression area. The land use type is mainly rice field and dry land.

The second type of basin has relatively undulating topography, whose slope is mainly gentle slope, and the type of land use is mainly grassland and woodland. There are slope farmland distribution, fruit forest distribution, river network distribution is relatively sparse, farmland and rocky desertification landscape alternate, and the ecological environment is relatively fragile.

The third type of basin is characterized by high mountain slope and large surface undulation. The land use is dominated by unused land, shrubs and barren grass land, with less river network distribution, lack of water resources, sparse vegetation, fragile ecological environment, and comparatively developed rocky desertification landscape.

Figure 3. Basin boundary and slope, undulation, vegetation cover and land use superposition
4. Conclusion
The problem of boundary inconsistency between above-ground and underground drainage basins in karst basin is solved by using the method of correcting the basin extracted automatically from the surface basin.

According to the calculated average fractal dimension of contour line of each river basin, and combined with the geomorphological characteristics of each river basin, the dividing threshold of each river basin was determined, and the fractal dimension value greater than or equal to 1.64 was divided into the first type of river basins. The fractal dimension between 1.64 and 1.72 is the second type of basin. The fractal dimension value greater than or equal to 1.72 is divided into the third type of basin.

The three types of basin are obviously different in elevation, slope, undulation, vegetation cover and land use, providing theoretical basis and technical support for comprehensive control of rocky desertification in basin according to local conditions.

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