Dynamic Analyzing in Karst Rocky Desertification Based on the Landscape Model Spatial Pattern

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Abstract

Small watershed is the basic element of rocky desertification management in karst area. For strengthening the comprehensive management plan, it is necessary to extend the management in a larger scale as the basis of the ecological management in small watershed. It is to make the quantitative analysis of the rock desertification landscape pattern dynamic changes based on the landscape types model in the study area of Tongjin village of Dafang county. The study basis is the geographic information system. The key technology is the landscape spatial pattern analyzing methods. By the quantitative model statistically analyzed the related indices of two periods rocky desertification landscape. It is indicated that the whole landscape pattern becomes more complex. But different degrees of rocky desertification landscape pattern have improvements. Higher rocky desertification imporved to the low one. Among them, the most obvious change is moderate and intensive rocky desertification. The comparison analysis among the rock desertification spatial pattern in the typical karst area will reveal the ecological management meaning and provide the reference for the coming-up planning.

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Keywords: Karst Rocky Desertification; Geographic Information System; Landscape Model; Patch Characteristics; Spatial Pattern

Introduction

Field investigations and statistical analysis demonstrate the development degree of rocky desertification affected mainly by slopes. The majority of soil layers are the dual structures. The upper layers is soil and the lower is rocks in the area. And More abundant rainfall in the region. There are multiple sinkholes, fracture, solution gap and cave in depression. Subsurface karst water is fractured mainly carbonate clastic rocks fissure cave water, and swallow stream is flowing through the demonstration area, surface water is infiltrating strongly. It is easy to make soil erosion, landslide,
mudflow, soil erosion, soil thin, bedrock loss, and to take the land loss productivity in such a fragile ecological environment. Finally the exposed rock develops into the rock desertification. The surface regional native vegetation of demonstration area has been destroyed. Large amounts of land has been reclaimed for agricultural and uncultivated land or abandoned after reclamation region covered with a small amount remainder of highly degraded regional native vegetation. Current agricultural infrastructure is very weak without any irrigation facilities, which is in lack of platform, cellar, pool, common soil and water conservation facilities in karst regions. Agriculture is still dominated by traditional farming methods. People living condition mainly rely upon the nature. As many people with little field, there is a large number of rock outcrop land, which is still cultivated for agricultural purposes. Farmers in the sizes of the "pit", "swallet", making use of every bit of space for corn, potato and so on. it is resulted in serious soil erosion. After years of cultivation, the study area has became the vicissitudes. Through the landscape model selection analyze the typical spatial pattern of karst rocky desertification. It is important for sustainable planning. It has important ecological significance of describing the landscape pattern to establish the relation between the landscape and the ecological process. Grasping the dynamic phenomenon of the landscape, more objectively and directly reflects the spatial pattern of the fore and after management in the demonstration area. It is necessary to make the next step of planning more reasonable and effective.

Analysis Method and Technical Flow

FRAGSTATS, the Landscape pattern analysis software, calculates rocky desertification landscape pattern indices to analyze the landscape pattern. By the GIS ways, it is to establish the rocky desertification landscape model database. Then it’s applying landscape pattern analysis software FRACSTATS3.3 to analyze rocky desertification landscape pattern parameters of demonstration area and calculating the associated landscape index model [1]. While based on the landscape class level on the analysis of landscape indices, emphasized select 7 landscape indices model, such as Number of Patches(NP), Patch Density(PD), Percentage of Landscape(PLAND), Largest Patch Index(LPI), Landscape Shape Index(LSI)COHESION and DIVISION.

Data Collection(Geology, Terrain, Hydrology, Climate, Population, Economic etc.)

Two periods Image data pretreatment and preliminary interpretation

Slope map, two periods Distribution of rocky desertification landscape and other related preliminary drawing maps

Field investigation, background information sound

Indoor interactive interpretation, detailed interpretation and revision of maps

GIS System platform

Landscape distribution of rocky desertification status map

Establish rocky desertification Landscape model database

Calculate rocky desertification landscape pattern indices

Dynamic analyzing in rocky desertification landscape pattern

Fig.1 Flow chart of rocky landscape pattern model analysis
Spatial Analysis of Landscape Pattern in Rocky Desertification

**Distribution of Rocky Desertification in Demonstration Area in 2008.** On the basis of GIS platform, the spatial analysis reveals that rocky desertification mainly appear in the relatively steep slope. The slopes between 15° - 30° lay the most widely, intensive rocky desertification mostly located in the steep slope of the mountains. Although the steep, human activities are more frequently, then low vegetation coverage, excessive rocky desertification mainly developed on more than 25° of the hills (Figure 2).

![Distribution of rocky desertification landscape of demonstration area in 2008](image)

**Distribution of Rock Desertification in Demonstration Area in 2010.** By planning the ecological environment of the demonstration area, it is to design management model and technical measures. In the light of local conditions and scientific rational way acting in accordance with natural, closed forest and grass taken, afforestation, planting drugs and grass and other measures to strengthen the construction of vegetation and increase percentage of vegetation cover. The rocky desertification control will be transformed to the backward production and lifestyle. The ecological environment has been improved considerably. There are different degrees of rocky desertification landscape improvement respectively (figure 3).
Fig. 3 Distribution of rocky desertification landscape of demonstration area in 2010

Landscape Spatial Pattern Analysis of Index Model in Rocky Desertification. On the method of GIS, RS and GPS, at landscape ecology point of view, research of rocky desertification landscape pattern was carried on in the demonstration area. FRAGSTAT calculated the selected relevant landscape indices model. Quantitative values of the landscape index model reflects the patch characteristics of the landscape.

Index Model Analysis of Landscape Class Level. According to Table 1, based on landscape class level index model, using FRAGSTATS calculate rocky desertification landscape pattern indices NP, PD, PLAND, LPI, LSI, COHESION and DIVISION. From the landscape class level, reflecting the distribution characteristics of rocky desertification landscape pattern (Table 2 and Table 3).

Table 1 Landscape index model choose of class level

<table>
<thead>
<tr>
<th>Landscape index model</th>
<th>Quantified model</th>
<th>Indices description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Patches(NP)</td>
<td>$NP=n_i$</td>
<td>$n_i$ is the number of patche of i</td>
</tr>
<tr>
<td>Patch density(PD)</td>
<td>$PD=n_i/A_i$</td>
<td>$n_i$ is the number of patch of i, $A_i$ is the area of i</td>
</tr>
<tr>
<td>Percentage of Landscape (PLAND)</td>
<td>$PLAND=P = \frac{\sum_{i} a_{ij}}{A} (100)$</td>
<td>$P_i$ is the Percentage of Landscape of i, $a_{ij}$ is the area of ij($m^2$), $A$ is the total area</td>
</tr>
<tr>
<td>Largest patch index (LPI)</td>
<td>$LPI=\frac{\max(a_{ij})}{A} (100)$</td>
<td>$a_{ij}$ is the area($m^2$) of patch ij, $A$ is the total landscape area($m^2$), i is the patch tape, j is the number of patch</td>
</tr>
</tbody>
</table>
**Landscape Shape Index (LSI)**

\[ LSI = \frac{e_i}{\min e_i} \]

- \( e_i \) is the circumference of patch, \( \min e_i \) is the minimum value of \( e_i \)

**COHESION**

\[ COHESION = \left[ 1 - \frac{\sum_{i,j} P_{ij}}{A} \right] \left[ 1 - \frac{1}{j^2} \right] (100) \]

- \( P_{ij} \) is perimeter of patch \( ij \) in terms of number of cell surfaces, \( a_{ij} \) is area of patch \( ij \) in terms of number of cells, \( A \) is the total number of cells in the landscape

**DIVISION**

\[ DIVISION = 1 - \sum_{i=1}^{n} \left( \frac{a_{ij}}{A} \right)^2 \]

- \( a_{ij} \) is the area (m²) of patch \( ij \), \( A \) is the total landscape area (m²)

*Annotate: Table 1 according to Landscape pattern analysis software FRAGSTAT induction obtained.*

**Table 2** Different types of rocky desertification landscape spatial pattern model quantitative value in 2008

<table>
<thead>
<tr>
<th>Landscape Types</th>
<th>NP</th>
<th>PD</th>
<th>PLAND</th>
<th>LPI</th>
<th>LSI</th>
<th>COHESION</th>
<th>DIVISION</th>
</tr>
</thead>
<tbody>
<tr>
<td>None rocky desertification</td>
<td>38</td>
<td>10.4819</td>
<td>23.4863</td>
<td>13.2559</td>
<td>9.9854</td>
<td>99.3126</td>
<td>0.9812</td>
</tr>
<tr>
<td>Potential rocky desertification</td>
<td>19</td>
<td>5.2410</td>
<td>38.1506</td>
<td>14.6196</td>
<td>13.3745</td>
<td>99.5838</td>
<td>0.9609</td>
</tr>
<tr>
<td>Mild rocky desertification</td>
<td>52</td>
<td>14.3437</td>
<td>14.1077</td>
<td>3.4478</td>
<td>12.5031</td>
<td>98.2146</td>
<td>0.9982</td>
</tr>
<tr>
<td>Moderate rocky desertification</td>
<td>45</td>
<td>12.4128</td>
<td>17.1233</td>
<td>8.6115</td>
<td>11.7909</td>
<td>99.0505</td>
<td>0.9916</td>
</tr>
<tr>
<td>Intensive rocky desertification</td>
<td>81</td>
<td>22.3431</td>
<td>5.5535</td>
<td>1.1896</td>
<td>12.4133</td>
<td>96.5693</td>
<td>0.9998</td>
</tr>
<tr>
<td>Excessive rocky desertification</td>
<td>68</td>
<td>18.7572</td>
<td>1.5787</td>
<td>0.2334</td>
<td>9.3500</td>
<td>93.0363</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

**Table 3** Different types of rocky desertification landscape spatial pattern model quantitative value in 2010

<table>
<thead>
<tr>
<th>Landscape Types</th>
<th>NP</th>
<th>PD</th>
<th>PLAND</th>
<th>LPI</th>
<th>LSI</th>
<th>COHESION</th>
<th>DIVISION</th>
</tr>
</thead>
<tbody>
<tr>
<td>None rocky desertification</td>
<td>47</td>
<td>12.9653</td>
<td>26.8521</td>
<td>15.5151</td>
<td>9.7490</td>
<td>99.1058</td>
<td>0.9746</td>
</tr>
<tr>
<td>Mild rocky desertification</td>
<td>79</td>
<td>21.7927</td>
<td>18.8077</td>
<td>4.3276</td>
<td>16.6852</td>
<td>98.2325</td>
<td>0.9964</td>
</tr>
<tr>
<td>Moderate rocky desertification</td>
<td>111</td>
<td>30.6201</td>
<td>9.8152</td>
<td>2.2748</td>
<td>17.6957</td>
<td>96.1677</td>
<td>0.9993</td>
</tr>
<tr>
<td>Intensive rocky desertification</td>
<td>105</td>
<td>28.9649</td>
<td>3.9657</td>
<td>0.6757</td>
<td>13.6737</td>
<td>93.6567</td>
<td>0.9999</td>
</tr>
<tr>
<td>Excessive rocky desertification</td>
<td>83</td>
<td>22.8961</td>
<td>0.9631</td>
<td>0.1805</td>
<td>9.8298</td>
<td>88.3136</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

(1) NP reflects the landscape spatial pattern, and it is often used to describe the heterogeneity acrossing the landscape. There is a good positive correlation between the NP value and landscape fragmentation. General law is NP large, high fragmentation and NP small, low fragmentation.
The NP values of each degree of rocky desertification was increased in 2010. It is illuminated that the landscape fragmentation has improved after the ecological treatment. It is mainly because that the patches were deformed, separated or reduced after the controlled in higher rocky desertification.

(2) PD characterises the landscape fragmentation. It is reflected the complexity of landscape spatial structure. To some extent, it is reflected the degree of human disturbance on the landscape.

PD values of the landscape were increased after management. The PD values of potential, mild, moderate and intensive rocky desertification were increased more. Because implementing the training works in large area. Control measures by human disturbance reduced the rocky desertification area but produced some small patches.

(3) PLAND measures the components of the landscape and determines the advantages of landscape elements. It is a important factor of ecosystem indicators to decide the landscape biodiversity, dominant species, quantity and so on. The landscape patch type has become very scarce when its value tends to zero. Oppositely the landscape composed by only one class of patch when its value tends to one hundred.

In the different rocky desertification landscape types, PLAND values of mild rocky desertification were decreased from 17.1233 in 2008 to 9.8152 in 2010, intensive one decreased from 5.5535 in 2008 to 3.9657 in 2010, excessive one was decreased from 1.5787 in 2008 to 0.9631 in 2010. PLAND values of higher landscape types were decreased, that is to say the patches area are reduced. Some of the rocky desertification landscape were improved to a lesser ones, accordingly the areas of none, potential and mild rocky desertification were increased and the PLAND values were increased.

(4) LPI is equal to a patch type occupies the largest patch in the proportion of the landscape area. The value reflects the dominant patch impact on the whole landscape. It is indicated that the control degree of large patches on the landscape.

The LPI values of low rocky desertification landscape were increased and high rocky desertification landscape were decreased. It is reflected that the dominant patch type sloping trend to the low rocky desertification landscape increasingly. Among them, the LPI values of moderate and intensive rocky desertification were from 8.6115 and 1.1896 in 2008 reduced to 2.2748 and 0.6757 in 2010 respectively. LPI values of none rocky desertification landscape increased from 13.2559 to 15.5151. Through human forward interference moderate and intensive rocky desertification area decreased rapidly.

(5) LSI is based on the standard square shape index. By calculating deviation between the patch area and the same square area to measure the complexity of its shape.

The landscape shape index of different rocky desertification were increased in the demonstration area. It is indicated that the landscape patches become more complex. Among them, the LSI values of mild and moderate rocky desertification landscape were increased from 16.6852 and 12.5031 to 11.7909 and 17.6957 respectively. The LSI values of mild and moderate rocky desertification were most increased significantly. The landscape patches become irregular and more complex after the implementation of various projects.

(6) COHESION is a indicator to measure related physical connection between the patch types. When the patch types more aggregation, the greater the value. That is to say the physical connectivity of the related patch types become stronger. Among them, the largest change on COHESION values were none, intensive and excessive rocky desertification landscape. None rocky desertification reduced from 99.1058 to 99.3126. Since some developed high patches transformed into none rocky desertification after management. And its value was smaller, therefore, the cohesiveness were reduced. Intensive and excessive rocky desertification from 96.5693, 93.6567 reduced to 93.0363, 88.3136 respectively. As part of such patches were evolved to the lower landscape. It is result patch separation and small patches.

(7) DIVISION means the separable degree of landscape elements or patches distribution. To some extent, it reflects human activity had made a impact on landscape structure. The greater separation, the more geographically dispersed and the worse the stability [2]. Among them, the DIVISION values of
none rocky desertification landscape were increased, i.e. the separation is increased. The DIVISION values of moderate rocky desertification landscape were reduced, i.e. the separation was reduced and connectivity was increased.

**Results analysis.** Based on GIS platforms and landscape pattern analysis software, quantitatively analysis about the landscape pattern characteristics of rocky desertification was carried out in the demonstration area [1].

By comprehensive analysis of landscape indices model in rocky desertification spatial patterns, it is revealed that there is a certain link among the landscape indices. Statistical analysis results are consistent and can explain each feature of the landscape.

From the landscape class level index, the analysis results of NP, PD, PLAND, LPI, LSI, COHESION and DIVISION commonly reflect the patches area were increased, separation were reduced and continuation were improved in the low rocky desertification landscape. Otherwise, the patches area were decreased, separation were increased, and part of the continuous were decreased in the higher rocky desertification landscape. The main reason is the result of ecological restoration treatment, and the rocky desertification control has a good improvement. Higher rocky desertification landscape was improved in the lower landscape. Management effect of moderate rocky desertification is controled better than intensity and followed by mild rocky desertification. The ecological effect of potential is slowest. Ecological control measures effectively improved the soil structure, enhanced soil fertility, improved ground biomass and vegetation coverage.

**Conclusion and Discussion**

The quantitative analysis of the landscape types index model in the study area reveals the more complex landscapes pattern, more scattered distribution, discontinuous patches and more embedded small patches. Each landscape index varies in different level. The most obvious one is the modest and strong rock desertification, which shows the reduction of the patches, increasing volume of separation and reduction of continuity. However, the non-rock desertification has the reverse index.

Rocky desertification management is a complicated and systematic project. It is necessary for participation of the governments either in state or local levels and the various experts and scholars. Macro adjustment is a great work concerning on many factors. The ecological recovery of the management unit in village or county levels is the base for the ecological construction in a large scale, which access the effect of management planning.

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References


