Research on the Characteristics of the Spatial Distribution of Landslides Based on Variable Dimension Fractal

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Abstract. This paper applies variable dimension fractal model to study the characteristics of the spatial distribution of the landslide hazards in the study area from Badong county to Zigui county in TGP reservoir region. The result shows that the spatial distribution of landslides has the characteristics of variable dimension fractal. The spatial distribution of landslides and slope, strata, elevation and river buffer show a second phase cumulant distribution, indicating that the spatial distribution of the landslide is more complicated than the variable dimensional fractal characteristics of the other four influencing factors. The slope, formation, elevation and river buffer have a higher impact on landslide development. This reveals the quantitative relationship between the developmental distribution of landslides and the various influencing factors from the perspective of fractal and provides a fractal basis for the further selection of evaluation factors for regional landslide risk analysis.

Introduction

The landslide is a kind of complicated phenomenon with nonlinear inter-reaction. The traditional theories and methods are difficult to study the uncertainty characteristics of dynamic evolution of the landslide. In recent years, the fractal theory has become a new method to study such complicated phenomenon as earthquake and landslide. At present, fractal research on landslide mainly focuses on the fractal characteristics of landslide bodies and the fractal characteristics of landslide influencing factors, but less on the relationship between landslides and influencing factors. In this paper, the relationship between landslide distribution and its influencing factors is explored by using the variable dimension fractal method, which provides a fractal basis for the selection of the landslide risk assessment index.The study area is located in Hubei Province from Zigui to Badong counties. There are many landslides, for example, Xintan landslide, Huangtupo landslide and Huanglashi landslide, which are usually located in the section with "hard" rock and "soft" rock jointly and along the bank of the river.

Variable Dimension Fractal Model

The concept of variable dimension fractal can be used to solve the problem that the two-logarithmic curve is non-linear (Fu, 1996, 2000). The fractal dimension D is a function of the characteristic linearity.

$$D = F(r) \tag{1}$$

The research (Fu, 1996, 2000) shows that any function $N = f(R)$ can be transformed into the form of constant dimension fractal $N = Cr^{-D}$. The method mainly includes the following steps:

The first step is to plot the logarithmic curve of the raw data points (N_i, r_i) (i=l, 2, …, n). If the logarithmic curve is not a straight line, then N_i can be arranged into the following sequence :

$$\{N_i\} = \{N_1, N_2, N_3, \mathbf{L}\} \quad (i=l, 2,…, n) \tag{2}$$

Based on the above basic sequence, the first phase, the second phase, third phase cumulant sequences can be further constructed:

$$\{S1_i\} = \{N1_1, N_1 + N_2, N_1 + N_2 + N_3, \mathbf{L}\} \qquad (i=1, 2, \ldots, n) \tag{3}$$

$$\{S2_i\} = \{S1_1, S1_1 + S1_2, S1_1 + S1_2 + S1_3, \mathbf{L}\} \qquad (i=1, 2, \ldots, n) \tag{4}$$

$$\{S3_i\} = \{S2_1, S2_1 + S2_2, S2_1 + S2_2 + S2_3, \mathbf{L}\} \qquad (i=1, 2, \ldots, n) \tag{5}$$

$$\{S4_i\} = \{S3_1, S3_1 + S3_2, S3_1 + S3_2 + S3_3, \mathbf{L}\} \qquad (i=1, 2, \ldots, n) \tag{6}$$

Where $S1_1 = N_1$, $S1_2 = N_1 + N_2$, $S1_3 = N_1 + N_2 + N_3$, and so on.

The second step is to establish the segmental variable dimension fractal model with the sum of each phase.

The third step, select the best transformation and determine the corresponding constant dimension fractal parameters.

Results and Discussion

Aspect. According to the digital elevation model (DEM) of the study area, the slope map of the study area was extracted. According to the interval of 45 °, the aspect map was divided into 8 sections and the distribution area of landslides in different sections were obtained from the superimposition of landslide distribution maps and aspect maps in the study area. According to the descending order of the corresponding landslides spatial distribution area, each section of slope will be arranged with numbers r =1, 2, 3, ..., 8, respectively representing eight slope directions from 0 ° to 360 ° segment. The logarithm of the logarithm of landslide distribution area N (r) and aspect r (Fig. 1-left) shows a significant non-linear relationship, indicating that the landslide distribution has a variable dimension fractal relationship with the aspect. After the data are the first phase accumulated and fractal dimensioned (see Fig. 1-right), the data are linear and the correlation coefficient is greater than 0.99, indicating a first-phase cumulative and fractal relationship between the landslide spatial distribution area and aspect (Dimension D1 = 0.7580).
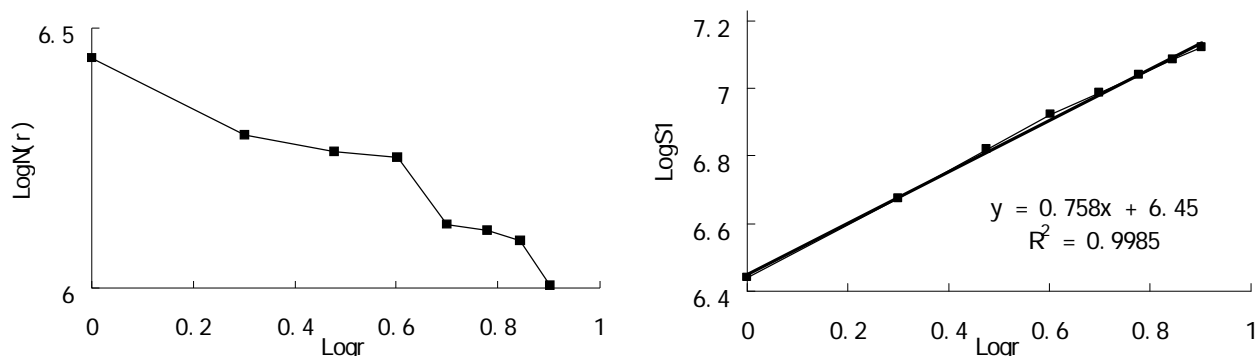

Fig. 1 Relationship between the series of aspect and the distribution ratio of landslides
(left: the primary dimension series, right: the first phase accumulation dimension series)

Slope. The slope map was divided into seven slope segments at 10 ° intervals. The slope sections are arranged in descending order according to the corresponding distribution area of the landslides. The result shows the relationship between the landslide distribution area N (r) and the slope r in different slope sections. The logarithmic relationship curve between landslide distribution area N (r) and slope r shows a significant nonlinear relationship at different slope sections, which shows that the relationship between landslide distribution and slope is variable dimension fractal. After the data is first-phase accumulated and fractal dimensioned (see Fig.2-left), it still shows a nonlinear relationship. The data points are further linearized by the second-phase cumulant transform (see Fig.2-right), and the correlation coefficient is greater than 0.99, indicating that the distribution area and slope of the landslide are in the second-phase cumulant and fractal relationship Fractal dimension $D_2 = 1.3353$).
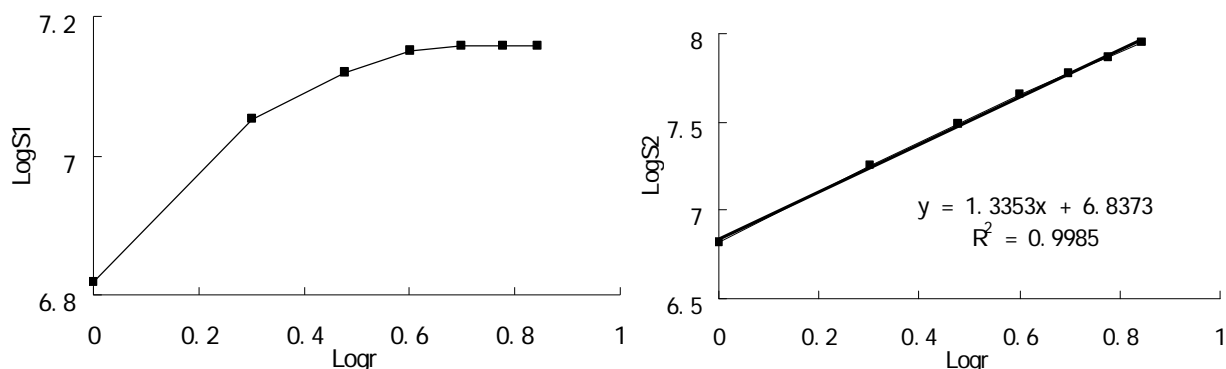
Fig. 2 Relationship between the series of slope and the distribution ratio of landslides
(left: the first phase accumulation series, right: the second phase accumulation series)

Stratum. Similar to the previous one, there is a linear relationship between the first-phase and second-phase cumulants and the fractal transformation (Fig.3), which shows that the distribution area of the landslide is proportional to the lithology second-phase cumulative and variable dimension fractal relationship (fractal dimension $D_2 = 1.2318$).
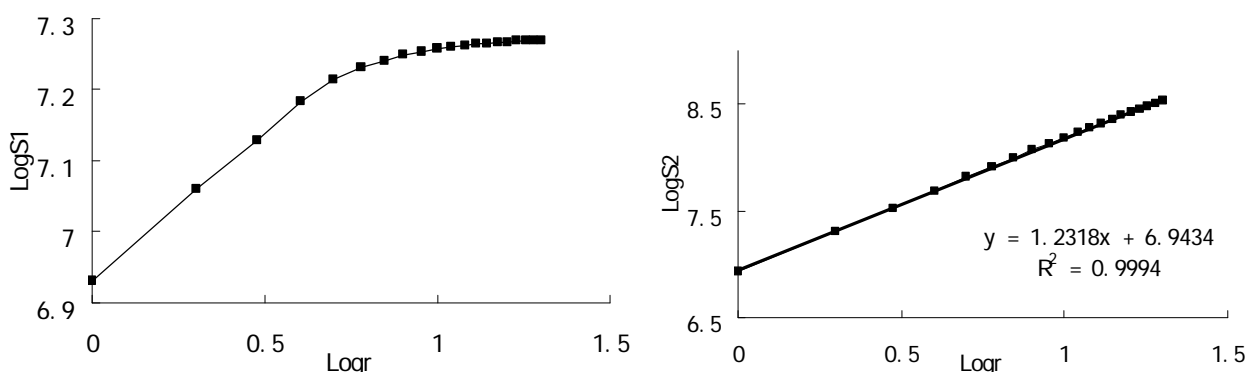

Fig. 3 Relationship between the series of stratum and the distribution ratio of landslides
(left: the first phase accumulation series, right: the second phase accumulation series)

Elevation. The logarithmic relationship between landslide distribution area N (r) and elevation r. The results of first and second-phase cumulants and fractal dimension transformation (Fig.4) show that there is a second-phase cumulant variable dimension fractal relationship between the distribution area and the elevation of the landslide Dimension value $D_2 = 1.2318$).
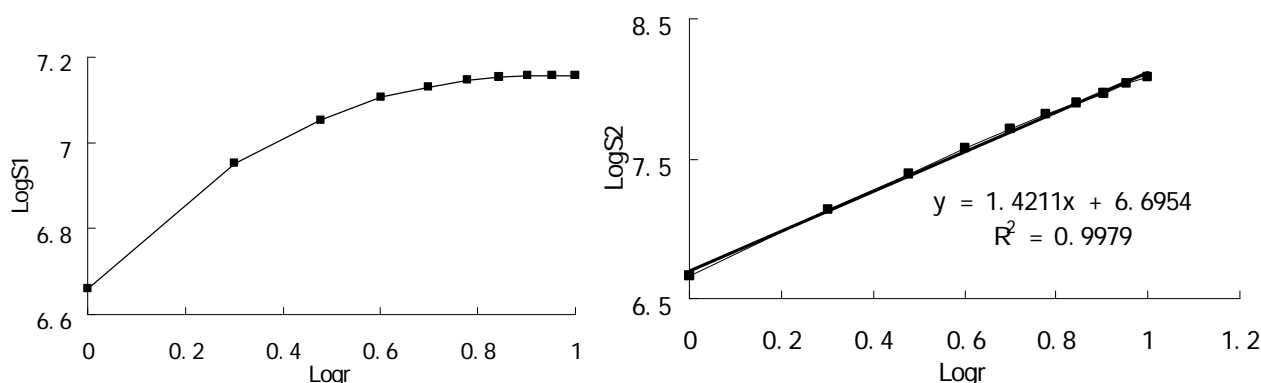

Fig. 4 Relationship between the series of elevation and the distribution ratio of landslides
(left: the first phase accumulation series, right: the second phase accumulation series)

River buffer. Similar to the previous one, the results of the first and second phase cumulant transformation (Fig.5) show that the distribution area of landslide is a second-order cumulation And fractal relationship (fractal dimension $D_2 = 1.3140$).
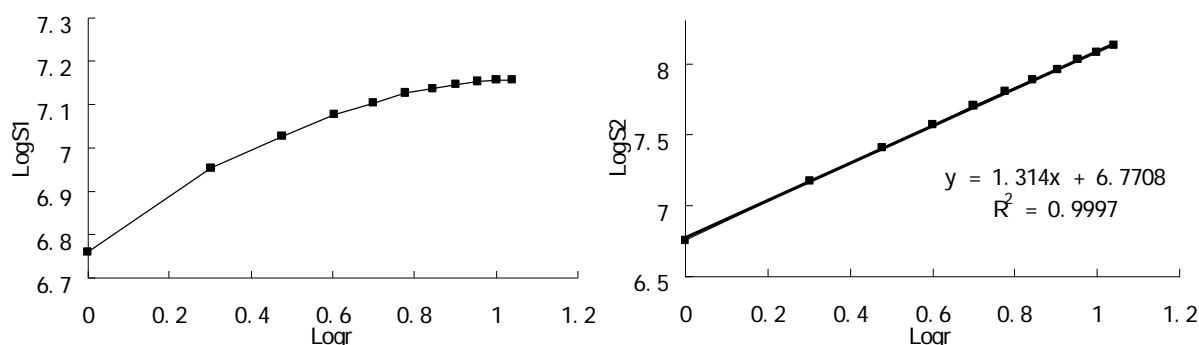
Fig. 5 Relationship between the series of river buffer and the distribution ratio of landslides
(left: the first phase accumulation series, right: the second phase accumulation series)

Conclusions

It can be seen from the above analysis that the spatial distribution of landslides has the characteristics of variable dimension fractal. The spatial distribution of landslide and slope, strata, elevation and river buffer show a second phase cumulant distribution, indicating that the spatial distribution of the landslide is more complicated than the variable dimensional fractal characteristics of the other four influencing factors. The slope, formation, elevation and river buffer have a higher impact on landslide development. The landslide spatial distribution is the first phase cumulant and fractal distribution, and its fractal dimension is small, which shows that the spatial distribution of landslide is relatively simpler than those of slope factor, and the slope has less influence on landslide development. That is to say, from the variable dimension fractal characteristics of landslide spatial distribution, it can be seen that the influence of slope, formation, elevation and river buffer on landslide development is relatively great, while the influence of slope on landslide development is relatively weaker. This reveals the quantitative relationship between the developmental distribution of landslides and the various influencing factors from the perspective of fractal and provides a fractal basis for the further selection of evaluation factors for regional landslide risk analysis.

Acknowledgements

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