Journal of Nepal Geological Society, 2000, Vol. 21, pp.1-4

Application of Morishita Spread Index to temporal and spatial distribution characteristics of landslides in Shanxi and Gansu provinces of China

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ABSTRACT

Morshita Spread Index I_δ was applied for the study of temporal and spatial distribution characteristics of landslides in the Shanxi and Gansu provinces of China. For this purpose, the landslides larger than 10^5 m^3 in volume were considered. In the study area, the spatial distribution of Morishita Spread Index $I_\delta(l)$ is greater than 1 and decreases with increasing mesh scale. Such a trend indicates cluster distribution of landslides. On the other hand, the temporal distribution of Morishita Spread Index $I_\delta(t)$ for the above landslides showed a maximum and a minimum, corresponding to the years with high frequency of landslide occurrence.

INTRODUCTION

Morishita (1959), a Japanese ecologist, first presented the Morishita Spread Index I_δ. He used it for the quantitative analysis of spatial distribution characteristics of biological species. Ouchi and Uekawa (1986) applied it for the study of spatial distribution patterns of smaller earthquakes before and after the occurrence of a large earthquake. Du (1994) and Feng et al. (1995) used I_δ for the investigation of spatial distribution characteristics of earthquakes and also for earthquake prediction.

Initiation and development of landslides is controlled by such factors as slope angle, relative relief, rock and soil types, texture and structure of rock and soil, drainage density, as well as rain intensity, land use, earthquake, and erosion intensity. Consequently, the temporal and spatial distribution characteristics of landslides area closely related to these factors.

Yan (1994) carried out quantitative research on spatial distribution characteristics of landslides in the Ganluo area with Poisson positive and negative binomial distributions. This method led to significant advances in the study of spatial distribution of landslides and their prediction by using statistical simulation. However, this method needs a large amount of data and assumes a random distribution of landslides. On the other hand, the analysis of landslides by applying I_d neither needs a large number of data nor a random hypothesis. This method can overcome the shortcomings of statistical simulation method, and quantitatively describe the temporal and spatial distribution characteristics of landslides. As an example of it, we investigated the landslides (larger than 10^5 m^3 in volume) in the Shanxi and Gansu provinces of China.

PRINCIPLE OF MORISITHA SPREAD INDEX

Morishita Spread Index I_d is defined as:

$$I_\delta = Q\frac{\sum_{i=1}^{Q} n_i(n_i - 1)}{N(N-1)} \quad (1)$$

where, N is the total number of samples in the study area, Q is the total number of meshes, and n_i is the number of samples falling in ith mesh $(i = 1,2,\ldots\ldots,Q)$.

I_d indicates the intensity of clustering. The greater value of I_d indicates the greater probability of two randomly selected samples to fall in the same mesh, and hence more clustering of samples. The measure of clustering of samples is dependent on the mesh scale.

Fig. 1 shows typical cases of I_d corresponding to three types of spatial distribution. If the distribution of landslide samples is random, the plot is a straight line as shown in Fig.1a. It is independent of the mesh scale and its pattern of distribution. If I_d increases with increasing mesh scale, the

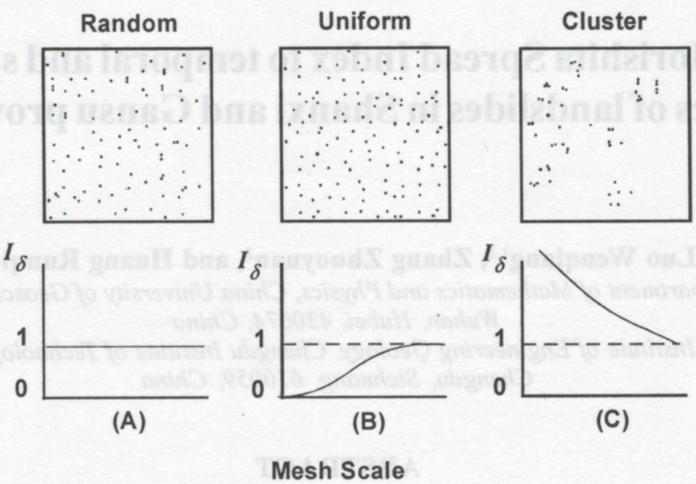

Fig. 1: Typical distribution patterns and their respective curves

distribution of landslide samples is uniform (Fig. 1b). If I_d decreases with increasing mesh scale, it indicates the cluster distribution of landslides (Fig. 1c).

We can test the relationship between I_δ and other distributions with statistics.

In expression (1), if n_1, n_2, ... n_Q obey the Poisson distribution, then the expression:

$$\frac{\sum_{i=1}^{Q} n_i n_i - N.N/Q}{N/Q} \quad (2)$$

obeys the distribution with *n-1* degrees of freedom. Form expression (1),

$$\sum_{i=1}^{Q} n_i.n_i = \frac{I_\delta}{Q} N.(N-1) + N \quad (3)$$

or,

$$\frac{\sum_{i=1}^{Q} n_i n_i - N.N/Q}{N/Q} = I_\delta (N-1) + Q - N \quad (4)$$

or,

$$\chi_0^2 = I_\delta (N-1) + Q - N \quad (5)$$

If χ_0^2 is greater than χ_α^2 at test level α, the distribution is regarded as nonrandom.

The calculation method of I_δ is simple, convenient, and practical. Furthermore, generally landslide samples are not random and it is not justified considering landslides as random samples obeying certain distribution. Besides possessing statistical function, I_δ can measure change and spread of spatial distribution of landslides. Therefore it is a good tool for describing the cluster extent of landslides.

By keeping mesh number Q or mesh scale l fixed, we may change I_δ with time. In this case, $I_\delta(t)$ is acquired by counting number of landslide samples falling in the ith mesh in certain time period t (generally t is one year). In this case, the time distribution characteristics of landslides are obtained.

EXAMPLE

As an example of $I_\delta(l)$ and $I_\delta(t)$, we investigated the landslides from south of the Shanxi and Gansu provinces of China. For this purpose, the landslides larger than 10^5 m³ in volume were considered. The study area is located in the upper reaches of the Yantze River, between the latitudes 32°4' and 34°40' N, and longitudes 104° and 106° 45' E. It covers 11 counties with the total area of 58,800 km². The landslides are widespread in this area and their frequency of occurrence is high. The total area of landslides in this region is about 11,700 km² and it is one of the main landslide-prone regions of China.

Spatial distribution characteristics of landslides

The number of instabilities with volume greater than 10^5 m³ is 186 in the study area. The area was divided into 1,4, and 16 meshes, corresponding to the mesh scales of 242, 121, and 60.5 km, respectively. From expression (1) above, $I_\delta(l)$ was 1, 1.09, and 1.86, respectively. The results are shown in Fig. 2.

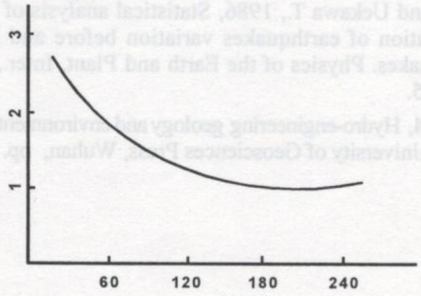

Fig. 2: The curve $I_\delta(l)$ in research region

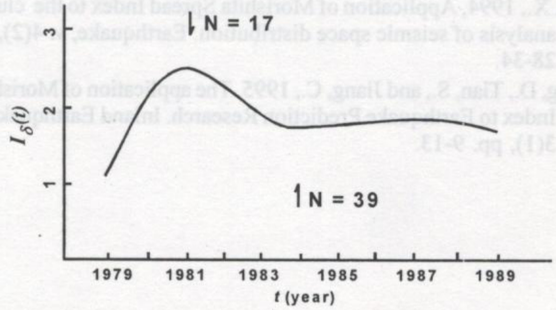

Fig. 3: The curve $I_\delta(t)$ in research region

Table 1: Year and frequency of landslides occurring in the south of Shanxi and Gansu provinces from 1979 to 1989

Year *(t)*	Frequency *(N)*	$I_\delta(t)$	Year *(t)*	Frequency *(N)*	$I_\delta(t)$	Year *(t)*	Frequency *(N)*	$I_\delta(t)$
1979	6	1.06	1983	6	1.87	1987	6	1.87
1980	6	1.87	1984	39	1.75	1988	6	1.87
1981	17	2.38	1985	6	1.86	1989	8	1.71
1982	6	1.87	1986	6	1.87			

Form Fig. 2, it is evident that I_δ *(l)* is greater than 1, and decreases with increasing mesh scale. The shape of Fig. 2 is similar to that of Fig. 1(C), indicating that it is a cluster distribution. In fact, the distribution of landslides in that region is a group cluster distribution along the Xihan River, Yanguan River, Beilong River, and Beimayu River. The environmental factors and failure factors control the clustering of landslides in that area.

The cluster type of spatial distribution of landslides is quite common in many landslide-prone areas. It points out that the new landslides will occur in the nearby region of earlier landslides. This observation has great significance for landslide prediction and control (Yan 1994).

Temporal distribution characteristics of landslides

Table 1 shows the number of landslides with volume greater than 10^5 m^3 that occurred from 1979 to 1989 in the region. The area was divided into 4 meshes, and by applying the expression (1), $I_d(t)$ was calculated for each year (Table 1; Fig. 3). Form Table 1, it is seen that 6 landslides occurred in 1979 as well as in 1982. But, as the landslides fell into different meshes, the difference of $I_d(t)$ is great (1.06 in 1979 and 1.87 in 1982). The distribution of landslides in 1982 is clustered more Morishita Spread Index than in 1979, whereas the distribution in 1979 is uniform. The average of $I_d(t)$ is 1.79 for the period from 1979 to 1989. The maximum in Fig. 3 is greater than 1.79 whereas the minimum is less than 1.79. The maximum and minimum in Fig. 3 correspond respectively to 1981 and 1984 when the number of landslides was 17 and 39, respectively. Form the trend of $I_d(t)$, it is predicted that the frequency and scale of landslides occurring in coming 1~3 years will be the same, and therefore, a scientific basis for taking precaution against landslide disaster could be provided.

CONCLUSIONS

Morishita Spread Index I_δ can quantitatively measure temporal and spatial distribution characteristics of landslides. It is convenient, easy to use, and there are no restrictions of random hypothesis. In the Shanxi and Gansu provinces of China, the spatial distribution of Morishita Spread Index $I_\delta(l)$ is greater than 1 and it decreases with increasing mesh scale. Such a trend indicates the cluster distribution of landslides in that area. On the other hand, the temporal distribution of landslides $I_\delta(t)$ for the same area shows frequent and regularly occurring landslide pattern with minima and maxima at an interval of about 3 years.

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