Journal of Nepal Geological Society, 2004, Vol. 30, pp. 123–126

Application of Morishita Spread Index in the study of landslides from the Kulekhani watershed, central Nepal

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ABSTRACT

The Kulekhani watershed was severely affected by sedimentation, landslides, and gully erosion in 1993. The sediments produced were ultimately supplied to the reservoir decreasing its gross storage capacity. A statistical tool, called Morishita Spread Index, was applied to detect the landslide distribution pattern in the watershed. Morishita Spread Index was greater than 1 and decreased with increasing mesh scale. Such a trend indicates a cluster-type of distribution pattern. The landslides are concentrated mainly in the gullies and streams, and there is a high probability that landslides will continue to occur there in the future.

INTRODUCTION

The Kulekhani watershed falls administratively under the Makawanpur district of the Narayani zone. The area is located between latitude 27°35' 04": 27°41' 00"N and longitude 85° 01' 30": 85°12'25" E (Fig. 1). Rocks of the area belong to the Kathmandu Complex and are represented by quartzite, schist, metasandstone, phyllite, marble and granite. The Mahabharat Synclinorium (Stöcklin and Bhattarai 1977), passes through this area and the Chitlang Formation lies in its core (Fig. 2).

The headwaters of the Kulekhani River contribute to the Kulekhani Reservoir, which operates two vital electric power stations (i.e., Kulekhani I and Kulekhani II). The reservoir was constructed by damming the Kulekhani River in the southeast corner of the watershed. Since the reservoir is the last destination of sediments derived from the watershed, it has faced a serious problem of sedimentation. In every monsoon, the sediments are deposited in the basin, resulting in the reduction of gross storage capacity of the reservoir.

The watershed was severely affected by landslides and gulley erosion in 1993. The sediments provided by these processes were ultimately supplied to the reservoir through various streams and tributaries. The 85.3 million m^3 of gross storage capacity of the reservoir was reduced to 72.41 million m^3 during 1981 to 1994. Among them, the unprecedented high precipitation of 1993 contributed the most (Sthapit et al. 1994). To prevent the reservoir from sedimentation and also to control the environmental degradation, it is essential to control the landslides and protect the gullies. On the other hands, to control the landslides effectively, it is desirable to have an idea on the landslide distribution pattern together with the factors playing a dominant role in the occurrence of landslides. The study of distribution pattern of landslides also allows to forecast probable landslide places.

In the present study, Morishita Spread Index, I_δ (Morishita 1959), a statistical tool, is used to analyse the landslide distribution pattern in the Kulekhani watershed. 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 pattern of smaller earthquakes before and after the occurrence of a large earthquake. Du (1994) and Feng et al. (1995) followed

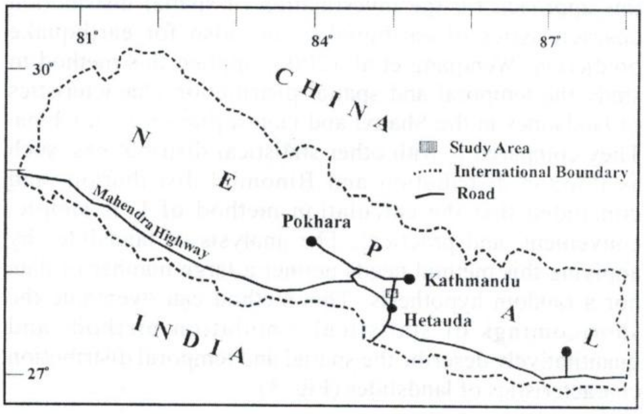

Fig. 1: Location map of the study area

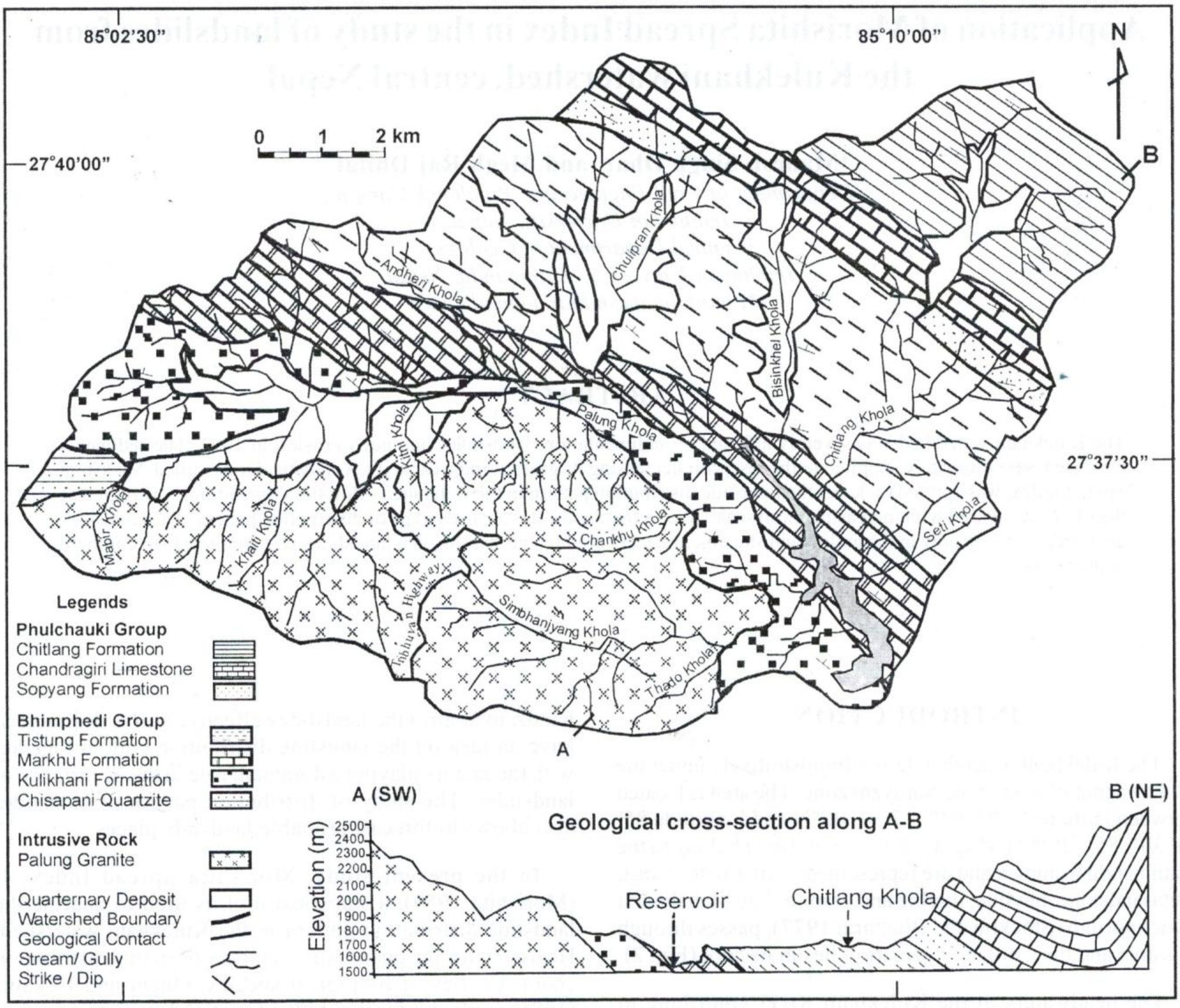

Fig. 2: Geological map of the Kulekhani watershed (Modified from Stöcklin and Bhattarai 1977)

this approach for the investigation of spatial distribution characteristics of earthquakes and also for earthquake prediction. Wenqiang et al. (2000) applied this method to study the temporal and spatial distribution characteristics of landslides in the Shanxi and Gansu provinces of China. They compared I_δ with other statistical distributions, such as Poisson distribution and Binomial distribution, and concluded that the calculation method of I_δ is simple, convenient, and practical. The analysis of landslides by applying this method needs neither a large number of data nor a random hypothesis. This method can overcome the shortcomings of statistical simulation method, and quantitatively describe the spatial and temporal distribution characteristics of landslides (Fig. 3).

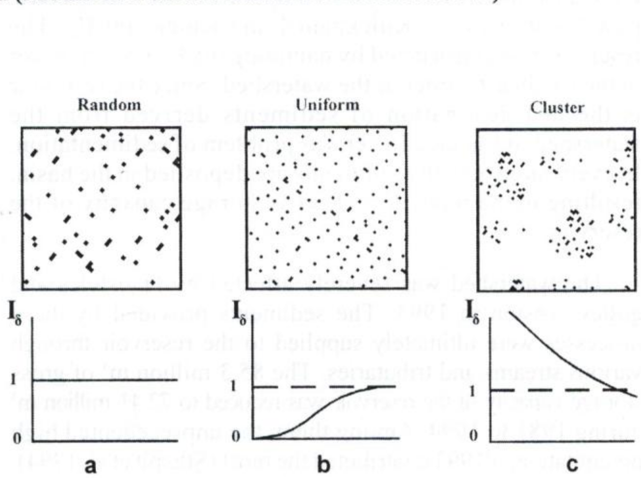

Fig. 3: Typical distribution pattern and their respective curves

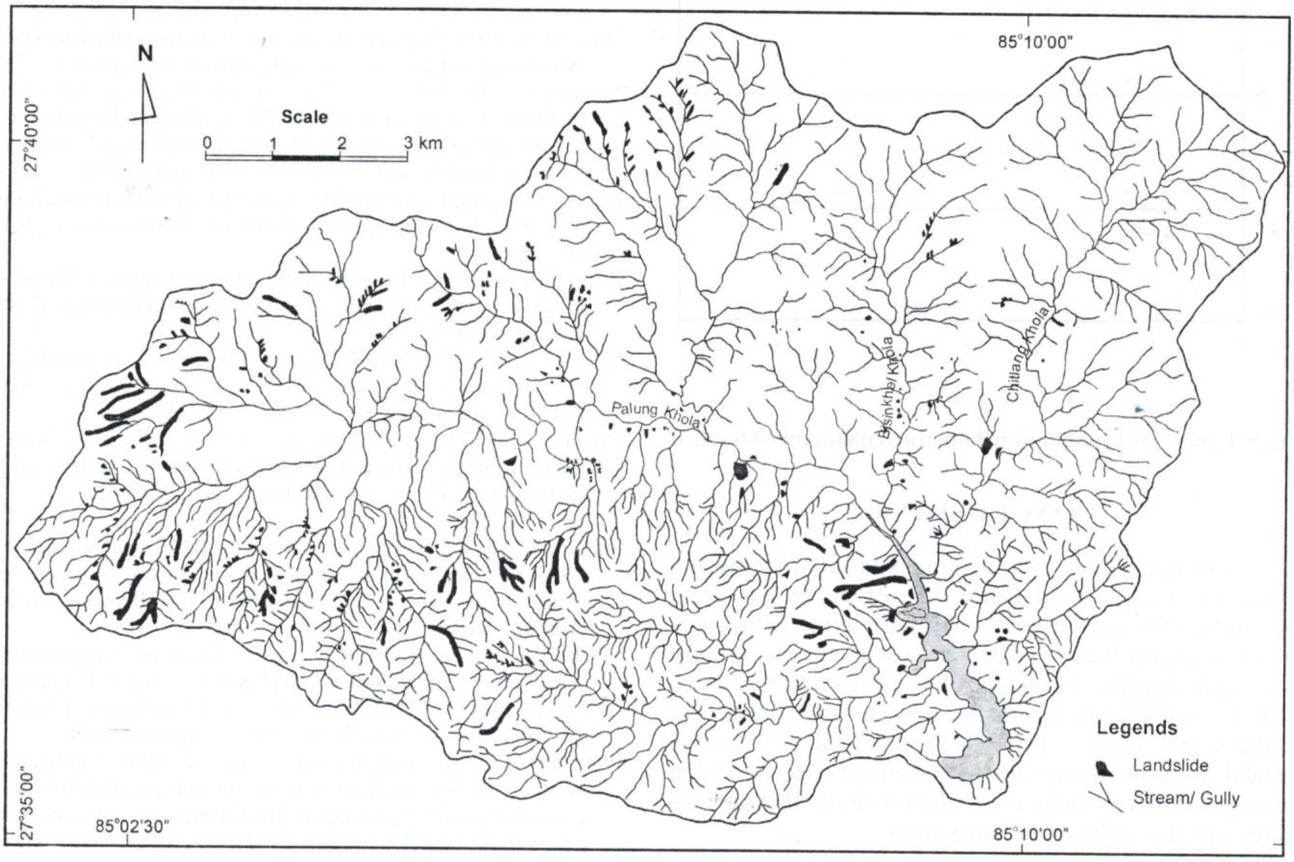

Fig. 4: Landslide distribution map of the study area (Dhar 2000)

Table 1: Calculation of I_δ

Total number of mesh, Q	Mesh scale, km	I_δ
1	5	1
4	2.5	1.47
16	1.25	2.12

PRINCIPLE AND METHODOLOGY

Morishita Spread Index (I_δ) is defined as

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

Where N = total area of landslides

n_i = area of landslides falling in ith mesh ($i = 1, 2, \ldots Q$)

Q = total number of mesh (grid)

According to Morishita (1959), there can be three types of distribution pattern: random, uniform, and cluster (Fig. 3). If the distribution of landslide samples is random, the plot is a straight line (Fig. 3a). If I_δ increases with increasing mesh scale, the distribution of landslide samples is uniform (Fig. 3b). If I_δ decreases with increasing mesh scale, it indicates the cluster distribution of landslides (Fig. 3c).

To detect the distribution pattern, a landslide inventory map (Fig. 4) was prepared within the watershed boundary of 126 sq km and the area of each slide was calculated. For the analysis, only the landslides greater than 500 sq m were taken into consideration. The watershed was divided into 1, 4, and 16 meshes, corresponding to the mesh scales of 5, 2.5, and 1.25 km respectively (Dhar 2000). I_δ was determined for Q = 1, Q = 4, and Q = 16 by applying equation (1). The results are shown in Table 1.

The values on Table 1 clearly depict that I_δ is greater than 1 and decreases with increasing mesh scale. A graph of mesh scale verses I_δ was plotted (Fig. 5). The curve type of Fig. 5 is similar to that of Fig. 3c, indicating that the landslide distribution pattern in the Kulekhani watershed is of cluster type.

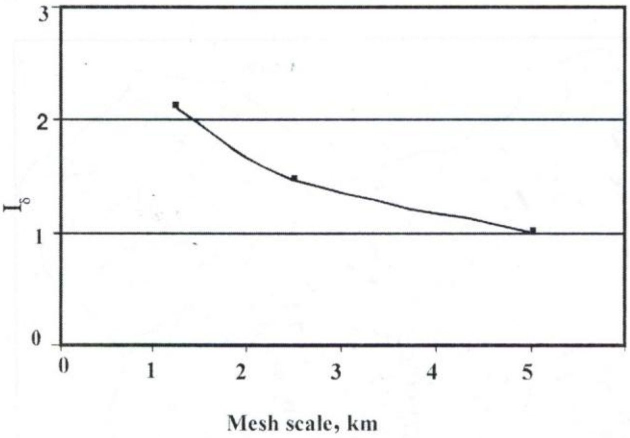

Fig. 5: I_δ curve for landslide distribution in Kulekhani watershed

CONCLUSIONS

I_δ can quantitatively measure spatial distribution characteristics of landslides. Therefore, it has great significance for landslide prediction and control. In the study area, I_δ is greater than 1 and decreases with increasing mesh scale, indicating the cluster type of distribution pattern. Such type of distribution points out that new landslides will occur in the nearby region of the earlier landslides. Since the instabilities in the Kulekhani watershed are concentrated in gullies and streams, there is a high probability that the new slides will also occur in the same areas.

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