Window size of slope relief on susceptibility of earthquake induced landslides

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Abstract It is considered that the extent of damage due to the sediment related disaster induced landslides were influenced the scale of landslide. Meanwhile, the Scale of landslide was controlled by scale of slope. So, we investigated relationship between slope relief and scale of landslide using 3871 landslides data due to the Iwate and Miyagi inland earthquake in 2008. At result, landslide susceptibility was confirmed by using slope relief. Also it is important that slope relief with necessary window size was changed as to scale of landslide.
Keywords. Slope relief, Window size, Landslide area classification, Iwate and Miyagi inland earthquake in 2008

1. Introduction

Landslides, which are often caused by earthquakes or heavy rains, may have serious effects on life and property. Since a large-scale landslide induced by an earthquake is highly likely to cause tremendous damage, it is important to identify potential landslide areas and take appropriate control measures. Besides geology and underground hydraulic characteristics, there are many other conditions that make particular areas prone to large-scale landslides. Above all, it is practically self-evident that slope size determines the upper limit of the size of a landslide, and it has been shown that slope size and landslide size are actually interrelated [1]. With this in mind, various studies on landslide risk evaluation have been conducted, paying attention to slope size [For example, 2, 3].

Improvements in recent years in the accuracy of topographic information and the availability of digital topographic information, coupled with the advances in recent years in analysis technology, have made it possible to analyze topographic quantity data for a extensive area with relative ease. Consequently, in the study on estimating landslide susceptibility, too, discussions on the relationship between topographic quantities and landslide occurrence have accelerated. As a result, it has been shown [For example, 4,5] that the relationship between topographic quantities and landslide occurrence is greatly affected by the scale at which topographic quantities are calculated. Many of the past studies, however, on the influence of the scale at which topographic quantities are calculated have dealt with landslide areas on the order of 102 to 103 m2, and few studies have looked at larger-scale landslides.

In this study, therefore, the influence of slope relief on landslide susceptibility and size was analyzed on the basis of information on a earthquake-induced landslides. In the study, the effect of the size of the window used to evaluate slope relief was also analyzed. The definitions of key terms used in this study are shown in Table 1.

Fig. 1 Definitions of key terms used in this study

Term	Meaning
Mesh	The smallest unit for assessing various inventory data
Slope relief	The difference between the highest and lowest elevations in the window size defined around a target mesh
Window size	The number of meshes in the area considered for slope relief calculation or the length of one side of a square defined for slope relief calculation
Landslide mesh	Any mesh overlapped by the landslide area polygon
Landslide mesh ratio	The ratio of the number of landslide meshes to the number of meshes existing in a given slope relief zone
Normalized landslide mesh ratio	The value obtained by dividing the landslide mesh ratio by "the number of landslide meshes divided by the number of meshes" in each area shown in Table 2
Cover ratio	The ratio of the number of landslide meshes in a slope relief zone having a given slope relief to the number of landslide meshes

2. Data set preparation

The earthquake considered in this study is the Iwate–Miyagi Inland Earthquake of 2008, and the study area (see Fig. 1) including strong ground motion areas have a total area of 914 km2. This earthquake caused not only shallow landslides but also deep catastrophic landslides at many locations. A total of 3,871 landslide sites were identified through the interpretation of 1:10,000 to 1:15,000 scale aerial photographs taken 1 to 18 days after the earthquake, and landslide polygon data were created. The areas thus identified were classed by using landslide area (Table 2). The study area was divided into 50 m mesh grids, and the landslide mesh was defined by superposing the data thus obtained on the landslide polygon data.

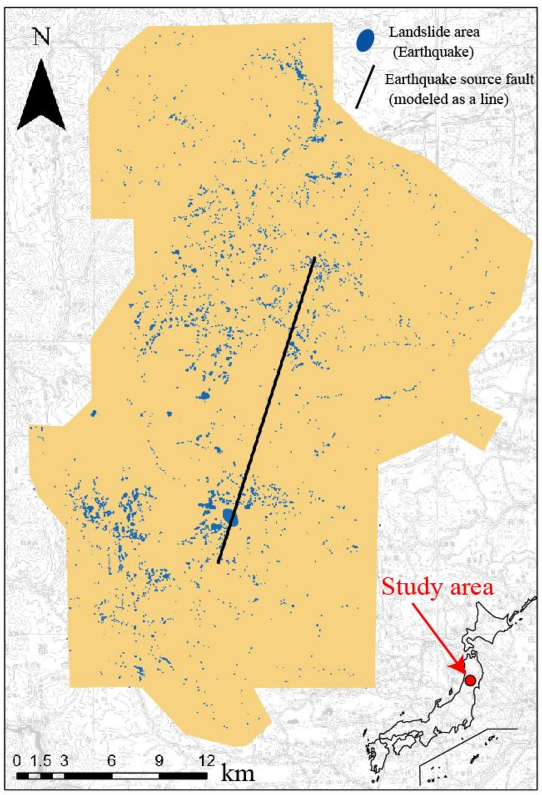

Fig. 1 Study area (covered light brown color)

Table. 2 Landslide area classification

Landslide area class	Number of landslides	Number of landslide meshes / Number of meshes
100 – 1,000	2769	0.01674
500 – 5,000	1805	0.0165
1,000 – 10,000	966	0.01219
5,000 – 50,000	196	0.00571
10,000 – 100,000	89	0.00388

In this study, slope relief was used for the assessing scale of slope. Slope relief was calculated for each mesh by using 50 m DEM. For the window size (see Fig. 2), four patterns including 150m×150m (3×3), 250m×250m (5×5), 350m×350m (7×7) and 550m×550m (11×11) were defined.

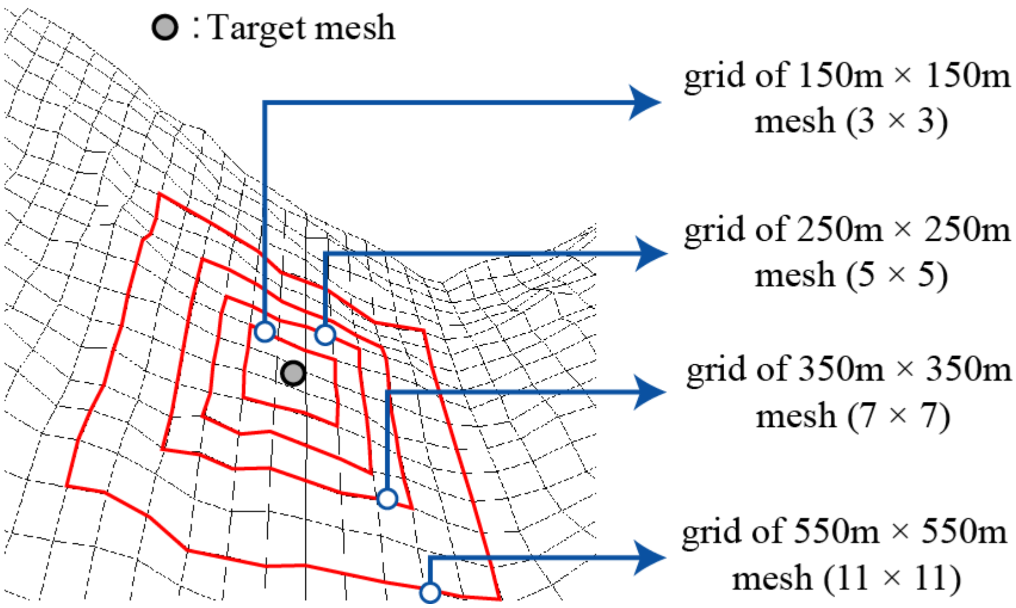

Fig. 2: Concept of window size for slope relief calculation

3. Study Results

Fig. 3 shows the relationship of slope relief with the Normalized landslide mesh ratio and the cover ratio for a window size of 150m×150m. In this figure, as slope relief increased, the normalized landslide mesh ratio increased, regardless of landslide area. This means that in areas where slope relief is large, the landslide susceptigility is high, regardless of landslide area. Also, as relief increased, the cover ratio decreased; it was about 0.5 when slope relief was around 60 m. This means that there are roughly half of the landslide meshes in the areas where slope relief is greater than 60 m. The normalized landslide mesh ratio did not show any significant differences depending on landslide area in cases where slope relief was less than 75 m. In cases where slope relief was greater, however, differences in the normalized landslide mesh ratio increased, The cover ratio did not show any significant differences depending on landslide area except in cases where the landslide area was in the range from 100 to 1,000 m^2.

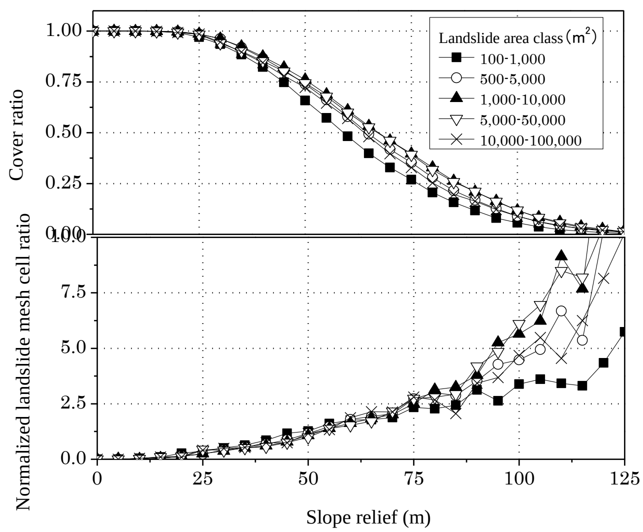

Fig. 3 Relationship of slope relief with the normalized landslide mesh ratio and the cover ratio

(Window size 150m ×150m)

As the next step, the cover ratio and the normalized landslide mesh ratio were calculated (Fig. 4) for different window sizes and different landslide sizes in order to investigate the relationship between window size and landslide size. As shown, as the cover ratio decreased, the normalized landslide mesh ratio increased. On the basis of he relationship between the cover ratio and the normalized landslide mesh ratio shown in Fig. 4 the normalized landslide mesh ratio for a given cover ratio was calculated for different window sizes and different landslide areas. The results thus obtained are shown in Fig. 5.

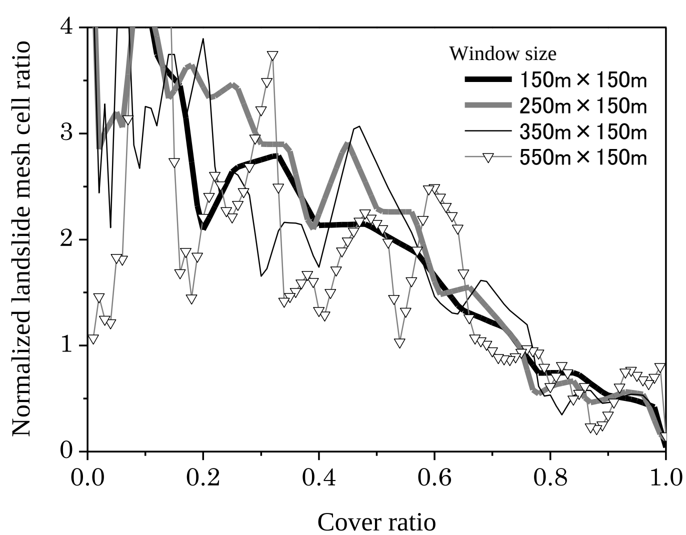

Fig. 4 Relationship between the normalized landslide mesh ratio and the cover ratio

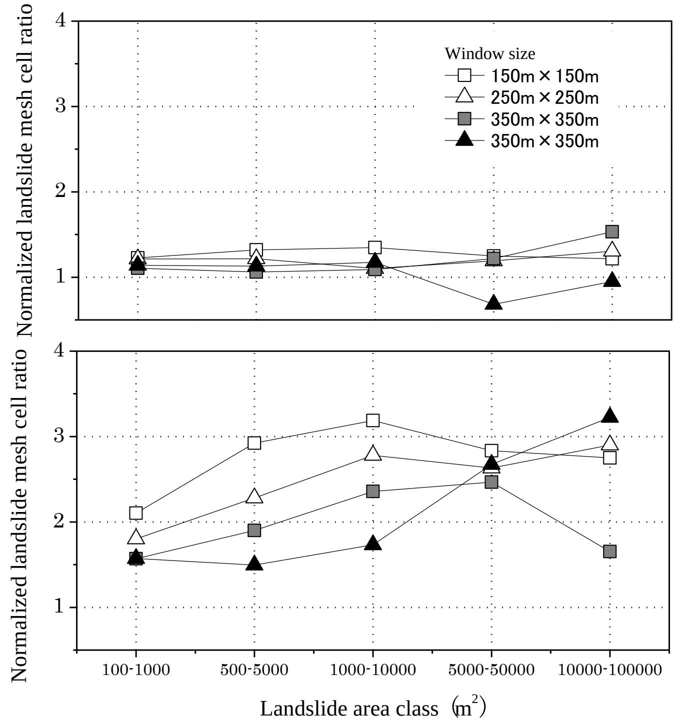

Fig. 5 Relationship of landslide area class to the normalized landslide mesh ratio for each window size (Upper : cover ratio is 0.7 Lower : cover ratio is 0.3)

As shown, when the cover ratio is 0.7, the normalized landslide mesh ratio is smaller than 1 in some cases. The normalized landslide mesh ratio of 1 means being equal to the ratio of landslide area in the 914 km2 study area. Being smaller than the ratio of landslide area means that the landslide susceptibility cannot be assessed by using slope relief as an indicator.

When the cover ratio is 0.3, the normalized landslide mesh ratio is high, and window sizes corresponding to high normalized landslide mesh ratios vary depending on landslide area. In each landslide area category, a window size indicating a high normalized landslide mesh ratio indicates that the occurrence of a landslide in that landslide area category is assessed with the highest accuracy. In the landslide area classes is from 100–1,000 m2 to 5,000–50,000 m2, the window size indicating the highest landslide mesh ratio is 150m×150m in most cases. In the 10,000–100,000 m2, however, the window size of 350m×350m when the cover ratio is 0.7 and the window size of 550m×550m when the cover ratio is 0.3 indicates the highest normalized landslide mesh ratio.

Window sizes, therefore, from which the highest normalized landslide mesh ratio can be obtained for each landslide area classes have been determined in the cover ratio range from 0.2 to 0.9. The results obtained ae shown in Table 3. As shown, all normalized landslide mesh ratios at cover ratios of 0.9 and 0.8 are smaller than 1 for all window sizes. It can also be seen that as the landslide area class becomes larger, the window size indicating the highest normalized landslide mesh ratio becomes larger.

Table. 3 Window size indicating the highest normalized landslide mesh ratio at each cover ratio

Cover ratio	Landslide area class (m^2)				
	100 - 1,000	500 - 5,000	1,000 -10,000	5,000 -50,000	10,000 -100,000
0.9	Landslide mesh ratio smaller than 1				
0.8					
0.7	150m×150m	150m×150m	150m×150m	150m×150m	350m×350m
0.6	250m×250m	150m×150m	150m×150m	250m×250m	550m×550m
0.5	150m×150m	150m×150m	250m×250m	250m×250m	350m×350m
0.4	150m×150m	150m×150m	150m×150m	150m×150m	250m×250m
0.3	150m×150m	150m×150m	150m×150m	550m×550m	550m×550m
0.2	150m×150m	150m×150m	150m×150m	150m×150m	350m×350m

4.Conclusion

These results can be summarized as follows:
(1) Earthquake-induced landslide risk is influenced by slope relief.
(2) The window size most suitable for slope relief calculation differs depending on landslide size.

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