Hazard Mapping of Earthquake-induced Deep-seated Catastrophic Landslides for Different Scenario Earthquakes by Using LIDAR DEM and Airborne Resistivity Data

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1 Introduction

Earthquake-induced landslides are one of the most damaging natural disasters. Shikoku Island in Japan has been hit by great earthquakes in the past, which mainly occurred repeatedly along the Nankai Trough at far south on Pacific coast of Shikoku and the Median Tectonic Line that intersects the island in east-west direction. The estimated magnitude of next Nankai Earthquake is between M8.0 and M9.0 while a Median Tectonic Line earthquake in northeastern part of Shikoku may be 8.0 or more. Therefore, estimation of damage during the earthquake-induced landslides in Shikoku is very important for the management of disaster.

Uchida et al. (2004) have developed a topographical parameter-based empirical relationship for landslide analysis during an earthquake. This method is generally applicable for shallow-seated landslide not the deep-seated landslides. Nonomura et al. (2012) have proposed a method for evaluating earthquake-induced deep-seated landslides by using LIDAR DEM and airborne resistivity data, but they mainly address toppling failures in their study and it needs verification for the application of the method in various geological conditions. In this paper, we have applied this method in at part of Shikoku for three scenario earthquakes.

2 Study area

The study area is located in northern part of Shikoku where the Ikeda fault, one of the Median Tectonic Line active fault system runs between the northern Sanuki Mountain Range and the southern Shikoku Mountains (Fig. 1). The Sanuki Mountain Range is underlain by the Upper Cretaceous Izumi Group which consists mostly of alternating beds of sandstone and shale. The Sambagawa metamorphic rocks are distributed in the southern Shikoku Mountains, and are mainly composed of pelitic schists and greenschists. The Umaji River, a tributary of the Yoshino River flows eastward along the valley between the Sanuki Mountain Range and Shikoku Mountains. The Yoshino River flows northward from Shikoku Mountains and changes the flow toward east at the confluence of the Umaji River.

3 Methodology

The methodology is illustrated in chart in Fig. 2.

Fig 1. Red Relief Image Map of the study area

Fig 2. Flow chart of the study
4. Topographical analysis

4.1 LIDAR DEM

The 5m LIDAR DEM dataset used in this study is obtained with high spatial resolution of at least one laser strike per square meter using 150-kHz laser beams.

4.2 Red Relief Image Map

The DEM data were visualized using a red relief image map (RRIM) composed of three topographic element layers, i.e., slope, positive openness, and negative openness (Chiba et al. 2008) (Fig.1).

4.3 Analysis of shallow landslide risk

The susceptibility of earthquake-induced shallow landslide (F-value) is estimated based on the following formula, as proposed by Uchida et al. (2004).

\[
F = 0.075 \times \text{"Slope"} - 8.9 \times \text{"Average Curvature"} + 0.0056 \times \text{"Maximum Acceleration"} - 3.2
\]

Based on an assumption that the influence of lithology is spread to some extent and loosened zones are more locally distributed, openness filter is applied to resistivity data and “ruggedness of resistivity” is calculated for mapping loosened zones using 140 kHz returns HEM resistivity data (Fig.5).

5. Resistivity analysis

5.1 Resistivity data by HEM

Resistivity data were obtained by helicopter-borne electromagnetic (HEM) resistivity survey. Resistivity map was prepared based on the resistivity data by 140 kHz (Fig.4). The 140kHz Hz returns data for depths of 5-30 m is useful for estimating loosened zones of the slope.

5.2 Ruggedness of Resistivity

“Ruggedness of resistivity” was proposed as an index parameter for differentiating the loosened zones due to flexural toppling by Nonomura et al. (2012).

Based on an assumption that the influence of lithology is spread to some extent and loosened zones are more locally distributed, openness filter is applied to resistivity data and “ruggedness of resistivity” is calculated for mapping loosened zones using 140 kHz returns HEM resistivity data (Fig.5).

6. Earthquake-induced deep-seated catastrophic landslide susceptibility map

Earthquake-induced deep-seated catastrophic landslide is defined by multiplying F-value and “Ruggedness of resistivity”. Fig. 6 shows the earthquake-induced catastrophic susceptibility maps for three scenario earthquakes. Also In this study, negative value of F-value and “ruggedness of resistivity” are treated as zero. The susceptibility classes are divided into four based on the evaluation value as high (more than 80), moderate (40-80), low (0-40), very low (less than 0). As the earthquake acceleration increases, susceptibility of the slopes will increase.

Fig. 3 Earthquake-induced shallow landslide susceptibility maps for three scenario earthquakes.

Earthquake-induced shallow landslide susceptibility maps for three scenario earthquakes are shown in Fig.4, and based on the F-values, the susceptibility classes are divided into four as high (F≥4), moderate (4>F≥2), low(2>F≥0), very low(F<0).

Fig.5 “Ruggedness of resistivity” of the study area

Fig.6 Earthquake-induced deep-seated catastrophic landslide susceptibility maps for three scenario earthquakes.

References

