# A Mapping Method of Deep-seated Landslide Susceptible Slopes Using Digital Elevation Model

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## 1. Introduction

Deep-seated landslides have been triggered by earthquakes or heavy rainfall (Chigira et al., 2010; Kuo et al., 2013). The volume of the debris is in many cases is above $10^7 m^3$. It causes the secondary damage by paralyzing road network and isolating villages for a long duration. In order to mitigate the damage as much as possible, it is necessary to estimate the susceptible slopes and the damage of deep-seated landslide beforehand.

Hutchinson (1988) showed that single-sided sagging is initial stage of deep-seated landslide both of rotational type and compound type. The topographical characteristics of the single-sided sagging slopes are multiple depressions over gentle upland slopes.

In this study, we proposed a mapping method of deep-seated landslide susceptible slopes using 10m resolution DEM and the relationship between pre-landslide topography and the catastrophic landslide are discussed, taking an example from a landslide in Nara, Japan.

## 2. Study area

The study area, Akadani reion, is located between 34°05'28"N and 33°09'34"N latitude and between 135°42'47"E and 135°46'50"E longitude in Kii Peninsula, Nara, Japan. (Fig. 1).

In September 2011, catastrophic landslides were triggered in Akadani and Akadani-higashi region by record breaking rainfall due to Typhoon 1112 (Talas) (Fig. 2). The total rainfall recorded by the Kazaya raingauge (Automated Meteorological Data Acquisition System: AMeDAS) operated by the Japan Meteorological Agency from 31st August to 4th September reached 1359 mm, which corresponds to two-thirds of the mean annual precipitation. The total rainfall over a large area of the Kii Peninsula exceeded 1000 mm from the evening of 30th August (when rainfall due to Typhoon Talas began in the Kii Peninsula) to 24:00 on 4th September. (Fig. 2). This rainfall caused deep-seated catastrophic landslides in this region.

It was reported that in Akadani and Akadani-higashi region, the rainfall-triggered landslides are large scale deep-seated landslide: the width is 300m, the length is 820m, and the depth is 70m.

## 3. Topographical analysis

Slope movements are related with several factors. Topography is one of the important factors. Sagging of mountain slopes is associated with initial stage of deep-seated landslide (Hutchinson, 1988). Sagging deforms slopes, especially near the top of the mountain; and gentle slopes with linear depressions.

In this study, rules are proposed for mapping sagging slopes and applied by using DEM. As a DEM data, 10-m resolution DEM, which is processed by interpolating 1:25,000 scale contour data. The data is published and distributed by the Geospatial Information Authority of Japan.

The rules are composed of three rules.

Rule1: Gentle pixels (< 30°) are widely distributed near the top of the mountain (Fig.3). The area is set 200,000m$^2$ (200- pixel).

Rule2: The gentle slopes are located higher. Elevation difference is larger than 200m than that of surroundings. The surrounding is defined by using moving window. The window size is set 1km (100- pixel)

Rule3: At the top of the slopes, there are linear depressions. Linear depressions are extracted by using profile curvature.

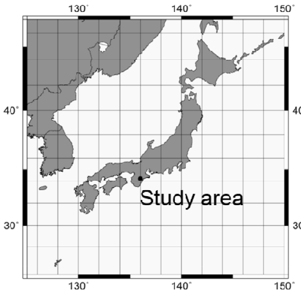


*Fig. 1 Study area*


*Fig. 2 Rainfall triggered deep-seated landslide in Akadani and Akadani-higashi region*

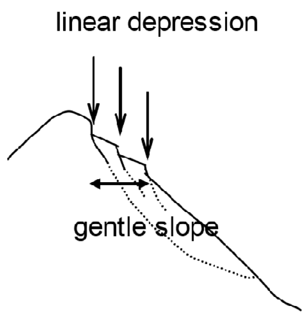


*Fig. 3 Schematic of sagging slope (Hutchinson, 1988)*

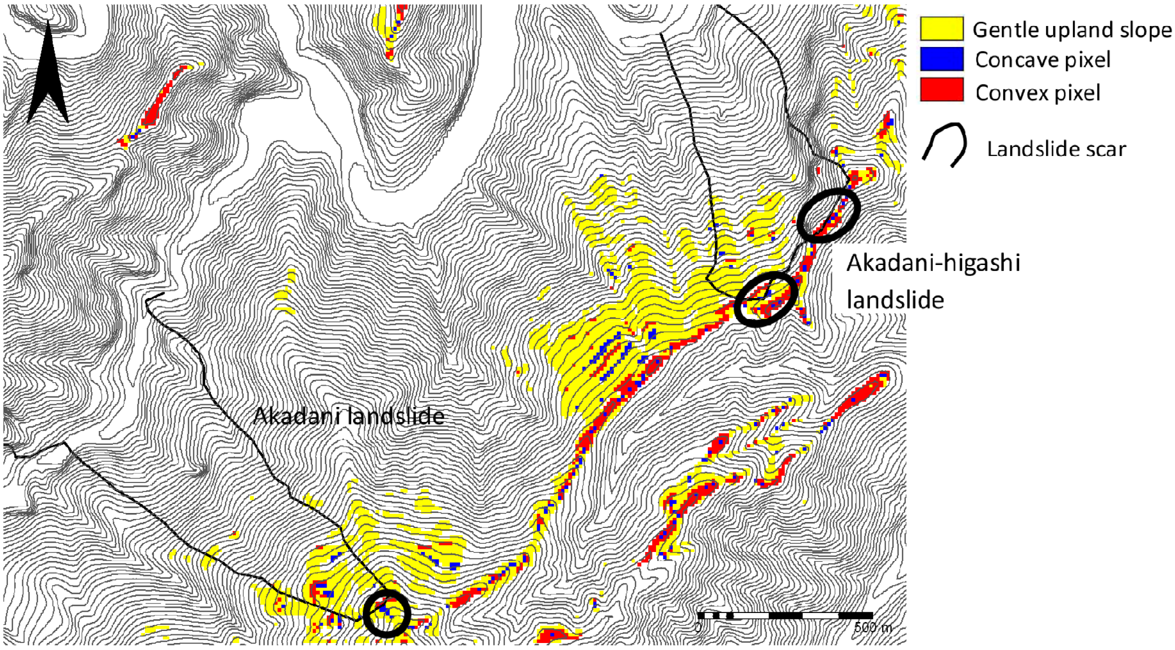


*Fig. 4 Estimated deep-seated landslide susceptible slopes*

Fig. 4 Estimated deep-seated landslide susceptible slopes upland gentle slopes, which indicate linear depression of the upper part of the sagging slopes. Near the crown, linear depressions are found on the gentle slope. It can be said that linear depressions on the upland gentle slopes show deep-seated landslide susceptible slopes. In the study area, there are gentle upland slopes with linear depressions. On these slopes, deep-seated landslide might occur in the next catastrophic rainfall or large-scale landslide.

Our proposed method can be used for first screening. The estimated distribution should be confirmed by detailed geological surveys in the field.

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