SENSITIVITY ANALYSIS OF LANDSLIDE TRIGGERING EARTHQUAKES

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BACKGROUND

Earthquakes are often mentioned as a trigger for landslides. Commonly, research focus on strong motion earthquakes. In this study also medium sized earthquakes are analyzed. Different mechanisms and combinations of earthquake strength and depth as well as different substrate properties for two regions of Germany are assumed to run scenarios for earthquakes with the potential to trigger landslides. Landslide motions are herby modeled by applying the 'Newmark Displacement' method.

METHODOLOGY

The 'Newmark Displacement' method was defined by Newmark (Newmark, 1965) to calculate the effects of earthquakes triggering landslides on artificial slopes. For natural slopes the substrate data are normally not known in detail. Therefore the effect of earthquakes on landslides can only be estimated. With a sensitivity analysis the lower limits of the probable earthquake magnitude and respective landslide areas triggered by these earthquakes was evaluated. Fig. 1 shows the necessary steps for the calculation with the 'Newmark Displacement' method and a resulting 'Probability of Failure' map.

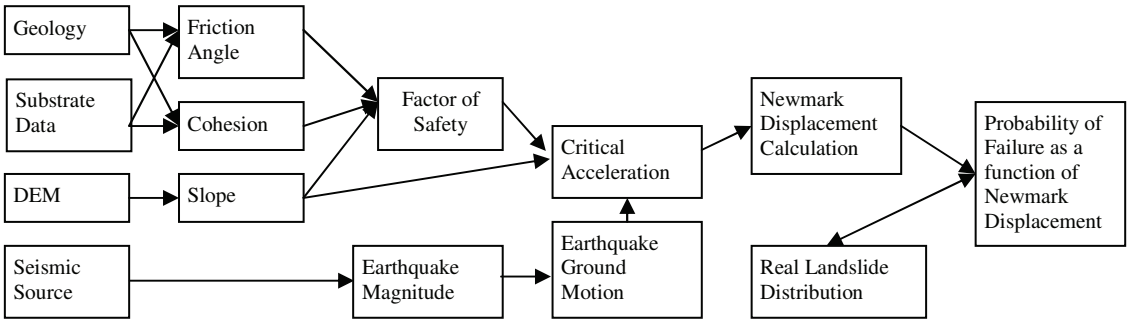

Fig.1: Flow chart showing steps necessary for the calculation with the 'Newmark Displacement' method after Jibson et al (1998), modified.

The first step was to characterize the relevant earthquakes with known strength and depth. For most historical earthquakes strength is provided by intensity, but in calculations, magnitude values (ML) are required. An unpublished formula of the BGR (Bundesamt für Geologie und Rohstoffe, Hannover, Germany) was applied to convert intensity data into magnitude values. These date as well as the respective coordinates were compiled in a database based on an historical earthquake catalog from the BGR.
Secondly, the geology of the study areas and the distribution of the prevailing substrates were compiled using digital geological maps. For areas where digital maps were not available, the analog maps were digitized. Unfortunately, the descriptions and legends of similar units differ from map to map. To resolve the harmonization of all data, the stratigraphy and the descrip-

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tions of the substrates from the geological maps were digitized and transformed into tables which could be used within the software ArcGIS, which was used for the further calculations. In addition, missing substrate data such as specific unit-weight, friction angle and cohesion were taken from literature and also added to the database. Due to resource limitations, no laboratory or field measurements were carried out in the study areas to gain local substrate data. Because this study is a regional assessment and the consequent variability of substrate data is rather large, the use of referenced data is an acceptable assumption. The range of values selected for the sensitivity analysis was based on the respective entries of the compiled database. The final calculation of the probability maps is based on the most reasonable values.
The third step was to calculate the 'Factor of Safety' (FOS) using the formula published by Miles (2003). The required data include cohesion, unit weight and internal friction angle of the relevant substrates, slope angle, thickness of the moving mass and the respective water saturation. These entries were grouped according to their most common property values in order to simplify the number of calculations within the 'Newmark Displacement' method. The slope angles were calculated with ArcGIS using different DEMs for the study areas.
The fourth step was to calculate the spatial distributed 'ARIAS-Intensity' by applying the formula of Wilson & Keefer (1993). Minimum and maximum values for reasonable combinations of magnitude and depth of earthquakes were determined.
Finally, the 'Newmark Displacement' was calculated by the formula of Jibson (1998) for slope angles ranging from 0° to 90° and applying the determined values of 'ARIAS-Intensity'. The 10 cm movement value defined by Keefer (2002) was chosen as the criteria for landslides displacement, e.g. any value equal and larger than 10cm is displayed in the map as failure, any value smaller than 10cm is assumed as stable.

RESULTS

This analysis was performed for the Bonn and Swabian Alb regions, both located in Germany. Results determine the substrates and areas with high potential for future landslides. Sensitivity analysis demonstrate the influence and weight of some variables used in these calculations for the results. For example, changes in friction angle and moisture have more influence on results than changes of specific unit weight. Finally, hazard maps were created for the study areas showing detailed areas, where an earthquake of a specific strength could cause a failure of a slope and endanger the society.

LITERATURE

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