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# A time probabilistic approach to seismic landslide hazard estimates in Iran

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ABSTRACT

Understanding where seismically induced landslides are most likely to occur is crucial in land use planning and civil protection actions aimed at reducing property damage and loss of life in future earthquakes. For this purpose an approach proposed by Del Gaudio et al. [1] has been applied to the whole Iranian territory to provide the basis to assess location and temporal recurrence of conditions of seismic activation of slope failures, according to the Newmark's model [2]. Following this approach, occurrence probabilities for different levels of seismic shaking in a time interval of interest (50 years) were first obtained through a standard hazard estimate procedure. Then, empirical formulae in the form proposed by Jibson et al. [3] and calibrated for the main seismogenic Iranian regions were used to evaluate the slope critical acceleration $(Ac)_x$ for which a prefixed probability exists that, under seismic shakings, Newmark's displacement $D_N$ exceeds a threshold × corresponding to landslide triggering conditions. The obtained $(Ac)_x$ values represent the minimum slope resistance required to limit the probability of landslide seismic triggering within the prefixed value. A map reporting the spatial distribution of these values gives comparative indications on regional different exposure of slopes to shaking capable of inducing failures and provides a reference for hazard estimate at local scale. The obtained results show that the exposure to landslide seismic induction is maximum in the Alborz Mountains region, where critical accelerations up to ~0.1 g are required to limit the probability of seismic triggering of coherent type landslides within 10% in 50 years.



## 1. Introduction

Some of the most severe effects of earthquakes are related to the triggering of ground-failure phenomena. The most common of such phenomena are landslides that, on occasion of strong earthquakes, can impact on property, and infrastructures, leading to large economic losses and fatalities. In addition, diffuse landsliding causes interruption of roads and lifelines, which make more problematic rescue operations and emergency management in the earthquake aftermath.

This problem is particularly serious in areas where active seismicity is combined with rough topographic relief as in some region of Iran. In the recent years, several earthquakes caused many fatalities and damages to civil facilities, e.g. the Manjil (1990), Avaj (2002), Bam (2003) and Firuzabad-e-Kojur (2004) earthquakes. In all these events a noticeable contribution to damaging derived from the mobilization of a large number of landslides. For instance, the Manjil Earthquake ($M_s$=7.7) in 1999 triggered catastrophic landslides that buried Fatalak village, killed more than 130 people and cut many important road and other lifelines, resulting in major economic disruption [4].

To improve preparedness to future earthquakes and to mitigate their effects, land use planning should take into account where slopes are likely to fail, to take measures reducing the exposure of buildings and critical facilities to the effects of landslides (choosing properly the location of designed structures and/or increasing slope resistance where slope failure can threaten the safety of existing structures).

This has motivated the development of methods for regional scale assessment of seismically induced landslide hazard, adopting simplified model, like Newmark's model [2], to represent conditions of landslide triggering in an extended area. Some of these methods evaluate spatial distribution of hazard for a scenario event (cf. Jibson et al. [3]), others (Del Gaudio et al. [1], Saygili and Rathje [5]) are focused on probabilistic evaluation of recurrence time of landslide triggering under seismic shaking.

In particular, the method proposed by Del Gaudio et al. [1] provides at regional scale the basic elements needed for local

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