Evaluation and comparison of the performance of linear regression (LINEAR) and geographically weighted regression (GWR) models in hazard zoning of the size of landslides triggered by the 1990 Rudbar-Manjil earthquake (Mw=7.3) based on controlling parameters

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Abstract

This study has reviewed and completed the database of landslides triggered by the 1990 Rudbar-Manjil earthquake (Ww=7.3), using previous studies, stereoscopic interpretation of aerial photographs, and checking satellite images (before and after the earthquake). We mapped 223 coherent landslides as polygons and central points using a digital elevation model (DEM, 12.5 m) by GIS software. A quantitative hazard zoning of the size (area and volume) of landslides was implemented based on controlling parameters by automatic linear regression (LINEAR) and geographically weighted regression (GWR) models. The controlling parameters include geotechnical group (cohesion and internal friction angle), topography (elevation, slope, aspect, and curvature), and seismic (distance from the fault rupture surface and the epicenter of the earthquake, the intensity of Arias, and the peak ground acceleration). The results showed that the quantitative zoning of the GWR model is more consistent with the size of existing landslides compared to the LINEAR model. The landslide area (LA) and landslide volume (LV) have a multimodal distribution compared to seismic and topographic parameters. Therefore, the nonlinear GWR model prepares a more accurate prediction of zoning than the linear regression model owing to the local effects of controlling parameters on the size of landslides.

***Keywords**: Llandslides triggered by the earthquake, Linear regression model, Weighted geographically regression, Rudbar-Manjil.*

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Extended Abstract:

1. Introduction

The area and volume of landslides are two significant characteristics that control the hazards of seismic landslides under the influence of various parameters (Li et al., 2014; Parker et al., 2011). From this, in studies of the landslide hazard, LA and LV, together with the landslide number density (LND, n/km^2), have special importance. General linear regression and logistic regression (LR) mainly apply to landslide hazard zoning (LHZ) models (Kavzoglu et al., 2014; Dagdelenler et al., 2015; Youssef et al., 2015b), in which the local influence of controlling parameters is not measured (is assumed constant for the entire region). The local regression models, e.g., geographically weighted regression (GWR), apply spatial changes to the controlling parameters. Therefore, the GWR demonstrated better performance than the general regression model in the LHZ by considering the local effects of the controlling parameters (Erener Duzgun 2010, Sabokbar et al. 2014). Feuillet et al. (2014) illustrate the GWR-based modeling by highlighting local variables (undescribable in linear models) that provide significant inputs for landslide hazard zoning. This study investigates and compares two statistical approaches: linear multivariate regression and geographically weighted regression (non-linear) in hazard zoning of the landslides size (LA, LV), based on controlling parameters and actual data of landslides triggered by the 1990 Rudbar-Manjil earthquake (Mw = 7.3).

2. Materials and Methods

In this study, 133 landslides were detected using aerial photographs at a scale of 1: 20,000, prepared before and after the earthquake (1981 to >1990) by the Geological Survey and Mineral Exploration of Iran, and verified with Google Earth satellite images (Fig. 1). In addition, 90 other landslides were mapped by the database of Komk Panah and Hafezi Moghadas (1993) and field data. The landslide area (LA, m^2) was extracted using polygons with boundaries determined in the GIS software. Three groups of control parameters include topography (elevation, slope angle, slope aspect, and curvature), geotechnical (friction angle, degree-cohesion, kPa), and seismic parameters (distance from the epicenter and rupture of the fault surface, Arias intensity (Ia), and peak ground acceleration (PGA)). A DEM (12.5 m) before the earthquake was used to prepare the maps containing topographic features. We estimated the PGA and Ia based on the studies of Mahdavifar et al. (2008) and Ghasemi et al. (2009). A geological map at a scale of 1:100,000 was provided by the Geological Survey and Mineral Exploration of Iran to determine the lithological units of the region.

In the first step, the database related to landslides triggered by the 1990 Rudbar-Manjil earthquake has been reviewed and prepared. The landslide size maps (LA and LV) and distribution of landslides (percentage of landslide area, LAP%, and the number of landslides per area, LND) were mapped on the GIS platform. In the second step, the GWR model and automatic linear regression (LINEAR) applied the landslide hazard zoning by the GIS and SPSS (IMB Co. Ver. 21) software. Quantitatively, the LHZ was elevated and compared with the size of the landslides that occurred in the earthquake of 1990 to determine their agreement with reality.

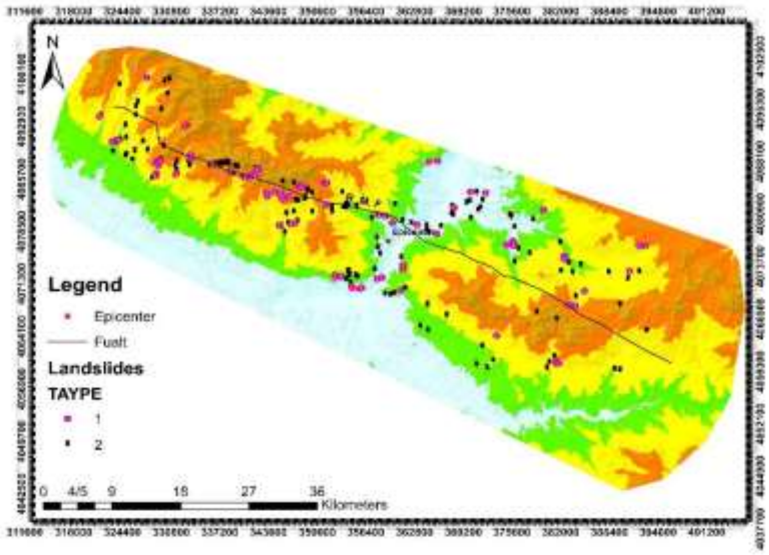

Figure 1. Distribution of landslides triggered by the 1990 Rudbar-Manjil earthquake, separated by 1 (new finding) and 2 (Hafezi Moghadas and Komk Panah, 1993).

3. Results

The highest frequency of landslides (N) was related to limestone, sandstone, and recrystallization shale in hard rock and dacite-andesite tuffs, and conglomerate in soft rock. Guo et al. (2014) and Huang and Li (2009) showed that landslides occur in hard rocks (e.g., igneous rocks, carbonates, and conglomerates) more than in soft rocks (e.g., sandstone, and shale) during the 2008 Wenchuan earthquake. Cui et al. (2014) stated that 361 landslides occurred on hard rock and 171 on a soft rock during the 2013 Lushan earthquake. Low-strength rock and more fractures cause a higher density of landslides (with small LA) in the high elevations and steep slopes of the Manjil-Rudbar northwest. In the southeastern part of the fault, the high-strength rocks at lower elevations with more vegetation have led to a low density of landslides with larger LA. The LA and LV are high in the slope aspect of the SE-SW to NW, and along the fault rupture line (NW-SE). It is must be case by the orientation of the seismic fault and the propagation of seismic waves. The high values of LV (m^3) are around the epicenter (within a radius of 5 to 10 km) and both ends of the fault, while the PGA values decrease from the center to the two ends of the fault. The largest landslides aren't necessarily observed at the epicenter (Bao et al., 2019, Zhang et al., 2016, Tong et al., 2010).

According to the LINEAR model, the most important controlling parameters on the LA are seismic (distance between the fault rupture surface and the earthquake's epicenter, Ia), geotechnical (adhesion, friction angle), and finally topography. The volume of landslides depends more on the geotechnical and topographical parameters (slope, aspect, and elevation) than the LA. Based on the GWR model, the predicted area values (LA, km^2) are consistent with the LA that occurred in the 1990 earthquake at the epicenter and both ends of the fault, with $R^2 = 0.35\text{-}0.85$. The volume values (LV, m^3) predicted in all parts, except for the southeast end of the fault and the northwest end in a limited way, are consistent with the LV that occurred in the earthquake with $R^2 = 0.3\text{-}0.85$. Where the correlation coefficient in the LINEAR model for area and volume is consistently equal to 55% and 45%.

4. Conclusion

The findings emphasized that the distance from the fault rupture surface is more important than other seismic, topographic, and geotechnical parameters in the LHZ, which is consistent with the studies of Xu and Xu (2014) and Tang et al. (2019). While Valagussa et al. (2019) showed that the size of the landslide decreases with the distance from the fault rupture surface, this trend is not clear for the distance from the earthquake epicentre. Massey et al. (2018) discovered that the distance from the fault predicts landslide probability better than the PGA modelled by Shake Map. In the study, the GWR model provided more accurate results than the LINEAR model in the landslide hazard zoning. The local effects of the controlling parameters can explain this by the GWR model as compared to the uniform effects of the parameters by the LINEAR model. To improve landslide hazard zoning, spatial regression models, e.g., the GWR, should be integrated with other statistical and data-mining methods.

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