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Landslide susceptibility mapping at central Zab basin, Iran: A comparison between analytical hierarchy process, frequency ratio and logistic regression models

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ABSTRACT

The purpose of this study is to compare the landslide susceptibility mapping models of logistic regression (LR), analytical hierarchy process (AHP) and frequency ratio (FR) applied in the central Zab basin (West Azerbaijan—Iran). Eight factors were used for landslide susceptibility mapping including slope, aspect, land cover, precipitation, lithology and the distance to roads, drainage, and faults that affect the occurrence of landslides. To get more precision, speed and facility in our analysis, all descriptive and spatial information was entered into GIS system. Satellite images (Landsat ETM + and SPOT 5) are also used to prepare for land use and landslide-inventory mapping respectively. Landslide events as used as dependant variable and data layers as independent variable, making use of the correlation between these two variables in landslide susceptibility. The three models are validated using the relative landslide density index (R-index) and the receiver operating characteristic (ROC) curves. The predictive capability of each model was determined from the area under the relative operating characteristic curve and the areas under the curves obtained using the LR, AHP, and FR methods are 0.8941, 0.8115, and 0.8634, respectively. These results indicate that the LR and FR models are relatively good estimators of landslide susceptibility in the study area. The interpretations of the susceptibility map reveal that precipitation, lithology and slope played major roles in landslide occurrence and distribution in the central Zab basin. In general, all three models were reasonably accurate. The resultant maps would be useful for regional spatial planning as well as for land cover planning.

1. Introduction

As a natural hazard, landslides cause great damage to human lives and infrastructure (Nefeslioglu et al., 2008). Statistics from the Center for Research on the Epidemiology of Disasters (CRED) show that landslides are responsible for at least 17% of all natural hazard fatalities worldwide (Pourghasemi et al., 2012). According to the Iranian Landslide Working Party (2007), about 187 people have been killed in Iran by landslides and losses resulting from mass movements to the end of September 2007 have been estimated at 126,893 billion Iranian Rials (almost $12,700 million dollars) using the 4900 landslide database (Iranian Landslide Working Party, 2007). Given the degree of loss in both human and economic terms, recognizing the identifying the risk factors inherent to landslide hazards makes zoning a necessity (Iranian Landslide Working Party, 2007).

Western Iran has some parameters which affect landslides such as slope, precipitation, lithology, soil, earthquake and human activity. The central Zab basin, in the south-west mountain sides of West Azerbaijan province, is having landslide problems. The landslides observed and found in the area include old and new landslides. Although the area is not a complete agricultural zone, it has cultivated land which is affected by landslides (Shahabi et al., 2012a).

Identifying the different types and processes of landslide formation counts as major factors in preventing landslide induced damage. The preparation of a landslide susceptibility map is a major step in overall landslide hazard management. Landslide susceptibility is defined as a quantitative or qualitative assessment of the classification, volume (or area) and spatial distribution of landslides which exist or potentially may occur in an area (Bednarik et al., 2010). Landslide susceptibility assessment in a GIS environment is based upon a suitable selection of factors which play a dominant role in slope stability.

There are many qualitative and quantitative techniques available to analyze the relationship between a landslide and conditioning parameters (Ayalew and Yamagishi, 2005). In recent years, many studies have been carried out on landslide hazard evaluation using GIS (Akgün and Bulut, 2007; Akgun et al., 2008; Bednarik et al., 2012; Kayastha et al., 2013; Pradhan et al., 2012; Wan and Lei, 2009; Wan et al., 2010).

Many statistical models are used in landslide hazard analysis including logistic regression (Akgun et al., 2012; Bai et al., 2010; Bui et al.,

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2011; Shahabi et al., 2012a; Wang et al., 2013), analytical hierarchy process and frequency ratio (Akgun et al., 2008; Shahabi et al., 2012b).

Previous investigations have not studied landslide hazard susceptibility nor utilized satellite images and statistical methods to study the landslide susceptibility map in the study area. In previous studies in the study area, researchers only used limited traditional methods.

Many previous studies using GIS technology have applied a single model, discussed relevant factors, and validated landslide susceptibility maps to assess the performance of the applied model. The main difference between previous studies and the present study is there has been no comprehensive study to date involving the application, assessment, and validation of various statistical models in the same area or an accurate method for improving prediction accuracy. Therefore, there is significant demand for landslide susceptibility mapping generated by LR, AHP and FR models in central Zab basin with high predictive accuracy.

The purpose of this paper is to assess and compare the results of landslide susceptibility maps using three statistics based approaches in the central Zab basin. This comparison involves four main steps. The first step involves identifying the categories of the causative factors responsible for the occurrence of landslides based on the characteristics of the landslide inventory. The second step estimates the relative contribution of these categories causing slope failure and establishes a relation between the categories and the landslides. Then, the significant or the most influential categories to assess the best statistical model are determined. Finally, the best indirect susceptibility map is compared with the best direct susceptibility map using two validation methods, R-index and ROC.

2. Study area

Zab basin occupies the southwestern section of West Azerbaijan and the northwestern part of Kurdistan. The area under present study covers parts of mountains and slopes in southwestern West Azerbaijan in the central portion of Zab basin between latitude (36° 8′ 25″) N and (36° 26′ 27″) N and longitude (45° 21′ 21″) E and (45° 40′ 44″) E. Central Zab basin has a north–south orientation and stretches almost 30 km in an east–west direction. The study area covers some 520 km^2 of its total area (Fig. 1). It is one of the most populated geographical basins and includes a city, three towns or small cities, and over 80 villages (Khezri et al., 2013b). Most landslides are seen within a 1000 m boundary of the main Sardasht–Piranshahr and Sardasht–Rabat roads. Here, a north-west extension branches off from the east–west oriented ridges of Zab Valley, creating a different landscape from that of the internal sections of Azerbaijan and Kurdistan provinces.

As the study region is located in a major Zagros thrust direction, tectonic faults are the main cause of slope failures. The regions morphology is strongly affected by tectonic forces. The most important faults are located in western Iran, highlighting and giving importance to this cause in the region of study. The target research zone, tectonically, is located in Sanandaj–Sirjan region, and its north-east region is located in Mahabad–Khoy zone (Khezri et al., 2013a). Also, due to the steep rocks and several faults as well as their different functions, steep and layer lengths are different (Fig. 2). Stones, homogenous phylite formations, marble, lime, green andesite, dolomite and sandstone are the dominant lithology in these zones.

3. Material and methods

3.1. Landslide inventory

Landslide susceptibility mapping is based on a landslide inventory including geology (lithology), geomorphology (slope, and aspect), land cover, precipitation and distance to roads, faults, land cover, and drainage network. Landslide inventory map of the study area was

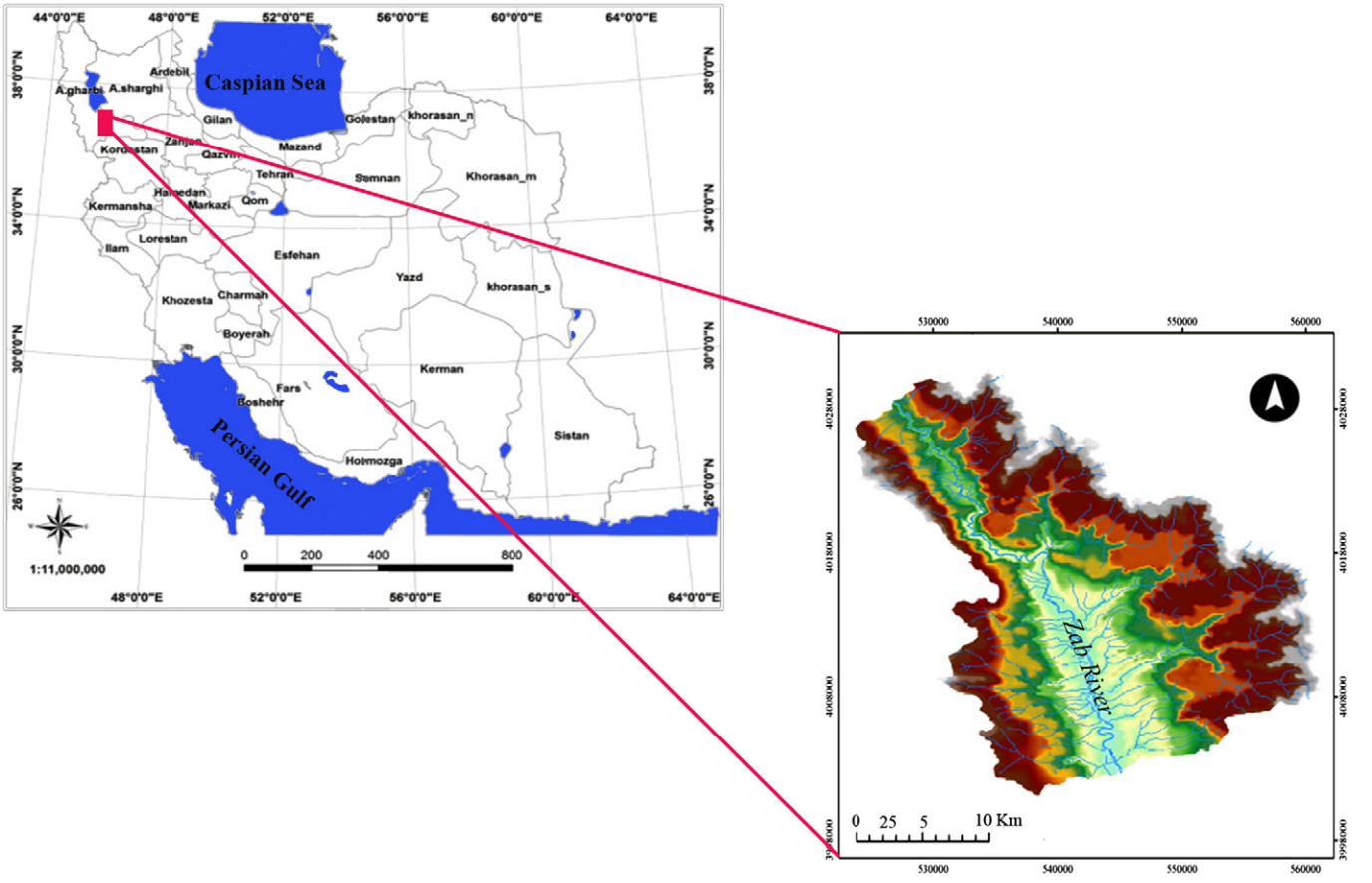

Fig. 1. General position of Zab basin regarding the political provincial and national borders.