GIS-Based Quantitative Landslide Risk Assessment Approach for Property and Life at Bartin Hepler

Arzu Erener
Kocaeli University, Turkey

Gülcan Sarp
Süleyman Demirel University, Turkey

Şebnem Düzgün
Colorado School of Mines, USA

INTRODUCTION

Landslides are the second most common natural disasters that cause damages in Turkey after the earthquakes (Ergunay et al., 2003). 89% of the middle and the eastern parts of the Black Sea Region are reported to be susceptible to landslides (Toprak Su 1978; Öztürk 2002). Thus, landslide risk assessment is of crucial importance in decreasing the potential losses.

However, attempts to determine qualitative and/or quantitative risk assessment seems to be fewer (e.g. Wang and Unwin 1992; Fell 1994; Chung et al. 1995; Carrara et al. 1995; Jibson et al. 1998; Aleotti and Chowdhury 1999; Chung and Fabbri 1999; Chowdhury and Flentje 2002; Dai et al. 2002; Bell and Glade 2004; Remondo et al. 2008; Erener and Düzgün 2010; Silva and Pereira, 2014; Luna et al., 2014; Erener, et al., 2016, Erener et al. 2017; Pereira et al.,2017; Vega and Hidalgo, 2017; Hidalgo et al., 2018; Vega et al., 2019) which might be due to the difficulties in obtaining data.

One of the chief advantages of a Quanitative Risk Assesment (QRA) is that it can be compared with other types of risk that can affect a community and since of its quantitative nature it can be communicated more comprehensible to the policy and decision-makers to be used for risk management policies (Luna, et al., 2014). In recent years, Geographical Information Systems (GISs) and Remote Sensing (RS) have proven to be common tools adopted for various studies. In this study, a GIS-aided quantitative landslide risk assessment approach is proposed with an application to local-scale.

BACKGROUND

Quanitative Risk Assesment (QRA) requires quantification of losses due to a given landslide hazard. When landslide hazards are investigated in a local scale, it is necessary to predict the run-out area to identify the potential damages to elements at risk. In any QRA it is of fundamental importance to identify and characterize elements at risk (e.g. buildings, roads, utilities, lifelines) for predicting losses. If insufficient or no digital data exist on a local scale, remote sensing products can be used to extract the element at risks, such as road networks and buildings. Most of the works in the literature concentrates only on the extraction of a single object such as only buildings or only roads. Typical examples of early

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works in building detection are Lin and Nevatia (1998), Kim and Nevatia (1999), Peng and Jin (2007), Vakalopoulou et al. (2015). On the other hand, Klang (1998), Laptev et al. (2000), Amini et al. (2002), Mena and Malpica (2003) Christophe and Inglada (2007), Yang and Wang (2007), Aytekin et al. (2012) used the most common algorithms for the detection of road.

The population data is required for each individual building to estimate the loss of life due to landslides for risk assessment studies. The population data can be collected through surveys that are time-consuming and costly. On the other hand, recently RS has proved to have the potential for predicting the population with low cost and up-to-date data. Zhang (2003), Lu et al. (2006), Morton and Yuan (2008), and Erener and Düzgün, (2009) has examined residential population dynamics from satellite remote sensing images.

Vulnerability is another fundamental component in QRA (Leone et al., 1996). Reviews of landslide vulnerability are made by Glade (2003) and Lee and Jones (2004). The vulnerability of static elements at risk, such as buildings, land-use, roads, etc. does not vary with time. They are always exposed to threats for all time in all day or all year. On the other hand, the vulnerability of dynamic elements at risk may change depending on their geographical and temporal existence with respect to landslides and it is more difficult to estimate the vulnerability for these elements. Thus, for dynamic elements (residents of the buildings, cars, trains, etc.) daily and seasonal movements are also required for a reliable estimation. Quantification of elements at risk requires a compilation of data from different organizations through interviews with the employees, which is a time-consuming process. Therefore, the assessments of vulnerability for landslides in the literature are usually qualitative (Rautela and Lakhera, 2000) and mostly depend on historical records (Dai et al., 2002; Glade, 2003). For effective use of QRA, generalized quantitative models for vulnerability assessment are essential. Several procedures are described in the literature for the assessment of vulnerability, (e.g. Mejia-Navarro et al. 1994; Fell 1994; Leone et al. 1996;, Glade 2003; Uzielli et al. 2006).

FOCUS OF THE ARTICLE

This study introduces a GIS based approach for QRA and illustrates its implementation to Hepler village in Bartın Province, Turkey. GIS is very modern and useful data entry, processing, analysis, query and update tool for both spatial and attributes data (URL1) used at whole parts of this study. On the other hand, RS is an effective data collection method for GIS. A generic algorithm (Aytekin, et al. 2012) that consider road and building extraction together from remote sensing images is adopted in this study for detection of elements at risk. Landslide run-out models being used for assessing the vulnerability values quantitatively on local scale. The velocity of landslide in its run-out area and the number of inhabitants per house are taken into account to quantify the vulnerability related to the elements at risk at GIS environment. In contrast to the property, human exposure to the landslide occurrence may vary depending on the temporal impact. Therefore, the temporal impact is considered for the residents living in buildings. In this context, the occupancy of buildings by people at different times is considered in the study. Hence, the vulnerability of human life is evaluated for temporal scales of day time, night time, high season time, and low season time. Furthermore, the vulnerability of buildings and road are estimated by adopting the damage probability matrix approach by Düzgün (2008). This approach is used in earthquake engineering for evaluating the damage of building stock for a given earthquake intensity (Ko Ko et al., 2004).

As a result of the analysis, quantitative risk maps for both life and property were obtained by the evaluation of hazard, vulnerability and consequence maps for each element at risk at GIS environment. A combined landslide risk map was obtained by adding risk for each element at risk on a continuous

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