Physics and Chemistry of the Earth 35 (2010) 162–171

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Landslide susceptibility assessment of the Kraľovany–Liptovský Mikuláš railway case study

Martin Bednarik [a,*], Barbora Magulová [a], Mirko Matys [a], Marian Marschalko [b]

[a] Comenius University, Faculty of Natural Sciences, Department of Engineering Geology, Mlynská dolina, 842 15 Bratislava, Slovak Republic
[b] VŠB-Technical University of Ostrava, Faculty of Mining and Geology, Institute of Geological Engineering, 17. listopadu 15, 708 33 Ostrava, Czech Republic

ARTICLE INFO

Article history:
Received 3 November 2008
Received in revised form 11 November 2009
Accepted 21 December 2009
Available online 28 December 2009

Keywords:
Landslide susceptibility assessment
Parametric maps
Statistical methods – bivariate statistical analysis
Entropy index
Geographic Information System (GIS)
Line structures

ABSTRACT

The paper deals with bivariate statistical landslide susceptibility assessment for the territory of the Kraľovany–Liptovský Mikuláš railway case study. Bivariate statistical analysis with weight determination of each input parametric map, based on entropy index calculation, within the Geographical Information Systems (GIS) environment has been used, since bivariate and multivariate analyses are the most commonly used statistical methods. For the statistical assessment of landslide susceptibility, aerial entities of the main scarps were taken for bivariate analysis.

The evaluated area presents an irregular buffer, delimited by the Vah River watershed, and it spreads 50 km along the railway between Kraľovany and Liptovský Mikuláš townships in the Slovak Republic.

The effectiveness of landslide susceptibility assessment using GIS and statistics is based on appropriate selection of the geological factors which play a dominant role in slope stability. In this case study, five factors influencing slope stability are evaluated – lithology, slope aspect, slope angle, hypsographic level and actual landuse. These factors were prepared in vector form (parametric maps) and subsequently processed to the raster form. Bivariate statistical analysis was used to construct the final prognostic landslide susceptibility map.

1. Introduction

Currently, the main railway lines in Slovakia are under reconstruction in order to deliver a designed speed of 160 km/h. The rail section between Kraľovany and Liptovský Mikuláš represents one of the main line sections to be re-designed.

The buffer around the railway line delimited by the Váh River watershed has been therefore evaluated. The reviewed line section has a length of 50 km and it is displayed on 17 maps in a scale of 1:10,000 (Fig. 1). The territory of interest covers an area of 99.8 km^2, where-in registered landslides have a spatial distribution of 14.1 km^2.

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 (AGS, 2007). Landslide susceptibility assessment in a GIS environment is based upon suitable selection of factors which play a dominant role in slope stability. The evaluated input factors reflect geological, climatic and hydrologic conditions as well as morphometric characteristics of the relief, and actual landscape structure of the studied area. Landslide susceptibility assessment and statistical processing are based on an axiom of actualism, i.e. we presume that future landslides will occur under the same conditions as in the past. The selected factors were processed in the form of parametric maps (in the raster form of 10 × 10 m cell size) and statistically processed, underpinned by the map algebra in the GIS environment.

Bivariate and multivariate statistical analyses were used because of their high reliability rate. The first paper dealing with such a statistical approach was published almost 25-years ago, Carrara (1983, 1988); later, the author modified his original methodology to the GIS environment (Carrara et al., 1990, 1991). The term "apparatus" for statistical evaluation of landslide susceptibility is well defined in both papers mentioned above, and also in Brabb (1985). A quantitative statistical approach in the world literature has been widely used since the early 1990s. Most interesting is Van Westeńs (1993) work dealing in detail with univariate (bivariate) and multivariate statistical analysis as well as with landslide susceptibility analysis, the information value method and weight of evidence modelling. Landslide susceptibility assessment reached a high theoretical and practical level in the last decade (Irigaray and Chacón, 1996; Aleotti and Chowdhury, 1999; Dai et al., 2001; Donati and Turrini, 2002; Clerici, 2002; Clerici et al., 2006; Iovine et al., 2003a,b; Süzen and Doyuran, 2004; Castellanos Abella and Van Westen, 2007; Iovine, 2008).

* Corresponding author.
E-mail address: mbednarik@fns.uniba.sk (M. Bednarik).

1474-7065/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pce.2009.12.002

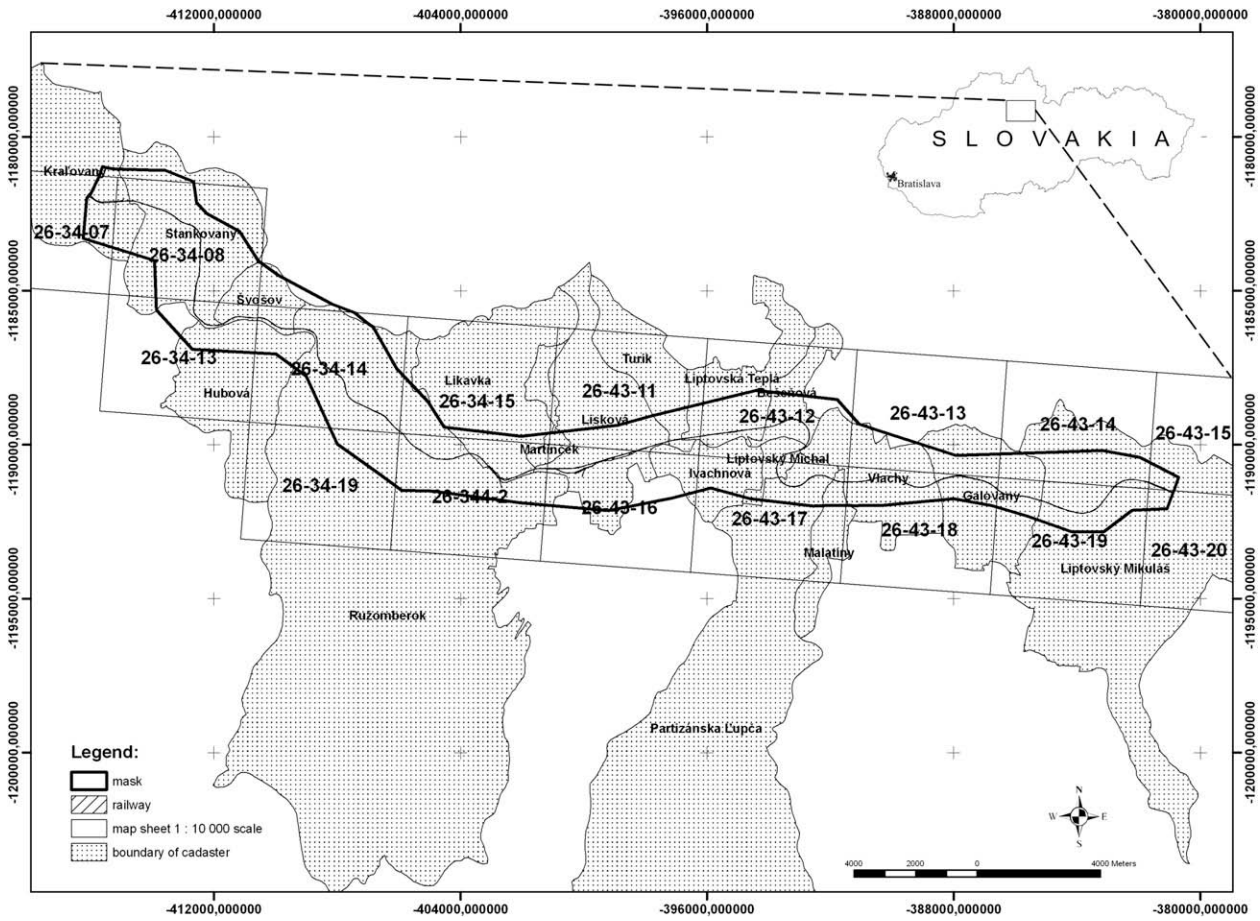

Fig. 1. Location map.

Bivariate statistical analysis is based on the comparison between a landslide inventory map as a dependent variable and all the separate input parametric maps (lithology/landslides, slope angle/landslides, etc.). This approach allows calculation of weights for each input variable. Here-in, the weighting process is based on methodology proposed by Vlčko et al. (1980), in which the weight value for each separate parameter is expressed as an entropy index.

The final prognostic landslide susceptibility map was created by a simple summation of weighted multiplications of secondary reclassified parametric maps. The result of this summation is a continuous interval of values and it represents various levels of landslide susceptibility. This interval is usually divided into three (represents low, medium and high level of susceptibility) or five conventional categories (represents very low, low, medium, high and very high level of susceptibility).

Landslide susceptibility processing and practical verification of the methodology can provide a basis for urbanism, landuse planning and for public administration offices and insurance companies. The methodical procedure in preliminary geological investigation stages presents low cost research, especially for larger areas and lined structures which are endangered both by extremely slow landslides (Greif et al., 2006) and by rapid debris flows (Vilimek et al., 2006).

2. Landslide susceptibility assessment – input parameters

2.1. Interpretation of geological conditions

The evaluated section of the main railway line is situated in two different geological and geographical units: the northern part of the Veľká Fatra Mts. and the western part of the Liptovská kotlina Basin. The slopes are dominantly built of Mesozoic rocks (massive dolomites, limestones, marls and marly limestones with layers of marly schists) and Quaternary sediments (slope deposits – clay loam, sandy loam, boulders, debris and alluvial deposits of the Vah River). Creep movements and rock slides are mainly abundant in this part. The Liptovská kotlina Basin territory is built of Paleogene (sandstones and claystones) and Quaternary sediments (fluvial and slope sediments, travertines, proluvial, organic and glacifluvial sediments), and to a lesser extent of Mesozoic (Choč Nappe, Krížna Nappe) and Paleozoic rocks (Páleník et al., 1988).

The studied area is characterized by occurrences of Quaternary travertines which have a linear arrangement (NNW–SSE and W–E striking). Generally, the travertines are Pleistocene and Holocene in age. Their occurrence is related to tectonic discontinuities which were most likely activated during the Quaternary. Neotectonic activity in this area is proven by the asymmetric pattern of the Quaternary terraces.

The identification of potential neotectonic forms of the relief was made from topographic data in a scale of 1:10,000 and available Digital Elevation Models (DEM), which were visualized by digital techniques. Special attention was paid to the identification of facet slopes, flat surfaces, valley characteristics, their general axes and various geomorphic markers in the identification of the potential neotectonic character of faults. Based on previous information there is a close relationship between the linear occurrence of landslide bodies and neotectonic activity in the study area.

Geological conditions represent one of the most important factors influencing slope stability. Based on similar lithological and engineering geological conditions, 20 lithostratigraphic units, as