THE APPLICATION OF GIS FOR MAPPING LANDSLIDE SUSCEPTIBILITY IN MĂHĂCENI TABLELAND

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The application of GIS in Mapping Landslide Susceptibility in Măhăceni Tableland. As a first step forward in regional hazard management, the likelihood frequency ratio model was used to produce a landslide susceptibility map in Mahaceni tableland. We constructed the essential spatial database of landslides using GIS techniques. Landslide inventory followed measurements on 73 new and partial stabilized landslides, using a Magellan Explorist 600 Gps with a 3m precision on field. Landslide data was then processed in GIS and we realized a present-day susceptibility map in Măhăceni Tableland. The map was then verified on field and the results were validated. The affecting factors such as lithology, slope angle, elevation, aspect, land use, distance to stream network, fragmentation depth and slope curvature are recognized. The relationship between the factors and the landslides were calculated using frequency ratio model. The relationships were overlaid to determine each factor’s rating for landslide susceptibility mapping. By combining each factor’s weighted values, we could realize the landslide susceptibility map for Măhăceni Tableland. Information on susceptibility map could be useful for explaining the known existing landslides, making emergency decisions and relieving the efforts on the avoidance and mitigation of future landslide hazards.

1. INTRODUCTION

Landslides are dangerous natural hazards that occur suddenly and cause considerable damage. Through scientific analysis of landslides, we can evaluate landslide susceptibility areas, prediction of landslide prone areas, and thus, decrease landslide-damage employing suitable mitigation measures. To carry out this, landslide susceptibility mapping were carried out and verified in the study area because landslide susceptibility maps are the first stage of the landslide hazard mitigation measures. GIS software was used as a basic analytical tool for space management and data manipulation.

The first stage in all the landslide susceptibility assessment studies consists in the collecting of existing information and data for the investigation area. For landslide susceptibility assessment, several spatial data controlling the landslide occurrence are necessary, together with the landslide inventory data. In the study, eight parameters were considered during the landslide susceptibility zoning of the study area: slope angle, lithology, elevation, aspect, land use, distance to stream network, fragmentation depth and slope curvature. These factors were transformed into a raster-type spatial database, using GIS. For the DEM creation (5x5 m spatial resolution), 10-meter interval contours were extracted from 1:25000-scale topographic maps. Using the DEM, slope angle, slope aspect, slope curvature, were calculated. For the fragmentation depth map we used an ESRI script. The drainage buffer was calculated at 200 meter intervals and classified into five equal area classes. The lithology map was prepared from 1:200000-scale geological map and the land use map from Corine database.

2. STUDY AREA AND DATA

The considered area- Măhăceni Tableland lies in the central- north- western part of Romania, as a contact region between Trascău Mountains and The Transylvanian Basin, extended between Trascău Mountains in the west, the Mureş-lower Arieş Way in the east, north and south. The northern part of the Alba Iulia-Turda Way, with the great curl of the Arieş river, reveals a hilly region with a peninsular aspect ("The Arieş river peninsula"- V. Mihailescu, 1965), which goes deeply eastward into the Mureş- lower Aries Way. This hilly massif is known in the geographical literature as Măhăceni Tableland or Vințu Piedmont.

Lithostratigraphically, Măhăceni Tableland is a Miocene formation, through which Badenian and Sarmatian structures are aged in almost parallel strips, the tectonic of the region revealing Badenian anticlines- the most important being Măhăceni anticline (sedimentary consisting of: marls, sand marls, sandstones) separated by Sarmatic synclines (mostly with: sandstones, marl clays and sandstones).

Concerning the climatic regime, Măhăceni Tableland follows the moderate continental- temperate tipe, with the soft penetration of the Atlantic air mass and the action of the foehn phenomenon on the south-eastern flank of the Apuseni Mountains, manifested by the increase of the annual mean temperature (8.5ºC at Turda) and the decrease of rain quantity (550mm at Câmpia Turzii). Analizing observation data from the main meteorological stations in the studied area (Turda station, Luna station) between 1966 and 2002, reveals a mean annual temperature of 8.5ºC (at Turda station), with a decreasing tendency towards the contact with the mountain region. The annual mean amplitude for Turda station is 15.4ºC. The mean annual precipitations go between 500 and 600mm per year (600mm at Turda station, 539mm at Luna station), the annual evolution is characterized by a maximum of precipitations in the warm period of the year (839mm in june, for Turda station) and a minimum, in the colder period of the year (144mm for Turda station).

3. FREQUENCY RATIO MODEL AND LANDSLIDE-RELATED FACTORS

In general, to predict landslides, it is necessary to assume that landslides occurrence is determined by landslide-related factors and the future landslides will occur under the same conditions as past landslides. Likelihood ratio model is based on the observed relationships between the distribution of landslides and each conditioning parameter of landslide occurrence, to exhibit the correlation between landslide locations and the parameters controlling landslide occurrence in the study area.

The spatial relationship between landslide location and each parameter's conditioning landslide occurrence were obtained using the LRM. In this model, the ratio is that of the area where landslides occurred, to the total area, so that a value of 1 is an average value. If the value is >1, it means that the percentage of the landslide is higher than the area and it refers to a higher correlation, whereas the values lower than 1 mean lower correlation.

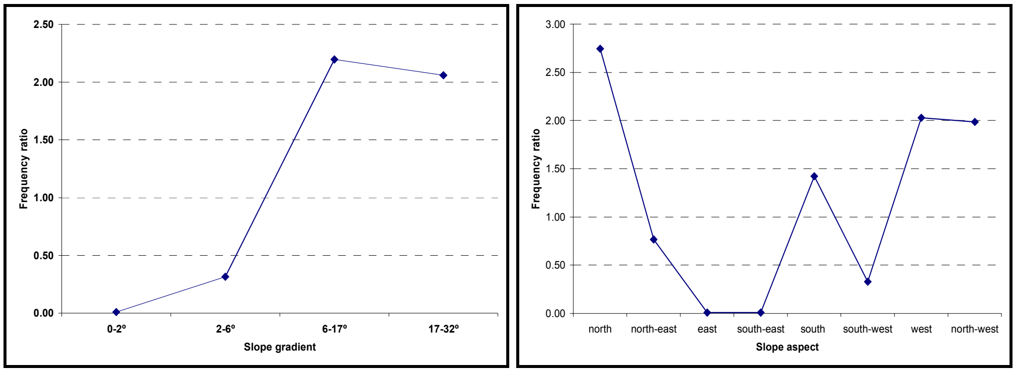

Fig. 1,2. Frequency ratio value for slope gradient and slope aspect

Slope gradient has a great influence on the susceptibility of a slope to landsliding. The relationship between landslide occurrence and slope shows that steeper slopes have greater landslide probabilities. Gentle slopes are expected to have a low frequency for landslides due to the generally lower shear stresses associated with low gradients. Below a slope of 6º, the frequency ratio is under a value of 0.32, which indicates a very low probability of landslide occurrence. For slopes above 6 º, the ratio is higher than 1, which indicates a high probability of landslide occurrence.

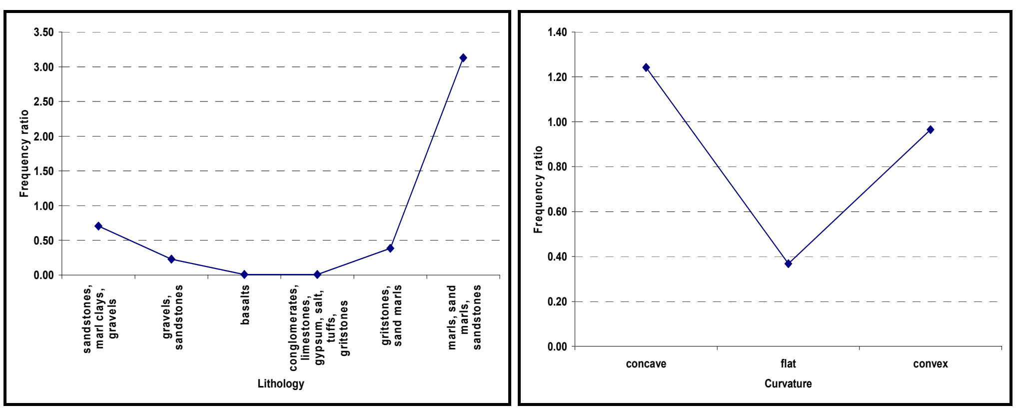

Fig. 3,4. Frequency ratio value for lithology and slope curvature

The aspect of a slope can influence landslide initiation. Moisture retention and vegetation is reflected by slope aspect, which in turn may affect soil strength and susceptibility to landslides. If rainfall has a pronounced directional component by influence of a prevailing wind, the amount of rainfall falling on a slope may vary depending on its aspect. In the study area, landslides were most common on north, northwest to west slopes. The slopes aspecting from south have also high susceptibility to landsliding but they are relatively less susceptible than the northwestern-western slopes.

In the case of rellationship between landslide occurrence and curvature, the more positive or negative the value, the higher the probability of a landslide occurrence. A positive curvature indicates that the surface is upwardly convex at the grid and a negative curvature indicates that the surface is upwardly concave at the grid. A value of zero indicates that the surface is flat. The shape of a slope influences the direction of the surface runoff. Following heavy rainfall, the concave slope contains more water and retains this water for a longer period. This is the reason why the concave slope has a frequency ratio value greater than 1.

The properties of the slope forming materials, such as strength and permeability which are involved in the failure, are related to the lithology, which should affect the likelihood of failure. With respect to relationship between landslides and lithology, the landslide occurrence value is the highest in the areas with marls, sand marls, sandstones (73.1 % of landslides area).

Regarding the relationship between landslide occurrence and distance from drainage, as the distance from a river increases, the landslide frequency generally decreases. At a distance less than 200m, the ratio was greater than 1, indicating a high probability of landslide occurrence. This can be attributed to the fact that terrain modification caused by the gully erosion and undercutting may influence the initiation of landslides.

The investigations have shown that land use cover, especially of a woody type, helps improving the stability of slopes. Vegetation provides both hydrological and mechanical effects that are beneficial to the stability of slopes. In Măhăceni Tableland, the landslide occurrence values were higher in pastures and transitional woodland-shrub areas.

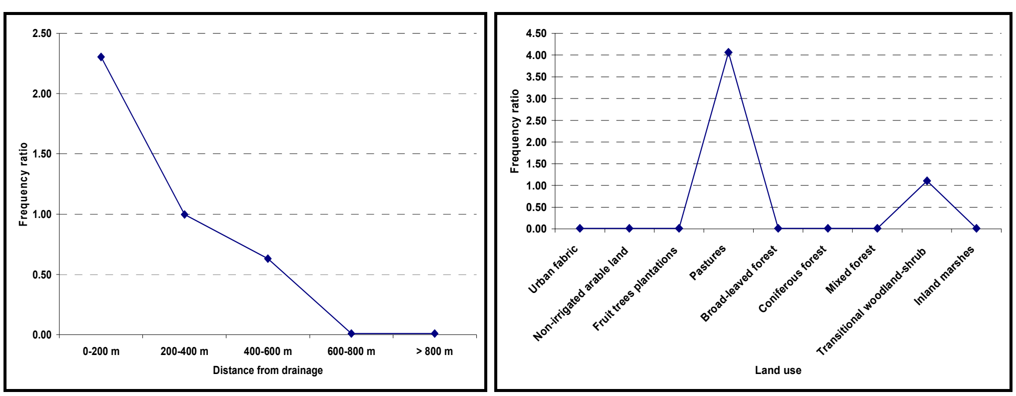

Fig. 5,6. Frequency ratio value for distance from drainage and land use

Fragmentation depth has a tight connection with all the valley's generations, the intensity of neotectonic upheavals, lithology and hydro-climatic conditions differentiated on terrain's degrees. There are different values between 0.1 – 260 m/km², almost half of the area being characterized by values between 0.1 – 100 m/km². The values are higher with the increasing of the terrain energy.

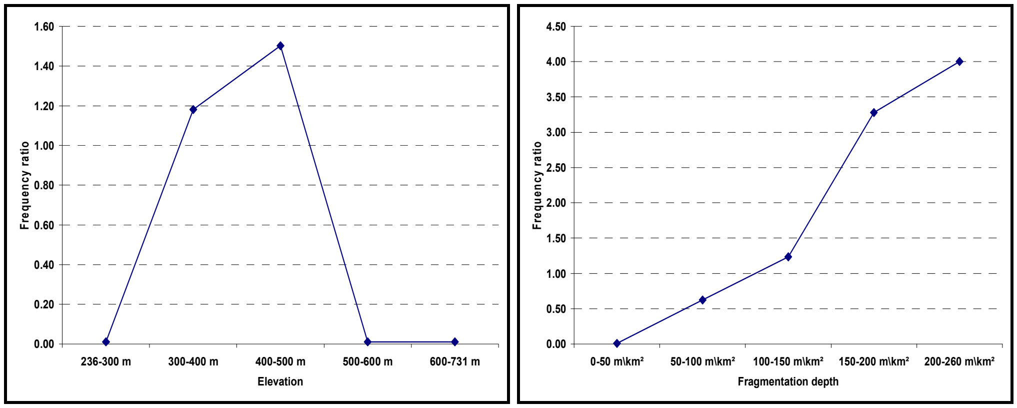

Fig. 7,8. Frequency ratio value for elevation and fragmentation depth

The correlation of landslide frequency with elevation emphasize that at intermediate elevations (300-500 m), slope tends to be covered by a thin colluvium, which is more prone to landslides. For these areas we found a ratio value greater than 1. At very low elevations, the frequency of landslides is low because the terrain itself is gentle.

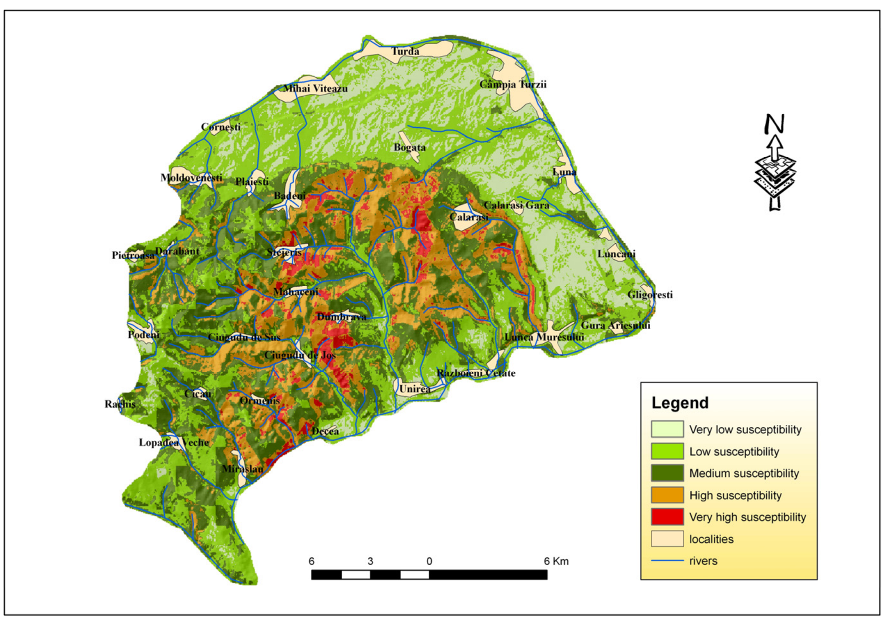

Fig. 9. Landslide susceptibility map for Măhăceni Tableland

In order to calculate the likelihood ratio, the area ratio for landslide occurrence was determined for the class of each parameter contributing to landslide occurrence. For this purpose, the landslide inventory map (realized with a Magellan eXplorist 600 GPS) was overlaid with thematic layers, and an area ratio for the class of each parameter to the total area was calculated. Therefore, frequency ratio for the class of each parameter was calculated by dividing the landslide occurrence ratio by the area ratio. Then, the frequency ratios of each parameter's class were summed and the total values of the frequency ratios obtained were assigned to each relevant parameter map as a weight value.

The parameter maps weighted were combined to determine the landslide susceptibility index (LSI), as presented below:

$$LSI = Wr1 + Wr2 + . . . Wrn ,$$

where Wr is the parameter map weighted.

4. CONCLUSIONS

The higher the LSI value, the higher the landslide susceptibility, whereas lower value means a lower susceptibility of landslide. Since the LSI map obtained has a continuous scale of numerical values, a necessity of dividing these values into 5 susceptibility classes has appeared. After calculation using LSI equation, we found a minimum value of 0.66 and a maximum value of 20.14, with an average value of 7.8 and a standard deviation of 3.9. Figure 9 shows the landslide susceptibility map generated with the frequency ratio model.

According to this susceptibility map, 54.3% of the total area is found to be low and very low susceptible. Moderate and high susceptible zones constitute 28.2% and 14.9% of the area, respectively. The very high susceptible area is 2.5% of the total study area. 17.4% of the study area, where the susceptibility index had a higher rank (high and very high susceptibility), could explain 97.03% of all the landslides.

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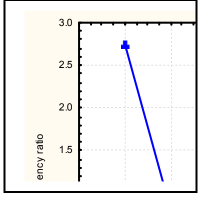

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