Scenarios of land cover change and landslide susceptibility: an example from the Buzau Subcarpathians, Romania

Žiga Malek[1,2], Veronica Zumpano[3], Dagmar Schröter[1], Thomas Glade[2], Dan Balteanu[3], Mihai Micu[3]

[1] International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

[2] Department of Geography and Regional Research, University of Vienna, Universitätsstrasse 7, 1010 Vienna, Austria

[3] Romanian Academy, Institute of Geography, 12 Dimitrie Racovita, 023993 Bucharest, Romania

contact: ziga.malek@gmail.com

Since 1990 the Subcarpathians in Buzau County, Romania have witnessed substantial socio-economic changes and resulting changes in the land cover. Influenced by the interplay of poor economic conditions, land ownership reforms, and institutional difficulties, these changes have been difficult to manage, resulting in a dispersal of built-up areas. Even though, the spatial extent of land cover changes has not reached critical levels as similar areas in the Carpathians, our analysis suggests that in the future the area might experience more extreme land cover changes. Moreover, the litho-structural traits and the high relief energy of the Romanian Subcarpathians favored the occurrence of various types of mass movements, imposing different levels of risk to people, buildings and infrastructure. Increase of human influence in form of expansion of built-up areas in the area could therefore result in slope instability and changes in the temporal and spatial patterns of hydro-meteorological hazards. This study shows, that possible future changes in land cover will not have a major influence on hazards, however risk might increase due to the increased value and number of elements at risk.

Keywords: Land cover change, Scenarios, GIS, Landslide susceptibility.

1. Introduction

In mountain areas even minor land cover changes can aggravate the consequences of hydro-meteorological hazards such as landslides, avalanches, and flash floods. Whereas most of conditioning factors for landslides (e.g. topography, geology, hydrology) can be considered as stationary, land cover can change in a relatively short time span, therefore directly affecting the landslide spatial distribution occurrence. Our research addresses the possible land cover changes in form of expansion of built-up areas in the Romanian Carpathians, under a set of scenarios of socio-economic change. Through our research, we tried to evaluate how different land cover change scenarios might result in changes in landslide susceptibility and in which susceptibility classes the major changes might happen.

1.1 Study area

The study area lies in the Buzau County Carpathians and Subcarpathians, in South East Romania. It covers an area of about 3300 km^2. The Carpathians are rising up to 1772 m, with the geology being represented mainly by Paleogene flysch deposits. Landslides cover large areas in the case study site, in some parts more than two-thirds of the total area (Muică and Turnock 2009). After land ownership reforms since the 1990s, poor socio-economic conditions, and institutional difficulties, the pressure on the environment in form of deforestation and expansion of built up areas has increased. As discussed by the involved stakeholders, a further increase in economic activities and living standard is expected.

2. Methods

2.1 Land cover change

The evaluation started with the classification of several LANDSAT images between 1989 and 2010, to identify the land cover trends in the last 20 years. For future land cover scenario modeling we used Dinamica EGO, to develop a spatially explicit cellular automata based model (Soares-Filho et al. 2002). The spatial allocation module of the model generates a land cover change probability map by weighting the defined landscape attributes (elevation, slope, distance to settlements, roads and main employment centers, and protected areas) of past land cover changes. The demand for built-up areas is calculated by the non-spatial scenario module, where the amount of new built-up areas is defined as a function of population change and increase in the living standard. For GDP growth and population change rates we used projections provided by the Romanian National Statistics Institute and IIASA (INSSE 2012; IIASA 2012). We generated land cover scenarios until 2035, for two scenarios of population decrease (a projected trend in Romania), and added another scenario where population remains stable. The year 2035 presents a medium term interest, suitable for local scale land cover analysis in rural areas.

2.2 Landslide susceptibility

Landslide hazard assessment at regional scale is very often performed through susceptibility analysis. In this work the susceptibility analysis was performed using the weight of evidence (*WofE*) modeling technique, very well documented and widely applied in many scientific fields (van Westen et al. 2003; Masetti et al. 2008; Duke & Steele 2010; Sterlacchini et al. 2011). WofE is a log-linear form of the data-driven Bayesian probability model that uses known occurrences as training points to derive a predictive output (response theme). The method is based on the calculation of positive and negative weights (W+ and W−) by which the degree of spatial association among training points and each explanatory variable class may be modeled (Sterlacchini et al. 2011). For the analysis 8 explanatory variables were used (altitude, aspect, profile and planar curvature, slope, lithology, soil, internal relief and land cover).

3. Results and discussion

3.1. Land cover scenarios

The 3 future scenarios are described in terms of population change and built-up areas in Table 1. The scenarios also differ in the spatial pattern of land cover changes, an example of expansion of built-up land in a smaller area is shown in Figure 1. We assumed that depopulation has a limiting effect on the expansion of built-up areas, as there is less demand for new land even though the living standard will increase. Therefore, both depopulation scenarios result in fewer new built-up areas. Still, in all scenarios, built-up areas increased. This is mainly due to the assumption that the projected growth of GDP would result in urbanization of the region and new economic activities.

3.2. Changes in the landslide susceptibility classes

The analysis was run using the three different land cover scenario maps in order to obtain different susceptibility set-ups. Due to the fact that the scenarios used as input address only changes in the built-up areas, few changes can be observed comparing the susceptibility map for the actual and modeled land cover. As expected, the human impact (attributed to the increase of built-up areas) is not influencing the slope instability substantially, but more probably the related exposure of the elements at risk. It is also important to underline that less than 1% of the whole area is projected to change. Such changes are not sufficient to be observed from the analysis with a low level of sensitivity. Furthermore, we analyzed the occurrence of projected changes in each susceptibility class for the three scenarios. The results are summarized in Graph 1, which highlights, that the major changes occur in the low susceptibility class.

4. Conclusion

Looking at the foreseen 2035 scenarios, no considerable expansion of human settlement can be expected in areas with high slope instability. Nevertheless, even though projected land cover changes might seem unimportant, it has to be taken into account that the number and value of elements at risk might rise, which would lead to an increase in risk.

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Tables and Figures

Table 1: Land cover scenario results

Year - Scenario	Population	Urban areas (km^2)
1990	187404	203.70
2010 – baseline	168513	211.84
2035 high depopulation	138945	226.58
2035 low depopulation	157054	230.51
2035 constant population	168513	237.95

Graph 1: Land cover changes distribution in susceptibility classes

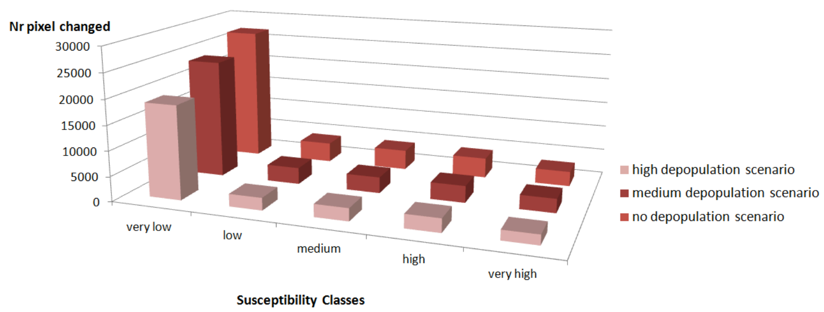

Figure 1: Example of land cover scenarios