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Summary: *This paper presents a methodology developed within the cross-border project GeoSES for assessing landslide risk in the municipality of Sighetu Marmației. The method employs GIS software to generate landslide risk maps. Two methods were devised: one involves a statistical model highlighting landslide risk, using input data from samples and a set of relevant variables. The second method utilizes GIS analysis and data obtained from UAV flights to monitor ground deformations. These integrated approaches provide a detailed and up-to-date image of landslide risk, facilitating decision-making and efficient land management.*

Keywords: landslide, GIS, UAV, GNSS, spatial analyses.

1. Introduction

The importance of landslide risk assessment is significant in the context of its impact on human communities (Irimuș et all. 2017). Climate change has increased the vulnerability of border regions between Romania, Hungary, Slovakia, and Ukraine to landslides. Sighetu Marmației, situated in the Maramureș Depression on the cross-border with Ukraine, is one such area of concern. The municipality monitors hazardous landslides through its civil protection department. In this context, the development of landslide risk maps, both locally and cross-border, becomes essential.
This research was conducted as part of the 'Extension of the Operational 'Space Emergency System' towards Monitoring of Dangerous Natural and Man-made Geo-processes in the HU-SK-RO-UA Cross-border Region' project, funded by the ENI CBC Programme 2014-2020 (Rădulescu et al. 2021). The research aimed to contribute to two major objectives of the project: reducing natural disaster risks through landslide monitoring and developing a joint innovative strategy for ecological disaster prevention and climate change adaptation in the Carpathian region. This paper presents the project's results regarding landslide risk mapping and the monitoring of deformations caused by landslides.

2. Methods

Our research involved conducting an inventory of landslides and identifying correlations with a set of variables that explain landslide incidence. These variables encompassed geological structure, relief energy, slope, slope curvature, aspect, altitude, and distance from the hydrographic network (Sestraș et al. 2021). The research hypothesis assumed a correlation between the dependent variable (landslides in the sample) and the independent variables, while the null hypothesis posited a random distribution. We utilized data from various sources, including topographic and geological maps, satellite imagery, and GNSS measurements. Data processing was performed using the following GIS software: ArcGIS Pro, QGIS, Google Earth, and Maxent. For landslide monitoring, we conducted four measurement cycles in six identified zones within the municipality of Sighetu Marmației and neighboring localities (Kalmar et al. 2022b). We employed GNSS technology and aerial photogrammetry, utilizing DJI Phantom 4 and DJI Matrix 210 TK V2 drones. Photogrammetric data processing was carried out using Agisoft Metashape software (Kalmar et al. 2022a).

3. Results and Discussion

The results of the statistical analysis have led to the development of a landslide risk map, highlighting the probability of these phenomena occurring (Phillips and Dudik, 2008; Phillips et al. 2017). The map reveals three risk categories: low, moderate, and high. Significant correlations between landslide risk and independent variables include steep slopes and the presence of rocks from the Cenozoic era, especially those from the Neogene and Miocene geological periods. These types of rocks, such as clays, marls, and sandstones, are known for their high susceptibility to landslides. Additionally, northern and eastern exposures showed a stronger correlation with landslide risk compared to southern or western exposures. To emphasize the importance of the variables within the model, we present their statistical contributions as follows: slope - 35.8%; geology - 22.8%; altitude - 16.3%; relief energy per square kilometer - 15.6%; slope aspect - 6.2%; distance from the hydrographic network - 2.8%; normalized difference vegetation index (NDVI) - 0.3%; slope curvature - 0.2%. Model validation tests indicated excellent predictive capacity regarding landslide risk in the study area (Măran and Herbei, 2021).

Deformation analysis was carried out based on elevation models of surfaces obtained from UAV measurement cycles. To obtain deformation values, the "Compute Change Raster" tool in ArcGIS Pro was utilized. The resulting data were generalized using a 50 cm rectangular grid, and the average deformation values from one measurement cycle to the next were calculated. The resulting data were mapped, resulting in a deformation map for each of the six monitored landslides. For a better understanding of the obtained results, spatial analyses such as Hot Spot Analysis and Cluster and Outlier Analysis were performed, highlighting statistically significant deformation areas. However, the results obtained were not conclusive enough, prompting a terrain scan using Lidar technology.

4. Conclusions

The research underscores the significance of assessing and mapping landslide risk amid climate change and heightened vulnerability along the Romania-Hungary-Slovakia-Ukraine borders. Notable correlations emerged between landslide risk and variables like steep slopes, geological substrates, and slope exposure. Employing the Maxent program, the landslide risk model produced detailed three-category risk maps, simplifying decision-making and territorial management (Nicula et al. 2021). Monitoring terrain deformations via UAVs generated valuable insights into landslides within the GeoSES project area, albeit inconclusive regarding deformation trends. This work contributes to GeoSES project goals, addressing natural disaster risk reduction and innovative climate change strategies in the Carpathian region. Future investigations should leverage advanced technologies for precision terrain assessment."

5. References

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