THE USE OF GEOGRAPHIC INFORMATIONAL SYSTEMS IN THE STUDY OF NATURAL HAZARDS

A. Ursu[1]

ABSTRACT
This study presents the results of GIS applications in Natural Hazards studies. We have attempted to evaluate the direct and induced effects of the sudden manifestation of a geomorphologic process upon the communication networks and rural settlements, as well as on the terrain accessibility. Spatial analysis proves very useful in risk assessment and crisis management.

*

In our modern world there is a paradox between the extraordinary accomplishments from the fields of science and medicine which make life safer and healthier, and the important human and material losses caused by the so called natural hazards. The paradox is complicated due to the fact that science itself isn't hazard-free, situation that leads to the occurrence of recent threats caused by the errors from the technologic systems (Keith Smith-1996).

Thus, human society is now exposed not only to the risks caused by natural phenomena such as earthquakes, floods, tornados, droughts etc., but also to the technologic ones such as explosions, toxic substances seepages, accidents etc.

Risks represent an integrating part of the day by day life, and their elimination is impossible, the only option being that of reducing the losses, departing from the idea that disaster prevention is always cheaper that the aftermath recovery. This may be realized on two ways: through the modification of the natural processes or through the reduction of their impacts on the human society.

The present paper proposes to use a series of GIS techniques with the declared purpose of developing analysis possibilities of the geomorphologic risk processes through simulations and modeling that would be useful in the decision taking in crisis situations, or in a future territorial planning.

Main objectives:

1. The realization of thematic layers with the spatial distribution of the present geomorphologic processes, as well as with the morphometric characterization of the region;

[1] *"Alexandru I. Cuza" University, Faculty of Geography and Geology, 700506, Iaşi, Romania,*

2. The realization of the thematic layers of the human properties that may be affected by geomorphologic risk processes;
3. The use of the GIS methods in the evaluation of the effects resulting after the manifestation of geomorphologic hazards.

The present landscape is subject to permanent modifications because of the actions of the contemporaneous modeling processes, often increased by that of the human factor, directly on the landscape or indirectly through the modification of the other geosystem components.

From the present geomorphologic processes, we have analyzed the rock downfalls, landslides and muddy flows, due to their importance among the risk generating natural processes.

Also, the modifications caused by the human interventions from the last years such as the deforestation of some surfaces, the slope over-charging with constructions, the modification of the slopes angle, the digging at the slopes base for house or roads constructions, etc have had as effect the activation or reactivation of some geomorphologic processes with possible disastrous effects in the near future.

The Digital Elevation Model has been realized on the basis of the topographic maps and represents the departing point for a whole series of thematic layers: slope, slope exposition, relief fragmentation height, hydrographic basins, discharge direction maps, etc.

The realization of the thematic layers of the human properties that may be affected by the geomorphologic risk processes. For the realization of these thematic layers we needed to draw the map of the roads network and that of the land use types. These were realized through on screen digitization, on the basis of the 1:25000 scale topographic maps and of the satellite images, and later through the attachment of attributes in the table database for each road segment, according to its importance, respectively to each polygon according to the terrain use.

The use of GIS methods in the evaluation of the effects resulting from the manifestation of geomorphologic hazards has implied the use of the overlay method, of the simulation of a barrage occurrence, and of the network and multilayer type analyses.

Through the OVERLAY method we have integrated the spatial data referring to downfalls, landslides and muddy flows with the data referring to the land use and the rods network, thus evidencing the areas exposed to the geomorphologic risks.

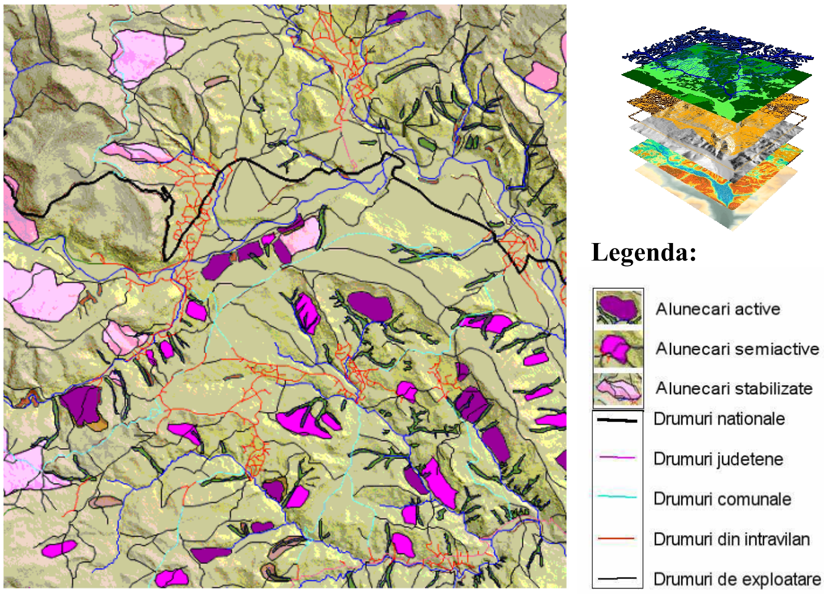

Fig.1. ***The distribution of the present geomorphologic processes according to the roads network (Legend from top to bottom: active landslides, semi-active landslides, stabilized landslides, national roads, county roads, township roads, outside-town roads, exploitation roads*****)**

For the simulation of the direct and indirect effects that occur as a consequence of the manifestation of the natural hazards we have realized three applications on raster and vector files in some sample areas, mentioned below:

1) For the evidencing of the direct effects we have chosen an area situated near Greşu, which has been strongly affected during the past by landslides, situation confirmed by the local toponymy of „Fugitura" ("The Downfall"), and that presently is highly regarded by the inhabitants of the nearby counties for the construction of residences. This landslide has lately given signs of reactivation on certain sectors.

We have departed from the assumption that an eventual earthquake may destroy the equilibrium position of the landslide body that may thus slide up to the valley blocking the course of Putna River. We have chosen three situations according to the height of the new formed dam: 7, 14 and 20 meters, and have simulated the water accumulation upstream the dam, obtaining in each case the surface occupied by water and the water volume retained by the dam.

Overlaying these layers over that of the properties (constructions, roads) we may observe which of these will be flooded in each of the three cases. Thus we have considered that the areas that are flooded by the water gathered behind the 7 meters dam present a high degree of risk exposure, those flooded by the waters behind the 14 meters dam a medium exposure risk, and those flooded at a 20 meter water height a small exposure degree. The areas that remain un-flooded in the last case are considered as not being exposed to risk. This classification is based on the fact that the probability of the formation and maintenance of a 7 meter dam is higher than that of the occurrence of a 20 meter one.

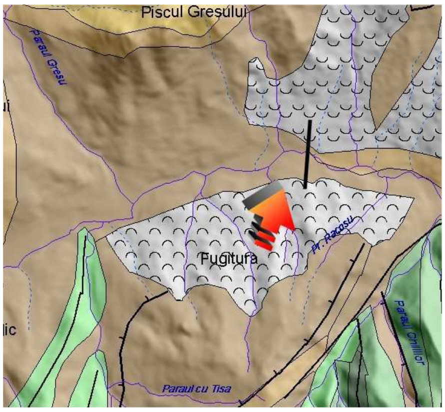

Fig. 2. ***The sliding direction and the dam position***

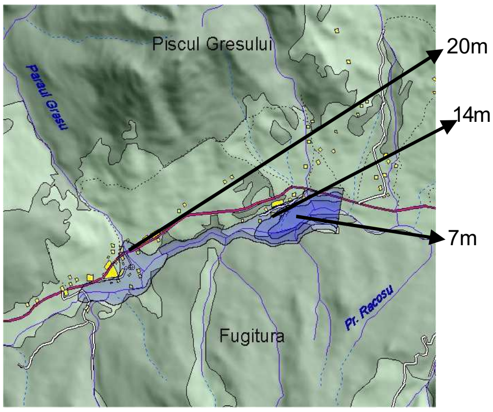

Fig. 3. ***The areas flooded in the three situations***

Legend:

- **-- Properties unexposed to flooding risk,**
- **-- Properties with low risk exposure,**
- **-- Properties with medium risk exposure,**
- **-- Properties with high risk exposure.**

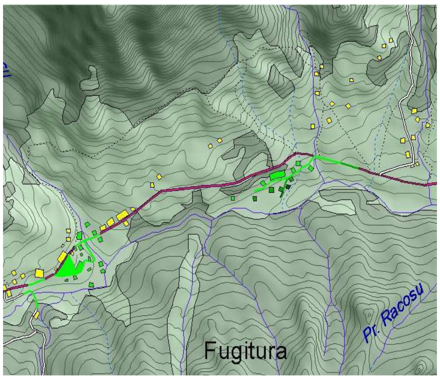

Fig. 4. ***Flooding risk***

2) Another application has been developed on the basis of the vector files that have a NETWORK type topology, respectively those of the communication networks.

Thus we have given impedance (friction) values for each road sector and calculated different optimum directions before and after the manifestation of a geomorphologic risk process, in this way being possible the evaluation of the un-functionalities induced to the transportation system.

This application proves to be useful in the optimization of the transportation network, in the finding of optimum routes for arriving in the affected area and in the evaluation of the effects of a road sector blocking on the transportation activities downstream the blockage and the finding of the alternate variants.

As the impedance value attached to the line is higher, the resistance to movement along this will be higher. Along the low impedance lines the movement is produced easier, situation due to which the Network Analysis operation directs the optimum routes along these lines. The impedance value may be directly proportional with the length of the road sector, case in which may be calculated the shorter directions between two points, without taking into account other parameters that influence movement. To reach a model closer to reality, we have to take into account several variables.

Thus the initial impedance value for each sector of the line is of 1.00, this value characterizing sectors of the national roads, on plane surfaces, with asphalt carpet in a good state, situated outside the towns, where the maximum admitted speed limit is of 90km/hour, and that do not have many curvatures. Having as landmark these sectors, the impedance value increases for all the other road sectors with the increase of the slope value, of the "meandering coefficient", the decrease of the road rank, the existence of the speed limitations, the modification in the road carpet type or its degradation.

If the application would have included an urban area, it would have been possible the characterization of the intersection nodes through the limitation of veering on certain directions, the introduction of one-ways etc.

In our study area we have applied this methodology in the Valea Sării-Barsesti sector.

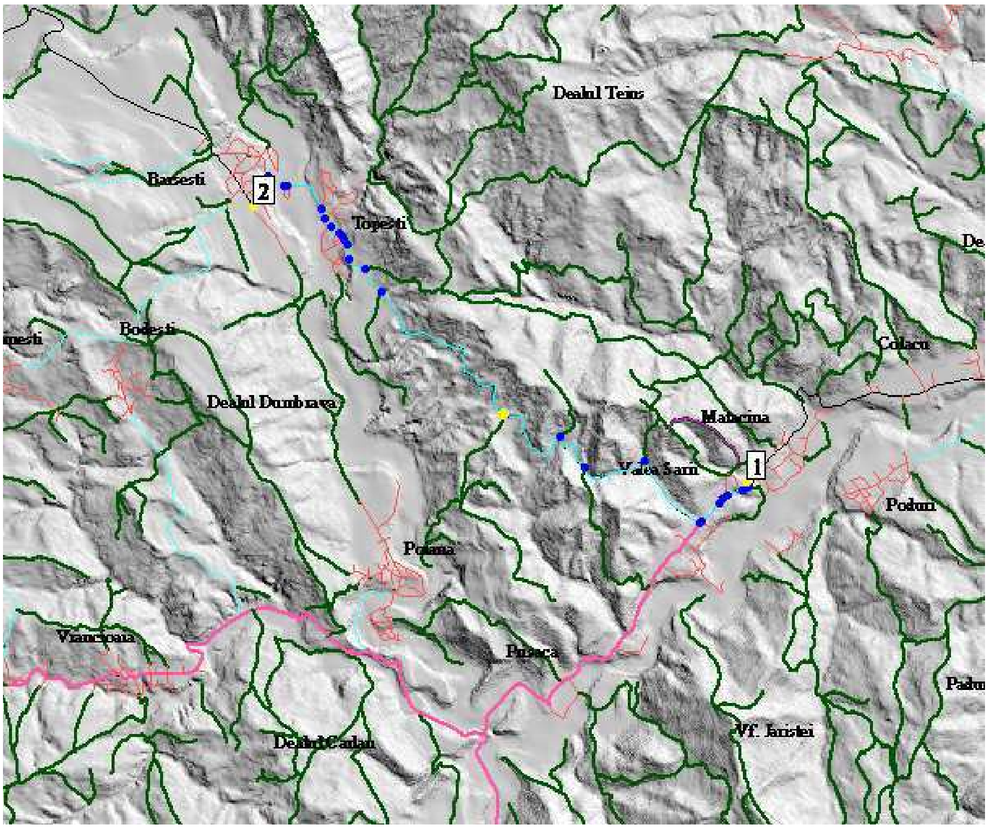

Fig. 5. ***The optimum route between Valea Sarii-Barsesti in normal conditions***

After the construction of the database that includes the impedance values for each road sector, we have determined the optimum route in normal conditions, as it may be seen from the above picture. Later we have introduced a virtual barrier, corresponding to eventual rock falls, and have recalculated the optimum route, the result being visible in the below image.

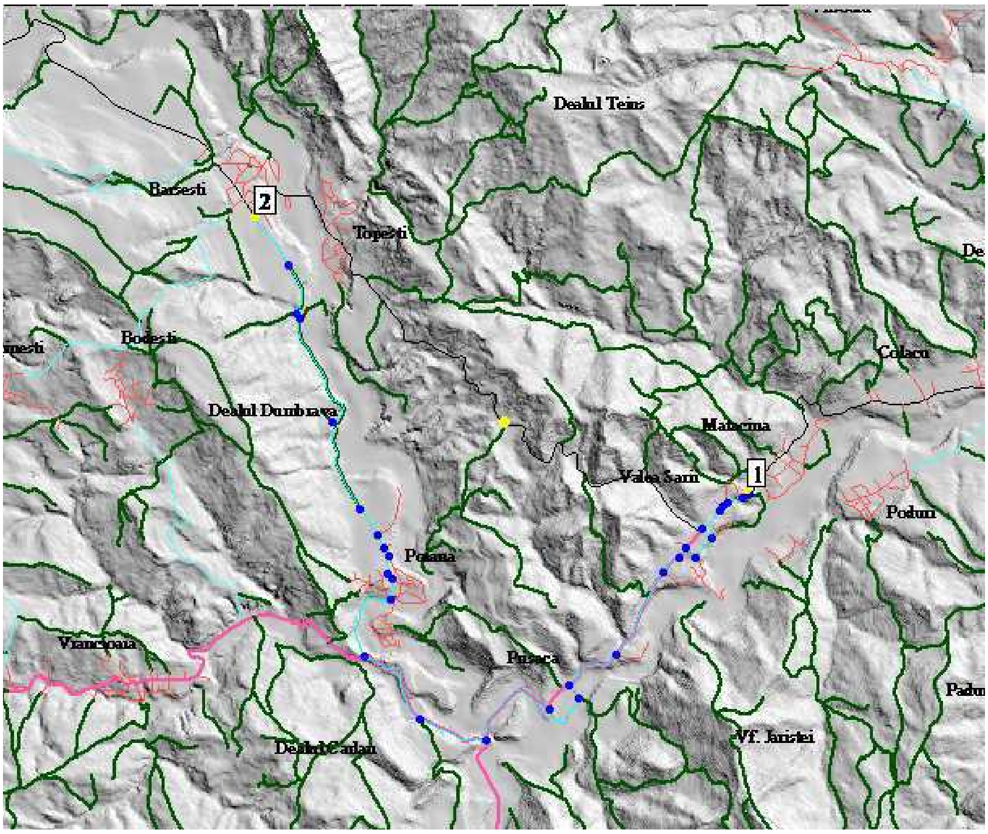

Fig. 6. ***The bypath route between Valea Sarii-Barsestiin the case of the DN 20 A road blocking***

It may be observed that the second route does not correspond to the shortest one from the traversed distance point of view, because it would have chosen agricultural exploitation roads. Instead it corresponds to the route with the lowest impedance, in this case being obvious the importance of the road type (county, local).

This operation is very useful in the risk management, if we have in view the fact that once the database is realized, the route calculation is conducted in a very short time.

3) If we desire to observe the influence of the geomorphologic processes on the terrain accessibility on the ensemble, and not only on the communication network, it is necessary to integer as many raster and vector files in more costly operations.

For the calculation of the accessibility, it is necessary in the first phase to realize a layer (Friction) that would integrate several factors that influence movement, respectively slope, land use, roads, rivers, bridges, etc.

Each folder will be classified in ten classes, value 1 corresponding to the minimum impedance (low slope, national road), and the value 10 to the maximum one (high slope, forested area etc). The 0 value will correspond to the barriers of the river or escarpment type. These folders will be multiplied one with each other and thus we will obtain the final impedance or friction layer.

On this layer we have conducted the Cost operation, so as to estimate the cost of the movement in all the directions, departing from a central point situated in the centre of Tulnici Township.

Later we have taken into consideration the situation of a landslide reactivated on Putna, and we introduced a barrier in the corresponding impedance raster, and we have led the Cost operation again, thus evidencing the problems induced by the landslide on accessibility.

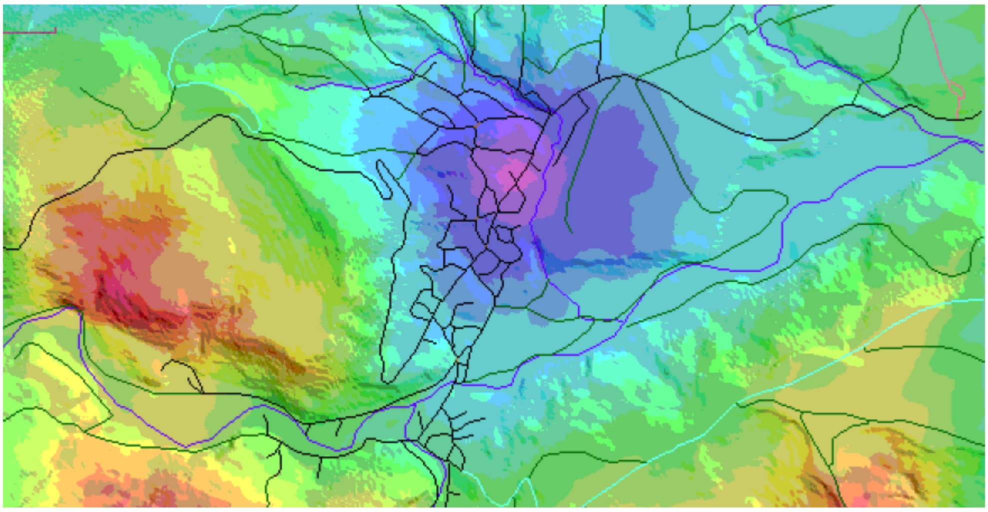

Fig.7. ***Map of terrain accessibility around Tulnici***

In conclusion we consider that the use of GIS in the physical geography studies proves to be advantageous during all the research stages.

Also, for the management of some utilities or communication systems there is the possibility of the simple or multi-criteria analysis of the databases, offering a helping hand in the user decisional activity.

REFERENCES

90. Burrough P. A., McDonnell R. A. – *Principles of Geographical Information Systems*, Oxford University Press, 1998.
91. Campagnoni A., Carta Michele - *Mapping Environmental Risk by Application of GIS Technologies in the Southern Part of Venice Province*, Proceedings of ITC – ISSS Conference on Geo-Information for Sustainable Land Management, Enschede, 17-21 August 1997.
92. Donisă V., Donisă I. – GIS – *An Instrument for the Documentation of the Plan for Territory Organization and Sustainable Development*, Analele Şt. Univ. Al. I. Cuza Iaşi, tom XLIV-XLV, s II c, Geografie, 1998-1999.
93. Haidu I., Haidu C. S.I.G. – *Analiză spaţială*, Ed. HGA, Bucureşti, 1998.
94. Imbroane A. M., Moore D. – *Iniţiere în GIS şi teledetecţie*, Presa universitară clujeană, 1999.
95. Morariu N., Popovici N., Ungureanu R., Sainiuc I., Teodorescu T., Zamfirescu C. – *Reprezentarea digitală la nivelul judeţului Suceava a zonelor expuse calamităţilor (inundaţii)*, Lucr. Simpoz. „Sisteme Informaţionale Geografice", nr. 5/1997, Analele Şt. Univ. „Al. I. Cuza" Iaşi, tom XLIV-XLV, s II c, Geografie – supliment, 1998-1999.