NATURAL HAZARDS OF IZVORUL CRIȘULUI

GHEORGHE ROŞIAN [1], *CSABA HORVATH* [2], *LIVIU MUNTEAN* [1]

Abstract: **Natural hazards of Izvorul Crișului**. The presence of the Izvorul Crisului local territorial administrative unit (commune), in the western part of the Transylvanian Depression, not far from its border with the Apuseni Mountains, implies the existence of various natural hazardous processes. Their manifestation, in the presence of anthropic components and their activities and goods, determines their hazard attributes. Of the possible natural hazards (geological, geomorphological, atmospheric, hydrological, biological, etc.), only the geomorphological, hydrological, and meteorological ones will be addressed in this paper. The presence of these natural processes may cause material damage and victims, for this it is necessary to know their magnitude. Thus, the present study aims to identify the potential hazards which exist in the Izvorul Crisului administrative unit and to assess the susceptibility to these natural processes. To achieve this objective, specific maps will be made, which finally, beside the supporting role for the analysis of natural processes, will become tools for the management of these conditions, tools to reduce the induced risks.

Keywords: natural process, hazard, susceptibility

1. INTRODUCTION

The Izvorul Crișului territorial administrative unit is located in the most western part of the Transylvanian Basin. Regionally, it overlaps with the following morpho-structural units (Figure 1): Păniceni Plateau, Huedin Basin and Almaș-Agrij Basin (Pop, 2001; Roșian, 2020). From an administrative perspective, it belongs to the Cluj County and it is a commune composed of four villages: Izvoru Crișului (commune seat), Nearșova, Șaula and Nadășu. It has 1.620 inhabitants, grouped into 775 households.

The manifestation of some hazardous processes, within the studied territory, is related to the existence of a natural setting, superimposed on the specific relief of the contact zone between the Transylvanian Basin and the Apuseni Mountains.

[1] Babeș–Bolyai University, Faculty of Environmental Science and Engineering, 400294, Fântânele Street, No. 30, Cluj–Napoca, Romania; e-mail: georgerosian@yahoo.com; liviumuntean@yahoo.com

[2] Babeş-Bolyai University, Faculty of Geography, 400006, Clinicilor Street, No. 5-7, Cluj-Napoca, Romania; e-mail: hcsaba@gmail.com

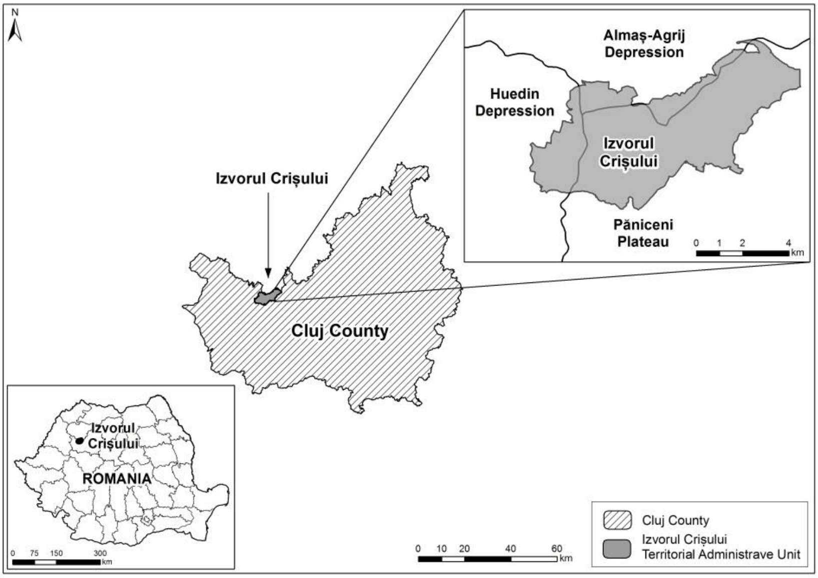

Fig. 1. Spatial localization of the study area

As a result of a long-term geomorphological evolution, the relief is represented by fluvial landforms made by an alternance of valley corridors and interfluvial ridges (Figure 2). The Crișului Repede and the Nadăș valleys are the most noticeable, together with their tributaries. The most outstanding interfluvial ridges are Meșmal Hill, La Trandafiri Hill, Crucii Hill, Ursului Hill, Citera Mică Hill etc. (Figure 2). The 150-200 m altitude differences, between the interfluvial areas and the lower part of the valleys, present a high risk for geomorphological processes, of which, the landslides stand out.

Due to its shape and configuration, the relief can influence also other processes which may become natural hazards. For Izvorul Crișului, from this point of view, the hydrological processes (flash floods on steep slopes and floods in the valleys) and the atmospheric processes (torrential rain, hailstorms, frosts, snow, ice and fog deposits) stand out.

2. MATERIALS AND METHODS

We used specific methodology to highlight each type of natural hazards in Izvorul Crișului territorial administrative unit.

Geomorphological hazards are represented mainly by landslides in this case. Beside identifying them in the field, to better identify the current situation, we created with the help of GIS techniques, a database which allowed the design of a landslide susceptibility map. The procedure used was according to the recommendations in the Gt–019-98 national guide (Guide for creating risk maps for landslides to ensure building stability).

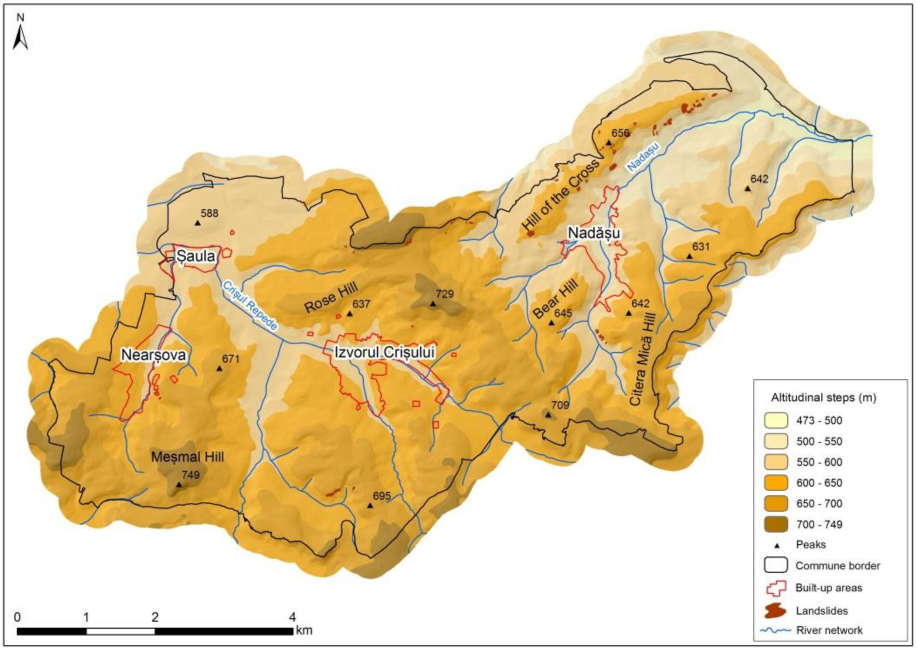

Fig. 2. Relief map of Izvorul Crișului

By using this methodology, one must overlap several thematic layers contain various data. These are represented by: lithology, altimetry, landform parameters (slope, fragmentation depth and density), rivers, current geomorphological processes, land use etc.

After the creation of the database, we continued by rating the values of each layer according to the current methodological requirements and the particularities of the study area to obtain susceptibility clues concerning the geomorphological processes and thus determine the landslide probability (Dhakal et al., 2000; Bălteanu et al., 2010). The calculation was made in raster format and the operations where at pixel level, with a 100x100 m size, allowing a real and punctual dimensioning of the phenomena.

Centralizing the collected data in a single map allows a general perspective on the morpho-dynamic potential, on the surface stability regarding their natural balance and on the degree of risk for economic activities (roads/civil engineering, buildings etc.)

To draft the map predicting the probability of landslides, the formula given by the Gt-019-98 norm was applied.

$$K_m = \frac{K_a \cdot K_b}{6}\left(K_c + K_d + K_e + K_f + K_g + K_h\right) \qquad (1)$$

K_a = lithology factor;
K_b = geomorphological factor;
K_c = structural factor;
K_d = hydrological and climatic factor;
K_e = hydrogeological factor;
K_f = seismic factor;
K_g = forestry factor;
K_h = anthropogenic factor.

The values for the eight factors have been determined as follows: the lithology factor was determined based on geological maps and field investigations; the geomorphology factor is based on a high resolution DEM (Digital Elevation Model) from which slope and landform depth maps were obtained; geological structure was extracted from geological maps along with the hydrogeology factor; climatic and hydrological data is obtained from the meteorological station near the study area (included as a constant); seismicity was introduced as a constant value (considering the limited spatial extension of our study area there are no differenced regarding this factor), as specified in the Gt-019-98 Guide; land use and anthropogenic factors were obtained by field investigations and measurement but also using ortophoto data (Sarkar and Kanungo, 2004; Roșian et al., 2016). Finally, in the processing phase, all data was converted to raster (100 m spatial resolution), thus resulting 8 raster files (Roșian et al., 2016). All raster data was reclassified and final scores were assigned according to the 6 classes required by Gt-019-98.

In the final stage, all data was included in the formula by using Raster Calculator in ESRI ArcGIS 10.6 and the landslide probability map was obtained (Roșian et al., 2016).

In this context, the analysis of landslide probability represents a spatial component of the hazard, depending on the feasibility of the land to certain risk processes (Corsini, 2005; Crozier and Glade, 2005).

Hydrological hazards, represented in this case by local flash floods from the slopes and floods in the valleys, were highlighted because of the precipitation amounts that are recorded and the particularities of the land on which the runoff occurs.

For the study of the hydrological conditions, six hydrometric stations were used, two belonging to Someșului Mic basin and the other four to the Crișului Repede basin.

The correlation between the average specific drainage values and the average altitude of the catchments of the hydrometric stations allowed the identification of a validity curve (Figure 3). This curve corresponds to a validity zone in the field, where the increase of the average runoff values with the altitude is based on the identified correlation function (of the model).

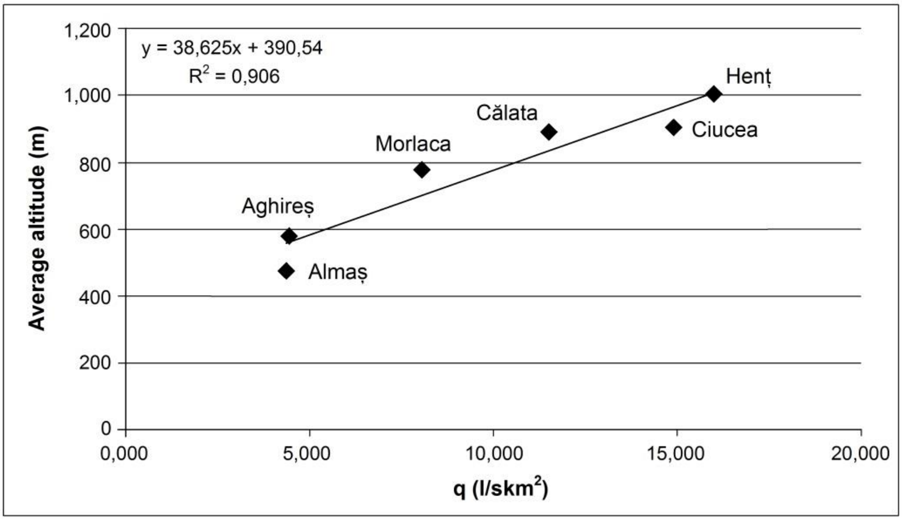

Fig. 3. *Correlation between average altitude and specific flow*

With the help of the extension incorporated in the Esri ArcGIS Spatial Analyst tools / Map algebra / Raster calculator, the curve function was integrated in GIS and the result is a grid where each pixel represents the corresponding catchment runoff value (Figure 5) (Rosian et. al. 2016). The application of this method was possible due to the calculation of the average runoff in the area, calculating the average drainage (Cell statistics) for each cell specific to the grid resolution.

As to the floods, based on the historical analysis of the phenomenon, it seems that there is only one outstanding event in July 1980, when, as a result of extreme rainfall, some land areas were flooded (29,9 km^2) downstream at the confluence of Șipotului River with Crișul Repede River (Horvath, 2008); the flood had a 10% frequency and thus a 1000 year return period; the heavy rainfall extended in all three basins of the Criș rivers.

As to ***atmospheric hazards***, in the Izvorul Crișului area, these stand out: heavy rainfall, hailstorms, freeze and hoarfrost, snow, ice, and fog deposits as they were introduced and presented in the literature (Cristea, 2004; Gaceu, 2005).

3. RESULTS AND DISCUSSIONS

As to the ***geomorphological hazards*** due in this case to landslides, by applying the Gt-019-98 methodology, we obtained data about the landslide probability. They can be found graphically on the landslide probability map of the Izvorul Crișului commune administrative area (Figure 4). On this map, one can notice the areas predisposed to landslides by overlapping several thematic maps in raster format representing: lithology, altimetry, slope, relief fragmentation, riverbeds, geomorphological processes, land use etc.

Out of the six landslide probability classes, according to Gt-019-98 - zero (0), reduced (0-0,1), medium (0,1-0,3), medium-high (0,3-0,5), high (0,5-0,8) and very high (0,8-1) – in this case, four of them are identified: reduced, medium, medium-high and high.

In terms of spatial distribution, in the administrative area of Izvorul Crișului, these are the situations:

- reduced risk probability class is located in the western part of the territorial administrative unit, corresponding to Huedin Depression, mostly where the flood plain areas and meadows get in contact with the slopes of the valley, as a result of reduced slope values and specific deposits; it represents 293 hectares, which means 7,3% of the total land surface of the Izvorul Crișului commune (4.155 hectares);
- medium risk probability class is located in the South-East part of the commune, afferent to the Păniceni Plateau (the right side of the Nadăș River hydrographic basin); it can be also noticed in the basin of Crișului Repede river, especially in the Șipotu valley; it represents 824 hectares (19,25%);
- medium-high risk probability class is typical for both slopes of the Crișului Repede River and for the left slope of the Nadășului river; it represents 3.028 hectares (73%);
- high probability risk class is typical for the left slope of Nadășului river (Crucii Hill, La Trandafiri Hill) and for the Eastern part of the Citera Mică Hill; representing an area of 10 ha (0,25%).

The collected values are relatively balanced and conform to the situation seen in the field. For the meadow area, there is a reduced landslide probability (still it has values above zero), while for some of the steep slopes the probability reaches 0,67 (high probability) without being categorized as high probability. These types of values are specific to areas which are affected by active landslides.

A specific focus should be put on the current landslides, representing the most valuable information potential on the slope's landslide probability. These processes are typical of the eastern (the slopes of the Nadăș valley and of its tributaries) and of the western side of the studied area (the slopes of the

Șipotu and Nerșova Valleys). 53 landslides have been identified in a total surface of 8,1 ha (0,2% of the Izvorul Crișului commune surface area).

The existence of the mentioned values for each landslide risk probability class, to which their presence is added in a fairly large number, even if they do not occupy large areas, indicates the existence of specific problems. In essence, the changes resulting from landslides are irreversible and can cause significant damage by destroying socio-economic elements or by removing large areas of land from agricultural use.

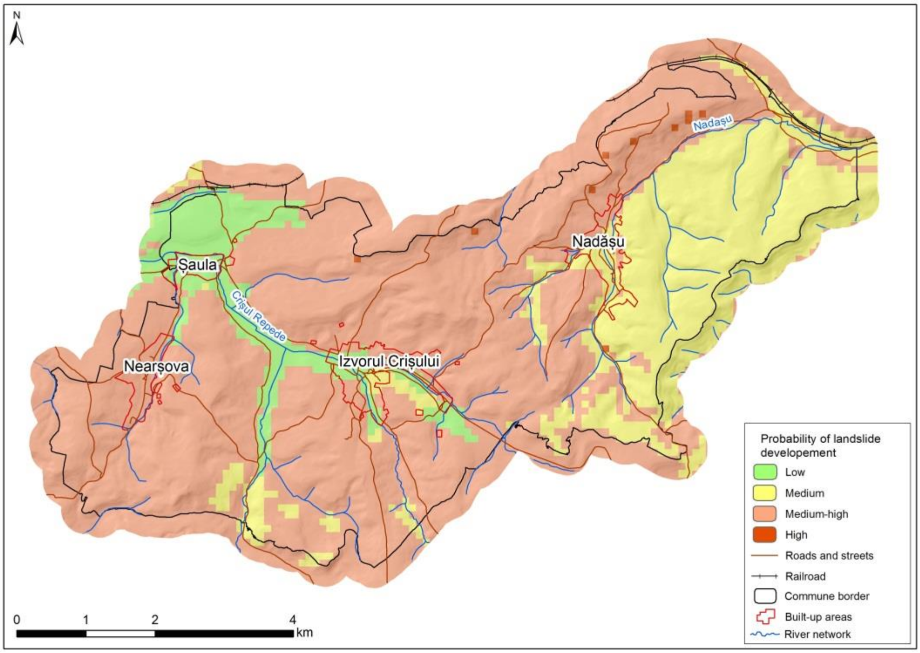

Fig. 4. The landslide occurrence probability map

This requires taking preventive and regulatory measures regarding landslides: restricting water seepage in the susceptible areas, restricting digging for civil engineering works, stopping deforestation, restricting human and animal access, improving natural drainage, forestation, collecting spring waters and supervising drainage.

As a result of processing the average ***runoff of the catchment***, a map resulted, the analysis of which allows the identification of the runoff and the average water volume for each pixel of the studied area (Figure 5); the average value of the runoff is of 5,788 l/s km^2.

It is important to acknowledge this parameter because drainage plays an essential role in transporting materials both on slopes and in small riverbeds

(Goțiu and Surdeanu, 2008). At the same time, water runoff plays a decisive role in transporting materials, and this process controls the dynamics and shape of the slopes.

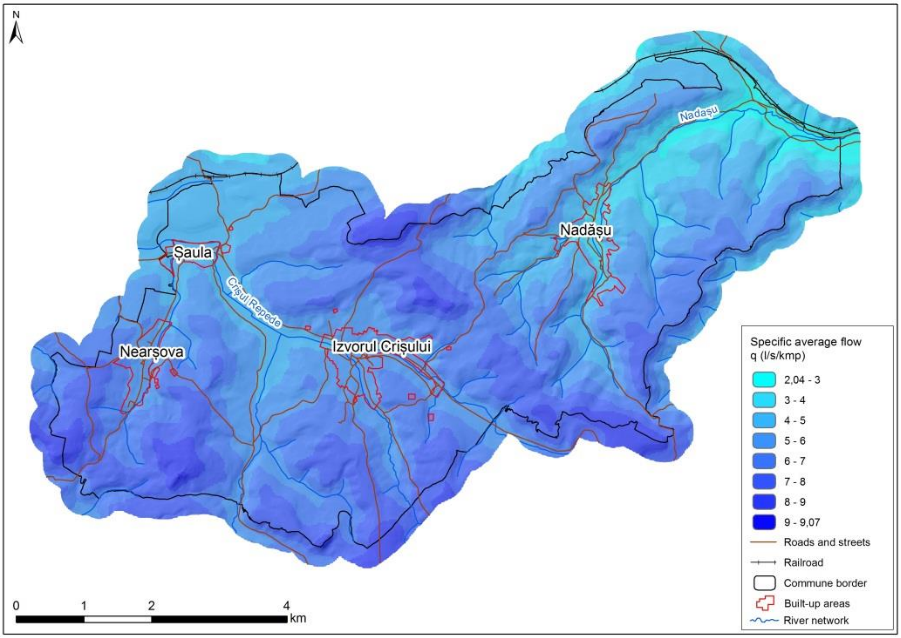

Fig. 5. Map of specific average flow

Regarding the ***floods*** in the Izvorul Crișului commune, the areas affected by this phenomenon are rather insignificant. According to the analysis made by ANAR ("Romanian Waters" National Administration), the area does not include flood-risk areas, only after the confluence of the Crișului Repede river with Șipotul river; and it is significant only for a 100 year return period. Some areas susceptible to floods have been identified also in the Nadăș river basin (Figure 6).

On the map especially designed for the Izvorul Crișului commune, two types of potentially flood-affected areas have been identified (Figure 6): non-embanked flood-prone areas (typical for non-embanked rivers) and embanked flood-prone areas (typical of Crișului Repede river).

The river embankments and riverbed engineering of the Crișului Repede, starting near to a spring, removed these surfaces from the flood prone areas. Simultaneously, the terraces of the railway and of the two-lane expressway play the role of embankments for any floods.

In the absence of hydrometric stations in the studied territory, the conclusions related to flood probability can be drawn based on correlations to similar basins in the area. Based on the history of the phenomenon and taking into account the river embankments after the floods in 1980, it seems that within the territorial administrative unit of Izvorul Crișului, there is no significant area exposed to floods except for Șaula where some potential problems with a long return period have been identified.

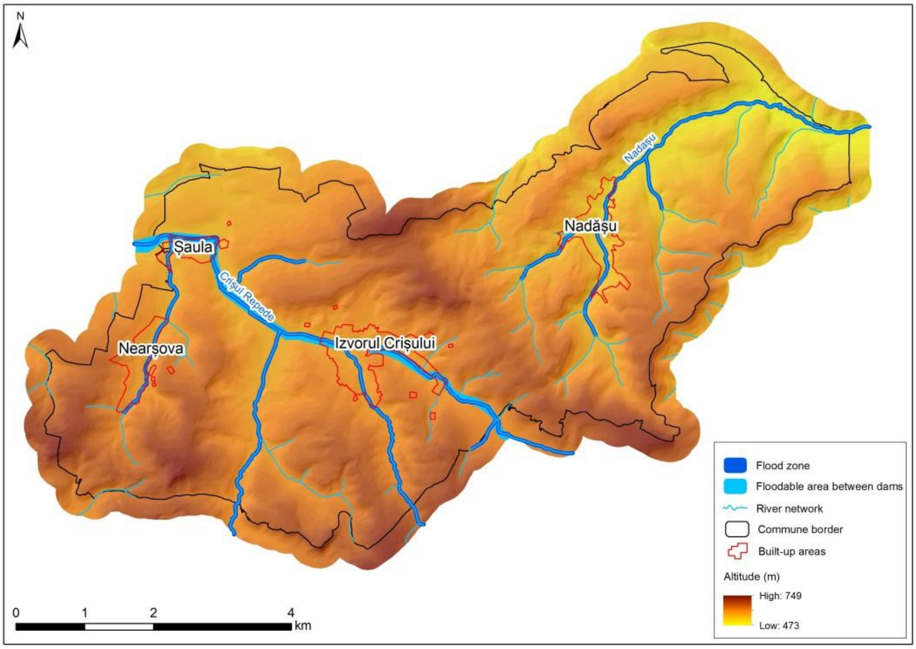

Fig. 6. Map of floodplains

Atmospheric hazards have the following characteristics (Cristea, 2004; Gaceu, 2005):

- *torrential rains*, mostly during summertime, are characterized by large quantities of water (30-40 l/m^2) in a couple of minutes or a dozen of minutes; the generated hazards are flash floods (they can affect buildings and can turn into floods) and accelerated erosion, mostly on inclined surfaces, areas without protecting vegetation cover, such as Crucii Hill, La Trandafiri Hill;

- *hailstorms* along with strong winds and lightnings can produce significant damage to socio-economic activities by destroying crops, buildings, vehicles, etc. The most significant damages occur when hailstorms appear during the peak vegetation season, when it lasts between 10-15 minutes, when it's accompanied by strong winds (more than 16m/s) and when there are large and dense hailstones. Hailstorms usually occur in April, May, June;

- *freeze and hoar frost* even if these are ordinary phenomena of the studied area, in some circumstances they become hazards: because of the cold episodes intensely, the timing when they occur and their consequences. The most dangerous freeze and hoar frosts are taking place outside their typical season, at the beginning of autumn and the end of spring when there's cold air from the north and North-West. Freeze and hoar frosts are facilitated by the temperature inversion conditioned by the cold air descending from the mountains. This process occurs especially in the first half of September and May when freeze and hoar frosts affect the crops in the beginning or end of the vegetation cycle;

- *snow* is another ordinary phenomenon which can produce damage when it appears outside its typical season or when it is very thick, and it facilitates the appearance of snowdrifts in areas accompanied by strong winds. The thickest snow layer is in January and February when it can reach from 30 up to 40 centimeters;

- *fog* in this respect, it represents the atmospheric hazard with the lowest destructive potential. Annually, there are about 40 foggy days. The highest annual number of foggy days where 60. In the studied area, fog has unpleasant consequences due to its persistence, poor visibility, and lower temperatures.

The appearance of these hazards, in the presence of man and his activities, considered as elements at risk, can lead to victims and material damage. It means that natural risks are closely related to anthropogenic presence, which also involves an assessment of human perception of hazards (Heijmans, 2001; Slovic and Weber, 2002; Chesney et al., 2002; Armaș et al., 2003; Sorocovschi, 2006 etc. .). Under these conditions, the results obtained can be a useful tool in the management of the created condition hazards to reduce the induced risk.

4. CONCLUSIONS

In the case of the less mediated territorial administrative units such as Izvorul Crișului, the natural processes, by their manifestation, receive the attribute of hazard. Of these, in this case the geomorphological (landslides), hydrological (flash floods and floods), and atmospheric (torrential rains, hail, freeze and hoar frost, snow and fog) stand out. Even if in recent decades they didn't had magnitudes that would cause significant damage and casualties, it is expected that in the future, amid already existing climate change, their intensity will increase.

Under these conditions, careful monitoring of the presented hazards is required to be able to act appropriately to avoid possible disasters involving the man, his goods, and activities considered as elements at risk. Furthermore, in this context, it is necessary to create a risk culture by informing the population by various means about possible dangers and how to act in case of emergencies.

REFERENCES

1. Armaș, Iuliana, Damian R., Șandric, I., Osaci-Costache, Gabriela (2003), *Vulnerabilitatea versanților la alunecări de teren în sectorul subcarpatic al văii Prahova*, Editura Fundației România de Mâine, București.
2. Bălteanu, D., Chendeş, V., Sima, Mihaela, Enciu, P. (2010), *A country level spatial assessment of landslide susceptibility in Romania*, Geomorphology, Volume: 124, Issue: 3-4 Special Issue.
3. Chesney, P. E. S., Cannibal, G. L., Baines, R. (2002), *The developement of a new holistic assesmentmodel for the inclusion of public perceptual values in the decision-making process*, in Risk Analisys III, WITPress, Southampton, Boston.
4. Corsini, A., Pasuto, A., Soldati M., Zannoni, A. (2005), *Field monitoring of the Corvara landslide (Dolomites, Italy) and its relevance for hazard assessment*, Geomorphology, 66.
5. Cristea, Maria (2004), *Riscurile climatice din bazinul hidrografic al Crişurilor*, Editura Abaddaba, Oradea.
6. Crozier, M. J., Glade Th. (2005), *Landslide hazard and risk: issues and options*, in Glade Th., Anderson M. G, Crozier M. J. (eds), Landslide hazard and risk, John Willey and Sons Ltd, London.
7. Dhakal, A.S., Amada, T., Aniya, M. (2000), *Landslide hazard mapping and its evaluation using GIS: An investigation of sampling schemes for a grid-cell based quantitative method*, Photogrammetric Eng. and Remote Sensing, 66(8).
8. Gaceu, O. (2005), *Clima şi riscurile climatice din Munţii Bihor şi Vlădeasa*, Edit. Universităţii din Oradea, Oradea.
9. Goțiu, Dana, Surdeanu, V. (2008), *Hazardele naturale și riscurile asociate din Țara Hațegului*, Presa Universitară Clujeană, Cluj-Napoca.
10. Heijmans, Annelies (2001), *Vulnerability – A Matter of Perceptions*, in Disaster Management Working Paper, vol. 4, Benfield Grey Hazard Research Center, London.
11. Horvath, Cs. (2008), *Studiul lacurilor de acumulare din bazinul superior al Crişului Repede*, Editura Casa Cărţii de Știinţă, Cluj-Napoca.
12. Pop, Gr. (2001), *Depresiunea Transilvaniei*, Presa Universitară Clujeana, Cluj-Napoca.
13. Rosian Gheorghe, Horvath Csaba, Reti Kinga-Olga, Botan Cristian-Nicolae, Gavrila Ionela -Georgiana, (2016) *Assessing Landslide Vulnerability Using Bivariate Statistical Analysis and the Frequency Ratio Model. Case Study: Transylvanian Plain*, Volum Nr: 60, P: 359 -371, Zeitschrift Fur Geomorphologie
14. Roșian, Gh., Maloș, C., Muntean, L., Mihăiescu, R., Dobrei, G. (2016), *Geomorphological Constraints in the Urban Development of the Gruia District in Cluj-Napoca*, Studia UBB Ambientum, LXI, 1-2, pp. 119-128.
15. Roșian, Gh. (2020), *Relieful din Depresiunea Transilvaniei*, Editura Presa Universitară Clujeană, Cluj-Napoca.

16. Sarkar, S., Kanungo, D. P. (2004), *An integrated approach for landslide susceptibility mapping using remote sensing and GIS*, Photogrammetric Engineering and Remote Sensing, 70(5).
17. Slovic, p., Weber, Elke (2002), *Perception of risk posed by extreme events*, in Risk Management strategies in an Uncertain World, Palisades, New York.
18. Sorocovschi, V. (2006), *Categoriile de atribute ce definesc evenimentele extreme. Un punct de vedere*, Riscuri și Catastrofe, an V, nr. 3.
19. Gt 019-98 (1998), *Ghid de redactare a hărţilor de risc la alunecare a versanţilor pentru asigurarea stabilităţii construcţiilor*, Institutul de studii și proiecte pentru îmbunătățiri funciare, București.
20. *** Raport - Evaluarea preliminara a riscului la inundaţii Administraţia Bazinală de Apă Crişuri.
21. http://www.rowater.ro/EPRI%20Rapoarte/RO8_ABA_Crisuri_PFRA_Report.pdf