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NATURAL HAZARDS GENERATING EMERGENCY SITUATIONS IN THE AREA OF BISTRIŢA VALLEY BETWEEN BORCA TOWNSHIP AND IZVORU MUNTELUI DAM (NEAMŢ COUNTY)

PHD THESIS ABSTRACT

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IAŞI
2015

Keywords: Bistriţa valley, Izvoru Muntelui – Bicaz dam lake, Bistriţa and Bistricioara rivers, area, natural hazards, freeze phenomena, ice frazil, ice jam, hydraulic exchange relations, slope processes, landslides, floods, emergency situations.

INTRODUCTION

A study of natural hazards generating emergency situations on Bistriţa valley in the area approached was needed due to the formation here in 1960 of the Izvoru Muntelui – Bicaz dam lake. This determined lots of consequences, while anthropic element interact with natural ones on larger and larger areas and with increased intensity.

This study has been conducted with the belief that the results of the research will contribute, as possible, to:

- establishing the particularities regarding the evolution of ice jam phenomena on Bistricioara and Bistriţa rivers;
- identifying solutions for diminishing or eliminating the disastrous effects produced by the anthropic and atypical ice jam which periodically manifests on Bistriţa;
- evidencing new causes that favor the extension and reactivation of landslides on the left slope of Bistriţa valley between Poiana Largului and Izvoru Muntelui.

Special attention has been given to drawing an improved map of geomorphological processes, based on previous researches, as well as of other thematic maps.

We desire that this paper will be a practical guide for the personnel involved in activities of emergency situations management, but also a start for a systemic and quantifiable approach of natural hazards and risks.

Geographic position and limits

Bistriţa, with a total length of 278.8 km, is on more than two thirds a Carpathian river. The river sector situated between Borca and Izvoru Muntelui – Bicaz dam lake is situated in the central-eastern part of the Moldo – Transylvanian Carpathians, has a length of **57.7 km**, a width varying between **6 - 10 km** and a surface of **485 sqkm** (fig. 1).

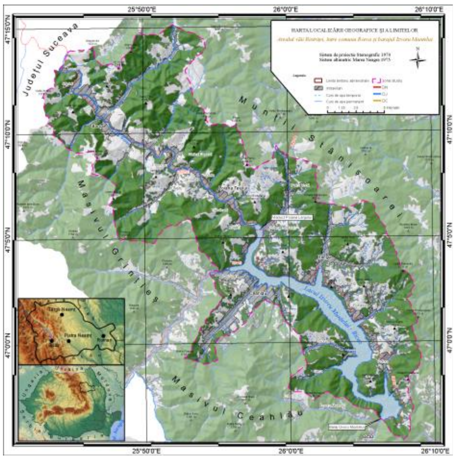

Fig. 1 Geographic position

Having in view the phenomena generating emergency situations along Bistriţa, we extended the study area on the valleys of the main tributaries. Also, for identifying physico-geographical conditions in which ice jams occur on Bistriţa and Bistricioara, the mechanism through which latent heat influences the evolution of these phenomena, as well as for obtainign data for the possibility of applying some of the solutions given by some researchers for diminishing the phenomena, we extended the study area upstream Bistricioara up to Capul Corbului. On Bistriţa we extended the research area up to Dorna Arini because the sources of the ice jam formations that reach Izvoru Muntelui is upstream.

CHAPTER 1. LANDSCAPE CHARACTERISTICS THAT INFLUENCE THE OCCURENCE AND EVOLUTION OF NATURAL RISK PHENOMENA. ANTHROPIC FACTORS

This chapter analyses the natural and anthropic risk factors that have an important role in the triggering and manifestation of the analyzed phenomena.

1.1. Geological characteristics

In the area of Bistriţa valley, flysch formations, mostly clayey and marly, determine the formation of a thick *weathering cover*, one of the main factors responsible for the presence of slope processes. An important role is held by *Quaternary deposits* that stock large reserves of water, ensuring river alimentation during periods of minimum discharge, as well as influencing the evolution of freeze phenomena.

1.2. Geomorphological characteristics

The relief of the area is very complex from a morphographic, morphometric and genetic aspect. An extremely important aspect from the hydrologic viewpoint in the occurrence of ice formations is the longitudinal profile of Bistriţa valley.

From the analysis of geomorphometric maps it results that dominant are surfaces with mean and high values of all elements analyzed. These explain the large extension of geomorphological processes, as well as their intensity and frequent reactivation.

Fluvial relief. ***Bistriţa's minor floodplain*** is made mostly of alluviums represented by boulders, gravels and coarse sands. It has widths of 40–80 m, a mean angle of 8–9 ‰ and a meandered course (sinuosity coefficient of 1.76–1.51).

The major floodplain. Its length varies between 200 m up to over 1000 m. Here have formed several terraces with relative altitudes of 0.5–1.0 m, 1–2 m and 2–4 m. In the valley sector between Borca and Dorna Arini an important role in the evolution of freeze phenomena is held by the alluvial deposits which contain underground water.

Slope terraces have been conserved as fragments with variable surfaces on both slopes, at relative altitudes between 5-7 and 260–275 m (at Izvoru Alb).

The map of present geomorphologic processes has evidenced the much larger extension of slope processes in comparison to other (surface and gully erosion) and their high importance as main geomorphological risk.

1.3. Climatic characteristics

For understanding and explaining the occurrence and manifestation of risk hydro-meteorological and geomorphologic phenomena, the main climatic elements from the study area have been analyzed.

Air temperature is characterized high local differences influenced by altitude, both in the annual regime of mean and absolute values, as well as the seasonal, monthly or daily one. Significant for defining the climate in this area (*moderate – warm*) are the mean annual and monthly temperature values. The changes occurred in the air temperature regime after 1960 are an expression of the caloric exchange between the newly created lake surface and atmosphere.

An important role in the evolution of winter phenomena on Bistriţa is held by *winds* with slow speed, which favors water cooling.

Based on created graphs (*variation of multiannual and mean monthly averages rainfall* during 1970 – 2013, *minimum monthly and absolute maximum rainfall*) have been conducted analyses on the *rainfall* regime with accent on the *maximum rainfall in 24 h,* which have a special influence through their effects.

1.4. Hydrological characteristics

Having in view that one of the thesis purposes is of analyzing and characterizing hydrological and geomorphologic risks, we conducted an analysis of the characteristics of underground and surface waters (discharge, level, thermal regime), mainly on Bistriţa, its tributaries and the Izvoru Muntelui lake.

Underground waters. The presence of underground waters in the fissures on the weathered rock cover at different depths or close to surface plays a defining role on the *occurrence of slope processes*, also determining their type and evolution. Also a large part of the phreatic waters are stored in the alluvia of Bistriţa's floodplain and terraces, of the main tributaries and in the colluvial deposits. The hydraulic exchange relations between the river and underground waters (losses or inputs through infiltration) strongly influence the water thermal regime, with consequences in the *evolution of freeze processes* on the river (Ciaglic, 2009).

Surface waters. Based on the recorded data the discharge regime of Bistriţa and its tributaries have been analyzed, with accent on maximum discharge rates, which are of great importance through their effects - floods. Not always the years with the largest flows contain the historical maximum discharges. Analyzing the maximum annual discharge on Bistriţa at Frumosu during 1967–2001, it can be observed that they are unevenly distributed and that most of the maximum values are recorded in April, when rainfall cumulates with snow and ice jam melting.

Special attention was also given to the *thermal regime*, having in view that each winter on Bistriţa and Bistricioara occur all type of ice formations (the mean number of days with ice formations for 1966 – 2005 is of 94 days, while shore ice and frazil ice are registered in 1535 days) with large development. Blocking of the flow section determines a decrease of the water level downstream and an increase behind the ice jam, which in the case of a sudden liberation can produce damages and even victims. A series of hypotheses have been presented regarding the genesis of ice jams: **through freezing** (the accumulation of frazil ice under the ice bridge) and **through thawing** (the accumulation of ice packs resulted from the fragmentation of the ice jam during spring warming) or ice jams with flowing or anchored base.

A different type of ice jam forms upstream the lake. Ciaglic *et al.* (1975) and Rădoane *et al.* (2008) consider it to be anthropic, because ice frazil and packs flows (without ice jam) have occurred in the area long time before the occurrence of the lake. The phenomenon is also considered atypical, because the river section blocking is made through the deposition of frazil ice on the bottom of the old floodplain under the ice bridge and not by the stitching to the lower base of the ice strata, from where it extends in the river floodplain and sometimes over its banks.

The existence on Bistriţa and Bistricioara, in identical climatic conditions, of some sectors with well-developed ice formations and in the immediate vicinity of some river sectors with small or even lacking such formations demonstrates the influence of other factors besides the meteorological and hydrologic. An important role is held by *hydraulic relations* established between the river and the nearby areas. These areas with free water surfaces are generating ice needles, bottom ice and slush. The water input from the underground prevents freezing, changing river water temperature and increasing the discharge. In the areas where the river presents water losses through infiltration in the floodplain, ice formations are much stronger and total freezing can be reached. According to measurements conducted in 1963-1965 by Ciaglic and Vornicu on Bistricioara infiltration losses vary between 19.5-71.4% and underground input can reach 49.5%.

This hypothesis of Ciaglic (1965) was confirmed through observations, measurements of water temperature, of freeze phenomena, of areas with infiltration losses or underground input. On Bistriţa the thermal input is smaller (0.3–0.6°C) because the discharge from tributaries and underground is lower.

To reduce the intensity of slush flows and ice jams it was proposed that in the points where Bistriţa presents infiltration losses to be built small submerged transversal rapids of 0.4-0.5 m. These would determine a level increase upstream and an increase in the discharge lost through infiltration. The effects would be a discharge increase and a water temperature increase by 4–5°C in the areas with underground, diminishing the formation of ice needles, bottom ice and frazil.

ANTHROPIC FACTORS

The main causes that govern the occurrence and evolution of natural risk phenomena (landslides and ice jams) are:

- *the existence of DN15 on the slope* at 550–600 m (artificial discontinuity), with intense and heavy traffic;
- *the lack of forest vegetation;*
- *irrational human intervention*, which led to the over-loading of slopes with heavy buildings and access roads lacking corresponding consolidation works; agricultural land use lacking crop rotation;
- *water level variations* in the lake (through abrasion, deposition and over-wetting of the deluvial slope base) and thermal regime (in winter the blocking with frazil under the ice bridge from the entrance into the lake).

We consider that to the phenomenon occurrence participates besides the *hydraulic exchange* relations also the *latent heat* coming from the disintegration of radioactive elements from surface and underground waters and soil surface. The areas where freezing does not occur or is weaker coincide with areas with uranium deposits.

CHAPTER 2. THE MAIN NATURAL HAZARDS GENERATING EMERGENCY SITUATIONS

2.1. Hydrometeorological hazards

Ice jams on Bistriţa between Izvoru Muntelui – Bicaz lake and Borca

After the formation of Izvoru Muntelui – Bicaz lake, in the mentioned sector occurred a special type of **ice jam** which blocked the floodplain on lengths of over 20 km and reaching thicknesses of 1–8 m. The duration of the ice jams varied between 24 days (1992–1993) to 124 days for 2002–2014. This type of ice jam was first mentioned by Ciaglic *et al.* (1975), who separate two phases: a first *submerged* one in which the frazil slush enters under the ice bridge from the lake on a certain distance. The blocking of the section is made by frazil slush deposition on the bottom of the floodplain inside the lake and not by its stitching to the lower base of the ice strata (as on rivers). From here it gradually extends upstream in the floodplain, filling it and sometimes exceeding the banks – the *emerged phase*.

The mentioned hypothesis has been confirmed through personal observations during March - April 2012. With the melting of the ice bridge from the entrance into the lake, on Bistriţa from Călugăreni up to Poiana Teiului the floodplain was filled with slush mixed with sediments and covered by a mud strata of 8-14 cm, covered itself by ice fragments. To continue its way into the lake, the river was forced to dig new routes in the lake sediments.

Comparing the evolution of ice jams in 2011-2014, it could be noticed that ice agglomerations formed at lake water levels under 487.11 m (2012). This indicates that the optimum level for preventing ice jam formation upstream Izvoru Muntelui is not of 499 m as suggested by Rădoane *et al.* (2009).

Proposals for preventing the occurrence and development of ice jams on Bistriţa

In the search for ways of preventing the evolution of ice jams on Bistriţa two different opinions have emerged:

a. Ştefănache (2007) proposes the close monitoring of areas with problems, a warning system for evacuation and limitation of flood effects caused by ice jams. This solution has been put into practice and used up to present.

b. Ciaglic (2008, 2009) considers that the only efficient way of solving the problem is *eliminating the causes*, which are well-known. He proposes two solutions. The first is destroying the ice bridge from the lake, so that the frazil slush would flow into the lake without being blocked at Călugăreni. The second implies diminishing the formation of ice needles, frazil, river bottom ice and implicitly ice jams (conducting works that would not modify the river discharge regime but would allow the infiltration of a larger water quantity from the river into underground in the infiltration loss areas, and implicitly an increase in the returned discharge downstream).

Up to applying this solution, the institutions responsible for emergency situations should continuously monitor the evolution of ice jams and to apply defense plans against floods and ice jams (warning the population, institutions and economical agents, applying prevention and protection measures specific for this type of risk, evacuating the affected area, interventions with special forces and means for the limitation and elimination of the negative effects, de-blocking of Bistriţa's course from ice packs and jams by using explosives, emergency help).

Having in view that during the winter discharge is reduced, to avoid ice jams we propose increasing the transport capacity by removing sediments from some sectors of the floodplain.

2.2. Hydrological hazards

Due to rainfall quantities in the study area, floods frequently occur on Bistriţa and its tributaries, with diverse durations and maximum discharge rates according to the volume of discharge coming from slopes, alimentation conditions and morphometric parameters of basins.

Analyzing the 1970-2013 period it can be seen that flood frequency and intensity have increased, the main natural and anthropic causes being:

- the increase in the torrential character of rainfall and slope discharge, the intensification of morphological processes in the floodplains;
- the reduction in the capacity of maximum discharge rates of transiting the floodplain;
- massive deforestation, the limited promotion of new works of correcting torrential valleys and re-forestations;
- the de-attenuation produced through impoundage works on large lengths without supplementary measures regarding their effects;
- the inadequate maintenance of floodplains, mainly in the area of bridges and localities (not conducting un-silting and vegetation deforestation in the floodplain, depositing garbage in the floodplain);
- impoundage works overcome due to exceeding of the transport capacity or under-dimensioning, inadequate maintaining of defense works damaged during floods;
- inadequate emplacement of buildings in the floodable area due to a lack of risk studies;
- the emplacement of unauthorized buildings in the area of torrential valleys and in the floodplains;
- under-dimensioned and silted sewerage systems that cannot eliminate torrential rainfall water.

During 2005, 2006, 2008, 2010 and 2013, torrential rainfalls from June-July have generated important discharge from slopes, torrents and brooks, discharge and level increases on Bistriţa's tributaries, producing floods in the study area and implicitly material losses.

Although the number of floods has increased in the analyzed period, after 2005 can be witnessed a reduction in the damage inflicted by these. This is the consequence of structural (upgrading of monitoring, prognosis and warning systems in the case of emergency situations, equipping intervention forces with performing equipment etc.) and non-structural measures (implementing the national management system of emergency situations, population education through mass-media and its preparation regarding behavior during extreme phenomena; a better instruction of the personnel of county inspectorates and voluntary services for emergency situations etc.) taken by local administration and institutions responsible for the management of emergency situations.

2.3. Geomorphological hazards

Research conducted during 2011–2013 have taken into consideration the most recent reactivations of slope processes from the left bank of Bistriţa valley in the Poiana Largului – Izvoru Muntelui sector, from its right bank at Izvoru Alb, as well as from other areas upstream Poiana Largului. On the left bank are met the most favorable conditions for the occurrence and reactivation of landslides, due to the presence of DN 15 route, with an intense and heavy traffic, as well as because of a constant increase after 1960 of anthropic. This influence stands in deforestations, new buildings and new access routes insufficiently stabilized, irrational agricultural land use. Beginning with 2000 slope processes from Poiana Teiului, Hangu and Potoci have witnessed visible reactivations, with effects on the road and protection works of DN 15. On the right bank at Izvoru Alb, in 2005, a natural dam lake occurred consequence of a deluvial reactivation.

CHAPTER 3. MANAGEMENT OF EMERGENCY SITUATIONS

In the field of emergency situations, defense is realized through general and special, preventive measures. The activity of preventing emergency situations generated by natural risk phenomena has been and still is a necessity, concretized in initiatives of reducing society's vulnerability. The capacity of national resistance in some possible emergency situations (H.G.R. nr. 762/2008) is given by:

- the resistance capacity of local communities, increasing their implication and participation;
- activities of preventing emergency situations, including reducing vulnerability;
- the capability of managing emergency situations;
- the capacity of eliminating the effects and rapidly coming back to normality.

In this context is imposed an increase of the measures for maintaining the security of people, collectivities and property, with the purpose of identifying, registering and evaluating risk types, warning the population, limiting, eliminating or counter risk factors as well as negative effects and impacts produced by exceptional events.

We consider that based on the map of landslide susceptibility of the study area, institutions responsible for the management of emergency situations can:

- identify and monitor landslide risk areas;
- ensure the management of crisis situations in the case of landslides;
- establish accordingly prevention and risk attenuation measures, as well as the conditions of authorizing buildings in the respective areas;
- detail the minimum content requirements of the urbanism and territorial planning documentation of the territories exposed to landslides.

CONCLUSIONS

1. The occurrence of dangerous phenomena during the last years on Bistriţa valley, strongly affecting human settlements, defense works, infrastructure etc. is due to **natural and anthropic factors**;

2. The existence on Bistriţa and Bistricioara, in identical climatic conditions, of some sectors with well-developed ice formations and of river sectors with small or even lacking such formations demonstrates the influence of other that can strongly influence the evolution of freeze phenomena (**hydraulic relations** between the rivers and the areas it flows through);

3. For the **reduction in the intensity of ice flows and ice jams** during the winter some small works can be emplaced, which would not modify the water flow, but would allow the infiltration of a large quantity of water from the river into underground in the areas with losses, and implicitly an increase in the discharge from underground downstream. The discharge being reduced during the winter, to avoid ice jams we propose an increase in the transport capacity by floodplain management in some sectors.

4. Beginning with the last decade of the 20th century, human activities have caused the occurrence of some **new favorable factors for the reactivation or intensification of slope processes**:

- *the lack of necessary measures for the good functioning of DN 15 protection works*, which led to the clogging of ditches, drains and micro-tunnels, not ensuring water drainage from slopes. The road embankment functioned as a dam, favoring deluviums storing water and blocking the carriageable part, fissuring or partial destroying of support walls, piers and viaducts;
- *traffic intensification on DN15* in the last two decades, determining frequent high vibrations;
- *the increase in the number of heavy civilian buildings*, most of them on insufficiently stabilized deluviums and lacking corresponding consolidation and water evacuation works;
- *the occurrence of new secondary transport ways on the slopes*, without necessary consolidation works;
- *the lack of management works on the floodplains of brooks crossing under DN15*, which would an increase in the height of thalwegs.

5. An **efficient management of emergency situations** is the result of interdisciplinary research, which includes risk management, territorial planning and urban development, environmental protection and sustainable development, protecting critical infrastructure, community and individual protection, each level with specific attributions.

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