COMPARATIVE STUDY ON POTENTIAL FLOODED AREAS IN THE MOUNTAIN AREA WITH PROBABILITIES OF MANIFESTATION 0.1% AND 1%, OBTAINED USING SIG TECHNIQUES. CASE STUDY: BISTRICIORA RIVER, THE CONFLUENCE SECTOR WITH THE BISTRIȚA RIVER

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Abstract
The study aims to outline the flood potential of a mountainous area, in the context of simulating flooded areas, GIS techniques being essential in determining the spatial and probabilistic impact of this type of hydrological phenomena. The resulting modeling highlights the floodplains and the probabilities of manifestation of 0.1 and 1%. The localities situated downstream of the Tulgheș hydrometric station are at risk, but the current methodology generates cartographic materials at an optimal resolution, initially for highlighting and later for the amelioration of vulnerable areas and the effective reduction of damages following a possible flood.

Keywords: *flood, flow, numerical terrain model, SIG, HEC-RAS*

INTRODUCTION

River processes "focus around a hydrographic artery and they are governed by the same laws, regardless of environmental conditions, scale and size, flow processes, erosion, transport and sedimentation" (Dumitriu, 2016).

Hydrological events can generate massive effects on the morphology of the riverbed, but especially on local communities, floods being phenomena with an impact on land-use changes, on built-up areas and sometimes can cause casualties, depending on their magnitude. The frequency and intervals of recurrence are also important, for which good statistical modeling can generate an estimate of the potential degree of damage to a territory.

Moderate floods have higher frequencies and low intensities, landforms are shallowly shaped and differ from those with recurrence periods of tens or hundreds of years, which are "considered extreme or catastrophic and which not only carry the sediments but produce essential changes in riverbeds" (Magilligan, 1992; Molnar et al., 2006).

The potential of a flood is related to the temporal aspect, respectively the duration of the flood, which substantiates the typology of changes within the basin. The maximum discharges recorded over a short period, in moderate situations, reduce the flashflood's ability to transform the morphology of the area. At the same time, "the tangential effort to engage the sediments, corroborated with the power of the current, over a longer period, with a lower maximum flow, increases the effectiveness of geomorphological modeling of the flood" (Costa, O'Connor, 1995).

The Bistricioara river basin is located in the Eastern Carpathian Mountains, with an area of approximately 780 km^2. The highest altitude is 1745 m, the confluence area being much lower, below 500 m. Among the most important tributaries in the studied range, there are Grințieșul Mare, Grințieșul Mic, Bradu, Pintec and Prisecani.

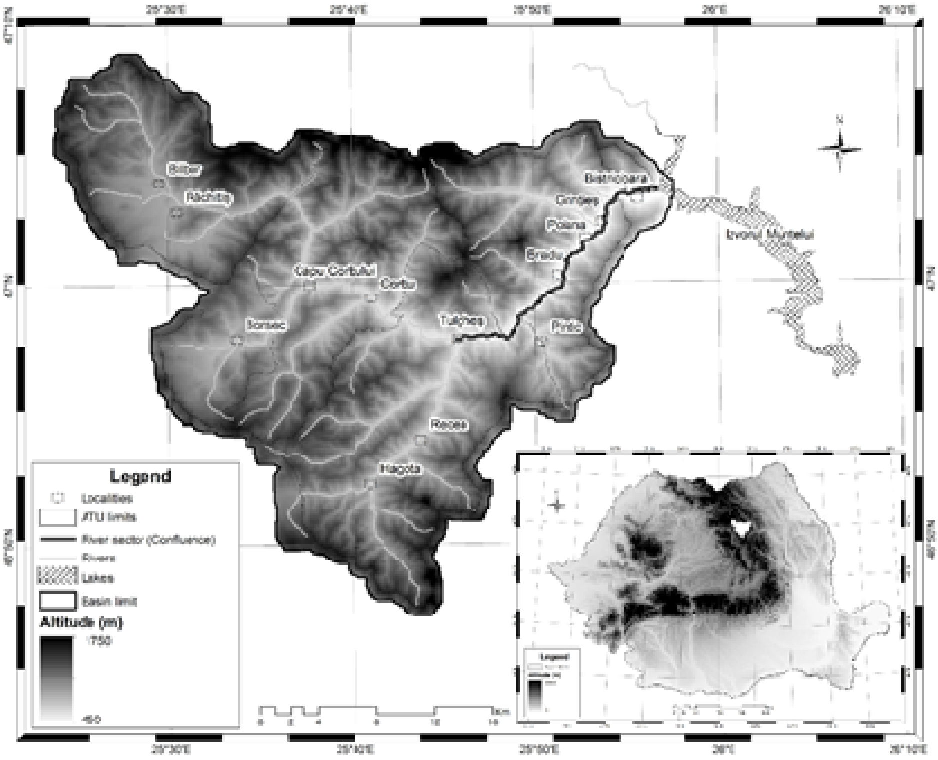

Fig. 1. Study Area – The Bistricioara River Basin

In the study, the two hydrometric stations, Tulgheș and Bistricioara, were taken into account, sites where the riverbed trend is different: aggradation for the downstream station (Bistricioara) and incision in the upstream part of the river (Tulgheș). These hydrometric stations are of particular importance because they record the highest values of discharges, and designate the largest localities. The mean discharge is about 6.4 m^3/s.

The Tulgheș hydrometric station has been moved since 1965, in a free profile sector, at an altitude of 640 m, in a unitary riverbed area, while the Bistricioara hydrometric station has been operating since 1974, at an altitude of 516 m, close to the output.

MATERIALS AND METHODS

To realize the study, a series of successive stages of obtaining and processing the details were followed. In the first stage, the data necessary for the flood simulation were obtained. An important role in obtaining the most accurate results has the topographic support with a high resolution, based on which the vectors necessary to simulate the flood will be drawn. In this case, an MNT (Numerical Terrain Model) obtained by photogrammetric methods with a pixel size of 5 m was used, which indicates a sufficiently good resolution for modeling a flood simulation.

The vector layers necessary to simulate a flood are: the thalweg, the drainage channel (which coincides with the thalweg vector), the banks, the boundary of the flood channel, the lakes, the land use, the transversal profiles, and the hydraulic structures. In this case, the hydraulic structures were omitted due to the lack of technical data. The vectors were mapped based on the MNT, as well as an orthophotoplan from 2012. They were extracted using the Hec-GeoRAS extension in the SIG ArcGIS 10.2 software, the extension version coinciding with the software version.

The thalweg was drawn from upstream to downstream, a necessary condition for indicating the direction of water flow. The banks were drawn according to the same principle as the trough, from upstream to downstream, being drawn first the left bank, followed by the right bank, as well as the case with the flood channel. The transversal profiles were vectorized with an equidistance that varies between 5 m and 50 m, depending on the sinuosity coefficient of the river. The land use was extracted from the OSM (Open Street Map), with its help calculating the roughness. Vector statures were exported from ArcGIS, the actual flood modeling being done in the HEC-RAS software (Renschler & Wang, 2017; Quiroga, Kurea, Udoa et al., 2016; Motevalli & Vafakhah, 2016) where the discharge for flood profiles with a probability of manifestation 0.1% (once every 1000 years) and 1% (once every 100 years) were also introduced.

To calculate the two probabilities, the maximum flows from the Tulgheș hydrometric stations and Bistricioara hydrometric stations for a period of 55, respectively 52 years and the Gumbel formula (Formula 1) were used (Buchmann Ferreira & Maller, 2021; Vasilescu et al., 2021).

$$X_T = \overline{X} + K\sigma_x \text{ (Equation 1)}$$

Where:

X_T = the probable discharge with a return period of T years (the magnitude of floods);

$\overline{X}$ = mean flood ;

n = size string of data;

σ_x = standard deviation of the maximum annual flow rates:: $\sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n-1}}$ (Equation 2);

K = frequency factor: $K = \frac{Y_T - Y_n}{S_n}$ (Equation 3);

Y_T = reduced variate : $-\left[LnLn\left(\frac{T}{T-1}\right)\right]$ (Equation 4);

Y_n și S_n = expected mean and standard deviations of reduced extremes found within Gumbel's table depending on the sample size.

RESULTS AND DISCUSSIONS

Following the application of the Gumbel formula (Formula 1) for the probability of manifestations of 0.1%, a discharge with a value of 79.18 m^3/s was obtained at the Tulgheș hydrometric station, and at the Bistricioara hydrometric station the value of 129,26 m^3/s was obtained (*Table 1.)*. The Bistricioara hydrometric station is located downstream of the Tulgheș hydrometric station, which also collects discharges of other tributaries, therefore a higher value was obtained compared to the Tulgheș hydrometric station. For the probability of manifestation of 1%, the value of 58,20 m^3/s at the Tulgheș hydrometric station and 95,12 m^3/s at the Bistricioara hydrometric station was reached *(Table 1.).*

Compared to the maximum discharge recorded at the two hydrometric stations, it is observed that the maximum value recorded at the Tulgheș hydrometric station exceeds the flow value of 1%, more precisely, it has a probability of 0.94%. At the Bistricioara hydrometric station, the maximum registered discharge does not exceed the probability of 1%, this having a probability of 1.11% (once every 90 years).

Table 1.

Flows obtained by applying the Gumbel formula compared to the maximum discharge recorded at the two hydrometric stations

Hydrometric station	Discharge 0,1 % (m^3/s)	Discharge 1% (m^3/s)	The maximum registered discharge
Tulgheș	79,18	58,20	61,60
Bistricioara	129,26	95,12	85,40

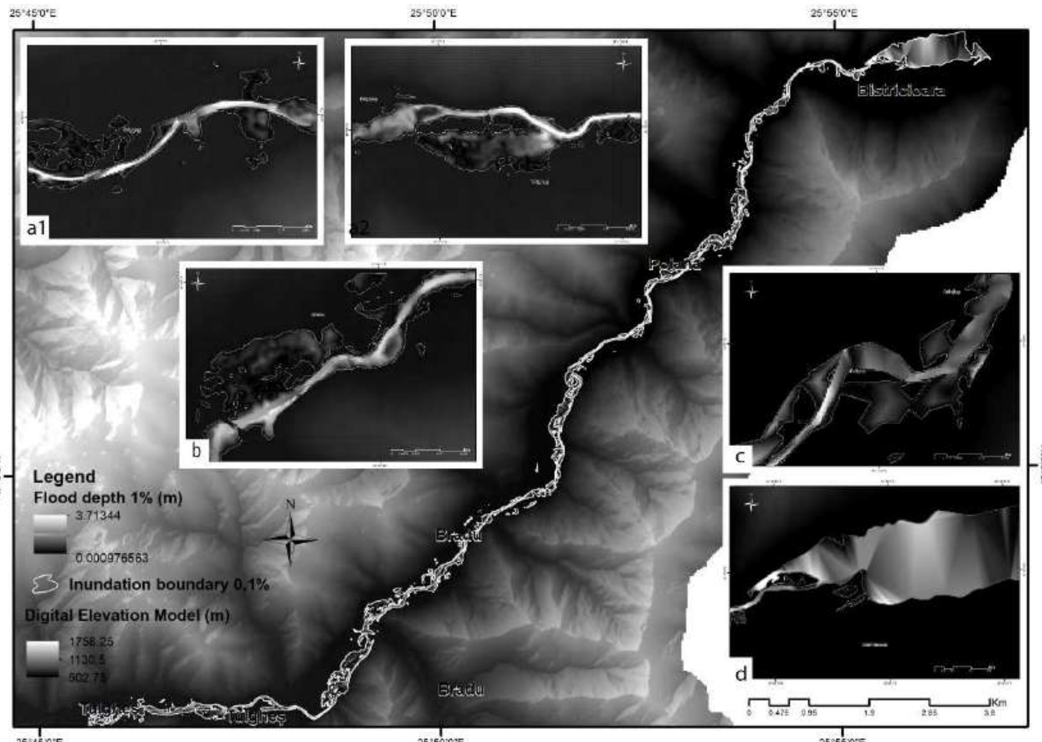

Fig. 2. Cartographic representation of flood areas and levels with the probability of manifestation of 0.1% and 1%: a1 and a2- Tulgheș locality, b-Bradu locality, c- Poiana and Grințieș localities, d-Bistricioara locality.

The Tulgheș-Bistricioara sector of the Bistricioara river (the confluence sector with the Bistrița river) crosses Tulgheș, Bradu, Poiana, Grințieș and Bistricioara localities, all being affected in case of a flood with the probability of manifestation of 0.1% and 1% *(Figure 2 .)* the most affected being the locality Bistricioara, the flooded surface being the same in both simulations *(Figure 2. (d)).* The biggest differences between the two simulations are observed in Tulgheş *(Figure 2. (a1)).* The total area affected by the discharge simulation with a probability of occurrence of 0.1% is 2.33 km^2 , while in the case of a discharge of 1% a potential area of 2.05 km^2 (*Figure 3)* which indicates a difference of only 0.28 km^2 ,this indicating large differences in altitude and large values of slopes, values specific to the mountain area, characteristics highlighted and in the level difference between the two simulations 4,09 m and 3,71 m respectively *(Figure 3),* the discharge speed being higher in the case of mountain areas.

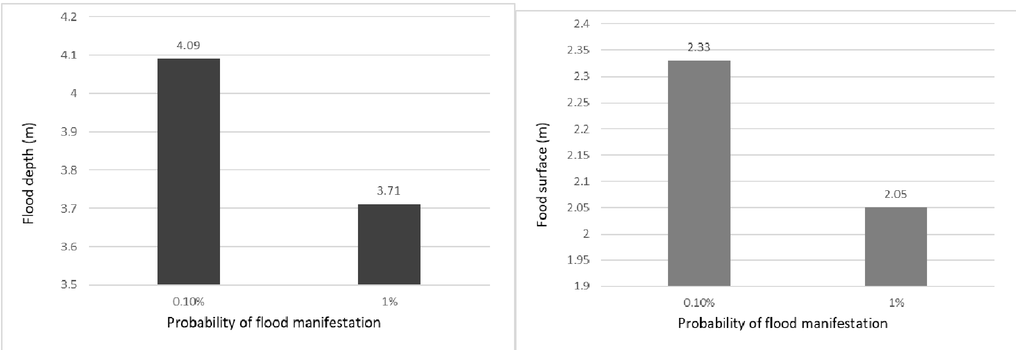

Fig. 3. Graphical representation of flooded areas and discharge levels with a probability of manifestation of 0.1% and 1%

CONCLUSIONS

In the present research, a hydraulic modeling was performed using the HEC-RAS methodology, following which there were discharge bands with a probability of manifestation of 0.1% and 1%. Following the research, discharge prevention measures can be taken because all localities that are crossed by the studied sector, will be affected in case of a discharge with a manifestation period of 0.1% or 1%, the differences between these two discharges being very small. Given that the maximum value of the recorded flow exceeds 1%, the present study is also a reconstruction of the discharge produced, but also an effective method to assess potential damage if it will be repeated in the near future.

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