THE ASSESSMENT OF ECONOMICAL LOSS CAUSED BY FLOODS AND FLASH-FLOODS BY USING COMPUTER TECHNIQUES. CASE STUDY: LOPĂTARI VILLAGE, SLĂNIC RIVER

COSTACHE R. [1]

ABSTRACT. – The assessment of economical loss caused by floods and flash-floods with the help of computer techniques. Case study: Lopătari village, Slănic River. The present study aims to provide an example of the assessment of economical loss caused by floods and flash-floods, by integrating GIS techniques of hydraulic and hydrological modelling. The case study was performed in Lopătari village, which is located in the upper area of Slănic River, one of the most affected areas by floods and flash-floods. The flood event produced on 29.V.2012 was considered in order to perform this study. Thus, a flood hydrograph was simulated by using software HEC-HMS 3.5, based on hourly precipitation data from Bisoca meteorological station from 29.V.2012. The peak discharge resulting from the hydrological modelling software was used in HEC-RAS 4.1 hydraulic modelling software in order to determine the extent of flooding band, the number of the affected elements and the local economical loss. Finally, 21 flooded buildings were identified and 550 m of affected road, the estimated economical damage being about 800,000 RON.

Keywords: hydraulic modelling, hydrologic modelling, GIS, flood, economical loss

1. INTRODUCTION

In the late decades, Romania was repeatedly affected by floods and flash-floods which caused both economic damage and life loss. The economic damage is mainly related to infrastructure (buildings and communication means).

The consequences are reflected on life quality and other sectors of the economy. In order to reduce the negative impact of these phenomena, several studies were performed by illustrating these phenomena occurrence at national and international levels. In this purpose, GIS techniques for hydraulic and hydrological modelling are widely used (Claus et al., 2009, Costache&Fontanine, 2013).

In this study, the flood from 29.V.2012 on Slănic River, Lopătari village, will be analysed. In a first phase, a flow simulation from 29.V.2012 was performed through HEC-HMS hydrologic modelling software.

Thereby, the extent of the flooding band, corresponding maximum flood flow was analysed. The hydraulic modelling underlies the quantification of the number and length of affected infrastructure and economic loss.

[1] University of Bucharest, Faculty of Geography, Bucharest, Romania
E-mail: romuluscostache200@yahoo.com

2. STUDY AREA

Slănic River Basin is located in the central-south-eastern part of Romania, mostly in the Carpathian area (Fig. 1). It is a left tributary of Buzău River, with an area of approximately 427 km^2 and altitudes ranging from 119 m at the confluence with Buzău River and 1353 m on the highest peaks included in the Carpathian Basin.

The studied river sector, from Lopătari village, has a length of about 2.1 km. Almost 650 houses and household annexes and 5.5 km of road network are located near this sector. Of these, 2.1 km belong to 203 K County Road.

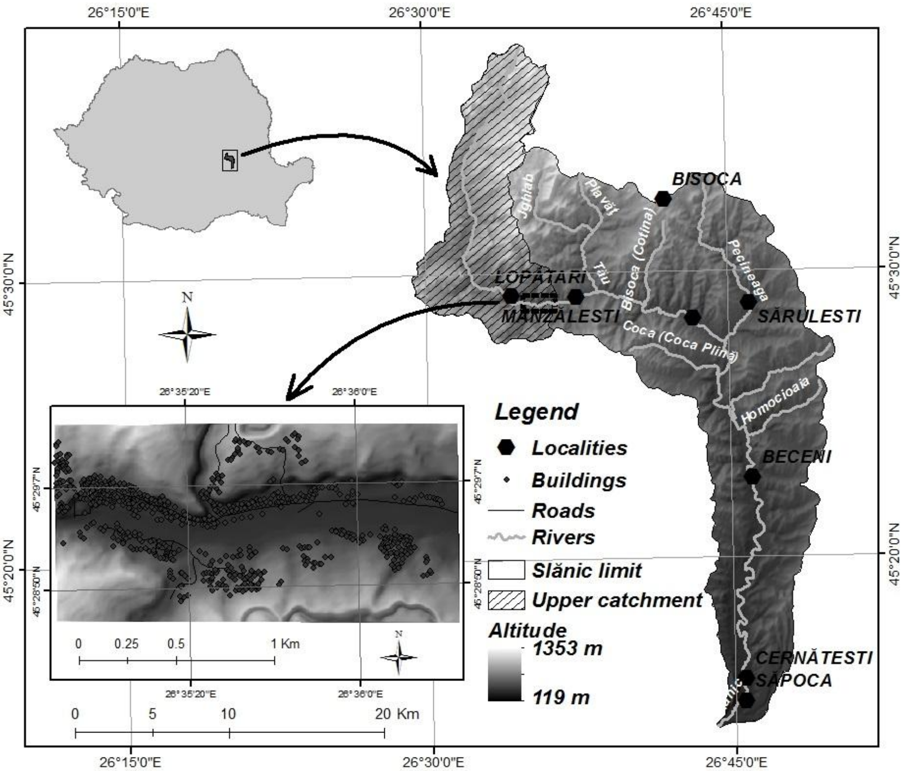

Fig. 1. ***Study area location***

The river sector from the upper area in relation to Lopătari village (Fig. 1) records 97 de km^2. Altitudes range from 438 m to the maximum recorded value of the river basin. The slope is one of the factors with the greatest influence on surface runoff (Bilaşco, 2008). Within the analyzed sector, slope values range between 1 ° - 43 °, with an average around 14°. Land cover is another essential factor in the analysis of surface runoff (Costache, 2014). Within the river basin, built areas occupy almost 7.2% of the total area, where surface runoff is active (Zaharia et al., 2012), while forested areas occupy about 63% of the upper sector, being less favourable to surface runoff.

Hydrologic soil groups are another indicator of the surface runoff potential (Costache et al., 2014). These are included in four categories: A, B, C and D. Within the study area, the hydrological soil group A is predominant, with an area of 57 km^2, respectively 59% of the total study area. Hydrological Group A is followed in terms of surface, by the hydrologic soil group C, which covers an area of 34 km^2, or 35% of the river basin.

3. METHODOLOGY

In order to evaluate the material damage caused by the flood produced on 29.V.2012 in the village Lopătari, three main stages were followed: i. Hydrological modelling; ii. Hydraulic modelling; iii.Evaluation of actual economic damages.

I. The hydrological modeling method was used to obtain the flood hydrograph recorded on 29.V.2012 on Slănic River, Lopătari village, based on rainfall recorded at Bisoca meteorological station.

A hydrodynamic model was based on HEC-HMS - hydrodynamic model with distributed parameters (Gyori, 2013).This software, developed by the US Army Corps of Engineers to simulate hydrograph, requires the creation of three components: basin model, meteorological model and time series model.

Regarding the basin model, SCS-CN method was used in order to express the initial loss of water from rainfall and also the method for the simulation of the flood hydrograph (SCS Unit Hydrograph). Data of the river basin parameters were also integrated:

- Initial discharge before the start of the flood (0.5 m^3/s);
- Area of upper river basin sector (km^2) - obtained after processing digital terrain model;
- Weighted Curve Number (CN_{aw}) – obtained by applying the following formula:

$$CN_{aw} = \frac{\sum_{i=1}^{n}(CNi * Ai)}{\sum_{i=1}^{n} Ai}, \text{ where:}$$

CNi - the curve number for each land use-soil group polygon;
Ai - the area for each land use-soil group polygon
n - the number of land use-soil polygons in each drainage basin.

- Impervious surface weight (%) – obtained by applying the following formula:

$$I_{\%} = \frac{I}{A} * 100, \text{ where:}$$

I - the total impervious area;
A - the total area of the catchment

- T_{lag}*(minutes)* – calculated through the formula:

$$Tlag = \frac{(L*3.28*10^3)^{0.8}*(\frac{1000}{CN_{aw}}-9)^{0.7}}{1900*Y^{0.5}}$$, where:

L - hydraulic length of the catchment in km;
CNaw - average Curve Number within the catchment area;
Y - average catchment slope in percent.

Meteorological and time series modules, will cover the period for which the hydrological modelling was performed (29.V.2012, between 00:00 – 23:00) and precipitation from Bisoca meteorological station (Fig. 2).

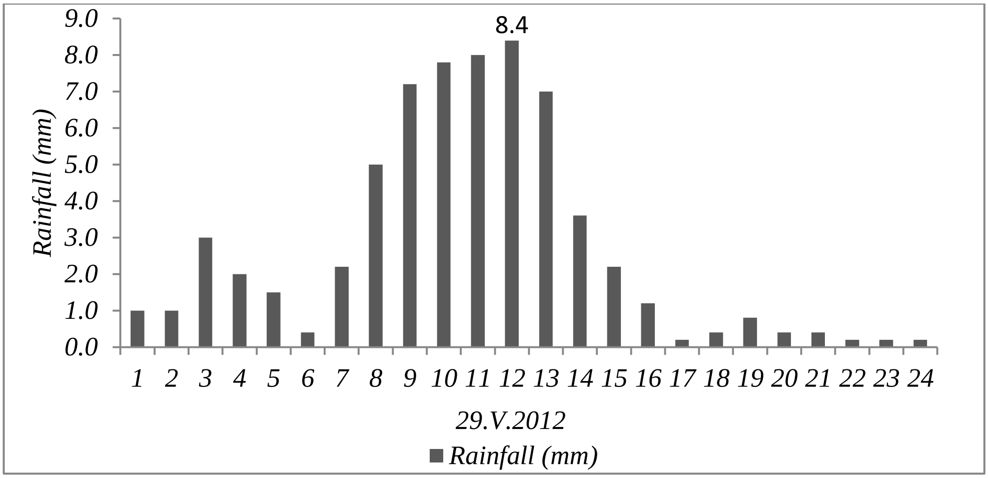

Fig. 2. ***Rainfall distribution on 29.V.2012 at Bisoca Meteorological station (Source: National Meteorological Administration, 2012)***

II. The Hydraulic modelling method was used to obtain the flooding band corresponding to the peak value of discharge recorded during 29.V.2012 flash-flood on Slănic river, Lopătari village.

In this purpose, the hydraulic modelling software HEC-RAS 4.1, developed by the US Army Corps of Engineers HEC and the extension 10.1 GeoRAS from ArcGIS 10.1 software were used. Firstly, geometric elements of the river bed were extracted: talweg line, two banks and a total of 20 cross sections at 100 m equidistance (Fig. 3). These were obtained due to HEC-GeoRAS 10.1 extension, based on the digital terrain model obtained from a cell size of 1 m, by interpolating contours from the Topographic Plan 1:5000. Considering land cover of the study area, the Manning roughness coefficients were also obtained.

Once the bed geometry obtained in *shp.* format, it was exported in specific *sdf.* format for HEC-RAS 4.1 software.

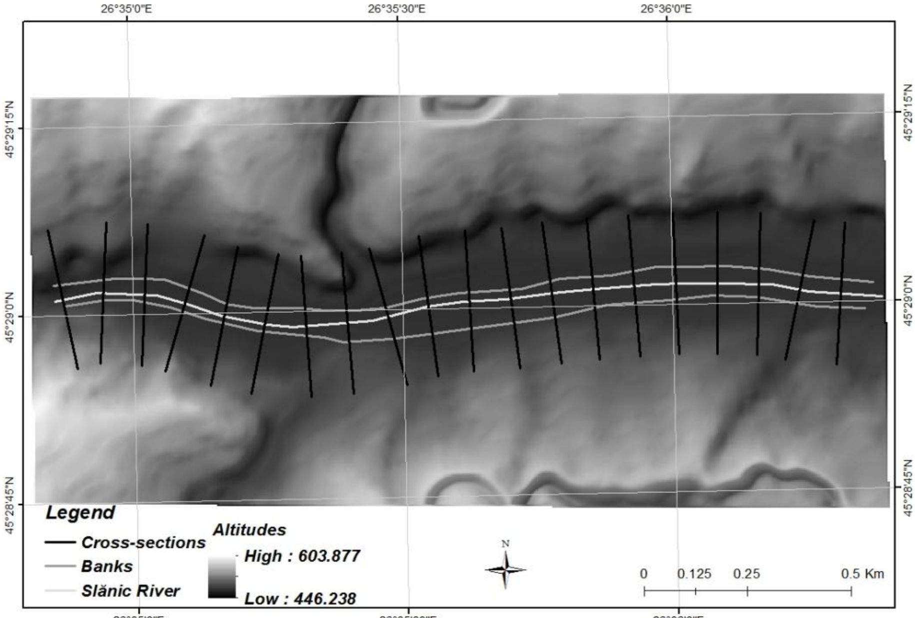

Fig. 3. ***Slănic river bed geometry in Lopătari locality***

Due to HEC-RAS 4.1 software the parameterization of the hydraulic model and the 1D and simulation of the flood band corresponding to the peak flow value, in steady flow regime, were performed.

Thereby, the boundary conditions (*Normal Depth*) were introduced for the first and the last cross section in order to calibrate the hydraulic model. The discharge value, obtained by running the hydraulic model, was finally added. The final results were obtained in GIS module, respectively RAS Mapper of HEC-RAS software, which were exported in shp format, in order to be mapped in ArcGIS 10.1 software.

III. The last stage of the study was to assess the actual economic damage caused by the flood on 29.V.2012, mainly regarding infrastructure. This assessment was possible by quantifying the elements affected by the flood band, and by calculating their economic unit value. Estimating the economic unit value was based on the Report of the effects of floods and dangerous meteorological phenomena produced in 2005 (Minister of Environment and Water, 2006).

4. RESULTS

By applying the hydrological modelling in HEC-HMS 3.5 software, the flash-flood hydrograph produced on Slănic River, Lopătari village, was obtained (Fig. 4). As a result of the hydrological simulation, a specific hydrograph of simple flash-flood with a single peak was obtained. The total time of flash-flood was 26 hours, between 4:00 a.m., 29.V.2012 and 6 a.m., 30.V.2012. Flash-flood rise time was about 11 hours, the discharge increasing from 0.5 m^3/s up to 23 m^3/s. The maximum discharge value was recorded at 3:00 p.m. on 29.V.2012. Flash-flood decrease time was about 14 hours, between 3:00 p.m. on 29.V.2012, and 6:00 p.m. on 30.V.2012, when Slănic River discharge recorded 0.5 m^3/s.

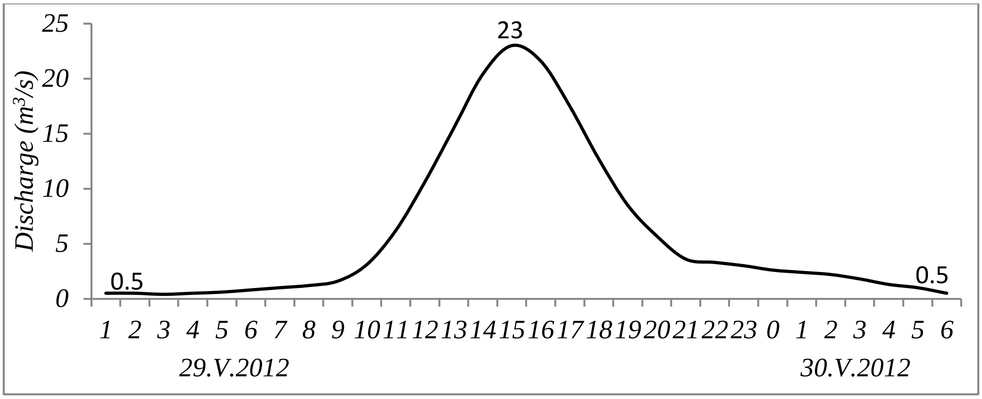

Fig. 4. ***Flash-flood hydrograph on 29.V.2012 at Lopătari***

The flash-flood on Slănic River, caused by 64.3 mm rainfall in 24 hours, created a flood band that affected many houses and household annexes (Fig. 5).

The extent of the flood band corresponding to the peak discharge of the flash-flood was simulated in HEC-RAS hydraulic modelling software. The flood band area was of almost 18.8 hectares (Fig. 5).

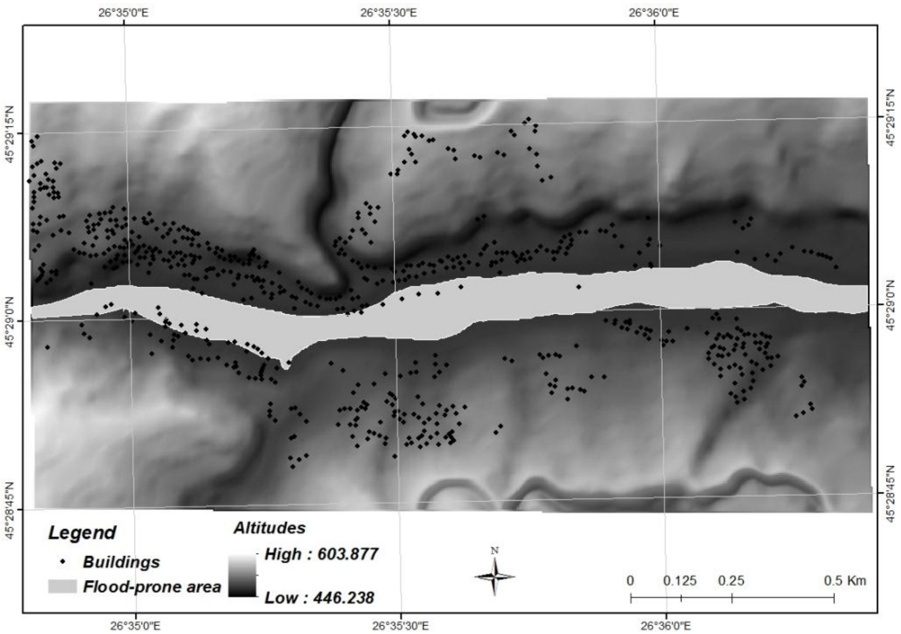

Fig. 5. ***Flood prone area on 29.V.2012 in Lopătari locality***

By overlaying the flood band with infrastructure, 21 flooded houses and household annexes resulted, and also over 550 m of road network. According to the official report of the damage produced in 2005, the average unit value of the economical damage regarding houses and household annexes was 6,500 RON/unit, while the average unit value for the road network was 12100 RON / km. Therefore, the economic damage value for buildings was of 136500 RON and 665500 RON for the road network. The overall flood damage in 29.V.2012 was about 800000 RON.

5. CONCLUSIONS

Integrated GIS, hydraulic and hydrological modelling techniques for the assessment of natural hazards such as hydrological phenomena, proves to be very useful due their practical utility. By GIS and hydrological modelling techniques, flash-flood hydrographs can be obtained for rivers which are not being hydrometrically monitored. The lack of hydrometric data is another reason to apply such techniques.

This study was based on a severe hydrik event which occurred in Lopătari village, frequently affected by such phenomena. By using advanced GIS techniques and considering the economical damage, caused by the severe flood in 2005, the assessment of the damage caused by the flash-flood on 29.V.2012 was possible.

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