USING GIS TECHNIQUES FOR ASSESSING LAG TIME AND CONCENTRATION TIME IN SMALL RIVER BASINS. CASE STUDY: PECINEAGA RIVER BASIN, ROMANIA

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ABSTRACT:
Pecineaga River, which is a tributary to Buzău River, forms a small river basin. Its low surface and its almost circular shape, but also high slopes exceeding 20% cause a high potential for flash-floods on slopes. Given the fact that Pecineaga river basin is not being hydrometrically recorded, various rain-flow models which use water lag time and concentration time as calibration parameters for modelling flash-flood hydrographs. In this study, lag time was firstly computed by the formula proposed by Soil Conservatin Service from USA. This formula contains, besides certain constants, values of parameters such as: L-hydraulic length catchment; CN_{aw} - weighted average value of the Curve Number; and Y-average slope of the river basin. These values were obtained through a work flow in ArcGIS 10.1. Having obtained these values, time lag was calculated for the closure section of the river basin. The result of time lag was used in order to determine the concentration time (Tc). The low values of the two parameters demonstrate that Pecineaga river basin is exposed to flash-flood on slopes.

***Key-words**: lag time, concentration time, Pecineaga, Curve Number.*

1. INTRODUCTION

Using the lately techniques for modelling hydrological processes is absolutely necessary nowadays, due to the need of finding the most efficient methods of extreme hydrik phenomena prognosis. Studying extreme hydrik phenomena is becoming more important in research, given the generation of the majority of global natural hazards (Hudson & Colditz, 2003). Romania, among other countries form the south-eastern part of Europe is one of the countries with the highest frequency of hydrik risk phenomena like flash-floods and deriving floods. As a result, many studies regarding rain-flow process can be found in the international and Romanian specialty literature. One of the most popular used method of estimating water flow on slopes form a certain precipitation value is the Curve Number developed by Soil Conservation Services from USA. It has been used in research studies by several authors, such as: Kumar, Tiwart and Pal (1991), Mack (1995), Scozzafava and Tallini (2001), Xiaoyong and Min-Lang (2004), Haidu, Crăciun and Bilașco (2007), Bilaşco (2008), Minea (2011), Gyori and Haidu (2011), Domnița (2012), Duncan et al (2013).

The aim of this study is to calculate the weighted Curve Number within Pecineaga river basin, by SCS-CN method. Obtaining this parameter for a certain area is very useful for calculating various parameters used for the calibration of other rain-flow models. In this case, the first target-parameter is lag time, from which water concentration time can be forwardly derived.

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The aim of this study is to estimate the punctual value of lag time and concentration time for the closure section of Pecineaga river basin, corresponding to the confluence with the main collector, which is Slănic River.

2. STUDY AREA

Pecineaga river basin is located in the central south-eastern part of Romania (**Fig. 1**). Pecineaga river is a tributary to Slănic river), overlain exclusively to the Curvature Sub-Carpathians from Buzău county (**Fig. 1**). The surface of the study are is of almost 60 km^2, a value which includes the study area in small river basins category. The shape coefficient of Pecineaga river basin is 0.55. This parameter was derived from the formula:

$Rc = \frac{4\pi * F}{P^2}$ (1), **(**Pișota, Zaharia & Diaconu, 2005); where: F – river basin surface (km^2); P – river basin perimeter (km).

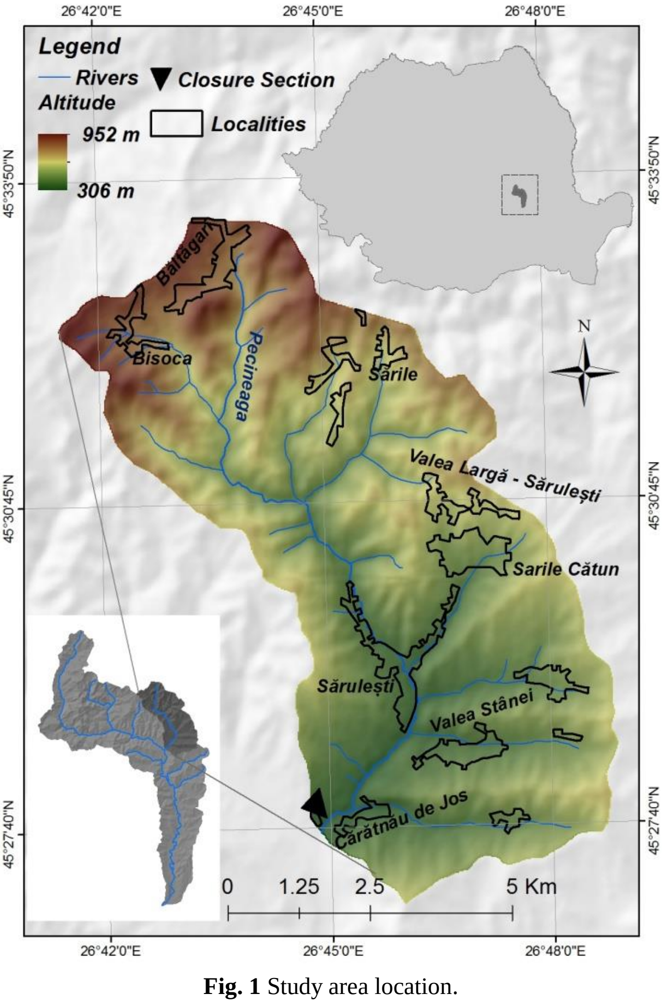

Fig. 1 Study area location.

The value of the area shape coefficient, which corresponds to a circular shape, related to its low surface, includes the area in the category of highly exposed to flash-flood river basins (Drobot, 2007).

The altitudes within the study area range between 306 m at the confluence of Pecineaga with Slănic River and 952 m in the northern part (**Fig. 1**). The average slope is of 20%, meanwhile slopes exceeding 27% occur on a half pound of the area. The high vertical deviation (approximately 650 m) of the small river basin and the occurrence of high slope values on large areas are other two factors which contribute to flash-flood generation.

Regarding vegetation, broadleaf forests record a high surface (**Fig. 3c**.), having a major hydrological role (Arghiriade, 1977) and causing the decrease of surface runoff potential. Broadleaf forests are mainly found in the central and northern part of the river basin. Fruit trees, mainly found in the central and southern parts of the area (**Fig. 3c**), and pastures, located on the highest areas, are also major types of land cover.

The soil coverage has a major role in regulating surface runoff processes (Prăvălie & Costache, 2013). Therefore, the soil types were grouped in 4 hydrological classes. Within the study area, soils from A and D groups occur on high surfaces (**Fig. 3d**).

3. METHODS AND RESULTS

3.1. Lag time is the time difference between the centre of the unit rainfall event and the runoff peak (DHI, 2009). In the present study, in order to calculate the lag time for the closure section of Pecineaga river basin, the Soil Conservation Service formula, adopted by DHI in 2009, was used:

$$Tlag = \frac{(L*3.28*10^3)^{0.8}*(\frac{1000}{CN_{aw}}-9)^{0.7}}{1900*Y^{0.5}} \quad (2)$$

Where: **T lag** – Lag time in hours;

L- Hydraulic length of the catchment in km;

CNaw –average Curve Number within the catchment area;

Y –average catchment slope in percent.

The values of the used parameters in the formula for the lag time calculation were obtained in ArcGIS 10.1. Software. There by, the average slope (%) in Pecineaga river basin and the hydraulic length of the catchment (km) were computed by following the work flow implemented in ArcGIS 10.1 through Model Builder, described in **Fig. 2**.

In the first stage of the study, contour data at 10 m equidistance, digitized from the Topographic Map 1:50000 (geospatial.org, 2013) and the limit of Pecineaga river basin (**Fig. 2**) were used. By ***Topo to raster*** tool, the DEM was computed in raster format with 10 m cell size.

The spatial modelling of the slope (%) within Pecineaga river basin (**Fig. 3a**) was performed by ***Slope*** tool. The average slope value, of 20%, was automatically extracted in ArcGIS 10.1. The hydraulic length of the catchment (**Fig. 2**) was obtained by processing the DEM gradually through Hydrology tool from Spatial Analyst toolset in ArcGIS 10.1. The hydraulic length of the catchment (km) within Pecineaga river basin is 14.7 km (**Fig. 3b**).

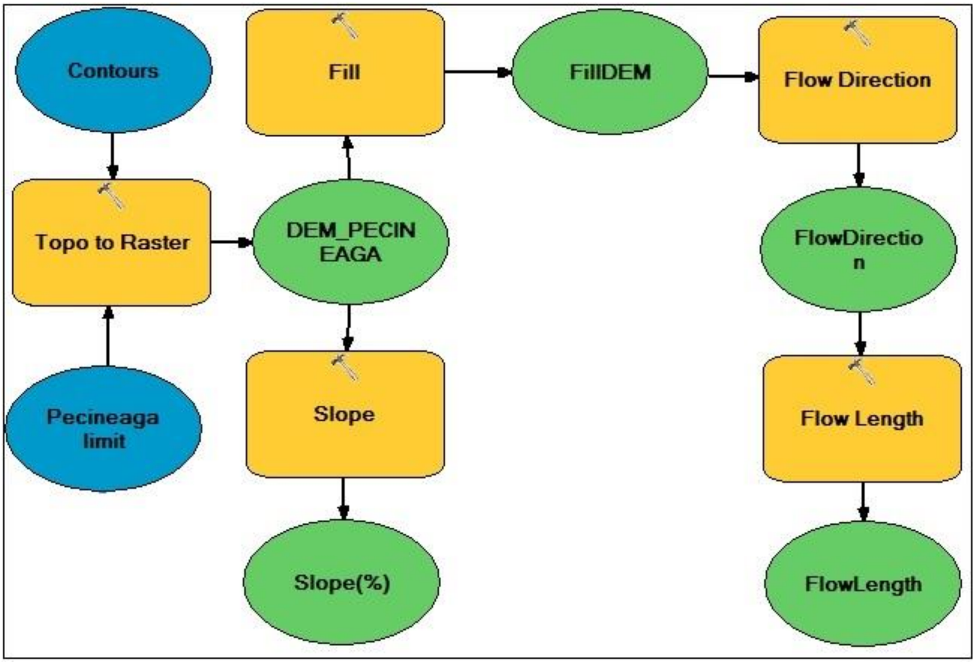

Fig. 2 Using Model Builder in ArcGIS 10.1 to obtain the average slope in percent and the hydraulic length of the catchment.

Another used parameter for the calculation of lag time is the weighted Curve Number (CN_{aw}). The Curve Number, developed in 1954 by Soil Conservation Service from USA is an indicator of the surface runoff potential from a certain quantity of precipitation (Ponce and Hawkins, 1996), depending on the type of land use (**Fig. 3c**) and the hydrological soil group (**Fig. 3d**). According to the formula (Ebrahimian et al, 2012):

$$CN = \frac{25400}{S + 254} \quad (3)$$

Where S - the potential for water retention in mm, the Curve Number is inversely proportional with water retention potential by land surface. Its values range between 0 and 100, the lowest corresponding to forested areas on hydrological soil group A and the highest CN values corresponding to impermeable surfaces with low potential for water infiltration and retention. Also, the CN value depends on the antecedent moisture condition (AMC) (Bilasco, 2008).

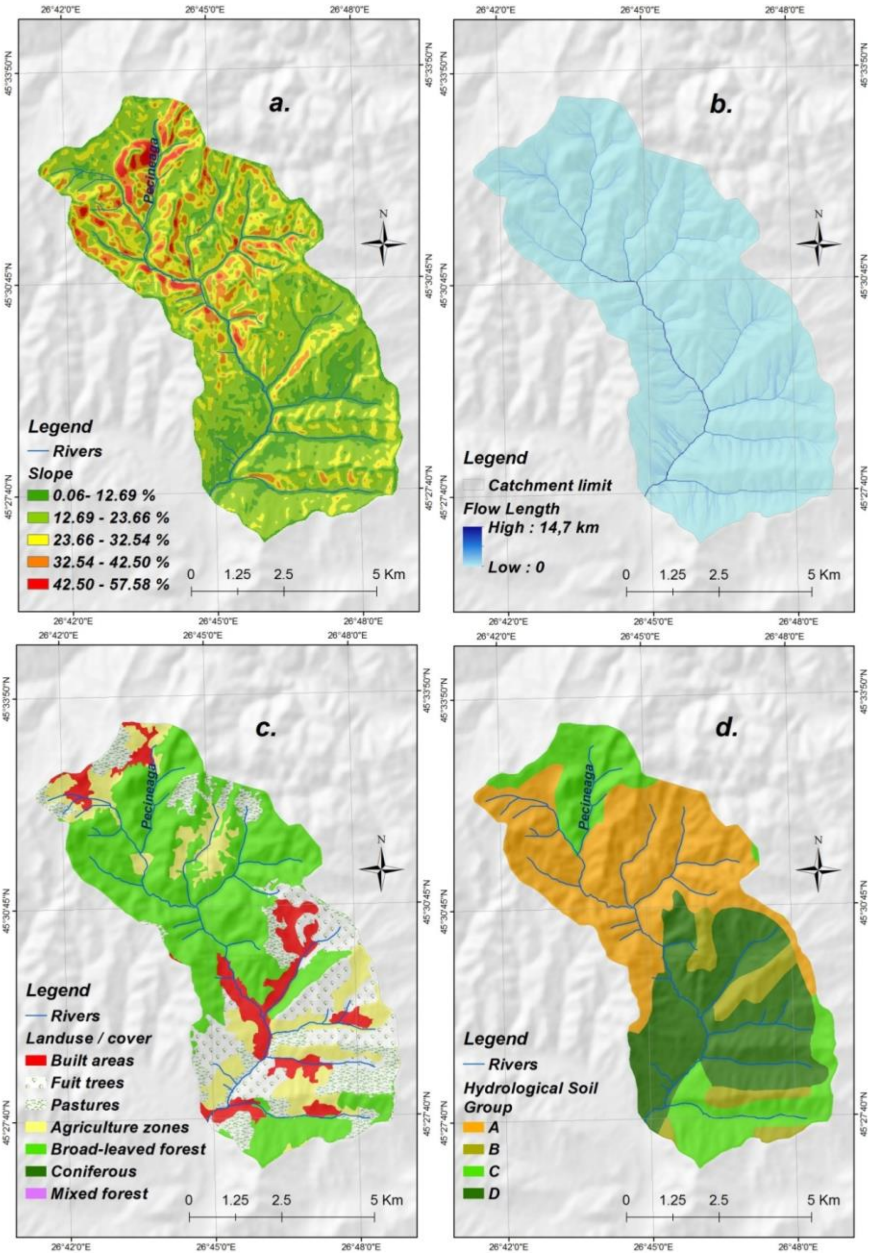

Fig. 3 a. b. The geographical factors of which values are used in lag time calculation; **c. d.** The geographical factors used for the weighted Curve Number calculation.

The moisture conditions are grouped in 3 classes: AMC_I – low humidity; AMC_{II} – medium humidity; AMC_{III} – high humidity. In the present study, CN values were considered for AMC_{II} (**Table 1**).

Table 1. Curve Number values and their surfaces within Pecineaga river basin (after Domnița, 2012)

Land use	Soil Group	CN_i	Ai (Ha)	$CN_i * A_i$ (Ha)
Built areas	A	77	72.1	5551.7
	B	85	1.3	112.7
	C	90	125.7	11312.7
	D	**95**	363.3	34512.9
Fruit trees	A	43	97.6	4195.3
	B	65	103.5	6728.6
	C	76	111.0	8434.7
	D	82	491.3	40287.1
Pastures	A	49	179.9	8816.2
	B	69	93.7	6465.4
	C	79	211.8	16733.9
	D	84	249.4	20950.7
Complex cultivation patterns	A	67	218.3	14628.5
	B	78	64.8	5058.0
	C	85	119.6	10163.3
	D	89	272.5	24256.2
Land principally occupied by agriculture	A	52	118.6	6166.7
	C	79	58.8	4647.2
	D	84	152.9	12840.7
Broad-leaved forest	A	**42**	**1667.7**	70044.9
	B	66	100.6	6641.9
	C	79	654.1	51675.2
	D	85	298.9	25404.7
Coniferous	C	73	**0.4**	25.9

Within the study area, the highest CN is value 95, corresponding to built-up areas overlain to D hydrological soil group. The surface of the areas with 95 CN value is 363.3 ha (**Table 1**). The lowest CN value is 42, on 1667.7 ha (**Table 1**), on approximately 30% of the study area.

In order to calculate the weighted Curve Number value (CN_{aw}) the following formula, proposed by Halley et al (2000), was used:

$$CN_{aw} = \frac{\sum_{i=1}^{n}(CNi * Ai)}{\sum_{i=1}^{n} Ai} \quad (4)$$

Where: **CN_{aw}** = the area-weighted curve number for the drainage basin;
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.

By applying the above formula **(4)**, the weighted Curve Number was obtained:

$$CN_{aw} = \frac{395655Ha}{5827.9Ha} = 67.8$$

Having obtained the parameters used for water lag time calculation, within the closure section of Pecineaga river basin, these can be integrated in the formula **(2)** in order to obtain the final result:

$$Tlag = \frac{(14.7*3.28*10^{3})^{0.8}*(\frac{1000}{67.8}-9)^{0.7}}{1900*20^{0.5}} = \frac{18979.35}{8497} = 2.23 hours = 133.8\min$$

3.2. Time of concentration (Tc)

Time of concentration is the longest travel time it takes a particle of water to reach a discharge point in a watershed (Wanielista et al, 1997). According to the formula proposed de Soil Conservation Service and used also by Bilasco (2008): Tlag = Tc*0.6 (5), results that: $T_c = \frac{Tlag}{0.6} = \frac{2.23hours}{0.6} = 3.71hours = 233\min$.

4. CONCLUSIONS

Pecineaga river basin is characterised by a high potential for surface runoff, a precursor factor of flash-floods, due to high slope values which are favourable to accelerated flow, and due to its low surface.

Water time lag **(Tlag)** and time of concentration **(Tc)** values computed in this study are specific to the closure section of the river basin. The low values of these parameters demonstrate that, in case of torrential rainfall, accelerated flow and water concentration within valleys at the slope base would cause a rapid transmissivity of the flood wave from uphill to downstream and an exponential growth of the discharge in a short time.

Practically, **Tlag** and **Tc** values are used for the calibration of several rain-flow hydrological models, like Hec-HMS model, aiming to obtain, for a certain transversal river section, the flash-flood hydrograph.

One of the most popular method of computing flash-flood hydrographs is the Unitary Snyder Hydrograph Method. These mathematical rain-flow models are used especially in the case of hydrometrically unregistered river basins.

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