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ASSESSING MONTHLY AVERAGE RUNOFF DEPTH IN SĂRĂȚEL RIVER BASIN, ROMANIA

Romulus COSTACHE
Faculty of Geography, University of Bucharest
romuluscostache2000@yahoo.com

Abstract. Due to its geographic position, Romania is one of the most exposed to hidryk risk phenomena areas, especially floods and flahs floods. In this context, estimating surface runoff depth is very useful for highlithging vulnerable areas. In this study the estimation of the average monthly runoff depth was performed due to SCS-CN method adjusted with slope. This method is focused on the estimation of the runoff depth caused by precipitation, depending on the retention caused by various land use types and hydrological soil groups. In the present study, the SCS-CN method adjustment was possible due to formulas experimentally determined, based on field studies. The precipitation values contained in the SCS-CN formula, in order to estimate the average runoff depth, were spatially modelled by correlating the precipitation values from 11 meteorological stations with the stations' altitude. The spatially modelled values were integrated the formula for SCS-CN method adjusted with the slope value and, finally, the surface runoff depth was spatially modelled within Sărățel river basin. The highest values of the parameter are about 92 mm, in June, when precipitation records its highest values. The lowest value of this parameter is recorded in January and February, when precipitation quantity is also diminshed. The analysis of the runoff coefficient values demonstrates that surface runoff depth grows simultaneously with the precipitation values.

Keywords: *Sărățel river basin, Curve Number, slope, land use, hydrological soil group*

I. INTRODUCTION

Global climate changes cause the growth of torrential precipitation frequency, which causes flash-floods (Guhatakurta et al., 2011). Flash-floods occur due to surface runoff and flood propagation in the main collector river and represent the main cause of the lately global floods (Townsend and Walsh, 1998; Dutta et al., 2000; Dolcine et al., 2001; Sheng et al., 2001; Bryant and Rainey, 2002; Hudson and Colditz, 2003; Knebl et al., 2005). Consequently, the estimation of the surface runoff depth caused by a certain precipitation quantity is very important for hydrological prognosis. Romania is one of the most exposed to flash-floods and floods countries in Europe (Roo et al., 2007).The most severe floods in the past 10 years affected Romania in 2005 (Irimescu et al., 2005), 2006, 2010 (Romanescu et al., 2011) and 2014.

In the specialty literature, there are many studies regarding various methods for estimating surface runoff. One of the most used methods is the Curve Number, developed by Soil Conservation Services from USA. It is widely used in research studies (Kumar *et al*., 1991; Mack, 1995; Scozzafava and Tallini, 2001; Ranakrishnan *et al.* 2009; Duncan *et al.* 2013), also in Romania (Haidu *et al.* 2007; Bilaşco 2008; Minea, 2011; Gyory and Haidu, 2011; Domnița, 2012, Costache, 2014). Initially, in order to estimate the surface runoff depth, the method considers the hydrological soil group and land use/cover types. The minus of this method is not taking into consideration the slope values (Crăciun *et al*. 2009). The improvement of the method due to slope values, Huang *et al*. (2006) obtained proper results in a case study for the Loess Plateau in China.

The aim of the present study is to estimate the surface runoff depth in Sărățel river basin, by applying SCS-CN method adjusted with relief slope. The calibration of the initial formula with slope is described by the following formula: $CN_{2\alpha} = CN_2 * K$ (Huang *et al*. 2006), where:

$$K = \frac{322.79 + 15.63 * \alpha}{\alpha + 323.52},$$

$CN_{2\alpha}$ – the value of the curve number adjusted with the slope;
CN_2 – SCS-CN value for a soil with medium antecedent humidity;
α – average slope (%).

II. STUDY AREA

Sărățel river basin is located in the central south-eastern part of Romania (Fig. 1), overlain to the Curvature Subcarpathians. Sărățel river is a main tributary to Buzău river which belongs to Siret river basin. The surface of the study area is approximately 190 km^2, a characteristic value to small river basins.

Due to its lhe low surface, with 0.46 shape factor (Table 1), the study area is a river basin with high potential for flash-floods (Drobot, 2008). Regarding Sărățel river tributaries, Slănicelul and Gura Văii have a shape factor of approximately 0.67 (Table 1), which indicates an almost circular shape of the river sub-basins.

The altitudes within Sărățel river basin range between 148 m at the confluence of the main collector river with Buzău river and 913 m in the northern part of the river basin at the contact area with the Carpathians (Fig. 1).

Slope is another important factor that influences surface runoff. The average slope is 11°, meanwhile slope values exceeding 15°, with low potential for water retention and high susceptibility to surface runoff, occur on over 20% of the study area.

Precipitation is also an important factor due to its influence on runoff depth.The average multiannual sum of the precipitation (1960 – 2013) within Sărățel river basin ranges between 558,69 mm in low areas close to the confluence with Buzău river and 725,16 mm on the highest hilly areas.The forest coverage has an essential hydrological role, causing the increase of water retention potential (Arghiriade, 1980). Sărățel river basin has a forest coverage of only 27% (Corine Land Cover, 2006).

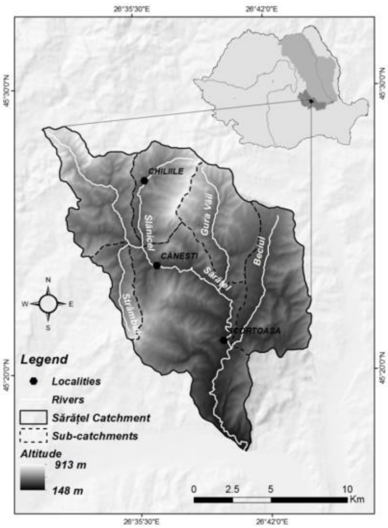

Fig. 1. Study area location

Table 1 Morphometrical features of Sărățel River Catchment and its main sub-catchments

River	*Sub-catchment*						*Hydrografic network*	
	Area (sq km)	Perimeter (km)	Rc (shape coefficient) Rc = $4\pi A/P^2$	Altitude (m) med	max	min	Length (km)	Imed (river slope) (m/km)
Slănicel	21.1	19.7	0.68	538	811	302	8.6	45.7
Gura Văii	26	22.2	0.66	490	811	238	9.3	57
Beciul	34.9	28.96	0.52	348	587	193	10	22.8
Strâmbul	9.78	16.81	0.43	468	760	317	6.4	55
Sărățel	188	72	0.46	415	913	148	34.6	30.2

In terms of pedology, over 78% of the soils within the study area have a predominant loamy – loamy-clay texture. Due to fine texture, these soils favour surface runoff by holding water infiltration during precipitation.

III. METHODOLOGY

In order to estimate the monthly average runoff depth, several main working steps were followed: assigning Curve Number values; adjusting Curve Number values for each surface by its average slope (%); determining the monthly evolution of the runoff depth by SCS-CN method adjusted with relief slope.

III. 1. Assigning Curve Number values

The Curve Number used by SCS-CN mathematical method, developed by USDA-Soil Conservation Services (SCS 1972), is an indicator with values between 0 and 100 depending on land use type (Fig. 2.a) and hydrological soil group (Fig. 2.b). The Curve Number was determined through experimental methods, by measuring runoff depth caused by a certain precipitation value (Huang et al., 2006).

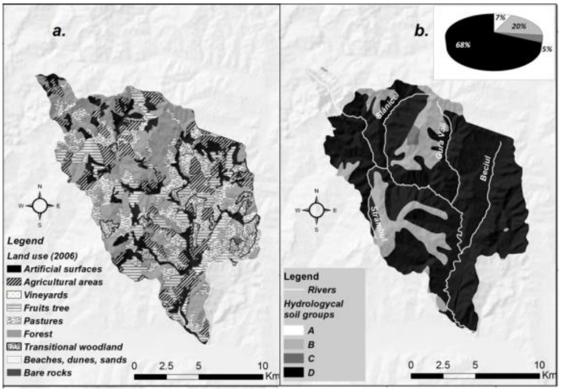

Fig. 2 Land use (a) and the hydrological soil group (b) within Sărățel river basin

This method is based on the equality relation between the ratio of the percent water that has been retained to the maximum potential retention and the ratio of percent water that ran off to the maximum rainfall available for runoff (NRCS, 1999). This relation is described by the ecuation:

$\frac{F}{S} = \frac{Q}{P - I_a}$, where:

F – is the amount of rainfall retained (after runoff begins);
S – is the maximum potential retention (after runoff begins);
Q – is the amount of runoff;
P – rainfall (mm);
I_a – initial abstraction (mm).

The closest values to 0 correspond to a high potential for water retention and high permeability, meanwhile the highest values of the CN, close to 100, are assigned to hydrological soil group D (predominantly clay texture). For Sărățel river basin, the CN values are contained in Table 2. In order to obtain the CN values, 2006 Corine Land Cover database was used for land use type data and the Map of Soils 1:200000 (ICPA, 2002) for the hydrological soil group. The lowest values of the Curve Number occur on coniferous areas with sandy texture and A soil group (Table 2). These values occur at the contact area between the Subcarpathians and the mountainous area (Fig. 3.a). Built-up and bare rock areas have the highest impermeability, so such areas overlain to predominantly clay texture were assigned the highest CN, close to 100 (Table 2).

Table 2. The values of the Curve Number of each intersection between the hydrological soil group and land use type (after Domnița 2012)

Landuse	***Soil Group***	***CN***	***Area(Ha)***
Built area	A	77	125.2
	B	85	343.8
	C	90	0.4
	D	95	1986.1
Non-irrigated arable land	D	87	115.8
Fruit trees	A	43	50.4
	B	65	195.9
	C	76	1.8
	D	82	2539.9
Pastures	A	49	47.6
	B	69	535.6
	D	84	3454.3
Complex cultivation patterns	A	67	104.9
	B	78	72.9
	C	85	0.9
	D	89	1349.5
Land principally occupied by agriculture, with significant areas of natural vegetation	A	52	13.5
	B	69	239.9
	D	84	959.2
Broad-leaved forest	A	42	279.5
	B	66	1540.6
	C	79	26.5
	D	85	2137.1
Coniferous	A	34	117.8
	B	60	230.0
	C	73	71.0
	D	79	639.9
Mixed forest	A	38	36.5
	B	60	61.7
	D	79	178.8
Natural grasslands	B	69	13.2
	C	79	21.0
Moors and heathland	A	49	110.0
Transitional woodland-shrub	B	60	44.3
	D	78	1162.4
Beaches, dunes, sands	A	63	0.8
	B	77	0.3
	D	88	39.4
Bare rocks	B	86	2.7
	D	94	26.0

III.2. Adjusting Curve Number values for each surface by its average slope (%)

Given the high slope values within the study area, where surface runoff is accelerated, slope was considered the most proper parameter to use for CN values adjusting. The average slope value (%) was computed for 590 surfaces within Sărățel river basin, which were assigned a CN value (Fig. 3.a) derived from the intersection of the land use and hydrological soil group polygon layers. Firstly, slope (%) was derived from a DEM with 10 m cell size, in raster format. Secondly, each surface with a CN value was assigned an average slope value, by Zonal Statistics in ArcGIS 10.1. By assigning the average slope value to the mentioned surfaces, this value could be used for CN values adjustment.
Therefore, the equation proposed by Huang *et al*. (2006) was used:

$$CN_{2\alpha} = CN_2 * \frac{322.79 + 15.63 * \alpha}{\alpha + 323.52} \quad \text{where:}$$

- $CN_{2\alpha}$ – the value of the Curve Number adjusted with slope;
- CN_2 – the SCS-CN value for a soil with antecedent humidity;
- α – the average slope (%) for each surface with a CN, this resulted form the intersection between land and hidrological soil group.

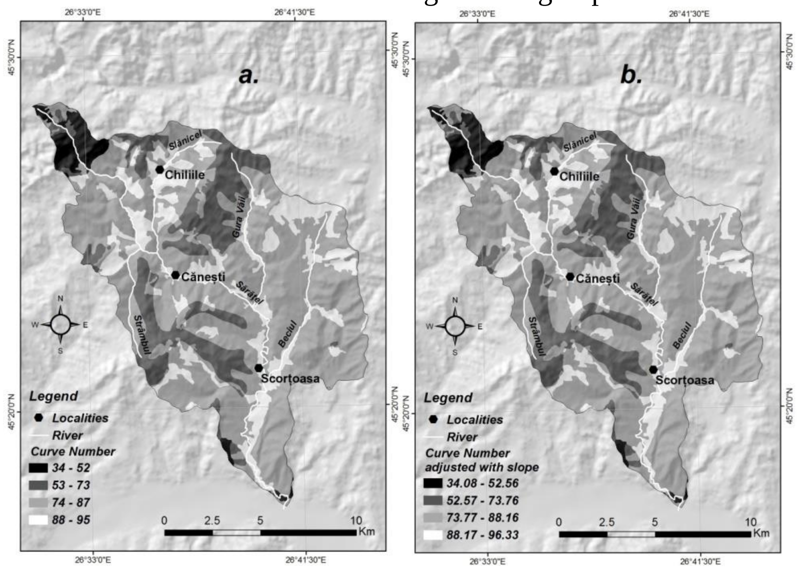

Fig. 3 The Curve Number values within Sărățel river basin (a.Initial Curve Number; b.Curve Number adjusted with slope value)

The $CN_{2\alpha}$ values for Sărățel river basin range between 34,08 and 96,33, meanwhile CN_2 values range between 34 and 94 (Fig. 2.a and b). On the whole, the results obtained by adjusting the CN with the average slope, demonstrate that for slope values under 5% the Curve Number values decrease, meanwhile they increase on areas with slope exceeding 5%. Within the study area, only 11 of the 590 surfaces resulted from the intersection between land use types and hydrological soil group recorded slope values under 5%, causing lower $CN_{2\alpha}$ values comparative to CN_2 values. In this case, we can conclude that, CN values increased by adjusting them the average slope values (%).

III.3. Determining the monthly evolution of the runoff depth by SCS-CN method adjusted with relief slope

In order to determine the monthly average runoff depth within Sărățel river basin, the SCS-CN method adjusted with relief slope was used. This method, widely used is based on the formula: Q = *P – Is – I – E – n* (Bilașco, 2008), where: Q – runoff depth (mm), P – precipitation, Is – water infiltration capacity, I – interception, E – evapotranspiration, n – other retentions of the precipitation. The mathematical SCS-CN model is based on the conventional representation of the maximum potential for water retention during rainfall (Bilașco, 2008), which depends on the land cover type and the hydrological soil group.

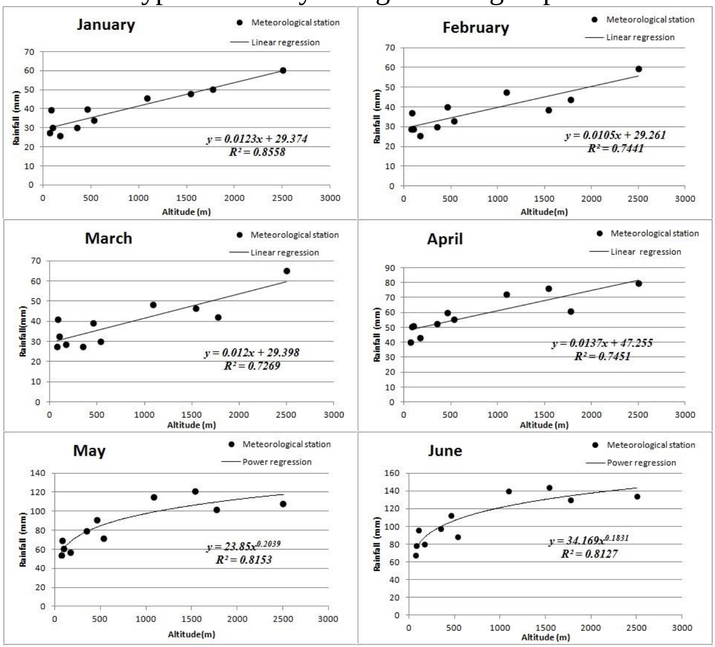

Fig. 4. The regression graphics between rainfall monthly average (January – June) and the altitude of meteorological stations

Mathematically, the estimation of runoff depth is based on the formula: $Q = \frac{(P - 0.2 * S)^2}{P + 0.8 * S}$ (Ponce and Hawkins 1996), where:

Q – runoff depth (mm);

P - precipitation (mm);

S – water retention potential (mm).

Water retention potential (S) calculation depends on the Curve Number given by the intersection between land use type and hydrological soil group. Its formula is:

$S = \frac{25400}{CN} - 254$ in the present study, the CN value was adjusted by relief slope (%), an equal value to $CN_{2\alpha}$, previously calculated in heading 3.2.

In order to determine the monthly average evolution of the runoff depth, the monthly average precipitation values, calculated in heading 3.3, were included in the SCS-CN equation. The monthly average precipitations values within Sărățel river basin were calculated and spatially modeled through Residual Kriging method. In order to apply this method, rainfall data were collected from 11 meteorological stations which are located near to study area. The dependence between monthly average rainfall amount and altitude for each considered meteorological station is shown in Fig. 4 and Fig. 5.

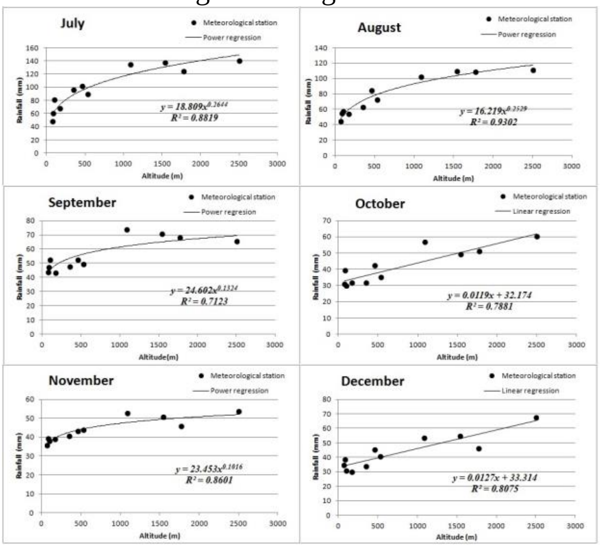

Fig. 5. The regression graphics between rainfall monthly average (July – December) and the altitude of meteorological stations

IV. RESULTS

By applying the methodology described above, based on SCS-CN method adjusted with slope, the monthly average runoff depth was computed (mm) and spatially modelled within Sărățel river basin (Fig. 6).

The temporal variation of the runoff depth is directly dependent on the monthly distribution of precipitation within the study area. Thereby, the highest values of the runoff depth are recorded in June, when the average precipitation value reaches 102,7 mm. In June, on the most susceptible surfaces to surface runoff, the runoff depth value is almost 92 mm (Fig. 6). In this case, surface runoff is approximately 90% of the average precipitation value.

The lowest values of the runoff depth occur, obviously, during months with the minimum precipitation values. These are January, February and March (Fig. 6). As a result, surface runoff is extremely reduced in the mentioned period on forested areas, when the average precipitation value is almost 34 mm, meanwhile the estimated lowest runoff depth values are near 0.001 mm (Fig. 6).

Regarding the monthly distribution of runoff depth within Sărățel river basin (Q – mm), there is a symmetry between its values and the values of the monthly average precipitation (Fig. 6), due to runoff depth direct dependence of precipitation quantity and intensity. Therefore, the monthly average runoff depth records minimum values in February, when only 8.58 mm of 33.7 mm average precipitation convert to surface runoff (Fig. 7). The highest value of the monthly average runoff depth is recorded in June, when over 55 mm of 102,7 mm average precipitation convert to surface runoff (Fig. 6). Hence, the surface runoff (mm) is over half of the average precipitation in June.

The value of the monthly runoff coefficient $C = \frac{Q_{(mm)}}{P_{(mm)}}$ between the average runoff depth and the average precipitation within Sărățel river basin demonstrates that surface runoff ratio from the precipitation increases once with the rainfall value (Fig. 8), due to rainfall exceeding the field capacity of soils, which generates significant runoff.

By subtracting the monthly average runoff depth from the monthly average precipitation $(F_{(mm)} = P - Q)$, the monthly average evolution of the amount of water loss by infiltration, interception and evapotranspiration was obtained (Fig. 9). During one year, the runoff depth exceeds water infiltration values only in June and July (Fig. 9). This means that, statistically, surface runoff can generate important water accumulation in river beds and flash-floods to the downstream areas.

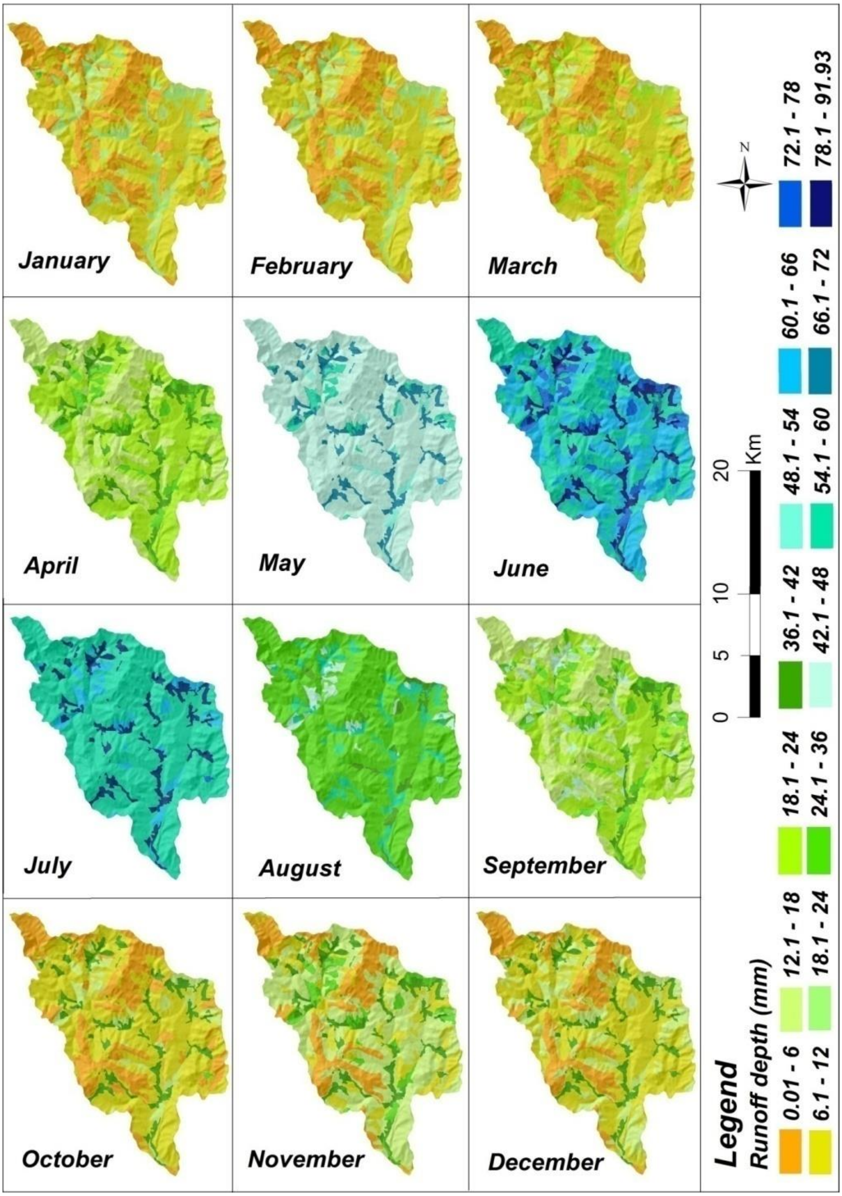

Fig. 6. The monthly distribution of the runoff depth within Sărățel river basin

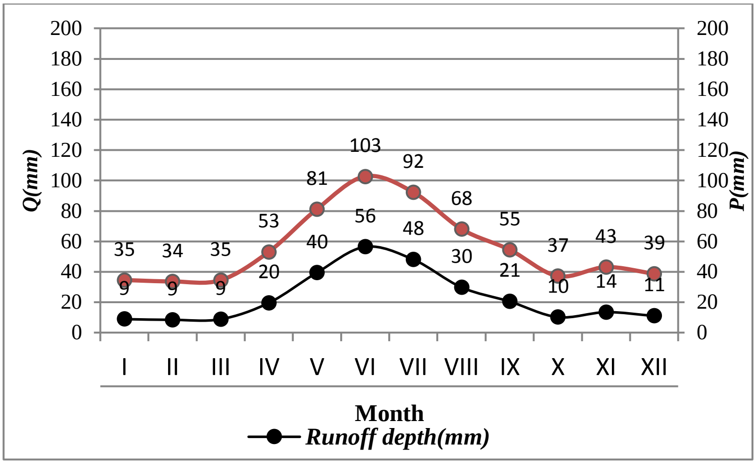

Fig. 7. The monthly evolution of the average precipitation and runoff depth within Sărățel river basin

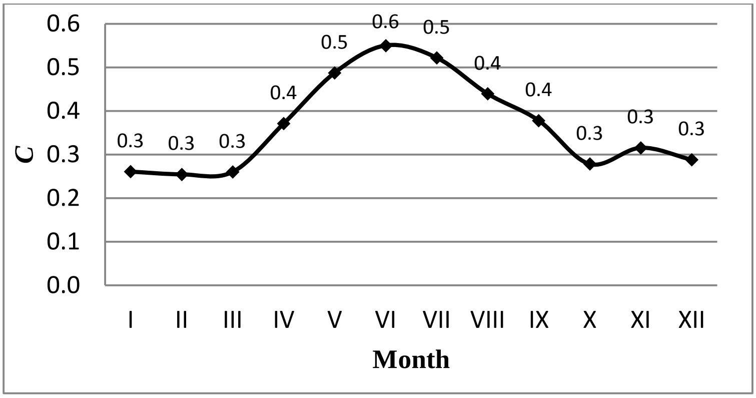

Fig. 8. The monthly values of runoff coefficient in Saratel River Catchment

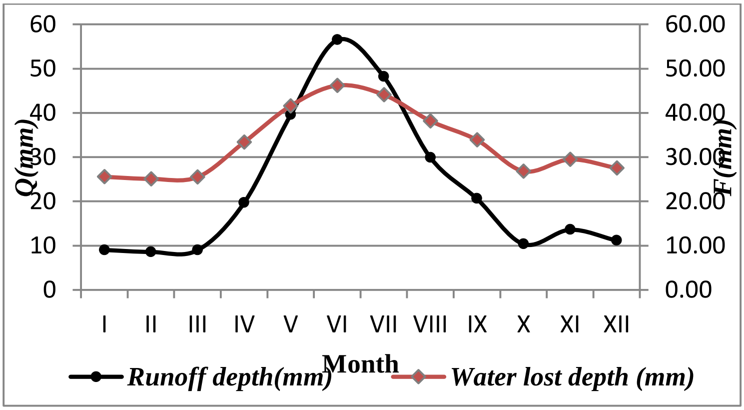

Fig. 9. The monthly evolution of the runoff depth (mm) beside the monthly evolution of water lost depth (infiltration, interception and evapotranspiration) (mm)

V.CONCLUSIONS

We can assert that the SCS-CN method adjusted with relief slope, used for runoff depth estimation, offers more adequate results than the classic SCS-CN method. The accuracy of the results is available especially for areas with important spatially varying slope values, where slope influence on surface runoff is obvious, such as in Sărățel river basin.

In the study area, the highest values of the runoff depth occur in June. It is also important to note that the average runoff depth ratio increases once with the monthly average precipitation. As a result, in case of important quantity of precipitation, water infiltration capacity decreases so much that surface runoff occurs, and furthermore, flash-flood occurrence at the base of the slope and propagation to downstream areas are possible. Also, the areas with high slope values, where surface runoff is active, are susceptible to geomorphologic phenomena such as: landslides, and muddy flows.

In terms of economical issues, the estimation of the runoff depth within Sărățel river basin, and also of the cumulated value from interception, infiltration and evapotranspiration (***F(mm)***) is very important due to agricultural land use.

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References

Arghiriade, C.: Rolul hidrologic al pădurii, Editura Ceres, București. 1977

Bilașco Ș.: Implementarea GIS în modelarea viiturilor pe versanți, Casa Cărții de Știință Cluj-Napoca, 2008

Bryant R. G. and Rainey M. P.: Investigation of flood inundation on playas within the Zone of Chotts, using a time-series of AVHRR; Remote Sensing of Environment, 82, 2-3, 360–375, 2002

Crăciun A. I., Haidu I., Bilaşco Ş.: The SCS-CN model assisted by G.I.S – alternative estimation of the hydric runoff in real time, Geographia Technica, 3, 1, 1-7, 2007

Crăciun A. I., Haidu I., Magyari-Saska Zs., Imbroane A. I.: Estimation of runoff coefficient according to soil moisture using GIS tehchniques, Geographia Technica, 9, 2, 1-10, 2009

Costache R.: Using GIS techniques for assessing lag and concentration time in small river basins. Case study: Pecineaga river basin, Romania, Geographia Technica, 9, 1, 31-38, 2014

Dolcine L., Andrieu H., Sempre-Torres D., Creutin D.: Flash flood forecasting with coupled precipitation model in mountainous Mediterranean basin; Journal of Hydrologic Engineering, 6, 1, 1–10, 2001

Domnița M Runoff modeling using GIS. Application in torrential basins in the Apuseni Mountains, Ph.D Thesis, Cluj Napoca, 2012

Dutta D., Herath S., Musiake K. : Flood inundation simulation in a river basin using a physically based distributed hydrologic model; Hydrological Processes, 14, 3, 497–519, 2000

Drobot R.: Ways of determining torrential river basins in which there are located human settlements prone to flash floods, (in romanian). Monitorul Oficial nr. 647/11.IX, 2008.

Duncan O. J., Tollner E., Ssegane H., McCutcheon S C.: Curve Number approaches to estimate drainage from a Yard Waste Composting Pad; Applied Engineering in Agriculture Vol.29, No.2, 201-208, 2013

Guhatakurta P, Sreejith O. P., Menon P. A.: Impact of climate change on extreme rainfall events and flood risk in India; Journal Earth System Science, 12, 3, 359-373, 2011

Gyori Maria-Mihaela, Haidu I.: Unit hydrograph generation for the ungauged subwatershed in the Monroștia Basin; Geographia Technica, 14, 2, 23-29, 2011

ICPA Bucureşti 2007 The soils map in electronic format, (1:200,000)

Irimescu A., Stăncălie Gh., Crăciunescu V., Flueraru C., Anderson E.:, *The use of Remote Sensing and GIS techniques in flood monitoring and damage assessment: a study case in Romania*, Threats to Global Water Security NATO Science for Peace and Security Series C: Environmental Security, 167 – 177, 2009

Huang M., Jacgues G., Wang Z., Monique G.: A modification to the soil conservation service curve number method for steep slopes in the Loess Plateau of China; Hydrological Processes, 20, 3, 579-589, 2006

Hudson, P. F. and Colditz R. R.: Flood delineation in a large and complex alluvial valley, lower Panuco basin, Mexico; Journal of Hydrology, 280, 229–245, 2003

Knebl M R, Yang Z.-L, Hutchison K., Maidment D. R.: Regional scale flood modeling NEXRAD rainfall, GIS, and HEC-HMS/RAS: a case study for San Antonia River Basin Summer 2002 storm event; Journal of Environmental Management, 75, 325-336, 2005

Kumar P., Tiwart K. N., Pal D. K.: Establishing SCS Runoff Curve Number from IRS Digital Data Base, Journal of the Indian Society of Remote Sensing**,** 19, 4, 245-252, 1991.

Mack Mary J.: HER—Hhydrologic evaluation of runoff; The Soil Conservation Service Curve Number technique as an interactive computer model; Computers&Geosciences, 21, 8, 929-935, 1995.

Minea G.: Bazinul hidrografic al râului Bâsca - Studiu de hidrogeografie, Teză de doctorat, Universitatea din Bucureşti, Facultatea de Geografie, Bucureşti, 2011

Natural Resources Conservation Service : Engineering Hydrology Training Series, Module 205 – SCS Runoff Equation, 1999.

Ponce V. M. and Hawkins R. H.: Runoff curve number: has it reached maturity; Journal of Hydrologic Engineering, 1, 1, 11–19, 1996.

Ranakrishnan D., Bandyopadhyay A., Kusuma K. N.: SCS-CN and GIS-based approach for identifying potential water harvesting sites in the Kali Watershed, Mahi River Basin, India; Journal Earth System Science, 118, 4, 355-368, 2009.

Roo A. D., Barredo J., Lavalle C., Bodis K., Bonk R.: Potential flood hazard and risk mapping at Pan-European scale, Digital terrain modelling Development and applications in a policy support environment, Peckham, R. J. and Jordan, G. (Eds), Springer Berlin Heidelberg, pag. 183-202, 2007.

Romanescu Gh., Jora I., Stoleriu C.: The most important high floods in Vaslui river basin - causes and consequences, Carpathian Journal of Earth System Science, 6, 1, 119 – 132, 2011

Scozzafava M and Tallini M.: Net Infiltration in the Gran Sasso Massif of Central Italy using Thornthwaite water budget and curve-number method; Hydrogeology Journal, 9, 5, 461- 475, 2001.

Sheng, Y, Gong P., Xiao Q., Quantitative dynamic flood monitoring with NOAA AVHRR; International Journal of Remote Sensing, 22, 9, 1709–1724, 2001.

Townsend P. A. and Walsh S. J.: Modeling floodplain inundation using an integrated GIS with radar and optical remote sensing; Geomorphology, 21, 3-4, 295–312, 1998.

***EEA, Corine Land Cover, 2006

***ICPA, Romania Soil Map, 2002

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