

## IMPLEMENTATION OF THE SCS-CN MODEL IN THE G.I.S. ENVIRONMENT

*Cosmin-Marian PAERELE, Eng., Romanian Waters Administration, Bacau Water Directorate, cosmin.paerele@gmail.com*

*Marius TELISCA, Lect. PhD Eng., Technical University "Gheorghe Asachi" of Iasi, Romania, mtelisca@tuiasi.ro*

*Catrinel-Raluca GIURMA-HANDLEY, Prof. PhD.eng., Technical University "Gheorghe Asachi" of Iasi, Romania, giralcat@yahoo.com*

**Abstract:** Brief description of the theme of the article and optional of the conclusions, in maximum ten rows. The hydrographic method of the SCS unit is used to transform precipitation into surface runoff. CN (Curve Number) represents a dimensionless index, with values between 0 and 100. CN depends on both the use of the land and the hydrological group of the soil and reflects the potential of water drainage on different lands. C.N values vary directly in proportion to the leakage potential and inversely proportional to the infiltration coefficient, having maximum values for soil class D or for urban areas, waterproofed. The paper presents a method of automatic calculation of the CN parameter using ArcGIS program.

**Keywords:** GIS; curve number; runoff; water drainage;

### 1. Introduction

The mathematical hydrological model, SCS-CN was developed by the Natural Resources Conservation Service (NRCS), also known as the Soil Conservation Service SCS, to provide users with procedures for calculating the maximum flow and volume of torrential rains, for a specific territory (Hawkins & Ponce, 1996).

The hydrographic method of the SCS unit is used to transform precipitation into surface runoff. Because the area has a low base flow, the base model was not used. The transformation method requires determining the delay time as input. SCS has developed a relationship between concentration time ( $T_c$ ) (Equation 1) and delay time ( $T_{lag}$ ) (Equation 2). The Kirpich formula is used to estimate the concentration time based on the characteristics of the sub-basin, including topography and coverage length.

$$T_c = 0,0078 * (L^{0,77} / S^{0,335}) \quad (1)$$

$$T_{lag} = 0.6 * T_c \quad (2)$$

where:

L – the riverbed length (m), S – the slope (%).

Initially, the method was developed as a methodology for transforming torrential rains from a certain period of time into runoff taking into account vegetation and soil, its purpose being to identify the suitable areas for agricultural land use in the US. Due to the high accuracy of the model, it has been used extensively, exceeding the US borders, in order to model and simulate extreme hydrological events.

Since the appearance of the model, in 1954 and so far there have been many revisions of the model, depending on the need to use it in one or another of the applicability areas, the method being based on the water balance relationship (Equation 3):

$$Q = P - I_s - I - E - n (m^3) \tag{3}$$

where:

Q – volume, P – rainfall,  $I_s$  – soil infiltration capacity, I - interception, E – evapo-transpiration, n - other retention of rainfall.

## 2. Curve number concept

Curve Number (CN) represents a dimensionless index, which can take values between 0 and 100. CN depends on both the use of the land and the hydrological group of the soil and reflects the potential of water drainage on different lands (Table 1). CN values vary directly in proportion to the runoff potential and inversely proportional to the infiltration coefficient, having maximum values for soil class D or for urban, waterproofed areas. The Curve Number may represent an average value for a sub-basin or an individual cell for part of a sub-basin (Chendes, 2007; Diaconu and Şerban, 1994). In addition, the basin and channel characteristics along with a spreadsheet template are linked to HEC-GeoHMS to assist the user in estimating the initial concentration time values. Also, the basin and channel characteristics can be used to calculate CN-Lag parameters and simple Muskingum-Cunge prismatic routing parameters.

Table 1- Informations regarding generation of CN

Name	Format	Attributes
Soil	Vector	Hydrological group: A, B, C, D
Land use	Vector	Type of use: Cereals, Agricultural crops, Meadow, Vegetables, Unused, Forests, Natural pastures
CN	Numeral	Type of use + Hydrological group

The soil moisture conditions are outlined as a very important factor in the water infiltration process, being estimated using the AMC (Antecedent Moisture Conditions) index, which is analyzed according to the precipitation quantities of the last 5 days; AMC I, corresponds to the dry soil with rainfall <12.7 mm during the summer season and rainfall <35.6 mm during the fall and spring rainfall season; AMC II - soils with normal infiltration conditions specific to precipitations between 12.7-28 mm in the light rain period and 35.6-53.4 mm in the heavy rain period; AMC III corresponds to saturated soil with precipitation >28 mm when there is no heavy rainfall and precipitation >35.4 when large amounts of precipitation are recorded (Craciun, 2011, Giurma, 2008).

Table 2 - The CN indicator derived based on the land use and soils according to their hydrological conditions (Man, T., Alexe, M., 2006)

Land use	Land management	Hydrological condition	Hydrological group of soil			
			A	B	C	D
Unused		-	77	86	91	94
Agricultural crops	Lines	Weak	72	91	88	91
		Good	67	78	85	89
	On level curve.	Weak	70	79	84	88
		Good	65	75	82	86
	Terrace	Weak	66	74	80	82
		Good	62	71	78	81
Cereals	Lines	Weak	65	76	84	88

		Good	63	75	83	87
	On level curve.	Weak	63	74	82	85
		Good	61	73	81	84
	Terrace	Weak	61	72	79	82
		Good	59	70	78	81
Meadows or vegetables	Lines	Weak	66	77	85	89
		Good	58	72	81	85
	On level curve.	Weak	64	75	83	85
		Good	55	69	78	83
	Terrace	Weak	63	73	80	83
		Good	51	67	76	80
Natural pastures		Weak	68	79	86	89
		Average	49	69	79	84
		Good	39	61	74	80
	-On level curve	Weak	47	67	81	88
		Average	25	59	75	83
		Good	6	35	70	79
Grassland		Good	30	58	71	78
Forest		Weak	45	66	77	83
		Average	36	60	73	79
		Good	25	55	70	77

### 3. Description of the study area

The Uz catchment is located in the western part of Bacău County, in the Comănești - Dărmănești depression, located in the central group of the Oriental Carpathians. The total surface of the catchment area is 475 km<sup>2</sup>, located on the territory of three counties, Bacău County, Covasna County and Harghita County (Figure 1).

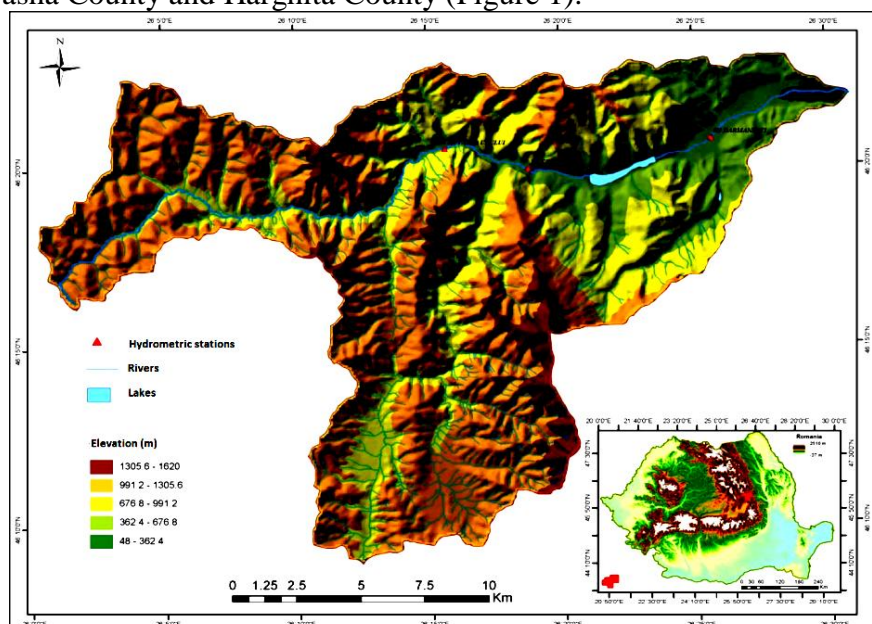


Figure 1 Uz catchment

The Uz river springs from the Ciuc Mountains, at an altitude of 1160 m and flows into the Trotuș River at an altitude of 340, with a level difference between the spring and the influx of 820 m [2]. Its springs are located on the territory of Harghita County, in the area of Eghersec, and flows for 46 km, until it spills into the Trotuș River near the city of Dărmănești.

#### 4. Using G.I.S. to calculate CN number

For the implementation of the model on the hydrographic basins studied, the ArcCN-Runoff was used extension, running under ArcG.I.S.

The extension realized by Xiaoyong Zhan and Min-Lang Huang in 2004, performs the calculation (Figure 2) of the maximum flow and volume based on the calculation of the "curve number - CN" for each spatial unit using a database (soil and land use mode) vector type to keep intact the irregular boundaries of the surfaces.

The vectors representing the territorial extension of the soil categories have created an attribution database with information related to the soil hydrological group, depending on the capacity of water infiltration in the respective soil profile.

The land use represents the degree and type of vegetal cover of the surfaces of a collecting basin (Giurma-Handley, 2017). The land use was derived from the CORINE Land Cover database and adapted to the requirements of the SCS-CN method.

Applying to the GIS methodology, for calculating the maximum leakage by means of the SCS-CN method, it was realized the intersection of the layers representing the soils and the use of the lands, which had previously been cut by the area of interest, to represent a unitary basis of calculation in to be able to identify the surfaces with the characteristics of the two spatial entities, the attribute table storing information about the type of land use and the soil hydrological group.

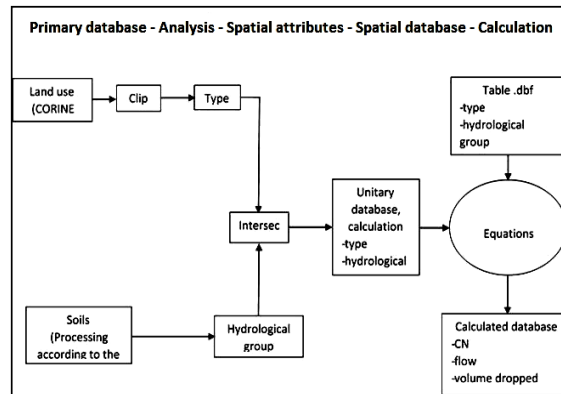


Figure 2 - Hydrological modeling scheme

It was necessary to have themes (characteristic layers) regarding the land use on the Uz river catchment respectively existing information on the soils.

The spatial analysis was continued with the automatic identification of the curve number and the creation of a column in the attribute table with the specific value of each combination between layers (Table 3), using as input element the .dbf table created in the database realization stage.

Table 3 - GIS attributes for CN generation

Row ID	Object ID	Lu value	Description	A	B	C	D
1	1	2	Discontinued urban space	77	85	90	95
2	2	22	Mixed forest	38	62	75	81
3	3	21	Coniferous forests	34	60	73	79
4	4	20	Deciduous forests	42	66	79	85
5	5	16	Pastures	49	69	79	84
6	6	18	Agricultural land with vegetation	52	69	79	84
7	0	25	Transitional woodland/shrub	45	60	73	78
8	0	23	Natural grassland	49	69	79	84

9	0	17	Complex agricultural areas	67	78	85	89
10	0	9	Industrial and commercial units	81	88	91	93
11	0	4	Transport networks	83	89	92	93

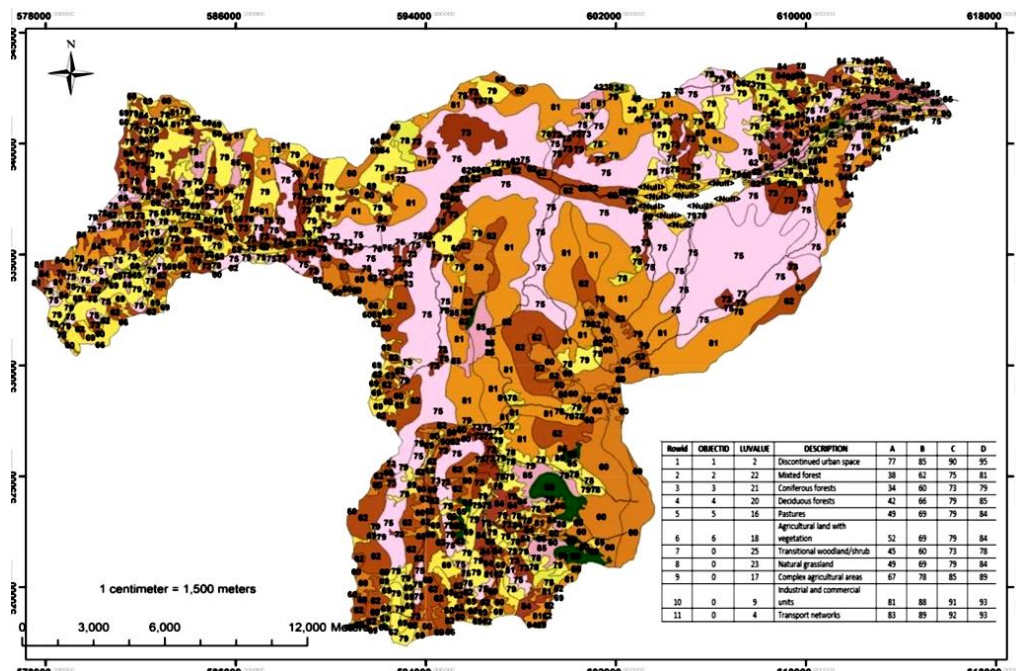


Figure 3 - Vector type map on CN

After the creation of the characteristics thematic layer, the CN is generated in raster format for automatic data extraction. The vector type C.N layer (Figure 3) is transformed into a grid layer (Figure 4), which allows the automatic extraction of C.N values at the level of small catchments.

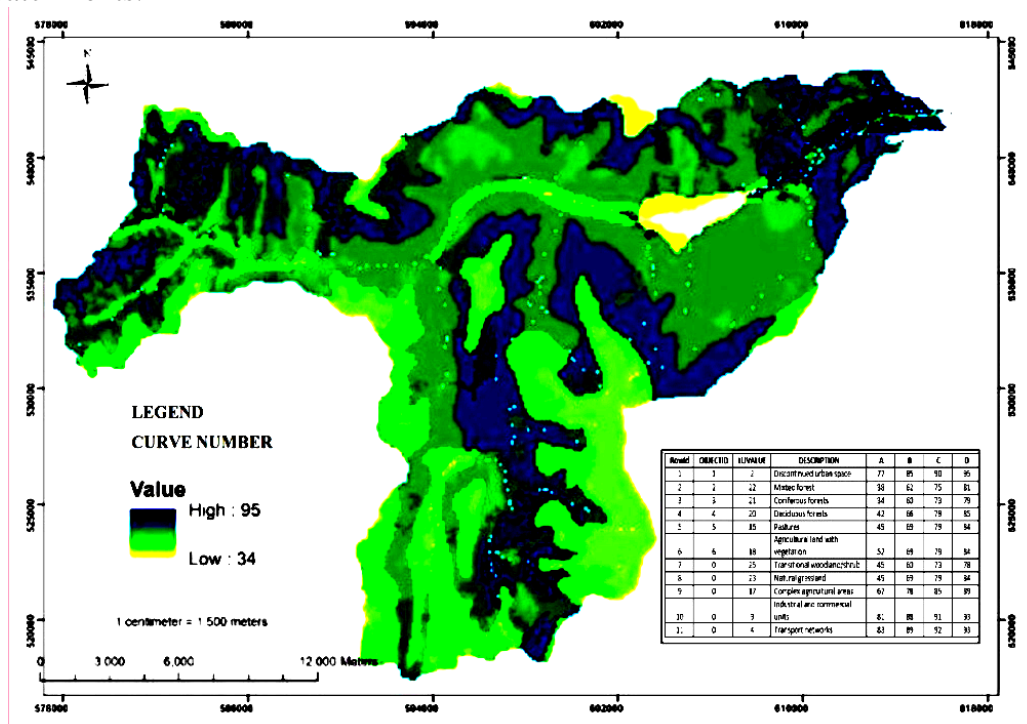


Figure 4 - C.N raster map for automatic data extraction

As can be seen in figure 3, the value of the number C.N is between 34 and 95 - where value 95 represents discontinuous urban space and value 34 represents coniferous forests.

Verification of the correctness and calibration of the data for the determination of the number C.N was also performed with the help of ortho-photo-plans (Figure 5).

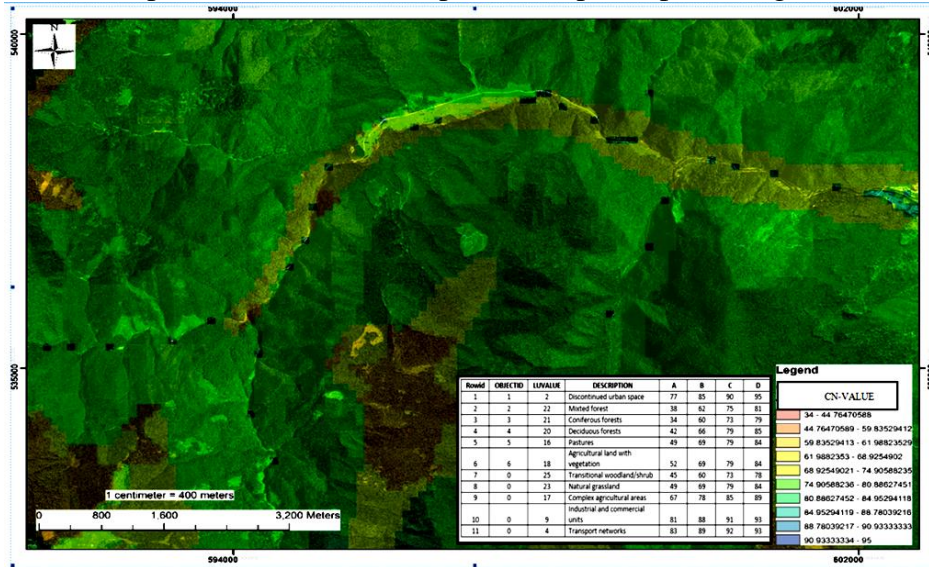


Figure 5 - Calibration based on orthophotoplans

The next step is to automatically extract from the newly created raster the C.N values, being exported from the G.I.S environment in the HEC-HMS hydrological modeling program (Figures 6 and 7).

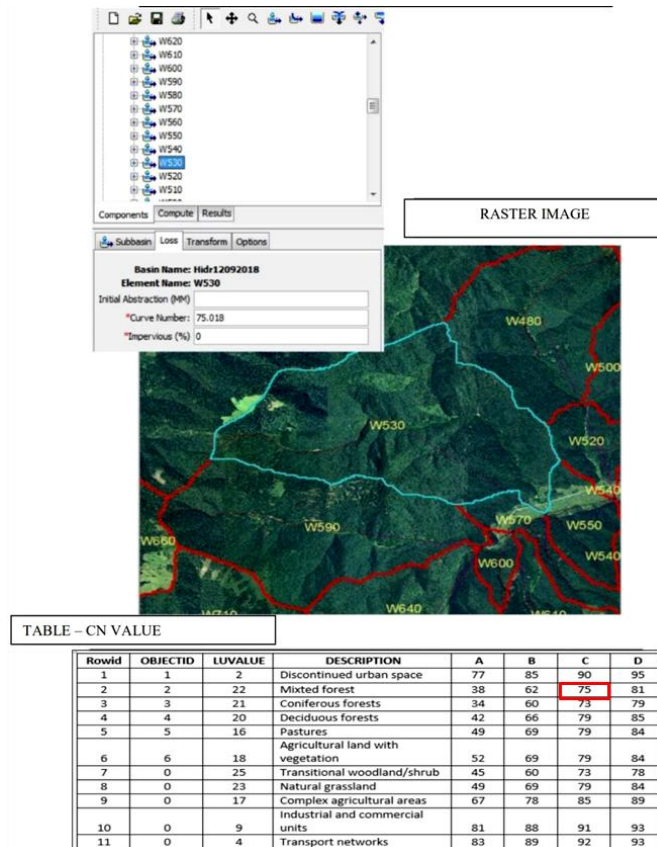


Figure 6 - Calibration of CN number for W530 sub-basin

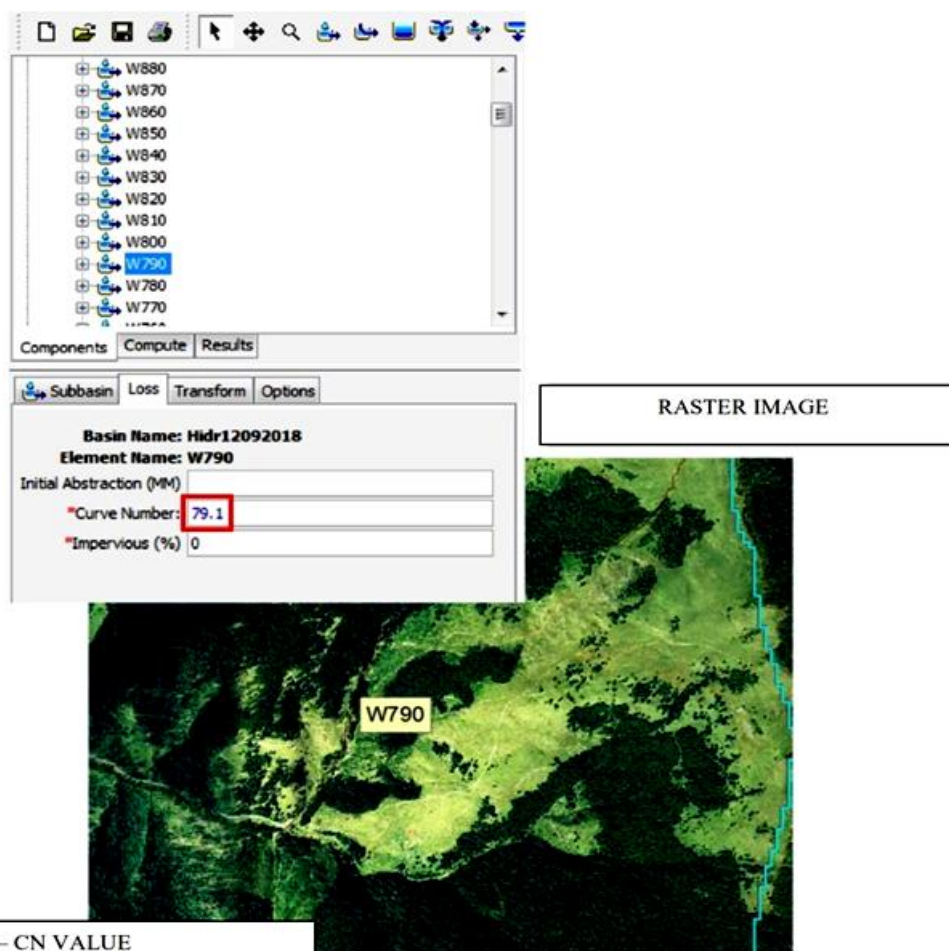


TABLE – CN VALUE

Rowid	OBJECTID	LUVALUE	DESCRIPTION	A	B	C	D
1	1	2	Discontinued urban space	77	85	90	95
2	2	22	Mixed forest	38	62	75	81
3	3	21	Coniferous forests	34	60	73	79
4	4	20	Deciduous forests	42	66	79	85
5	5	16	Pastures	49	69	79	84
6	6	18	Agricultural land with vegetation	52	69	79	84
7	0	25	Transitional woodland/shrub	45	60	73	78
8	0	23	Natural grassland	49	69	79	84
9	0	17	Complex agricultural areas	67	78	85	89
10	0	9	Industrial and commercial units	81	88	91	93
11	0	4	Transport networks	83	89	92	93

Figure 7 - Calibration of CN number for W790 sub-basin

## 5. Conclusions

The vectors representing the territorial extension of the soil categories created an attribution database with information related to the soil hydrological group. Applying the G.I.S. methodology, for calculating the maximum runoff by means of the SCS-CN method, the intersection of the layers representing the soils and the land use mode was achieved. Spatial analysis was continued with the automatic identification of the number of the curve, verifying the correctness and calibration of the data with the help of orthophotoplanes. The automatic extraction from the newly created raster of the C.N values, led to the possibility of being exported from the G.I.S environment in the HEC-HMS hydrological modeling program.

As so, the presented tool can be easily used to further calculation and modeling without the manual input of the required data.

## 6. References

1. Chendeş V., *Liquid and solid runoff in the Curvature Subcarpathians. Ph.D Thesis, Romanian Academy, Institute of Geography, Library of the Institute of Geography, Bucharest, 2007 (in Romanian);*
2. Crăciun, I., *Estimarea indirectă, cu ajutorul GIS, a umezelii solului în scopul modelării viiturilor pluviale, [Indirect estimation, using the GIS, of soil moisture for modeling of rainfall floods ],Cluj-Napoca, 2011(in Romanian);*
3. Diaconu, C., & Şerban , P., *Sinteze și regionalizări hidrologice,[ Hydrological synthesis and regionalization] Bucureşti, Technical Publ. house, 1994 (in Romanian);*
4. Giurma I. ş.a., “Hydrology”, *Politehniun Publ. House, Iasi, 2008;*
5. Giurma-Handley R.C., Giurma I., Bofu C., *Metode și modele probabilistice ale sistemelor de mediu, [Probabilistic methods and models of environmental systems], Politehniun Publ. House, Iasi, 2017(in Romanian);*
6. Man, T. & Alexe, M. *Modelare hidrologică în GIS. Implementarea modelului SCS-CN pentru evaluarea scurgerii, [GIS hydrological modelling. SCS-CN method implementation to evaluate the discharge], Geographia Technica, No. 1, 2006. (in Romanian) ;*
7. Hawkins, R. H., Ponce, V. M., *Runoff curve number: has it reached maturity, Journal of Hydrologic Engineering(1996);*
8. Xiaoyong Zhan Min-Lang Huang *ArcCN-Runoff: an ArcGIS tool for generating curve number and runoff maps, Environmental Modelling & Software,Volume 19, Issue 10, October 2004, Pages 875-879.*