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G.I.S APPLICATION IN ORDER TO DETECT THE SMALL HYDROGRAPHIC BASINS MENACED BY HIGH FLOOD DURING TORRENTIAL RAIN EVENTS

BY

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Abstract: This study aims the possibility of applying G.I.S technology in order to detection those hydrographic basins, that by their characteristics of land use, hydrologic soil conditions, morphometry, give the optimal conditions for flash flood manifestation. The algorithm is based on the integration of a method that takes into account some physical parameters of the basin (physiographical method) in G.I.S medium.

Key words: GIS, hydrographic basin, torrential events, algorithm.

1. Introduction

The evaluation of high flood produced in small basins, and in the same time finding some alternatives of their real time estimation, are usual interests for hydrologist researchers from Romania. Torrential rain events have the biggest impact in these basins, due to their high intensity, favoring the generation of “flash flood”.

For estimating the high flood in small basins there had been developed a number of stochastique and determinist methods in the same time (*Diaconu C., Şerban P., 1994; Mic Rodica, Corbuş C., 1999*).

The use of G.I.S for evaluating high floods of high flood risk, takes part of a group of recently concerns, knowing that we assist of an accelerate development of this domain in the last 10-15 years (*Haidu I., Sorocovschi V., Imecs Z., 2003, Păcurar V.D., 2005 ş.a.*).

Drobot R., 2007 identifies the characteristics of “flash flood” in torrential rain conditions as followed: the area of basin varies from some Km^2 to 200 Km^2; the time of concentration is smaller then 6 hours; the rainfall duration is smaller than the time of concentration of basin (maximum 3 hours); the depth of high flood generated is > 100 mm.

A number of researchers, especially French ones, use for small hydrographic basins the concept of *"bassin versant"* (*Ambroise, B., 1998, Laborde J. P., 2000*).

Some elements that contribute to producing and evolution of high flood in these basins are: the area and basin shape index, slope side, slope stream channel, drainage density, afforestation index, hydro-physical soil characteristics. On these adds some aspects of exploitation of environment by humans: the lack of anti-erosion means and of torrents correction, deforestations, inadequate agricultural activities, buildings or residual deposits near by the banks of rivers.

The effect of these factors is reflected in the increasing of runoff speed, decreasing of time of concentration, increasing of runoff coefficient, decreasing the vegetation and soil water retention capacity, increasing the erosion process that goes to increasing of alluvial deposits etc.

The main *objectives* of this study refer to:

• the analysis, using G.I.S, of the parameters that compose physiographical method;

• the study of some basins that, by their reduced surface, can be constitute areas of flash flood manifestation;

• the detection of basins with the biggest flood vulnerability in the conditions of torrential rains;

The detection of the basins susceptible for flood is very important in forecast activity, helping to the emission of warnings that can limit the damages induced by the flood. In the same time, it can be initiate some gauges of erosion rate reduction by increasing the afforestation areas, regularization of the river etc. For authorizing the houses construction, it would be recommended to take into account the risk of such hydrological events.

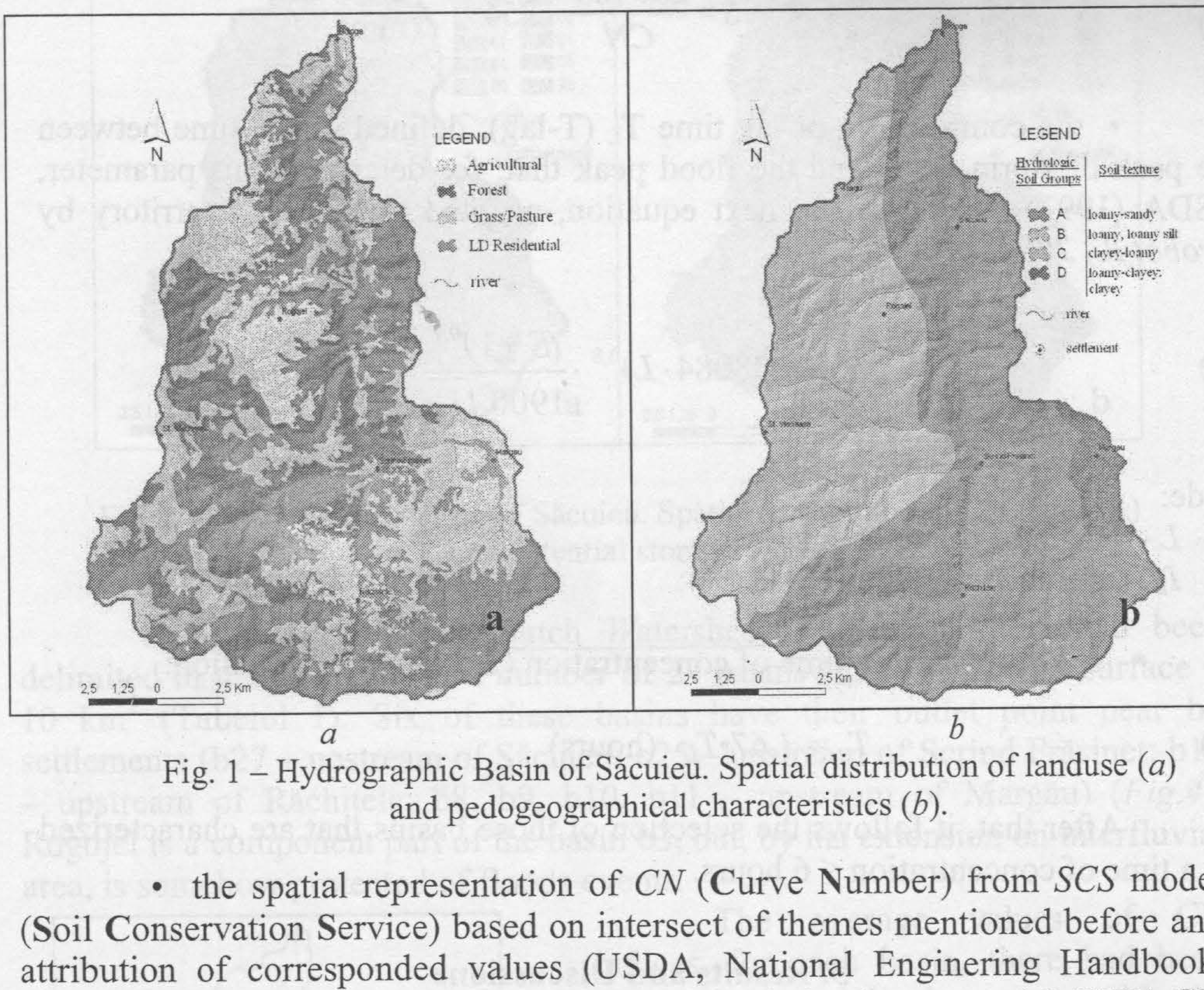
The area proposed for analysis corresponds to Hydrographic Basin of Săcuieu (Henţ), a component part of Vlădeasa Massif (in Apuseni Mountains), having a surface of approximately 220 km^2.

2. Methodology

For identify the hydrographic basins menaced by high flood generated by torrential rain events, it was used the *physiographic method*. This method is based on the analysis of some physico-geographical elements of the basin such as: *landuse, soil texture, hydrologic soil groups, soil and vegetation water storage capacity, lag time, time of concentration.*

The main steps in algorithm application are:

• generate the layers that refer to landuse and to Hydrologic Soil Groups (HSG) (Fig.1). According to USDA the soils can be classified, by water infiltration capacity, in four groups: *A* – high capacity, specific to sandy or loamy-sandy texture, infiltration rate >7,62 mm; *B* – medium capacity, specific to loam and sandy-loamy texture infiltration rate 3,81- 7,62 mm; *C* – low capacity, specific to clayey-loamy texture, infiltration rate 1,27-3,81 mm; *D* – very low capacity, specific to loamy-clayey and clayey texture, infiltration rate 0-1,27 mm.



a *b*

Fig. 1 – Hydrographic Basin of Săcuieu. Spatial distribution of landuse (*a*) and pedogeographical characteristics (*b*).

• the spatial representation of *CN* (**C**urve **N**umber) from *SCS* model (**S**oil **C**onservation **S**ervice) based on intersect of themes mentioned before and attribution of corresponded values (USDA, National Enginering Handbook, 1997). In this study for spatial repartition of CN index it was used *L-THIA GIS* (*L*ong-*T*erm *H*ydrologic *I*mpact **A**ssessment) extension. Through this extension, it was reclassified, by attributing values from 1 to 4 (for Hydrologic Soil Groups), respective from 1000 to 8000 (for landuse) and sum those two themes (Fig.2).

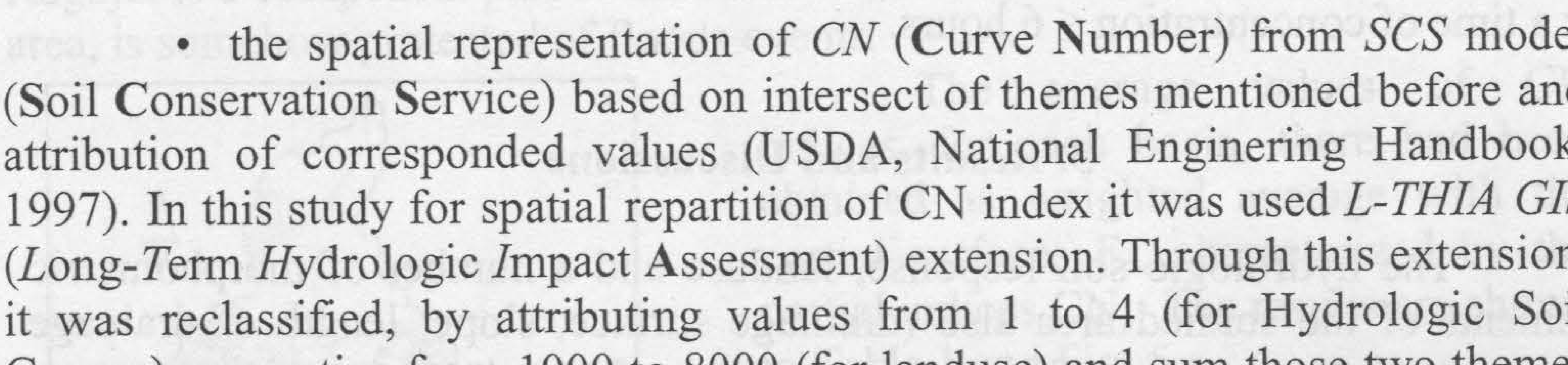


Fig. 2 – Sum of layers necessary for computation of CN index.

• the computation of potential watershed storage **S** using the equation:

(1) $$S=\frac{25.400}{CN}-254 \quad \text{(mm)}$$

• the computation of lag time T_L (T-lag), defined as the time between the peak of storm event and the flood peak that; for determine this parameter, USDA (1997) developed the next equation, adapted to Romania territory by *Drobot R., 2007*:

(2) $$T_L=(3{,}28084\cdot L)^{0{,}8}\cdot\frac{(S+1)^{0{,}7}}{1900\sqrt{I_B}} \quad \text{(hours)}$$

unde:

L – length of drainage line (m);

I_B – average watershed slope (%);

• the computation time of concentration (T_c) using the equation:

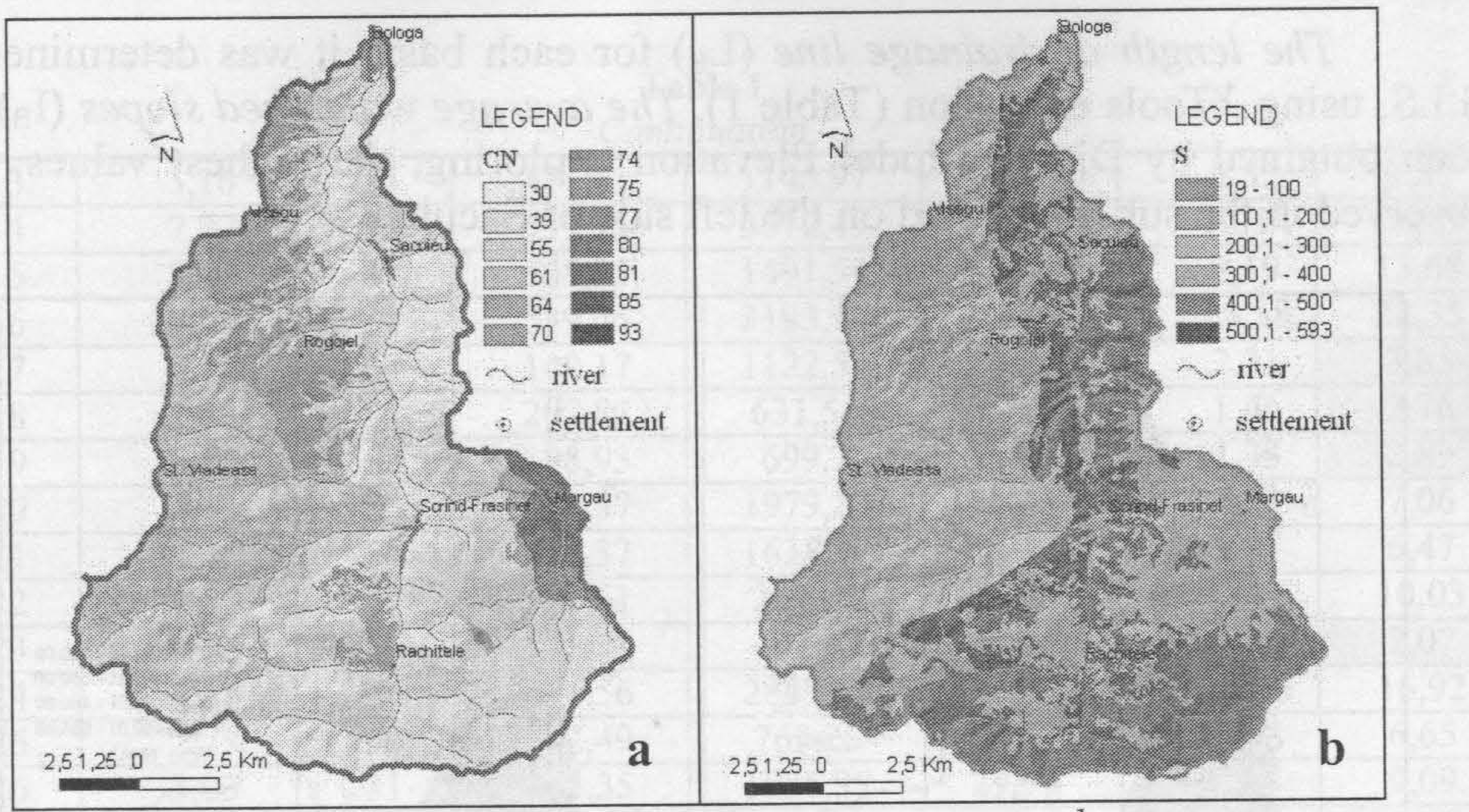
(3) $$T_c=1{,}67\cdot T_L \quad \text{(hours)}$$

After that, it follows the selection of those basins that are characterized by a time of concentration ≤ 6 hours.

3. Results and Discussions

The hydrologic soil response, landuse and a number of morphometric elements of the studied area also (drainage surface, slope, length of drainage line etc.) all these are variables that are used to determine a lot of parameters, such a soil and vegetation water retention capacity, lag time, time of concentration etc.

The computation of potential storage (**S**) was realized starting from CN index repartition (Fig.3*a*), using equation (1). Following the results (Fig.3*b*), we can observe the highest water potential storage in the afforestation areas from the eastern part of the basin, overlapped to loamy-sandy soil; these go to a reduction of runoff potential, favoring infiltration process. The lowest values correspond to agricultural areas and to settlements. Soil texture is loamy either loamy-clayey or clayey, having low infiltration rate, fact that can determine an acceleration of runoff.



a *b*

Fig. 3 – Hydrographic Basin of Săcuieu. Spatial distribution of CN index (*a*) and potential storage (*b*)

Using G.I.S function Batch Watershed Delineation there had been delimited in the studied area a number of 27 basins (*b1 ... b27*) with surface < 10 km^2 (Tabelul 1). Six of these basins have their outlet point near by settlements (b27 – upstream of Săcuieu; b25 – upstream of Scrind Frăsinet; b14 – upstream of Răchiţele; b8, b9, b10, b11 – upstream of Margău) (*Fig.4*). Rogojel is a component part of the basin b3, but, by his extension on interfluvial area, is somehow protected of floods events.

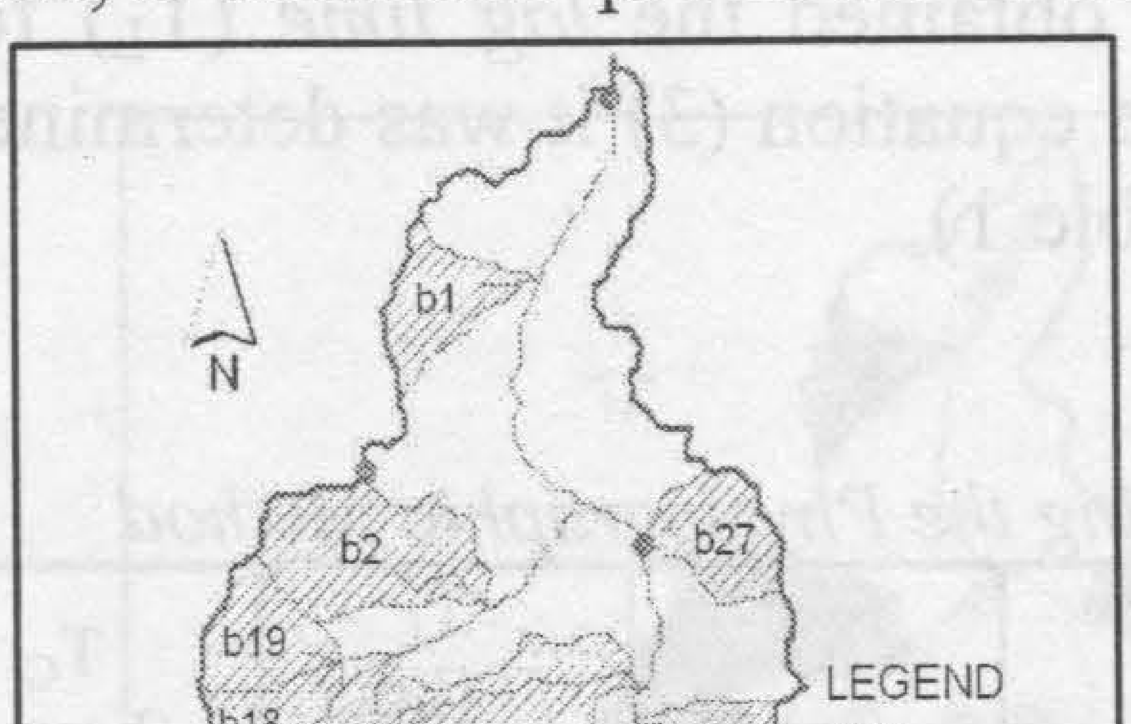


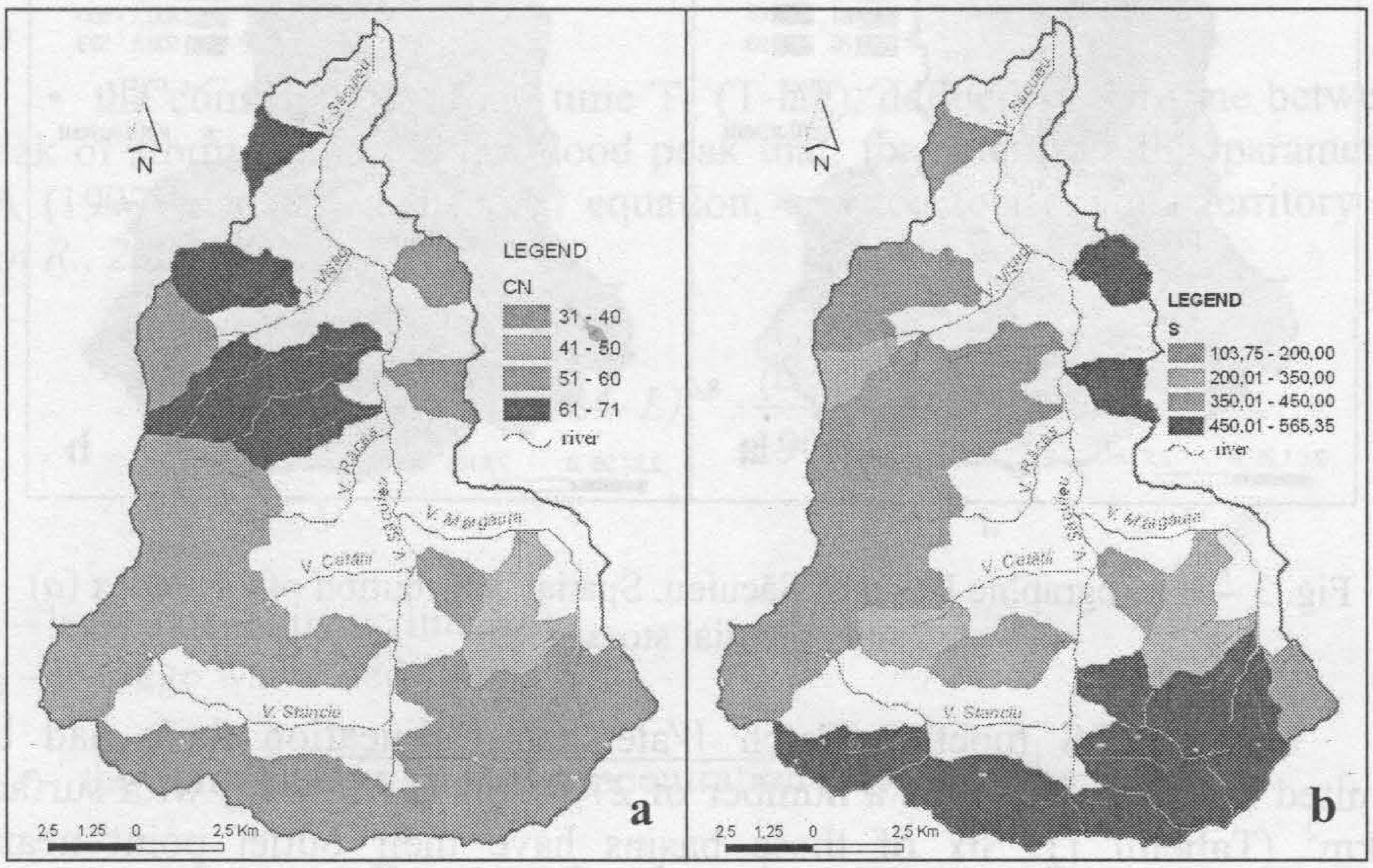
Fig. 4 – Watershed delineation for analyzed basins.

The average values of CN indices, for each basin, there had been obtained as weighted average with the partial surfaces F_p, characterized by the partial indices CN_p. The results are shown in Table 1 and Fig. 5*a*.

The lowest average values of CN index correspond to the basins that have a high afforestation index and hydrologic soil conditions specific to group A. Five of these basins, characterized by domination of agricultural and pasture landuse and a loamy soil texture, present the highest values of CN index (61 – 71). Starting from the average values of CN index it was determined the average potential sub-watershed storage using the equation *(1)*.

The results are presented in Fig. 5*b* and Table 1.

The length of drainage line (L_B) for each basin it was determined by G.I.S, using *XT*ools extension (Table 1). *The average watershed slopes* (I_B) had been obtained by Digital Model Elevation exploring, the highest values were observed in the sub-watershed on the left side of Săcuieu.



a *b*

Fig. 5 – Hydrographic Basin of Săcuieu. Spatial distribution of average CN index (*a*) and potential storage (*b*) for analyzed basins

Applying equation (2) there had been obtained the *lag time* (T_L) for each analyzed (Table 1, Fig.6*a*). Next, using the equation (3) it was determined the *time of concentration* (T_C) of each basin (Table 1).

Table 1

The Values of Parameters Necessary for Applying the Physiographic Method

Basin	F (km^2)	CN	S	L_B (m)	I_B (%)	T_L (hours)	T_C (hours)
b1	2,72	67	125,10	1172,84	21,81	2,46	4,11
b2	5,64	71	103,75	2259,36	22,39	3,60	6,01
b3	7,85	61	162,39	5084,57	23,45	9,19	15,34
b4	5,38	67	125,10	2781,95	22,5	4,83	8,07
b5	5,84	57	191,61	3476,76	31,55	6,56	10,95
b6	5,79	58	183,93	2297,81	30,96	4,62	7,71
b7	3,67	46	298,17	1261,83	13,82	5,99	10,01
b8	3,42	43	336,70	1997,93	19,32	7,97	13,31
b9	5,74	35	471,71	3120,78	20,26	14,07	23,50
b10	5,65	32	539,75	2831,66	17,44	15,42	25,75
b11	3,26	37	432,49	1331,66	10,23	9,43	15,75
b12	5,38	40	381,00	2482,79	28,71	8,48	14,16

Table 1

Continuation

b13	3,16	35	471,71	1145,97	26,46	5,52	9,23
b14	7,77	32	539,75	3672,49	27,4	15,14	25,29
b15	3,52	31	565,35	1491,54	23,62	8,19	13,68
b16	9,56	32	539,75	3193,91	28,06	13,38	22,35
b17	3,17	63	149,17	1122,54	29,53	2,31	3,85
b18	2,46	55	207,82	631,54	36,18	1,66	2,76
b19	2,85	58	183,93	699,7	33	1,73	2,89
b20	5,39	56	199,57	1979,23	32,63	4,23	7,06
b21	4,44	54	216,37	1638,52	32,13	3,87	6,47
b22	7,51	57	191,61	2673,2	24,68	6,01	10,03
b23	2,62	59	176,51	491,42	34,29	1,24	2,07
b24	5,68	36	451,56	2849,65	31,79	10,13	16,92
b25	2,77	37	432,49	763,25	23,51	3,98	6,65
b26	3,03	31	565,35	1036,98	29,95	5,44	9,09
b27	3,06	34	493,06	612,84	26,06	3,48	5,81

From the analysis of the results referred to time of concentration can observe that, from the 27 basins initial selected, just 7 of them are characterized by time of concentration ≤ 6 hours. These basins are shown in *Fig.6b* by red contour.

In consequence, the basins numbered by *b1*, *b2*, *b17*, *b18*, *b19*, *b23*, *b27*, with surfaces, in the most of cases, smaller than 5 km^2, present time of concentration values from 2,07 to 6 hours. These values are explained by very low afforestation rates, a dominance of loamy soil texture, average slopes in most of the case over 25 – 30 %, length of drainage lines < 2 Km.

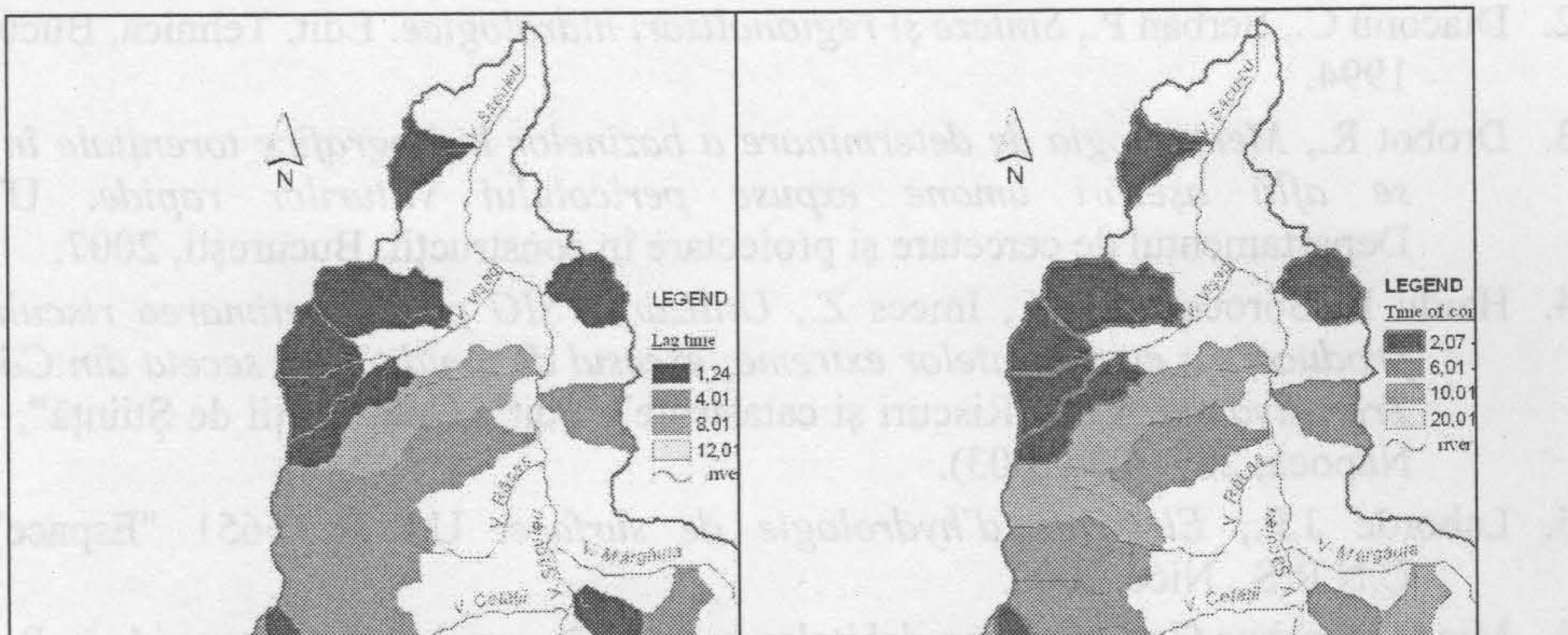


Fig. 6 – Hydrographic Basin of Săcuieu. Spatial distribution of average

lag time (a) and time of concentration (b) for analyzed basins.

4. Conclusions

The use G.I.S for hydrological analyses in the small hydrographical basins presents the advantage of fast recovery of the necessary information.

By using some G.I.S functions it can be realized the integration of calculus equation that permits spatial representation of the analyzed process.

Regarding this study, all the parameters that compose the physiographic method had been computed using some G.I.S functions such as: *D*erive *S*lope, *F*ield *C*alculator, *M*ap *C*alculator, *B*atch *W*atershed *D*elineation, functions of *L*THIA *GIS* extension, functions of *XT*ools extension ş.a.

For detection of the hydrographical basins menaced by high flood during the torrential rain events, must be used some other methods: runoff coefficient method; estimation of a stream power index, flood danger index etc.

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APLICAŢIE G.I.S PRIVIND IDENTIFICAREA BAZINELOR HIDROGRAFICE MICI AMENINŢATE DE VIITURI ÎN TIMPUL PLOILOR TORENŢIALE

(Rezumat)

Studiul vizează posibilitatea aplicării tehnologiei G.I.S pentru identificarea acelor bazine hidrografice, care prin caracteristicile legate de folosinţa terenurilor, trăsăturile hidrice ale solurilor, morfometrie, oferă condiţii optime pentru manifestarea unor viituri rapide. Algoritmul se bazează pe integrarea unei metode, ce ia în calcul o serie de parametrii fizici ai bazinului (metoda fiziografică), în mediul G.I.S.