The allocation of the torrents correction works according to the torrential degree of the river basins. Case Study: Upper Cârcinov Catchment

Eşalonarea lucrărilor de corectarea torenţilor în funcţie de gradul de torenţialitate a bazinelor hidrografice. Studiu de caz: bazinul superior al râului Cârcinov

Nicu Constantin TUDOSE[1], Şerban Octavian DAVIDESCU[1], Ioan CLINCIU[2], Adriana Agafia DAVIDESCU[1], Andrei ADORJANI[1], Cezar UNGUREAN[1]
[1] Forest Research and Management Institute
[2] Transilvania University of Braşov
cntudose@yahoo.com, s_davidescu@icas.ro, ioan.clinciu@yahoo.com,
agafiadavidescu@yahoo.com, adorjaniandrei@yahoo.com, ucezar@yahoo.com,

Abstract: Three factors define the risk to flash floods in small watersheds, mostly forested (Clinciu, 2006): the characteristics of the triggering rainfall, the parameters of the watershed where flash floods occur, features of flash floods receptors.

The first two categories are able to be embedded in the "torrential degree" equation, separately for sediment transportation and for liquid drainage *(Gaspar, 1967)*.

In order to apply the model for torrential degree due to the liquid drainage, in this paper the upper part of the Cârcinov Catchment was divided in 9 watersheds, for each one a hydrological reliability has been estimated. According to this evaluation 60% of the lands in upper Cârcinov Catchment have a low hydrologic efficiency and only 1% of them have a high efficiency.

In order to determine the characteristics of the rainfall triggering flash floods Platagea method was used *(Platagea, 1974)*. For the upper part of the Cârcinov Catchment the computed rainfall (1% threshold) characteristics are: 17.5 minutes duration, 2.4 mm/min intensity and a quantum of 41.8mm.

Using data collected a thematic map has been created containing the distribution of the torrential degree inside the 9 watersheds, giving us the possibility to plan torrent control structures execution in the upper Cârcinov Catchment.

Keywords: torrential degree, rainfall, torrent control structures, Cârcinov

Rezumat: Trei categorii de factori determină nivelul de risc la viituri torenţiale în bazinele hidrografice mici, predominant forestiere: caracteristicile ploilor generatoare de viituri torenţiale; caracteristicile bazinelor în care se formează viiturile torenţiale; caracteristicile receptorilor viiturilor torenţiale.

Primele două categorii de caracteristici pot fi încorporate în expresia „gradului de torenţialitate" al bazinului care se poate stabili separat pentru scurgerea lichidă şi separat pentru scurgerea solidă (Gaspar, 1967).

Pentru cercetarea de faţă s-a estimat gradul de torenţialitate indus de scurgerea lichidă, utilizând relaţia propusă de Radu Gaspar în 1967.

În acest scop s-a realizat mai întâi o împărţire a bazinului superior al Râului Cârcinov în 9 sub-bazine, iar pentru fiecare sub-bazin s-a realizat o caracterizare a bonităţii hidrologice pe categorii şi subcategorii hidrologice. Pe baza acestei încadrări a rezultat că 60% din terenurile bazinului superior al râului Cârcinov prezintă eficienţă hidrologică scăzută şi doar un procent de 1% din terenuri prezintă eficienţă hidrologică ridicată.

Pentru caracteristicile ploilor s-a realizat încadrarea bazinului în una din zonele pluviale descrise de sistemul Platagea obţinându-se astfel o durată medie a ploii de calcul de 17,5 minute cu o intensitate medie de 2,4 mm/minut şi respectiv un cuantum de 41,8 mm, pentru asigurarea de 1%.

Pe baza datelor obţinute s-a creat harta tematică cu distribuţia coeficientului de torenţialitate al scurgerii lichide la nivelul celor 9 bazinete şi a fost posibilă încadrarea pe urgenţe a viitoarelor intervenţii cu lucrări de corectare a torenţilor în bazinul superior al Râului Cârcinov.

Cuvinte cheie: grad de torenţialitate, precipitaţii, lucrări de corectarea torenţilor, Cârcinov

ISBN 978-973-0-15357-6

INTRODUCTION

Watershed management as part of environmental protection and restoration is substantiated on "the concept of efficient water and soil management" and consists in "the implementation, within the whole watershed, on slopes as well as on the river network, of an entire set of administrative measures together with vegetative, biotechnical and hydrotechnical works for a better torrent and erosion control" (*Munteanu, 1975*).

This concept was issued three decades ago, and it is confirmed nowadays in the "National Strategy of Flood Risk Management", in a different form: "a holistic approach regarding floods is required, taking into account the whole watershed; flood prevention strategy should promote a coordinated development and an integrated management of all activities related to water, land and adjacent resources. Non – structural measures (land zoning, flood forecast and warning system if flood occurs, crisis situations management and post – flood measures) tend to be more efficient, due to their effects, as long term solutions for water and water related issues and have to be increased, especial in order to reduce the vulnerability of human life, goods and proprieties" *(Tudose, 2012)*.

Some quantifiable targets of this strategy regard: proper maintenance of structures built for flood mitigation, regularization / recalibration of riverbeds (desilting existing hydrotechnical works and channels), etc. The intervention on both component of a watershed (slopes and riverbeds) is compulsory in order to ensure an optimal water transition during floods, meaning that interventions erosion control structures on slopes and hydrotechnical structures on riverbeds have to be plan and built in the same time within watershed.

Therefore, the scheduling of torrent control structures execution has to be related to the watershed's torrential degree (rather "*watershed susceptibility to floods*") which depends on the hydrological worthiness of land use and hydrological parameters of the watershed.

The objectives of the presented study were: (1) hydrological diagnose of all land use for each studied watershed, (2) torrential degree estimation for each watershed, (3) establishing the building order of future torrent control structures using the torrential degree of the watershed.

MATERIAL AND METHOD

Study area

Our study aimed Cârcinov watershed, tributary to Argeş River. The watershed (19,600 ha) is placed in southern side of Meridional Carpathians (25° 03' E, 45° 03' N), being the easternmost division of Getic Piedmont. The altitude varies from 185 m o.s.l., at the confluence with Argeş River, to 750 m o.s.l. at its origins (*Tudose, 2012*). Cârcinov watershed is in the climate zone Dfbx (according to Köppen climate classification), the annual average temperature varying between 8 ^{0}C and 10 ^{0}C. Season average temperatures are: - 9.0 ^{0}C in the winter, 9.9 ^{0}C in the spring, 20.0 ^{0}C in the summer and 10.5 ^{0}C in the autumn. The average annual rainfall varies from 650 mm to 800 mm.

Research area (fig. 1) is the upper part of the Cârcinov River Basin, namely in Perilor Valley watershed, composed from 9 smaller watersheds, covering 1,200 ha. Generally, the forest found in the upper Cârcinov Watershed represents 57.2% (*Oprea et al., 1996*). The most important tree species are Beech (31%) and Oaks (31%). Norway spruce, Pine and Douglas fir have a small representation, as a result of the former national program to promote coniferous trees, abandoned in the last past years (according to the last Forest Management Plan, 2005)

ISBN 978-973-0-15357-6

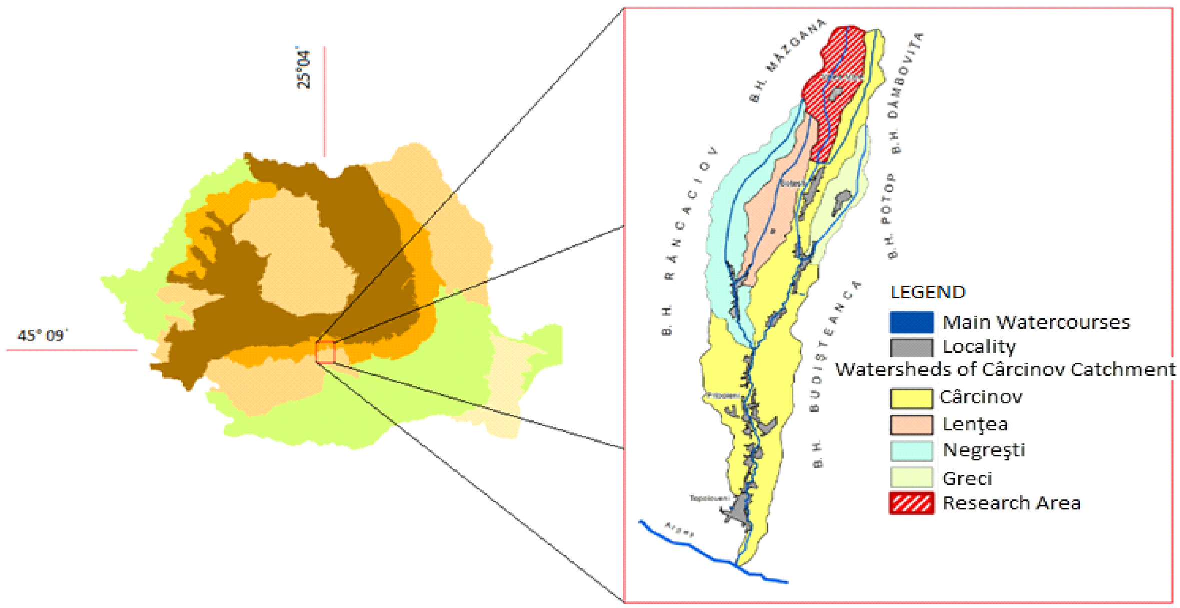

Figure 1. Research area

Field Methods

The hydrological mapping was done for all land use categories using a methodology (*Păcurar, 2001, 2005*), based on a geospatial database built in ArcMap, by connecting the vector that define boundaries of land use categories with description data of their characteristics (extract from AS software).

After the completion of the database, simple codes have been given according to four characteristics related to hydrological worthiness (*surface condition, forest age, consistency and stand site index*). More complex codes were created by addiction of the four simple codes, leading to a hydrological characterization of all 187 polygons identified in Upper Cârcinov Watershed.

The hydrological mapping gain practical value, for hydrological point of view, when for each hydrologic category a runoff coefficient is associated; for this paper we used the following equation (*Lazăr, 1984*):

$$c = 1 - c_z - c_i \qquad (1)$$

Where: c is the runoff index, c_z is the interception index and c_i is the infiltration index.

To calculate the two parameters (c_z and c_i), the critic rainfall water yield (H) was determine, taking account of its duration (T) and intensity (i), using from the well known equation:

$$H = T \cdot i \qquad (2)$$

Rainfall duration was established for all 9 watersheds having torrent control structures on their riverbeds, using the following equation (*Gaspar, 1967*).

$$t_s = 5 \cdot F^{0.25} \qquad (3)$$

ISBN 978-973-0-15357-6

where t_e (s) is the efficient duration of the rainfall (the period of rainfall time when runoff is present, F (ha) is watershed area.

For the rainfall intensity the Platagea zoning was used *(Platagea, 1974).*

The interception index (c_z) was determined according to the water yield of the rainfall (H) and an empirical coefficient (a) valued in keeping with the hydrological category, using the following equation:

$$c_z = a \cdot H^{-0.8} \quad (4)$$

The infiltration index (c_i) was estimated according to rainfall duration (T) and the water yield (H), taking account soil texture in conformity to soil diagnose presented in Forest Management Plan of Topoloveni Forest District, using following equations:

- very light texture (sands): $c_i = 0.64 \cdot T^{0.35} \cdot H^{-0.35}$
- light texture: $c_i = 0.51 \cdot T^{0.30} \cdot H^{-0.30}$
- average texture: $c_i = 0.49 \cdot T^{0.28} \cdot H^{-0.28}$
- heavy texture (clay): $c_i = 0.35 \cdot T^{0.18} \cdot H^{-0.18}$

In the same time the torrential degree (K_{tor}) due to the total runoff was estimated, after the determination of rainfall duration, by applying the following relation (*Gaspar, 1967*):

$$K_{tor} = \frac{Q - Q_1}{Q_{10} - Q_1} \leq 1.0 \quad (5)$$

Q represents the peak discharge in the studied watershed generated by a rainfall (1% threshold) and duration (T) equal to the efficient duration of the rainfall (t_e).

The other two terms (Q_1 and Q_{10}) represent runoff peak discharges generated in two suppositional situations, different from rainfall interception point of view. These situations are due to human interventions (voluntary or not) over vegetation within watershed.

In the first suppositional situation the peak discharge value is “low” (Q_1), because silvicultural interventions within the watershed improve the hydrological quality of forests. The situation was simulated admitting that forests within the watershed have a normal evolution according to Apostol system of hydrological mapping of forests (*Clinciu, 2001*).

In the second suppositional situation the peak discharge value is “high” (Q_{10}), because the considered hypothesis is that the entire watershed is deforested. Even if this theory is improbable nowadays, not long ago, this event was a reality for these specific watersheds. The simulation was done admitting that all forest terrains will be integrated in D1 hydrological category (surfaces to be forested).

For each presented situations (the two hypothetical and the one that is real) the peak discharge generated by a rainfall having 1% threshold was determined using Active Area method (*Gaspar, 1967*), validated in long term research done in small watersheds, mostly forested.

RESULTS AND DISCUSSIONS

Hydrological characterization of terrains

The hydrological classification of the studied area reveals: 10 ha (1%) are included in A category (high hydrological efficiency) 1292 ha (64%) are included in B category (average hydrological efficiency) 103 ha (5%) are included in C category (reduced hydrological efficiency) and 609 ha (30%) are included in D category (low hydrological efficiency).

ISBN 978-973-0-15357-6

The situation created by the important percentage of surfaces covered by reduced and low hydrological efficiency (35%) has a direct impact over the runoff coefficient (c) and over the other two parameters, related to these coefficient (c_z and c_i).

The interception index (c_z) was determined for each hydrological category *(Table 1).*

Table 1. Calculating interception index (c_z) based on hydrological categories

Hydrological category	***Values of coefficient "a", for each category***	***Equation for interception index***
A	8.5	$c_z = 8.5 \cdot H^{-0.8}$
B1	5.0	$c_z = 5.0 \cdot H^{-0.8}$
B2	5.5	$c_z = 5.5 \cdot H^{-0.8}$
B3	4.0	$c_z = 4.0 \cdot H^{-0.8}$
C1	4.5	$c_z = 4.5 \cdot H^{-0.8}$
C2	4.0	$c_z = 4.0 \cdot H^{-0.8}$
C3	3.0	$c_z = 3.0 \cdot H^{-0.8}$
D1	3.0	$c_z = 3.0 \cdot H^{-0.8}$
D2	2.0	$c_z = 2.0 \cdot H^{-0.8}$
D3	1.0	$c_z = 1.0 \cdot H^{-0.8}$

A high value of the interception index corresponding to a high hydrological efficiency (0.42), is characteristic for 1% of the studied area (fig. 2) , and the lowest value of this parameter (0.15), corresponding to a low hydrological efficiency characterize 30% of the watershed.

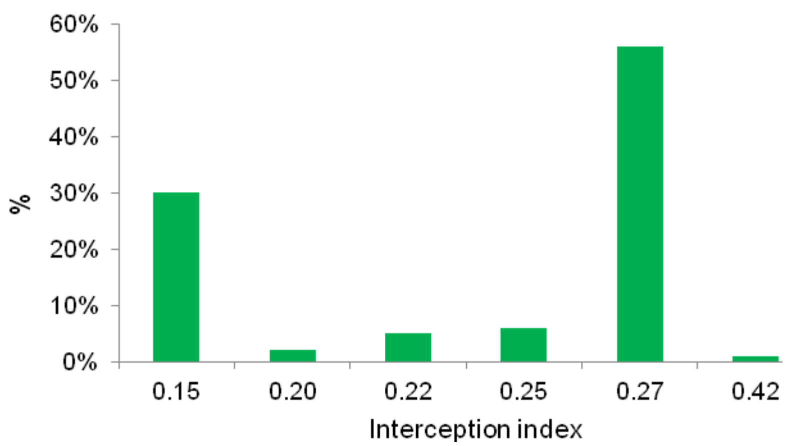

Figure 2: The frequency of the interception index (c_z) on upper Cârcinov basin (%)

For the entire watershed the average value of the interception index is 0.229, corresponding to C hydrological category (reduced hydrological efficiency). The average infiltration coefficient is 0.385.

For the rainfall duration it was adopted the weighted average value of t_e determined for all 9 component watersheds *(Table 2).* Adopted duration of the rainfall was 17.5 minutes.

Table 2: The effective duration of rainfall for each of the nine component watersheds

Nr. crt.	***Watershed***	***F ha***	***t_e min***
1	Mălăeşi Valley	101	15,9
2	Purcăreţii Valley	82	15,0
3	Rotării Valley	27	11,4
4	Anghel Valley	103	15,9

ISBN 978-973-0-15357-6

5	Şipot Valley	61	14,0
6	Perilor Valley	281	20,5
7	Hotarului Valley	272	18,0
8	Drogişi Valley	169	18,0
9	Talpei Valley	118	16,5
TOTAL	**-**	**1214**	**-**

The Cârcinov watershed is placed in D_9 rainfall zone (*Platagea, 1974*), relation between the intensity of the rainfall and its duration being illustrated in figure 3. Therefore the adopted intensity of the rainfall is 2.4 mm/min and the water yield of it is 41.76 mm, for 1% threshold.

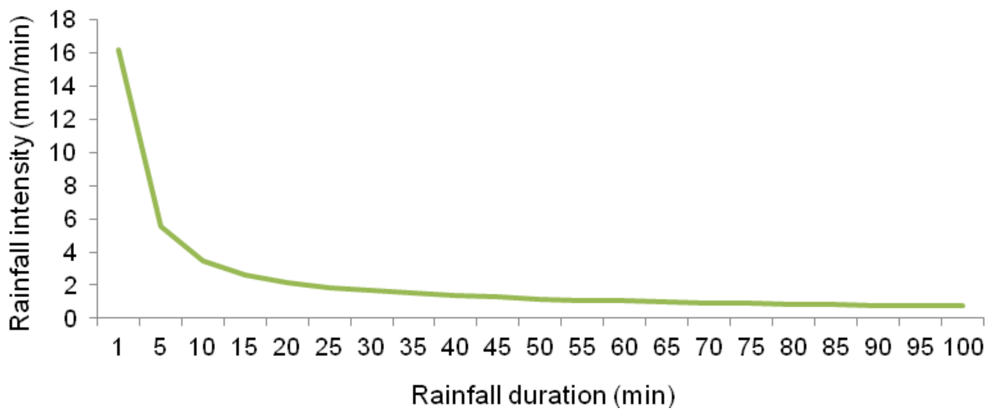

Figure 3. Relation between the duration and the intensity of rain (on a 1% threshold) in D9 rainfall zone

The variation of runoff coefficient is illustrated as a digital map *(Figure 4)* adopting a classification based the previous research result made in small watersheds, mostly forested (*Lazăr, 1984; Clinciu 2001; Păcurar, 2005*), as follows:

- class 1: low runoff coefficient ($0 < c \leq 0.2$);
- class 2: average runoff coefficient ($0.2 < c \leq 0.3$);
- class 3: high runoff coefficient ($0.3 < c \leq 0.4$);
- class 4: very high runoff coefficient ($c > 0.4$).

ISBN 978-973-0-15357-6

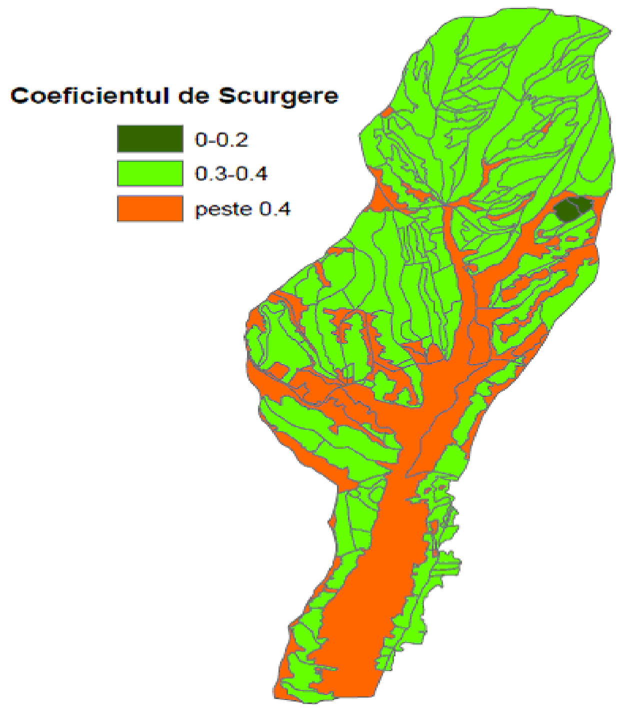

Figure 4. The spatial distribution of the runoff coefficient on the upper Cârcinov watershed

Taking account that in the upper Cârcinov, 6 component watersheds have torrent control structures and 3 of them don't have, and the fact that the future management structural measures have to be established for each watershed, the runoff coefficient was determined for all nine component watersheds *(Figure 5).*

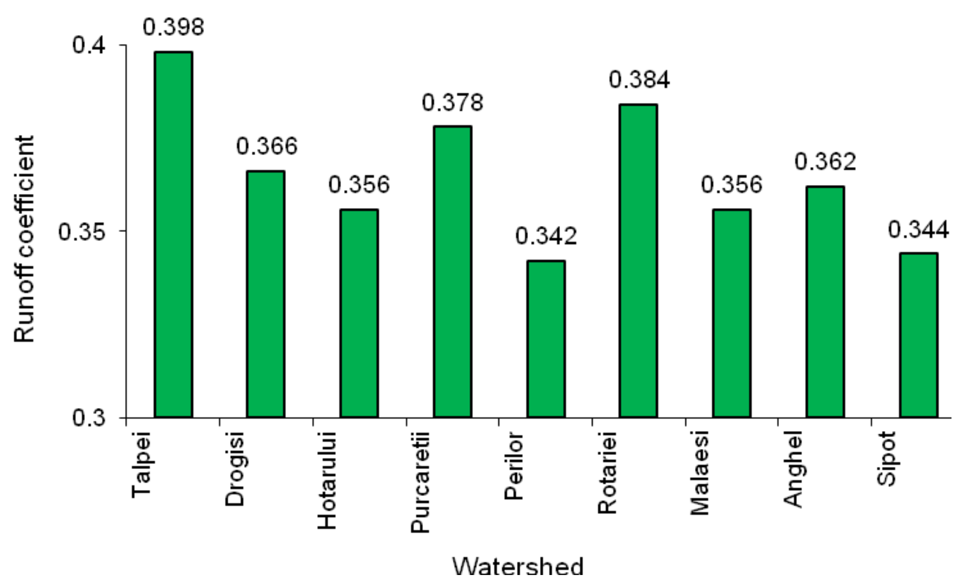

Figure 5. Average value for the runoff coefficient for each of the nine component watersheds

The figure emphasize that the runoff coefficient for Talpei Valley watershed, where a relative vast area (47% of the watershed) is covered by terrains with low hydrological efficiency (category D_1). This fact is favoured by the lack of torrent control structures on its riverbeds.

ISBN 978-973-0-15357-6

Estimation of the torrential degree for each component watershed

The values of the three characteristic peak discharges (Q, Q_1, Q_{10}), together with the torrential degree established on these values, for all nine watersheds, are presented as follows *(Table 3)*.

Table 3. K_{tor} coefficient for all component watersheds

Watershed	***F (ha)***	***Peak discharge at 1% threshold, for the three hypothesis (m^3/s)***			***K_{tor}***
		Real situation	***First suppositional situation***	***Second suppositional situation***	
		Q	***Q_1***	***Q_{10}***	
Şipot	61	5,8	2,7	9,1	0,479
Anghel	103	9,9	5,5	13,8	0,523
Mălăeşi	101	9,9	4,7	14,1	0,530
Rotăriei	27	3,5	1,8	4,6	0,607
Perilor	281	25,2	13,5	40,1	0,441
Purcăreţii	82	8,9	5,3	11,8	0,567
Hotarului	272	23,3	13,1	33,1	0,510
Drogişi	169	15,6	10,0	21,8	0,471
Talpei	118	13,3	8,1	15,6	0,695

Studying the correlative connection between torrential degree of each watershed and its average runoff coefficient, the chart presented in *Figure 6* resulted.

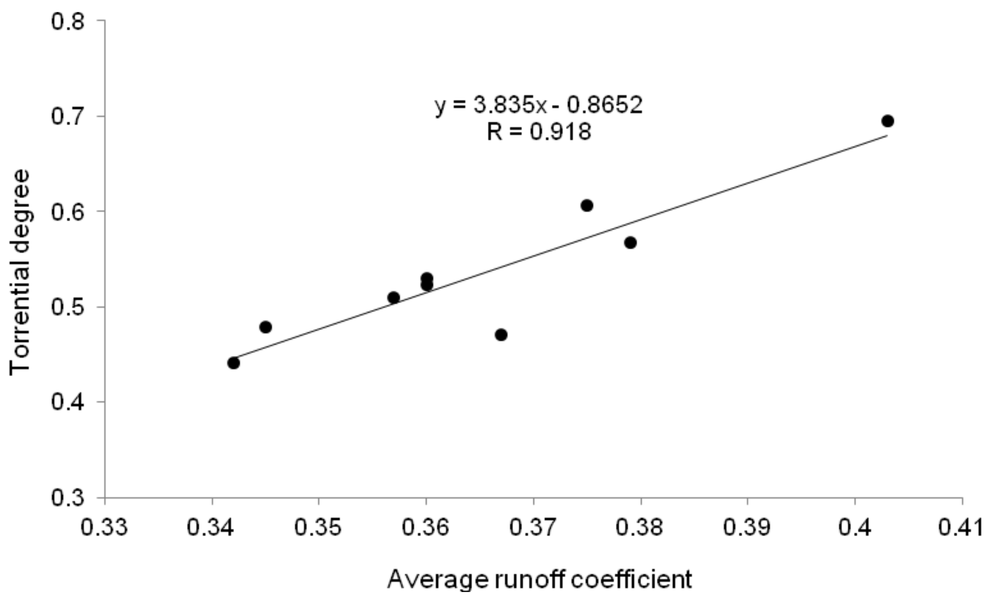

Figure 6. The correlation between torrential degree and runoff coefficient

The correlation coefficient (R=0.918) emphasizes the tight connection between the torrential degree (K_{tor}) and the average runoff coefficient (c). The linear regression will be useful in future projects, because starting from the average runoff coefficient, the torrential degree will be quickly evaluated, therefore, decision about the necessity and priority of riverbeds that need to be improved with torrent control structures will be easier to establish, in this region of Romania.

ISBN 978-973-0-15357-6

Using the torrential degree to establish the execution order of torrent control structures

A classification of the torrential degree using a 5 levels ranking system was defined, in order to establish the order of execution of torrent control structures depending on the watersheds predisposition to flash floods, as follows:

- low torrential degree $K_{tor} \leq 0.2$;
- average torrential degree $0.2 < K_{tor} \leq 0.4$
- high torrential degree $0.4 < K_{tor} \leq 0.6$;
- very high torrential degree $0.6 < K_{tor} \leq 0.8$;
- excessive torrential degree $K_{tor} > 0.8$.

An important step was the separation between watersheds not having torrent control structures and those which have. In the last case two situations have been established: one, where the consolidation and retention capacity of the hydrotechnical system is completed / realized and a second situation where these capacities are not fulfilled (therefore a retention reserve being available, which have to be considered when new torrent control structures will be proposed).

► In the first stage watersheds that don't have torrent control structures have been included, between them the order being established according to the level of their torrential degree. If more than one watershed doesn't have torrent control structures and have the present the same torrential risk, the order is established according to the importance of the flash flood receptors (social and economic objectives).

Therefore, Talpei Valley must be improved in the first stage and first priority; the value of its torrential degree K_{tor} (0,695) proves a very high torrential degree. The priority (1) is justified by the fact that this watershed gravitates in the village Valea Mare, and floods that occurred till now confirmed, through their violence, a dangerous torrential character of this valley.

In the same stage, but the second priority the watershed Hotarului Valley was included, because the value of the coefficient K_{tor} is 0.510; and with the third priority the watershed Drogişului Valley was included having the value of the coefficient K_{tor} 0.471. Even if both watersheds are in the same torrential class (high), Hotarului Valley was prioritized because this watershed is traversed by the communal road Valea Mare.

► In the second stage watershed with torrent control structures on their river network were included. In this case, the priority was established taking account of the torrential degree and the specific available retention capacity (m3/ha) of the existing transverse structures.

Associating both criteria, table 4 was conceived, with nine cells in which the six watersheds were included.

Table 4. Improved watersheds distribution according to their torrential degree and available retention capacity.

K_{tor}	Specific retention capacity (m^3/ha) Available		
	30 -20	20-10	10-0
0,2-0,4	-	-	-
0,4-0,6	V. Şipot	V. Anghel	V. Mălăeşi; V. Purcăreţii V. Perilor
0,6-0,8	V. Rotării	-	-

ISBN 978-973-0-15357-6

In order to decide the improving priority, the table was divided in 3 different areas (highlighted using different gray tones), each one revealing a priority level, starting from the area placed on the right down part of the table to the area placed on the left up part of the table.

Therefore in this stage the first priority will be accorded to the group formed from Mălăeşi, Purcăreţii and Perilor watersheds, and the second priority will be accorded to the group formed from Anghel and Rotării watersheds. Şipot Valley watershed earned the third priority.

CONCLUSIONS

For the studied area terrains having a high hydrological worthiness are very poor represented (only 1%), while terrains having a reduced and low hydrological worthiness cumulate an important percentage (35%). From the component watersheds, the following watersheds have an important area with low hydrological worthiness: Talpei (56 ha – 48%), Drogişi (47 ha – 28%), Rotăriei (7 ha – 26%) and Purcăreţii (16 ha – 20%).

The average value of the runoff coefficient is 0.380, corresponding to the third category (high runoff coefficient). Regarding component watersheds, Talpei watershed stands out, having a four class runoff coefficient (very high), and the rest 8 watersheds being included in the third class.

By determining the torrential degree (K_{tor}) values between 0.44 and 0.70 resulted, concluding that the studied area can be included in categories having a high and very high torrential degree. From the nine small watershed that were studied, seven of them (Anghel, Mălăeşi, Purcăreţii, Şipot, Perilor, Drogişi and Hotarului) have a high torrential degree, and two of them (Rotăriei and Talpei) have a very high torrential degree. As a single watershed, the upper Cârcinov have a torrential degree of 0.513, being included, according to the proposed raking system, in the class of high torrential degree.

Using the determined torrential degree, an order of building torrent control structures was established for the upper Cârcinov watershed, in the first stage being included watersheds that don't have riverbed improvements, the watersheds being prioritized according to their torrential degree. If watersheds having similar torrential degree were identified, the priority was established according to the importance of the flash flood receptors.

References

Clinciu, I., *(2001) Corectarea torenţilor*, Editura Universităţii Transilvania. Braşov

Clinciu, I., *(2006) Pădurea şi regimul apelor, de la primele abordări ale înaintaşilor la recentele preocupări de exprimare cantitativă şi de zonare a riscului de viituri şi inundaţii.* Silvologie, Vol. V – Pădurea şi regimul apelor. Editura Academiei Române, Bucureşti, pp. 107 – 154.

Gaspar, R., (1967) *Contribuţii la determinarea gradului de torenţialitate a bazinelor hidrografice şi a eficienţei hidrologice a lucrărilor de corectare a torenţilor.* Revista pădurilor nr.8, pp. 410 – 414.

Lazăr, N., 1984: *Contribuţii la studiul torenţilor din bazinul hidrografic Sebeş-Alba. Monografie morfohidrologică.* Teză de doctorat, Universitatea Transilvania din Braşov.

Munteanu, S.A., (1975) Premise fundamentale în problema amenajării bazinelor hidrografice torenţiale. Revista Pădurilor nr. 4.

Oprea, V., Manea, A., Frigură, G., Mirică, I., (1996) *Studiul de sinteză privind amenajarea bazinelor hidrografice torenţiale: Inventarul lucrărilor executate între anii 1950-1992, comportarea şi efectul lor, propuneri pentru continuarea acţiunii.* Vol. I, Memoriu Tehnic. Manuscris, I.C.A.S, 103 p.

Platagea, M., 1974: *Caracteristicile de calcul ale ploilor torenţiale necesare în determinarea debitelor maxime pe versanţi şi în bazine hidrografice mici de pe teritoriul României,* Revista Hidrotehnica, nr. 2.

Păcurar, V.D., 2001: *Cercetări privind scurgerea şi eroziunea în bazine hidrografice montane prin modelare matematică şi simulare.* Universitatea Transilvania din Braşov. Teză de doctorat, p. 380.

Păcurar, V., 2005: *O nouă metodă de cartare hidrologică a terenurilor forestiere utilizând sistemele de informaţii geografice.* Revista pădurilor nr., pp. 28 – 30.

Tudose, N.C.(2012) Fundamentarea Amenajării Torenților din Bazinul Superior al Râului Cârcinov, Bazinul Hidrografic Argeş, Editura Silvică, Bucureşti. p. 258. ISBN 978-606-8020-25-9

ISBN 978-973-0-15357-6