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Testing a New Torrentiality Index Methodology in a Representative Forest Watershed from Romania

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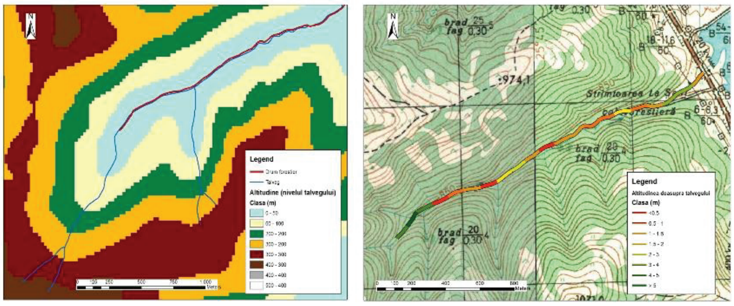
HIGHLIGHTS

- The proposed methodology was able to differente watersheds in the area based on torrentiality risks enabling an objective prioritisation of investments.
- Resources should be allocated most urgently to control the watershed characterized by very high- and high-risk indexes.

GRAPHICAL ABSTRACT



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ABSTRACT

This study tests and validates a simplified methodology for torrential risk assessment in forested watersheds. Theory and background of torrential risk index was presented in a previous paper. Located in the mountain area of Braşov, the studied watershed has an area of 364 ha and a forest cover of 55%. It contains 10 small watersheds, with areas ranging from 3 to 100 ha and forest covers of 24 to 77%. On a 10-class scale, where 1 stands for minimum and 10 for maximum, the torrentiality coefficient of the stream flow (K_{TOR}) varied from 0.35 to 0.53, and by the torrentiality coefficient of debris flow (K_{ERO}), varied from 4.63 to 27.08 t × year^{-1} × ha^{-1}. Following the study, most of the watersheds (seven) were classified in the 6th class; two watersheds were grouped in the 5th class, one in the 7th and one in the 9th class. As a result, the priority in allocating resources for torrentiality control should be the given to the watersheds characterized by a very high (9th class) and high (7th class) risk indexes.

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1. BACKGROUND

As it is known, in Romania, there is a considerable discordance between the financial resources needed for preventing and controlling the torrential flows and the limited financing possibilities of the forestry-related authorities. To answer the question on what should be the order of priority in designing and implementing projects related to torrential watersheds management, we recently proposed a simplified methodology for the determination, at a watershed scale, of a "conventional" level of risk for the 1% exceedance probability, computed as a "torrential risk index" [1], depending on which the decision-making authorities can proceed to an objective allocation of financial resources. This means that the available financial resources should be directed with priority to develop new projects in those watersheds where the torrential risk index is characterized by its highest values.

In the methodology of construction and development, we have accepted the following simplifying hypothesis: a "conventional" risk level at 1% exceeding probability, in small, predominantly forested watersheds, can be obtained by associating the three categories of characteristics involved in the occurrence of the phenomenon (for more details see [1]). These are the characteristics of rainfall generating torrential flows, characteristics of watersheds where torrential flows are formed and the characteristics of flow's receivers. The first two categories of characteristics can be coupled and integrated to characterize the "torrentiality degree of the watershed" which is defined by the means of two coefficients: torrentiality coefficient of the stream flow (K_{TOR}), and torrentiality coefficient of the debris flow (K_{ERO}). In order to establish the torrentiality degree, we determine first "the hydrologic characteristic" (K_h), and then "the transport characteristic" (K_t); afterwards, with a view to converting the results on the usual scales (Radu Gaspar) we introduce correction factors for each characteristic, obtaining torrentiality coefficients (K_{TOR} and K_{ERO}). Then, we formulate the risk index attributed to torrentiality degree (R_{GT}), by taking into consideration the joint influence of the two specific factors (K_{TOR} and K_{ERO}), different weights allocated to these factors as well as the fact that the assessment scales are different. In what concerns the risk index attributed to the receivers' characteristics, its values are determined by taking into consideration the number of receivers identified for each watershed in question, but also by the range of construction features, layout and functionality of receivers, which gives them a different vulnerability and a differentiated risk level to torrential flows. From receivers' point of view, our methodology refers to one of the most frequent cases found in practice: the managed watershed includes forest roads, it may be crossed by other public transportation routes and the receiver is a water storage lake that has to be protected against siltation [1].

In those cases in which the receiver belongs to the category of public transport routes, the risk index attributed to its characteristics (R_{REC}) is expressed using the following parameters: a conversion factor (a) standing for the importance category of the road, the average difference in height (weighted by the length of the road) between the road axis and the thalweg of the river transporting the stream of the flow (ΔH_T^D, m), the depth of the stream for a flow generated by a rainfall associated with an 1% exceeding probability ($h_{1\%}$, m), the estimated length to be affected (L_D, km), the specific unit cost for rehabilitation of the road (i_c^D, RON × km^{-1} or Euro × km^{-1}), and the equivalent value of the most important damage found for one of the roads in the investigated watershed (A_D, RON or Euro).

In those cases in which the receiver is a water storage lake, the risk index attributed to its characteristics (R_{REC}) is expressed by the following parameters: a conversion factor (a) of the importance category of the water storage lake (I), the distance measured from the lake dam to the watershed where the flow is formed (D_{bh}, km), the lake length (L_{lac}, km), watershed area (F, ha), the unit price valid for the removing, loading and transporting the alluvia to a certain distance (i_c^L, RON × m^{-3} or Euro × m^{-3}) and the equivalent value of the most important damage caused by siltation in one of the watersheds in the upstream area of the water storage lake (A_L, RON or Euro).

In order to express the risk index attributed to all the receivers, the methodology is relying on successively determining the values of the risk index attributed to each receiver, which are then summed up to obtain a final risk index characterizing all the receivers [1]. Finally, we accept the expression of risk index attributed to torrentiality degree and receivers' characteristics (R) as the square root of product between the risk index attributed to the torrentiality degree (R_{GT}) and the one attributed to the characteristics of the receivers (R_{REC}) [1].

The goal of this study was to evaluate to what extent the small forested watersheds from a given area can be differentiated and classified using the torrential risk index described above, so that this indicator could become a practical tool for resource allocation.

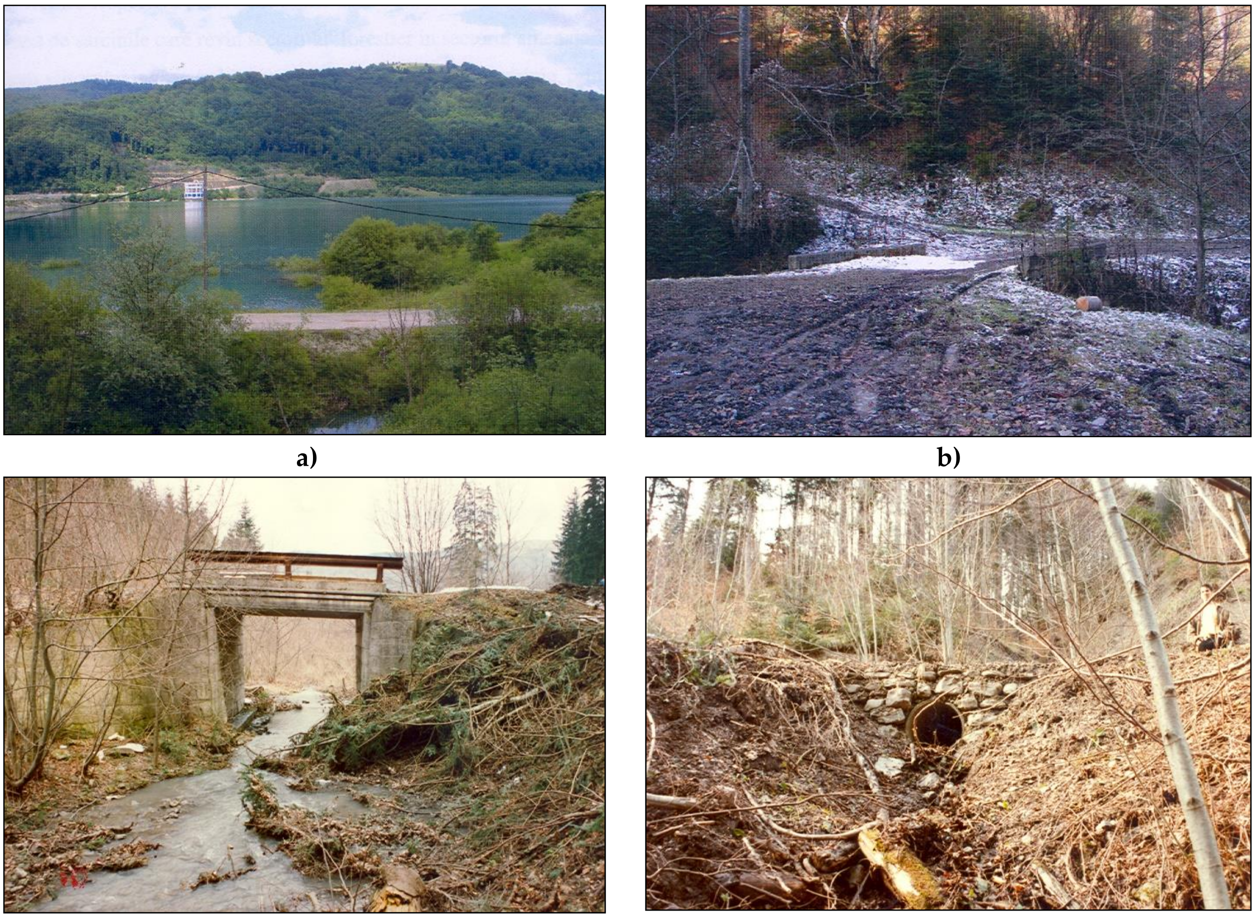
2. MATERIALS AND METHODS

2.1. Study Location

For a first test of the proposed methodology, we have chosen the “Adânca de Jos” Valley which connects directly to the “Săcele” water storage lake (**Figure 1a**), just upstream from the dam built to create the water accumulation.

Located in the mountainous area of Braşov, on “Tărlungului” Valley, the watershed taken into study has an area of 364 ha and forest cover of 55%. It contains other ten small watersheds, with areas ranging from 3 to 100 ha and forest cover in between 24 and 77%. Downstream, the “Adânca de Jos” Valley is crossed by the national road DN1A Braşov-Vălenii de Munte (**Figure 1a**). Its geometry is closely followed by a forest road (**Figure 1b**). In two locations of the route the forest road intersects the thalweg and passes from one slope to the other, by the means of concrete small bridges (**Figure 1c**).

Tributary streams located on the left slope of the valley cross directly and almost perpendicularly the forest road by the means of tubular culverts (**Figure 1d**) while those located on the right slope flow directly into “Adânca de Jos” Valley and they are not a direct threat to the forest road. However, the flow of alluvia from the watersheds, especially in the area of the river banks (**Figure 2a,b**), and these tributary rivers (along with those on the left slope) affect the water storage lake by siltation.



a) b) c) d)

Figure 1. Objectives endangered by floods: a) - Water storage lake and the national road; b) - Forest road; c) - Rectangular small bridges; d) - Tubular small culverts.

a) b)

Figure 2. Sources of alluvia in the riverbanks of the two direct tributaries that intersect the forest road: a) - Valea Lungă; b) - Valea Îngustă.

Table 1. Receivers affected by torrential flows in the "Adânca de Jos" watershed

#	Watershed			Affected receiver		
	Name	F (ha)	Forest cover (%)	"Săcele" water storage lake	DN1A Braşov - Vălenii de Munte	"Adânca de Jos" Forest Road
1	Adânca de Jos	363.5	55	X	X	X
2	Valea lui Dan	23.5	77	X	-	-
3	Valea lui Soare	49.1	65	X	-	-
4	Valea Lungă	19.5	70	X	-	X
5	Obârşia Văii	99.5	38	X	-	X
6	Valea Spurcată	16.5	34	X	-	X
7	Valea Mare	28.9	43	X	-	X
8	Valea Largă	7.5	70	X	-	X
9	Valea Îngustă	2.9	24	X	-	X
10	Valea Zimbrului	4.6	59	X	-	X
11	Valea Lupului	4.8	69	X	-	X

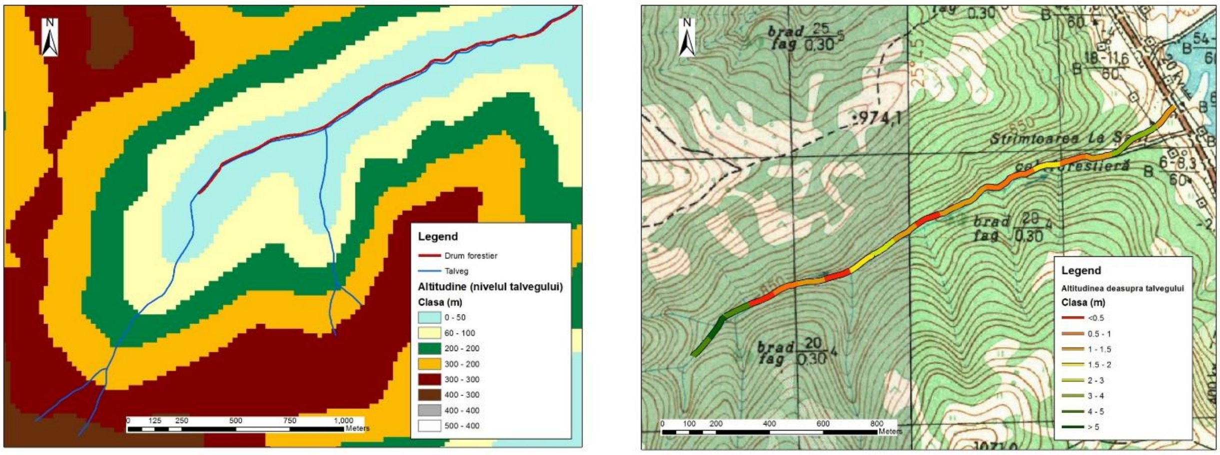
Table 1 shows all of the 11 watersheds taken into consideration in this case study by specifying two of their main characteristics - area and forest cover - and indicating (by "X") for each case the receivers that are affected by torrential flows.

2.2. Data Processing

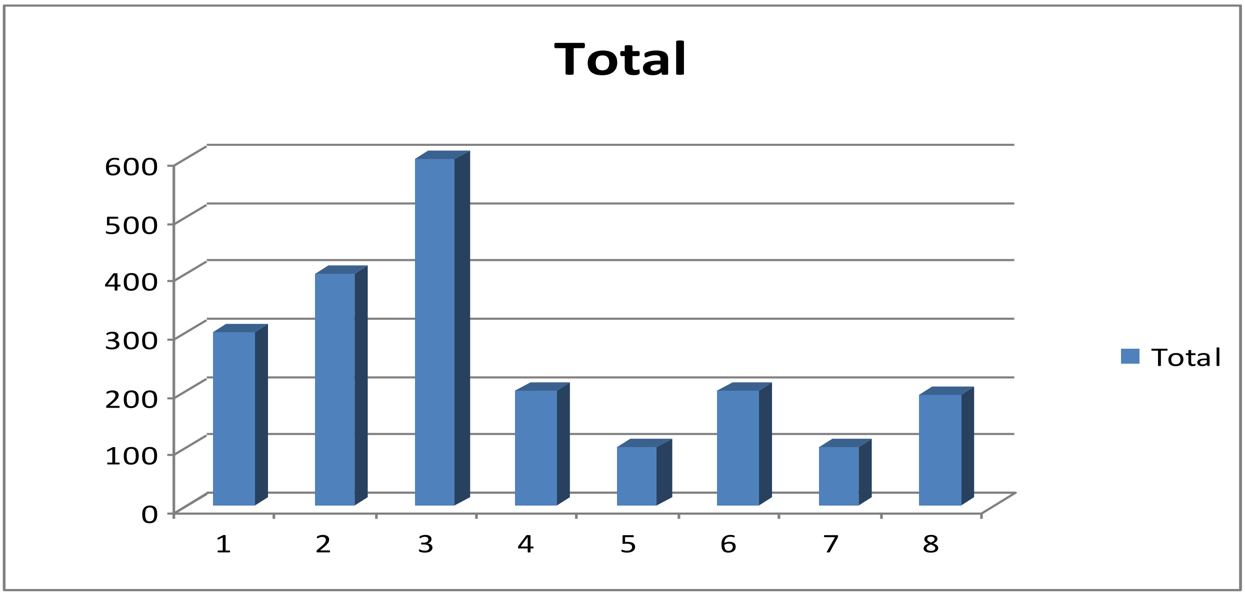
The way in which the primary calculation elements were systematized, as well as the computational stages undertaken to obtain the torrential risk index, are given in the **Appendices** section. Nevertheless, the following clarify some points:

- K_h and K_t values (**Appendix 1**) were determined using the method of Lazăr and Clinciu (1995), then the obtained values were converted to the classification scale developed by Gaspar. For the conversion we used **Equations 3** and **5** from [1];

- L_a and $h_{1\%}$ parameters (**Appendix 2**), were determined using the equations given in [1], starting from the known input parameters such as F, I_a and $Q_{max\ 1\%}$;



a)



b)

Figure 3. Identifying and determining the length of road sectors for classes of height difference: a - Classifying road sectors according to classes of height difference, b - Length (meters) of the road sectors (1…8) on classes of height difference

- The height difference ΔH_T^D, as an average for the entire road, was determined by the means of a digital elevation model (**Figure 3**), as follows: the road was divided into 100 m sections and the minimal altitudes from the thalweg were statistically extracted based on the pixels touched by each road section. Eight classes of height difference were identified, as shown in the legend of **Figure 3a**. The road length for each height class is given in the bar chart shown in **Figure 3b**. By weighting each of these lengths using the values corresponding to the center of each class, we obtained ΔH_T^D, as the average for the entire road. The obtained value (1,80) was written in column 6, under no. 1 in **Appendix 2**, and was used to estimate the exposure degree of the

"Adânca de Jos" forest road, which is approximately parallel with the route of the flow stream through the main riverbed of this valley. For the rest of the cases (4 -11, same appendix) the height difference was calculated according to specific cases. For the cases dealing with tributaries which are crossed by the forest road, the height difference ΔH_T^D was measured starting from the vertical of the road platform's center of gravity of the existing small bridges (cases 8 - 11, **Appendix 2**). For cases 4 and 7 (**Appendix 2**) the height difference was taken from the point of confluence with the main riverbed up to the road and, finally, from the vertical on the downstream extremity of the final road sector, considered the most likely to be destroyed or damaged as a result of an increased discharge from the watersheds located upstream (5 and 6, **Appendix 2**), whose control section is located at a very small distance from the end of the forest road;

- In order to estimate the length of road that is likely to be damaged (L_D) we mention that, for all the watersheds of the tributaries, where the forest road either crosses the riverbed or is in the direction of the riverbed (but downstream from the control section), we proposed and used the own empirical relationship ($L_D = 4.3 \cdot F^{0.363}$) while, for the entire watershed (no. 1), we have added up the sectors of the main riverbed that fulfil the condition $\Delta H_T^D \leq 1{,}0$ m, and we have included the cumulated length of the road sectors affected by tributaries;
- The average unit cost of rebuilding the road sectors, identified as likely to be damaged, was estimated at 70 euro per meter, standing for an average (approximate) cost for building forest roads in the physical and geographical conditions of Romania.

3. RESULTS AND DISCUSSIONS

3.1. General Results

The final results of the case study are compiled and shown in **Table 2**. The main calculation details can be followed in the **Appendices** section, for both, the case of the risk index attributed to the torrentiality degree (**Appendix 1**) and of the risk index attributed to the characteristics of the receivers (forest road - **Appendix 2**, water storage lake - **Appendix 3**). The discussions are aimed either at the end results exclusively or at both the end results and some of the intermediary ones obtained during the process.

3.2. The K_{TOR} coefficient

On a scale of 10 torrentiality classes where class 1 stands for the minimum torrentiality and class 10 for the maximum torrentiality, the coefficient of the stream flow (K_{TOR}) varied from 0.35 to 0.53, which means that, for the watersheds under study, a moderate torrentiality is dominant. Indeed, according to the K_{TOR} value, three watersheds are grouped in the 4th class, six in the 5th class and only two in the 6th class. On the same scale, out of only five torrentiality classes, three watersheds had a K_{TOR} in between 0.2 and 0.4 (weak torrentiality), and eight watersheds had a K_{TOR} in between 0.4 and 0.6 (moderate torrentiality). If we use as a classification criterion the hydrological characteristic (K_h) then, from the point of view of the stream flow, five watersheds are weakly torrential, and six are moderately torrential. The agreement between the K_{TOR} and the K_h indicators was, therefore, fairly good.

Table 2. Torrential risk index (*R*)

#	Watershed			Risk index attributed to:					Torrential risk index (R) expressed as:	
					Characteristics of the receivers:					
					DF	DN	Lake	Total	Variant 1	Variant 2
	Name	Area (ha)	Forest cover (%)	Torrentiality degree R_{GT}	R_{REC}^{DF}	R_{REC}^{DN}	R_{REC}^{L}	R_{REC}	$R = R_{GT} \cdot R_{REC}$	$R = \sqrt{R_{GT} \cdot R_{REC}}$
1	Valea Adânca de Jos	363.5	55	6.02	5.11	-	6.34	11.45	68.93	8.30
2	Valea lui Dan	23.5	77	5.57	-	-	3.60	3.60	20.05	4.48
3	Valea lui Soare	49.1	65	5.07	-	-	3.60	3.60	18.25	4.27
4	Valea Lungă	19.5	70	5.66	1.96	-	3.58	5.54	31.36	5.60
5	Obârşia Văii	99.5	38	5.85	1.98	-	3.68	5.66	33.11	5.75
6	Valea Spurcată	16.5	34	5.35	1.69	-	3.42	5.11	27.34	5.23
7	Valea Mare	28.9	43	5.80	1.98	-	3.64	5.62	32.60	5.71
8	Valea Largă	7.5	70	5.85	2.16	-	3.48	5.64	32.99	5.74
9	Valea Îngustă	2.9	24	6.26	2.23	-	3.41	5.64	35.31	5.94
10	Valea Zimbrului	4.6	59	5.68	2.24	-	3.45	5.69	32.31	5.68
11	Valea Lupului	4.8	69	6.61	2.33	-	3.67	6.00	39.66	6.30

3.3. The K_{ERO} coefficient

The variation of this coefficient ranged from 4.63 to 27.08 t × year^{-1} × ha^{-1}. On the used torrentiality scale consisting of eight classes, where the 1st class stands for 0-0.5 t × year^{-1} × ha^{-1} and the 8th class stands for 32-64 t × year^{-1} × ha^{-1}, the watersheds were classified mostly in the second half of the scale. Four watersheds were specific to the 5th class, five watersheds to the 6th class and two watersheds to the 7th class. An pronounced torrential feature of debris flow is to be expected, given the important sources of alluvia located at the level of the riverbanks (**Figure 2**). According to the value of the transport characteristic K_t, four of the watersheds were weakly torrential, five were moderately torrential, and two were strongly torrential. In this case, the agreement between K_{ERO} and K_t criteria was also relatively good.

3.4. The R_{GT} risk index

For the 11 watersheds under study, the "conventional" risk level attributed to the torrentiality degree (R_{GT}) ranged from 5.07 to 6.61, on a scale from 0 to 10. If the scale is divided into ten classes and the class interval would be 1, one could notice that the "conventional" risk level was located between 5 and 6 for eight watersheds, and between 6 and 7 for three watersheds. After a reclassification of the watersheds on the same scale but with only five classes, the risk index attributed to the torrentiality degree was located between 4 and 6 (medium risk) for nine watersheds, between 6 and 8 (high risk) for one watershed and between 8 and 10 (very high risk) also for one watershed.

3.5. The R_{REC}^{DF} risk index

The "conventional" risk level attributed to the forest road (R_{REC}^{DF}) ranged from 1.69 to 5.11. The maximum value was recorded for watershed number 1, where the road winds longitudinally (almost parallel with the riverbed thalweg), the stream depth for the flow associated with 1% exceeding probability was close to 1.5 m, and the length of the road segments most likely to be damaged summed up to approximately 750 m. However, on a scale from 0 to 10, the maximum value obtained indicated only a medium level of risk attributed to the forest road characteristics. For the rest of the cases, excepting case 7, where, although the forest road crosses the riverbed thalweg, the depth of the stream being relatively low (generally under 0.5 m), the extent of the potential damage was reduced. In this case, the "conventional" risk level (R_{REC}^{DF}) was around 2, which indicates a low level of risk induced by the characteristics of this receiver (forest road).

3.6. The R_{REC}^{DN} risk index

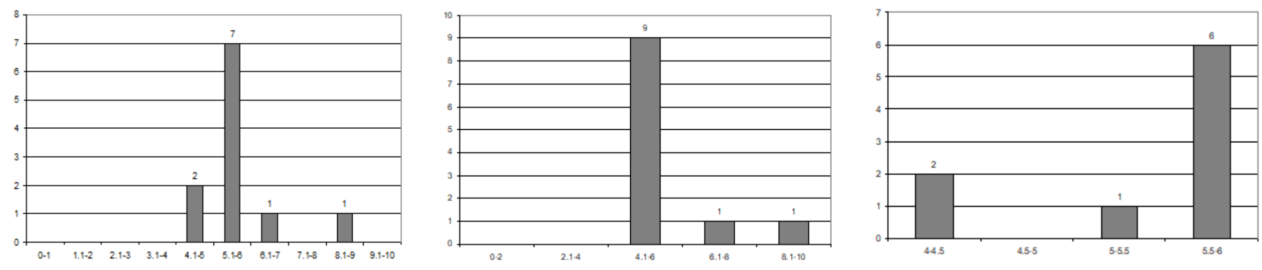
In the case of the national road DN1A Braşov - Vălenii de Munte, we did not estimate the risk because in the cross section of the "Adânca de Jos" Valley, the height difference ΔH_T^D was higher than five meters. Consequently, we accepted the hypothesis that, for torrential flows associated with 1% exceedance probability, for which the stream depth on the lower segment of the valley does not exceed two meters, this type of receiver would be not affected.

3.7. The R_{REC}^{L} risk index

From the water storage lake point of view, watershed number 1 was different from the others, although the vulnerability of this receiver was not so important. However, as the exposure degree was high, as well as the valley connects directly into the accumulation, and the value converted to the scale and corrected by the weight of the potential damage was also relatively significant, the "conventional" risk level (R_{REC}^{L}) obtained was equal to 6.34. For other watersheds, whose surface was much smaller, the risk level was much lower and the values were very among watersheds (between 3.4 and 3.7).

3.7. The *R* risk index

By taking into consideration the second variant (**Variant 2**) for expressing the risk (**Table 2**), which incorporates the joint influence of both, the torrentiality degree and the characteristics of receivers, as well as the fact that the estimated risk level was determined on a scale with ten classes, the distribution obtained was slightly asymmetrical (**Figure 4a**). The main differences were recorded mostly in the second half of the horizontal axis standing for the "conventional" risk level. Most of the watersheds (seven) were classified in the 6th class, two watersheds were grouped in the 5th class, one watershed was placed in the 7th and one in the 9th class. By reclassifying the watersheds using only five classes, the new distribution was more asymmetrical than the previous one (**Figure 4b**), showing that for nine watersheds the "conventional" risk level was located in the 3rd class (medium risk); accordingly, one of the watersheds was placed in the 4th class (high risk) and one in the 5th class (very high risk).



a) **b)** **c)**

Figure 4. The distribution of the torrential risk index (R): a - class interval equal to 1; b - class interval equal to 2; c - class interval equal to 2.

As a result, the intervention order for hydro-technical torrent control operations should be the following: the funds must be allocated most urgently to the two watersheds with high and very high-risk levels, and then to the other nine watersheds with medium risk level. On the other hand, the advantage resulting from determining the risk index for each watershed can also be used to make a hierarchy of the priorities for intervention in the watersheds in the same risk class. For example, in the case of the nine watersheds mentioned above, if we rely on a reclassification of *R* values in a new interval from 4 to 6, by adopting a class interval of 0.5 then, on the basis of the new distribution (**Figure 4c**), we can decide that, within the second intervention class, first priority in fund allocation should be given to the six watersheds classified in the interval 5.5 - 6.

4. CONCLUSION

1. An objective decision-making system aiming at rationally allocating the available financial resources and at prioritizing new investments is essential for the authorities in charge of preventing and controlling the torrential flows in small, predominantly forested watersheds, in the mountain area of Romania.
2. This case study shows that the proposed methodology which expresses the torrential risk index associated with the probability of exceeding the maximum discharge of 1%, leads to results that differentiate each watershed from the others, in the same area, allowing an objective hierarchy of decisions and prioritization of new investments.

SUPPLEMENTARY MATERIALS

No supplementary materials were submitted by the author.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

APPENDIX

The authors provided three appendixes.

Appendix 1. Risk index attributed to the torrentiality degree (RGT) in the "Adânca de Jos" watershed

#	Watershed			Torrentiality coefficient of stream flow (K_{TOR})				Torrentiality coefficient of debris flow (K_{ERO})			Risk index attributed to the torrentiality degree of the watershed (R_{GT})		
											$R_{GT}=\sqrt{60\cdot K_{TOR}+0.625\cdot K_{ERO}}$		
	Name	F (ha)	Forest cover (%)	$Q_{max.1\%}$ (m³/s)	$Q_{e1\%}$ (m³/s)	$K_h=\frac{Q_{max.1\%}}{Q_{e.1\%}}$	K_{TOR}=1.43 ·K_h	W_a (m³/year)	K_t=W_a/F (m³/year/ha)	K_{ERO}=2·K_T (t/year/ha)	60· K_{TOR}	0.625· K_{ERO}	R_{GT}
1	Valea Adânca de Jos	363.5	55	38.9	112.69	0.35	0.49	1925.0	5.30	10.59	29.62	6.62	6.02
2	Valea lui Dan	23.5	77	3.43	11.05	0.31	0.44	83.0	3.53	7.07	26.64	4.42	5.57
3	Valea lui Soare	49.1	65	5.82	22.10	0.26	0.38	122.6	2.50	4.99	22.60	3.12	5.07
4	Valea Lungă	19.5	70	2.38	8.97	0.27	0.38	145.3	7.45	14.90	22.77	9.31	5.66
5	Obârşia Văii	99.5	38	14.52	39.80	0.36	0.52	230.5	2.32	4.63	31.30	2.90	5.85
6	Valea Spurcată	16.5	34	2.22	7.76	0.29	0.41	54.1	3.28	6.56	24.56	4.10	5.35
7	Valea Mare	28.9	43	4.63	15.61	0.30	0.42	189.6	6.56	13.12	25.46	8.20	5.80
8	Valea Largă	7.5	70	0.97	3.98	0.24	0.35	80.0	10.67	21.33	20.94	13.33	5.85
9	Valea Îngustă	2.9	24	0.64	1.74	0.37	0.53	17.6	6.07	12.14	31.56	7.59	6.26
10	Valea Zimbrului	4.6	59	0.76	2.62	0.29	0.41	27.0	5.87	11.74	24.87	7.34	5.68
11	Valea Lupului	4.8	69	0.9	2.88	0.31	0.45	65.0	13.54	27.08	26.81	16.93	6.61

Appendix 2. Risk indexes attributed to the characteristics of the receivers. The case of the forest road "Adânca de Jos" (R_{REC}^{DF}).

#	Watershed					Characteristics of the receiver				
						Exposure (E)			Extent of potential damage (P)	
	Name	Area F (ha)	Maximum discharge $Q_{max1\%}$ (m³/s)	Riverbed width $L_{a=0.575 \cdot F^{0.363}}$ (m)	Riverbed slope I_a (m/m)	Average height difference ΔH_T^D (m)	Stream depth $h_{1\%} = \frac{0.35}{I_a^{0.3}} \cdot \frac{Q_{max\,1\%}^{0,6}}{F^{0.2178}}$ (m)	$E = \frac{5h_{1\%}}{\Delta H_T^D}$	Damaged length $L_D = 4.3 \cdot F^{0.363}$ (m)	Damage converted to scale and corrected by weight $P = \frac{20 \cdot L_D \cdot i_c^D}{A_D}$
0	1	2	3	4	5	6	7	8	9	10
1	Valea Adânca de Jos	363.5	38.90	4.89	0.17	1.80	1.48	4.12	753.0	20.00
2	Valea lui Dan	23.5	3.43	1.81	0.34	-	-	-	-	-
3	Valea lui Soare	49.1	5.82	2.36	0.24	-	-	-	-	-
4	Valea Lungă	19.5	2.38	1.69	0.28	1.50	0.45	1.50	12.7	0.34
5	Obârşia Văii	99.5	14.52	3.05	0.19	4.00	1.05	1.31	22.9	0.61
6	Valea Spurcată	16.5	2.22	1.59	0.30	4.00	0.43	0.54	11.9	0.32
7	Valea Mare	28.9	4.63	1.95	0.29	2.00	0.61	1.53	14.6	0.39
8	Valea Largă	7.5	0.97	1.19	0.40	0.60	0.29	2.41	8.9	0.24
9	Valea Îngustă	2.9	0.64	0.85	0.39	0.50	0.28	2.80	6.4	0.17
10	Valea Zimbrului	4.6	0.76	1.00	0.38	0.50	0.28	2.80	7.5	0.20
11	Valea Lupului	4.8	0.90	1.02	0.35	0.50	0.32	3.20	7.7	0.21

Appendix 2. Risk indexes attributed to the characteristics of the receivers. The case of the forest road "Adânca de Jos" (R_{REC}^{DF}) - continued

#	Watershed					Risk index attributed to the characteristics of the receiver (forest road)	
	Name	Area F (ha)	Maximum discharge $Q_{max1\%}$ (m³/s)	Riverbed width $L_{a=0.575 \cdot F^{0.363}}$ (m)	Riverbed slope I_a (m/m)	$R_{REC}^{DF} = \sqrt{2a \cdot I + \frac{5h_{1\%}}{\Delta H_T^D} + \frac{20 \cdot L_D \cdot i_c^D}{A_D}} = \sqrt{X}$ X = 2+col.8+col.10	$R_{REC}^{DF} = \sqrt{X}$
0	1	2	3	4	5	11	12
1	Valea Adânca de Jos	363.5	38.90	4.89	0.17	26.12	5.11
2	Valea lui Dan	23.5	3.43	1.81	0.34	-	-
3	Valea lui Soare	49.1	5.82	2.36	0.24	-	-
4	Valea Lungă	19.5	2.38	1.69	0.28	3.84	1.96
5	Obârşia Văii	99.5	14.52	3.05	0.19	3.92	1.98
6	Valea Spurcată	16.5	2.22	1.59	0.30	2.86	1.69
7	Valea Mare	28.9	4.63	1.95	0.29	3.92	1.98
8	Valea Largă	7.5	0.97	1.19	0.40	4.65	2.16
9	Valea Îngustă	2.9	0.64	0.85	0.39	4.97	2.23
10	Valea Zimbrului	4.6	0.76	1.00	0.38	5.00	2.24
11	Valea Lupului	4.8	0.90	1.02	0.35	5.41	2.33

Note: The social and economic importance (Ic) was attributed the value 1, because the road category is 4, and the conversion factor is 0.25. Admitting the hypothesis of the equality between Ic and V as well as $I_c = a \cdot I$, the first product under the square root of the expression R_{REC}^{DF} is 2 a · I = 2. The unit cost of rebuilding is i_c^D = 70 euro/m. The possible maximum value of the damage in a watershed is A_D = 52,710 euro.

Appendix 3. Risk index attributed to the characteristics of receivers. The case of "Săcele" water storage lake (R_{REC}^{L})

#	Watershed		Economic and social importance			Exposure (E)			Vulnerability (V)		Extent of potential damage (P) converted to scale and corrected by weight
	Name	F (ha)	Category of objective (cf. STAS) (I)	Conv. factor (a)	a·I	Length of lake L_{lac} (km)	Distance watershed -lake D_{bh} (km)	$E=\frac{L_{lac}}{D_{bh}}$	K_{ERO}	$V=\frac{625 \cdot K_{ERO} \cdot F}{10^7}$	$P=\frac{20 \cdot K_{ERO} \cdot F \cdot i_c^L}{A_L}$
0	1	2	3	4	5	6	7	8	9	10	13
1	Valea Adânca de Jos	363.5	1	10	10	2.5	0.25	10.00	10.59	0.2400	20.00
2	Valea lui Dan	23.5	1	10	10	2.5	1.21	2.07	7.07	0.0104	0.86
3	Valea lui Soare	49.1	1	10	10	2.5	1.52	1.65	4.99	0.0153	1.27
4	Valea Lungă	19.5	1	10	10	2.5	1.99	1.26	14.90	0.0182	1.51
5	Obârşia Văii	99.5	1	10	10	2.5	2.24	1.12	4.63	0.0288	2.39
6	Valea Spurcată	16.5	1	10	10	2.5	2.24	1.12	6.56	0.0068	0.56
7	Valea Mare	28.9	1	10	10	2.5	2.04	1.23	13.12	0.0237	1.97
8	Valea Largă	7.5	1	10	10	2.5	1.93	1.30	21.33	0.0105	0.83
9	Valea Îngustă	2.9	1	10	10	2.5	1.75	1.43	12.14	0.0022	0.18
10	Valea Zimbrului	4.6	1	10	10	2.5	1.53	1.63	11.74	0.0034	0.28
11	Valea Lupului	4.8	1	10	10	2.5	0.93	2.78	27.08	0.0081	0.68

Appendix 3. Risk index attributed to the characteristics of receivers. The case of "Săcele" water storage lake (R_{REC}^{L}) - continued

#	Watershed		Economic and social importance			Risk index attributed to the characteristics of the receiver (water storage lake)	
						$R_{REC}^{L}=\sqrt{a \cdot I+\frac{L_{lac}}{D_{bh}}+\frac{625 \cdot K_{ERO} \cdot F}{10^7}+\frac{20 \cdot K_{ERO} \cdot F \cdot i_c^L}{A_L}}=\sqrt{x}$	
	Name	F (ha)	Category of objective (cf. STAS) (I)	Conversion factor (a)	a·I	$X=\sum(col.5+col.8+col.10+col.13)$	$R_{REC}^{L}=\sqrt{X}$
0	1	2	3	4	5	14	15
1	Valea Adânca de Jos	363.5	1	10	10	40.24	6.34
2	Valea lui Dan	23.5	1	10	10	12.94	3.60
3	Valea lui Soare	49.1	1	10	10	12.94	3.60
4	Valea Lungă	19.5	1	10	10	12.79	3.58
5	Obârşia Văii	99.5	1	10	10	13.54	3.68
6	Valea Spurcată	16.5	1	10	10	11.69	3.42
7	Valea Mare	28.9	1	10	10	13.22	3.64
8	Valea Largă	7.5	1	10	10	12.14	3.48
9	Valea Îngustă	2.9	1	10	10	11.61	3.41
10	Valea Zimbrului	4.6	1	10	10	11.91	3.45
11	Valea Lupului	4.8	1	10	10	13.47	3.67

Note: Cost index for desilting i_c^L (euro/m^3) = 10. The possible maximum value of the damage A_L (euro) = 38,495.

EXTENDED ABSTRACT - REZUMAT EXTINS

***Titlu în română**: Testarea noii metodologii a indicelui de risc torențial într-un bazin forestier reprezentativ din România*

***Introducere:** Scopul lucrării de față este de a stabili măsura în care bazinele hidrografice mici dintr-un anumit teritoriu se pot diferenția și clasifica utilizând indicele riscului la torenţialitate, astfel încât acesta din urmă să devină un instrument pentru alocarea rațională a fondurilor și un criteriu în prioritizarea noilor investiții.*

***Materiale și metode:** Potrivit metodologiei propuse, indicele de risc indus de gradul de torenţialitate este reunit cu indicele de risc indus de principalele caracteristici ale receptorilor. Primul indice este exprimat în funcţie de doi factori caracterizanţi ai gradului de torenţialitate: torenţialitatea scurgerii lichide și torenţialitatea scurgerii solide, iar cel de-al doilea în funcţie de patru caracteristici principale ale receptorilor: importanța economică și socială, gradul de expunere, vulnerabilitatea și valoarea pagubelor potențiale. Studiul de caz se referă la una dintre situațiile frecvent întâlnite în activitatea de proiectare: bazinul de amenajat este dotat cu drumuri forestiere, este traversat de alte căi publice de comunicație (drumuri naționale, județene și comunale, căi ferate etc.) iar în aval există un lac de acumulare care necesită protecție împotriva colmatării. Localizat în zona montană a Brașovului, pe Valea Tărlungului, bazinul considerat în studiul de caz (Adânca de Jos) are o suprafață totală de 364 de hectare și un grad de împădurire de 55%. Pe teritoriul său, acest bazin încorporează alte zece bazine de rang inferior, cu suprafața între 3 și 100 de hectare și gradul de împădurire între 24% și 77%.*

***Rezultate și discuții:** Pe o scară cu zece clase de torenţialitate (clasa 1: torenţialitate minimă; clasa 10: torenţialitate maximă), coeficientul de torenţialitate al scurgerii lichide (K_{TOR}) a variat de la 0,35 la 0,53, ceea ce înseamnă că torenţialitatea moderată este dominantă. Într-adevăr, trei bazine din cele 11 se grupează în clasa a 4-a, șase în clasa a 5-a și numai două în clasa a 6-a. În cazul coeficientului $K_{ERO,}$ valorile determinate variază de la 4,63 la 27.08 $t{\cdot}an^{-1}{\cdot}ha^{-1}$. Pe scara adoptată, cu opt clase de torenţialitate (clasa 1: 0-0.5 $t \times an^{-1} \times ha^{-1}$; clasa 8: 32-64 $t \times an^{-1} \times ha^{-1}$), bazinele studiate se concentrează în cea de a doua parte a scării, respectiv: patru bazine în clasa a 5-a, cinci bazine în clasa a 6-a și două bazine în clasa a 7-a. Nivelul convențional al riscului indus de gradul de torenţialitate (R_{GT}) variază de la 5,07 la 6,61 pe o scară de la 0 la 10. Dacă scara se divide în zece clase (cu intervalul de clasă 1), indicele riscului se situează între 5 și 6 pentru opt bazine și între 6 și 7 pentru trei bazine. Cota de risc atribuită drumului forestier (R_{REC}^{DF}) variază de la 1,69 la 5,11. Valoarea maximă o înregistrează bazinul nr. 1, unde drumul se desfășoară longitudinal (aproximativ paralel cu talvegul albiei), unde adâncimea curentului la viitura cu probabilitatea de depășire de 1% este aproape 1,5 m și unde lungimea sectoarelor de drum expuse la acțiunea viiturii însumează aproximativ 750 m. Pentru restul cazurilor (excepție cazul 7), deși drumul forestier traversează talvegurile afluenților, paguba potențială este redusă întrucât adâncimea curentului este relativ mică (în general sub 0,5 m). Pentru drumul național DN1A Brașov - Vălenii de Munte, nu s-a estimat valoarea indicelui de risc (R_{REC}^{DN}), deoarece în secțiunea transversală a Văii Adânca de Jos diferența de nivel dintre talvegul albiei și platforma acestui drum este mult mai mare de 5 m, prin urmare afectarea receptorului este practic imposibilă. În privința indicelui de risc indus de lacul acumulării Săcele (R_{REC}^{L}), bazinul nr.1 se detașează față de toate celelalte. Într-adevăr, deși vulnerabilitatea receptorului nu este atât de importantă, totuși, fiindcă gradul de expunere este ridicat (Valea Adâncă de Jos debușează direct în lacul de acumulare, imediat în amonte de amplasamentul barajului de retenție), valoarea obținută a indicelui de risc este relativ mare (6,34). Pentru celelalte bazine însă, valoarea indicelui de risc este mult mai redusă (3,4…3,7). În sfârșit, distribuția obținută pentru indicele global al riscului (R), ușor asimetrică, arată că cele mai multe dintre bazine (șapte) se poziționează în clasa a 6-a, două bazine se grupează în clasa a 5-a, unul în clasa a 7-a și încă unul în clasa a 9-a. Dacă se recurge la o reclasificare a bazinelor pe numai cinci clase (clasa 1: risc foarte redus; clasa 5: risc foarte ridicat), se obține o distribuție mult mai asimetrică decât precedenta. Ea arată că, pentru majoritatea covârșitoare a bazinelor (nouă dintre cele 11), nivelul de risc este mediu (clasa a 3-a). Doar pentru câte un singur bazin, nivelul de risc este ridicat (clasa a 4-a) și respectiv foarte ridicat (clasa a 5-a).*

***Concluzie:** Ca rezultat al aplicării metodologiei bazate pe indicele de risc la torenţialitate, proiectantul și finanțatorul pot să procedeze la o alocare prioritizată a fondurilor de investiții. Pentru bazinul luat în studiu, prioritizarea*

ar trebui să fie următoarea: fondurile disponibile să fie alocate în primă urgență pentru execuția lucrărilor de corectare a torenților în cele două bazine identificate cu cel mai ridicat nivel al riscului (clasa a 9-a și respectiv clasa a 7-a).

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