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CORRELATIONS BETWEEN THE HYDROLOGICAL REGIME AND THE MORPHODYNAMIC PROCESSES IN THE GILORT RIVER BASIN

CORELAȚII ÎNTRE REGIMUL HIDROLOGIC ȘI PROCESELE MORFODINAMICE ÎN BAZINUL HIDROGRAFIC GILORT

Emil MARINESCU[1], Oana MITITELU-IONUȘ[2]

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Abstract: This study highlights the relationship between the dynamics of the hydrological regime in a river basin and the morphodynamic potential that appears in the context of increasing frequency and intensity of current climatic phenomena. Climate change characterized by the high frequency and intensity of torrential rains and floods, especially in the last decade, with a maximum amplitude in the summer months (June-July), alternating with periods of drought have brought to a series of geomorphological changes in the Gilort river basin. These processes are amplified by the high degree of fragmentation of the relief, by the presence of springs that feed the hydrographic network and by the important rainfall contribution to the formation of river flows. In the high mountainous area of the basin, there are a series of debris flows that have been triggered in the last ten years, during torrential rains and exceptional floods, by major changes in the land cover and by the transport of materials in the drainage section. At the exit of the mountain, the longitudinal profile of the river changes radically with the decrease of the slope, so that most of the coarse alluvium is deposited in the riverbed in the sectors of the contact depressions at the foot of the mountain. At the contact between the mountains and the Subcarpathian Depression, due to a pronounced decrease of the riverbed slope, the phenomenon of bed aggradation occurs. In this study, all these geomorphological processes are explained from the perspective of hydrological and climatic influence combined with changes in land cover.

Key-words: *riverbed modelling, morphodynamics, climatic changes, alluvium, debris flow, aggradation, Gilort River, Parâng Mountains.*
Cuvinte cheie: *modelarea albiilor, morfodinamică, schimbări climatice, aluvionare, detritus mobil, agradare, râul Gilort, Munții Parâng.*

1. INTRODUCTION

The Gilort river basin covers an area of 1,358 km^2 and extends over three distinct and clearly individualized relief units: the Carpathian area - the southern slope of the Parâng Mountains, the Subcarpathian area - Gorj Subcarpathians and the piedmont area - the Getic Piedmont with its two subunits: Gruiurile Jiului and

[1] University of Craiova, Geography Department, 13 A.I. Cuza Street, 410087, Craiova, Dolj, Romania, emilmrnsc@yahoo.com (corresponding author)
[2] University of Craiova, Geography Department, 13 A.I. Cuza Street, 410087, Craiova, Dolj, Romania, email: oana_ionus@yahoo.com

Olteţ Piedmont. This extension involves a layering of geomorphological and biopedoclimatic processes.

The erosion and accumulation processes produced by the action of water runoff and solid flow become important especially for floods, taking into account the size of the river basin in the upper part of the mountains (342 km^2) and the multitude of tributaries (4,652 1st order and 1,245 2nd order Horton-Strahler river segments). The intensity and the rhythm of the relief modeling are mainly influenced by the liquid and solid flow regime. The aquifers accumulated at the base of sandy deposits that stand on impermeable clays or marly rocks, also contribute to the initiation of mass movement processes, especially landslides (Badea, 1967; Bălteanu, 1982; Rădoane et al., 1999).

In the areas with landslides, groundwater is affected, as clogging determines either the drying of springs or, on the contrary, the appearance of springs, usually at the base of the displaced material, and the accumulation of water in the form of puddles. The rapid rise in groundwater levels after accelerated snowmelt or heavy rains sometimes leads to groundwater pressure on diluvial deposits and causes material movement along the slope at the border between the Subcarpathian and piedmont sectors.

The predominantly hydric processes are referred to in the literature also as pluvio-denudation (in the broad sense) and hydrodynamic slope processes that are due to the intermittent action of water or generated by temporary waters (Ielenicz & Nedelea, 2004). These processes include rainwater stripping/pluvio-denudation, surface erosion and linear erosion (gully erosion and torrentiality) that are entirely found in the Gilort river basin in all three sectors.

In the Subcarpathian sector, the intermittent action of water, which has a high intensity, takes place in mostly friable formations, on slopes with medium and large inclination and high relief energy. A large part of the slopes in Gorj Subcarpathians and the Getic Piedmont has a dense temporary network, fed predominantly by precipitations, which explains the broad spread of erosion processes. This is done by detaching the material (erosion itself), transporting and accumulating (depositing the material in the riverbeds), so that the transfer of materials from the slopes takes place in the riverbed network. In many cases, the torrential valleys are short, but with high relief energy.

The dynamic state of the relief of the river basin can be determined by the ratio of the slopes for each of the three sectors (Grecu & Comănescu, 1998). The most intense modeling processes resulting from the action of running water take place within the riverbeds. The formations present in the riverbed are the complex product of various phenomena related to hydrology, sedimentation and geomorphology.

Within the Gilort basin, there are both erosion beds formed on the hard rocks of Parâng Massif and alluvial beds or `mobile` beds from the Subcarpathian and piedmont sector, where the riverbed consists of sediments deposited over time by erosion, transport and accumulation (Ichim et al., 1989). There is also a third category, beds `*semi-controlled by the rock in situ*` (Grecu & Palmentola, 2003), which includes both rock sectors and sectors formed in alluvial deposits (the Gilort Gorges).

2. DATA AND METHODS

The Gilort basin has two hydrometric stations on the Gilort river (Tg. Cărbuneşti and Turburea), which ensure a well-founded interpretation of the flow regime and four hydrometric stations on its tributaries (the Galbenu, the Ciocadia and the Blahniţa) that, due to the relatively small number of years with observations, cannot be conclusive for the interpretation of multiannual characteristic values (Table 1). For the correlations with the rainfall regime, we used data from Polovragi meteorological station for the mountain sector and from Tg. Jiu and Logrești stations for the Subcarpathian and piedmont sector. Also, the Regional Meteorological Center Oltenia provided data of the maximum precipitation in 24 hours for Novaci, Polovragi, Obârșia Lotrului and Sadu meteorological and rainfall stations.

Table 1 Data on hydrometric stations in the Gilort river basin

River	Hydrometric stations	Length (km)	F (km^2)	Average height (m)	Year of establish-ment	Measurements and observations					
						N	Q	R	Ta	Fi	A
Gilort	Tg. Cărbuneşti*	61	630	749	1966	x	x	x	x	x	-
Gilort	Turburea*	94	1078	590	1921	x	x	x	x	x	x
Galbenu	Baia de Fier	22	57	1230	1988	x	x	-	x	x	-
Ciocadia	Ciocadia	28	105	848	1986	x	x	-	x	x	-
Blahniţa	Săcelu	35	48	725	1986	x	x	-	x	x	-
Blahniţa	Tg. Cărbunești	53	220	467	1986	x	x	x	x	x	-

* stations with long time series of data that were included in the study

(Source: The Jiu Basin Water Administration; *Atlasul Cadastrului Apelor din România,*1992)

The average annual runoff is the most general index of water resources with a role in assessing the degree of uniformity of a river runoff in the basin for a multiannual period of 50 years (1965-2015). The period was chosen to include July 2014 - the fourth rainiest month in the last 50 years in Romania (Polifronie, 2014), being the interval in which the most intense changes of the land cover in the Gilort mountain river basin were triggered, as will be seen below.

The variation of the average runoff is conditioned by meteorological factors (precipitation, air temperature, etc.), but also by the retention and restitution capacity of the Gilort basin. The equation of the annual water balance also includes the term Δu, which represents the variation of the water supply in the basin over a year (Savin, 2008). Within the basin, the climatic elements present more an altitudinal variation than a latitudinal one and drainage is strictly dependent on the direction and the precipitation load of the air masses. The very high rainfall in July 2014 was due to a series of cyclones of Mediterranean origin, very rich in moisture, which were responsible for the occurrence of historical floods in the Gilort river basin that year.

The highlighting of the variation of the annual flow ($Q_{an\ max/min}$) along the watercourses and on the whole basin was done with the help of the modulus coefficients ($K_{max/min}$) compared to the average multiannual flow (Q_o). The obtained coefficients express the full range of variation of the annual runoff over the analyzed time interval. The two extreme modulus coefficients represent the limits of the amplitude of variation. K_{max} and K_{min} are calculated based on the following formulas:

$$K_{max} = Q_{an\ max} / Q_o \ (1);$$

$$K_{min} = Q_{an\ min} / Q_o \ (2).$$

Comparative analysis of the share of alluvium along the Gilort basin was performed by estimates using the values of solid flow circulating through the control sections and the size of specific erosion correlated with the average altitude of the sub-basins:

$$R[kg/s] = f(H_{med}) \text{ and } r[t/ha/year] = f(H_{med}) \ (3).$$

The analysis of the data shows that the average suspended sediment flow has the highest values in Turburea section (R = 14.85 kg/s), much lower values being registered in Tg. Cărbunești section as a result of the lower suspended sediment flow coming from the mountainous and partially from the Subcarpathian sector.

3. RESULTS AND DISCUSSIONS

3.1. Hydrological regime

The maximum modulus coefficients of the flow (Q_{max}) vary within the limits of 2.07-2.24 (Table 2). This is due to climatic peculiarities from one sub-basin to another, to which it is added the influence of the soil type, the fragmentation of the relief and the degree of afforestation of the slopes.

Table 2 Characteristics of the average multiannual runoff (1965-2015) in the Gilort river basin

River	Station	Q_0 m^3/s	q_0 $l/s.km^2$	W_0 $mil.m^3$	Maximum average runoff			Minimum average runoff			Cv
					Q_{max}	K_{max}	Year	Q_{min}	K_{min}	Year	
Gilort	Tg. Cărbunești	7.54	11.96	237	16.92	2.24	2014	3.00	0.39	2000	5.7
	Turburea	10.67	9.89	336	22.19	2.07	2005	4.06	0.38	1990	5.4

(Data processed from the following sources: Savin, 1990; Barbălată, 2005; Savin, 2008; Jiu Water Basin Administration, 2020)

Note: Q_0 - multiannual average flow; q_0 - specific average runoff; W_0 - average volume of drained water; K_{max} and K_{min} - modulus coefficients of runoff; C_v - coefficient of variation of the average annual runoff

The minimum modulus coefficients (K_{min}) are recorded at Turburea hydrometric station (K_{min} = 0.38) and reflect a compensatory situation of the physical-geographical factors that determine the runoff. The multiannual variation of the average runoff is even better reflected in the ratio of these modulus coefficients (K_{max}/K_{min}), which, in the case of the Gilort basin, presents similar values for the two sections (5.4 in Turburea section compared to 5.7 in Tg. Cărbunești section). From the processed hydrometric data, it results that the years with the lowest precipitation (dry years) were 1990, 1993 and 2000, while the years with the highest runoff (between 1965 and 2015) were recorded on the whole basin in 1969, 1976, 2005, 2010 and 2014.

In the same region, the average monthly runoff varies from month to month depending on different climatic conditions. The highest average monthly runoff is in April-June, rising from about 15.5% in April to 16.3% in May, the month with the highest runoff in Turburea section, to decrease to 11.4% in June (Table 3).

Table 3 Variation of the average monthly runoff of the Gilort River (percent of the average multiannual volume) over a period of 50 years (1965-2015)

Hydrometric station	Months											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tg. Cărbuneşti (Gilort)	5.1	6.8	8.4	15.5	17.0	12.4	7.9	5.2	4.5	6.0	5.1	6.1
Turburea (Gilort)	5.7	7.8	9.2	15.5	16.3	11.4	7.0	5.1	4.0	5.4	6.0	6.6

(Data processed from the following sources: Savin,1990; Barbălată, 2005; Savin, 2008; Jiu Water Basin Administration, 2020)

At Tg. Carbuneşti, the highest runoff is also registered in May, having a share of 17.0% from the annual runoff. The values of the multiannual monthly average flows and the multiannual average flow are rendered in Table 4.

Table 4 Multiannual average monthly runoff variation and multiannual average runoff on the Gilort River for a period of 50 years (1965-2015)

Hydrometric station	Q_0 (m^3/s)	Months											
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Tg. Cărbuneşti (Gilort)	7,54	4.62	6.13	7.56	14.07	15.40	11.22	7.14	4.75	4.04	5.4	4.58	5.56
Turburea (Gilort)	10,66	7.27	9.94	11.81	19.82	20.83	14.62	8.90	6.53	5.23	7.0	7.58	8.46

(Data processed from the following sources: Savin,1990; Barbălată, 2005; Savin, 2008; Jiu Water Basin Administration, 2020)

The average seasonal runoff highlights the contribution of the river's power supplies under the influence of the climatic conditions specific to each season. The highest input is made in spring (about 41% of the amount of water circulated through the section), due to the overlapping frequency of liquid precipitation at the same time as the melting of the snow due to positive temperatures. The lowest shares are noticed in autumn and winter (about 15.5% and 19% respectively) being determined by the humidity deficit during autumn, while in winter the precipitations remain stored in the form of snow, especially on the southern slopes of the Parâng Mountains. The unequal runoff distribution over the seasons (Table 5) determines an accentuated hydrodynamic aggressiveness, which affects the intensity of the active processes in the riverbed and tributaries; the phenomenon is also highlighted by the ratio between runoff in the wettest season (A_p) and in the driest one (A_s).

Table 5 Variation of the seasonal runoff of the Gilort River (percent of the average multiannual volume)

Hydrometric station	Months				Ap /As
	Spring	Summer	Autumn	Winter	
Tg. Cărbuneşti (Gilort)	40.9	25.5	15.6	18	2.62
Turburea (Gilort)	41.0	23.5	15.4	20.1	2.66

(Data processed from the following sources: Savin,1990; Barbălată, 2005; Savin, 2008; Jiu Water Basin Administration, 2020)

Specific runoff. The analysis of data shows that specific runoff (q_o) depends upon the average altitude of the basin (H_m) and shows a hypsometric differentiation of the basin sectors developed upstream of the two sections. Values of the multiannual specific average runoff in the Gilort river basin are shown in Table 2. Maximum runoff is the most important hydrological phase of runoff in terms of importance in the erosion and accumulation processes, both in terms of effects (often negative) and importance for socio-economic activities.

During high water periods and floods, the maximum levels and flows reached, as well as their duration, depend on the physical and geographical conditions that generate the runoff: basin water reserve; snow melting speed; quantity, duration and the intensity of precipitation during the snow melting period or at other periods of the year; the state of soil saturation in water; the intensity of the evaporation process, etc.

Due to the large extension of the Gilort basin on the three relief units, the precipitations do not have homogeneous characteristics from one sector to another and there are some differences and discrepancies in their nature and distribution. The duration of the snow layer has an average of 145 days (up to 166 days in Parâng), while at Tg. Jiu, it has only 43 days. Under these conditions, in the mountainous sector of the basin, an important source of river supply is the layer of snow, whose existence extends in some years on the shady slopes until the middle of June.

Floods can be practically registered in any season, but the frequency of production of the highest annual floods on the Gilort River is different depending on the season. In the analyzed interval, it is 36-48% in spring (the most numerous floods appear in May); 29-34% in summer (the most numerous in June); 11-23% in winter and 8-10% in autumn (no floods were recorded in September). During winter, there are usually no major floods in this basin, and when they do occur, December is the most likely period. Winter floods have a double frequency in the piedmont sector (23%) compared to the Subcarpathian sector (11%), which is justified by the nature of winter precipitation in the two areas. The frequency of spring floods is 75% lower in the Piedmont than in the Subcarpathian sector, which can be explained by the overlap of snowmelt in the mountain unit with spring rains.

Regarding the maximum flows recorded in the analyzed multiannual period (1965-2015) in the Gilort basin from the analyzed data series, it stands out the flood from the 20th of August, 1976, which concentrated in the lower part of the Gilort a maximum of 1,160 m^3/s. This value represents a maximum specific runoff (Q_{max}) at the time that exceeded 1,076 l/km^2 in Turburea. Other important floods that strongly affected the Gilort basin were the floods of the 10th of May (437 m^3/s at Tg. Cărbunești) and the 11th of May, 1978 (604 m^3/s at Turburea). High flows were also those of 1972, 1974, 1998, 1999, 2005, 2010, and 2014. At the exit of the Gilort River from the mountain area, the highest flow was recorded on the 29th of July, 2014 (406 m^3/s at Novaci), when the water level (H_{max}) reached a height of 477 cm.

The highest rainfall in 24 hours (1965-2015) was recorded in the upper basins of the Gilort and the Sadu rivers (from high mountain area) on the 27th of July, 2014 (113 l/m^2). Between the 27th and the 29th of July, 2014, torrential and heavy rains exceeded 230 l/m^2 in the upper Sadu and Gilort basins and the cumulative amount of precipitation for the 4 days with precipitation (the 26th - the 29th of July, 2014) was about 254 l/m^2, which is a historical value for these basins (Polifronie, 2014).

3.2. Morphodynamic processes

These precipitations caused large debris flows in the glacial cirques from the upper basin of the Gilort: Ieșu (Fig. 1-3), Setea Mică, Gruiu, Mândra, which affected especially the alpine meadow and subalpine vegetation, and the runoff was prolonged in some cases in forest area (Fig. 1-4). The main factors controlling the trigger and mode of propagation are: the degree of cohesion of sedimentary rocks, the connectivity of moving deposits with those downstream, the slope and relief energy, the hydrological conditions closely related to the frequency, intensity and duration of precipitation, the degree of vegetation cover. The phenomenon is expected to spread in the future due to land conversion by destroying subalpine vegetation (subalpine dwarf pine shrubs) to obtain pastures (cumulative environmental change) (Marinescu et al., 2013).

Hydrological conditions are decisive for the initiation of the runoff process in debris flow (Johnson & Sitar, 1990, p. 789-792), but in case of triggering of the four debris flow in the Gilort basin, at these hydrological conditions (historical rainfall over 250 l/m^2 cumulated from torrential rains for 4 days: the 26th – the 29th of July, 2014) it was also added the lack of land cover with subalpine shrubs, which has a clear protective role in the denudation process (Fig. 1). Another determining factor in the initiation of debris flow is the slope of the receiving basin (Hungr et al., 2008, p. 355-358), in our situation, its value being between 45 and 65^0, as follows: Ieșu (55-65^0), Setea Mică (55-60^0), Gruiu (45-50^0), Mândra (45-55^0).

Undermining the slopes by floods causes their collapse and sometimes landslides as it often happens in the piedmont corridor of the Gilort in Tg. Cărbuneşti - Jupâneşti - Valea Socului sector. Floods also cause the undermining of the slopes of the gullies and ravines with steep and high slopes (Negoieşti, Burlani, Valea Mare-Mirosloveni, Valea Cireşului), generate alluvium in the minor riverbed and the swamping of the major riverbed, as in the middle and especially lower course of the Gilort, the Blahniţa, the Vladimir, the Cocorova and the Valea lui Câine rivers.

Fig. 1 Ieșu glacier cirque: before (2013) and after the debris flow (2014)

3.3. Correlations and discussions

Alluvium runoff. Water that causes surface erosion and torrential organisms are the basic agents that exert a fairly intense action for surface and depth erosion, which results in the formation of elementary runoff of suspended alluvium.

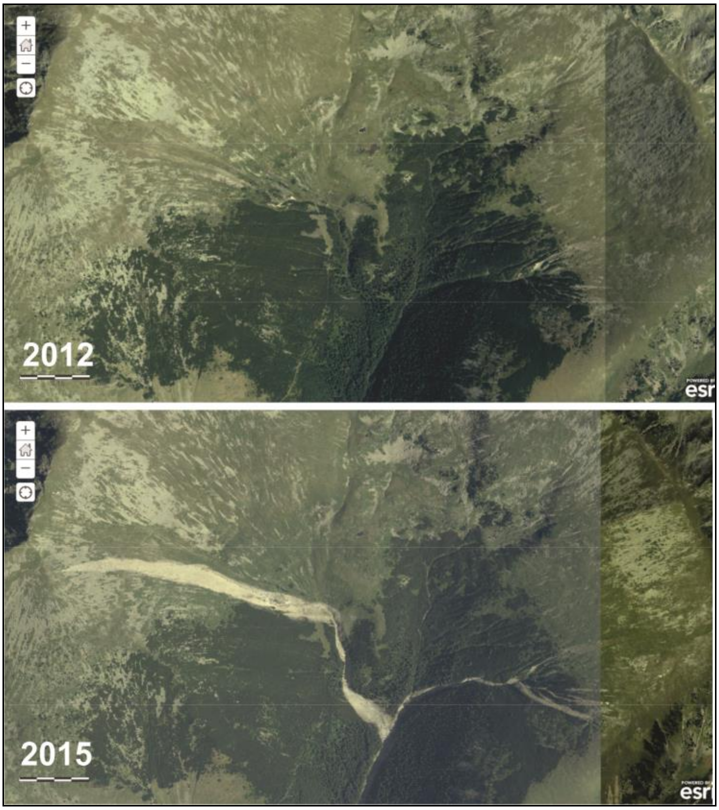

Fig. 2 Ieșu glacier cirque ortophotomaps: before (2012) and after the debris flow (2015)

(Source: ANCPI, https://www.ancpi.ro/)

Fig. 3 Ieșu glacier cirque: the stream channel of the debris flow (2014)

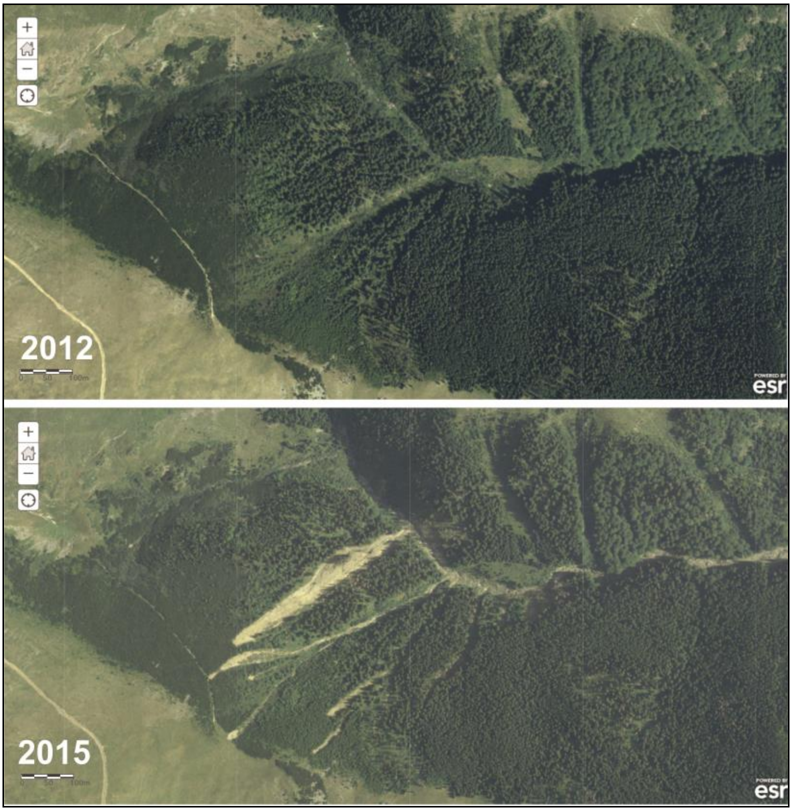

Fig. 4 Setea Mică glacier cirque ortophotomaps: before (2012) and after the debris flow (2015)

(Source: ANCPI, https://www.ancpi.ro/)

Among the natural factors that favor the solid runoff in this basin we mention: the hardness, poor in some places, of the surface rocks; the steep slope on most slopes; lack or poor development on certain slopes of the tree vegetation; the intensity and especially the value of the annual rainfall. The process of solid runoff is therefore directly dependent on the intensity of active factors as: rainfall, runoff speed on slopes and riverbeds, but also on the resistance (passivity) of the lands on which solid runoff is formed and evolves.

The slope and riverbed processes are the most dynamic during floods, the size of the alluvial flows being directly proportional to the value of the slope (or riverbed), the size of the water flow and indirectly to the intensity of the rains. The most dynamic area of the basin is the riverbed, especially its bed, which is usually composed of crumbly rocks (gravel, sand) and has a permanent or periodic instability, confirmed by topographic elevations (periodically made transverse and longitudinal profiles).

An important role in accelerating the erosion process, or in attenuating it, is played by the degree of afforestation of the basins. The slopes completely deforested and affected by intense slope processes justify the exceptional size of the solid transport through the riverbed at high and very high floods and the dynamics of the relief microforms from the minor and major riverbed of the basins.

The average runoff of suspended alluvium also reflects a correlation with the intensity of the aggradation of the Gilort River bed and its tributaries. The analysis of the data differentiates some peculiarities of the suspension alluvium runoff: the average multiannual runoff shows higher values on the Gilort River in Turburea section (R = 14.85 kg/s) due to the fact that this section concentrates the volumes of alluvium brought by most of the Gilort tributaries from the three morphostructural units. Lower values are achieved in Tg. Cărbunești section due to the lack of supply with suspended sediments in the piedmont sector (Table 6).

Table 6 Variation of the average multiannual and multiannual monthly alluvium runoff (kg/s) on the Gilort River

Hydrometric station	R (kg/s)	Months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Tg.Cărbunești (Gilort)	**6,80**	1.62	3.50	4.23	10.09	16.44	15.47	9.08	3.92	1.69	3.3	5.26	6.99
Turburea	**14,85**	4.67	12.2	9.86	16.41	30.56	30.64	25.6	9.81	5.77	16.2	5.46	10.9

(Data processed from the following sources: Savin,1990; Barbălată, 2005; Savin, 2008; Jiu Water Basin Administration, 2020)

The values of the average specific runoff of suspended sediments (r) are much closer to each other: 4.34 t/ha/year in Turburea section and 3.40 t/ha/year in Tg. Cărbunești section, and turbidity is 1.42 times higher in the piedmont sector than in the Subcarpathian sector (Table 7).

Table 7 Specific turbidity and erosion of water on the Gilort River

Hydrometric station	Q (m³/s)	R (Kg/s)	ρ (g/m³)	r (t/ha/an)
Tg. Cărbunești	7.54	6.80	901.8	3.40
Turburea	10.66	14.85	1393.0	4.34

(Data processed from the following sources: Savin,1990; Barbălată, 2005; Savin, 2008; Jiu Water Basin Administration, 2020)

The regime of liquid and solid runoff has a major contribution to the modelling of riverbeds. The erosion of the riverbed in the first stage involves the fragmentation of the rocks in the bed of the riverbed and then their movement and accumulation at a certain distance from the place from which they were dislocated. The processes that occur are corrosion (the set of physico-chemical and biochemical actions that remove matter differently from the surface of rocks) and corrosion by water (sanding the bed with the help of suspended materials and dragged particles).

Within the mountain sector of the Gilort basin, the glacial thresholds are very frequently sectioned by Holocene river valleys, forming microsectors of gorges in which the elements from the riverbed (blocks, boulders, and gravel) have a low degree of rolling. The axis of the anticline that passes south of the main edge requires that the tributary valleys of the Gilort in the alpine sector (Mohoru, Pleşcoaia, Setea Mică) have an obsequent character. This fact has structural implications in the configuration of the riverbed bed (the appearance of structural thresholds, steps and waterfalls).

Downstream the confluence of the Romanu and the Gilort, the presence of the Novaci granites imposes the formation of gorge-like narrow valley sectors. The Gilort Gorges dug in the Novaci granite are located 9 km upstream of Novaci. In their case, there are accumulations of debris on the slopes or at their base, sometimes reaching the watercourse. In the longitudinal profile, due to lithological changes (alternating granites with crystalline shales), thresholds, steps, waterfalls appear. The turbulent vortex movement of the water and the gravel caused by it formed in the lower part of the ruptures of the slope, on the bed of the riverbed of this sector, potholes which, later, after deepening the valley, remained suspended on the river banks. Vortex erosion determined their rounding and deepening (Fig. 5).

Fig. 5 Vortex erosion (potholes) in the Gilort Gorges

The lower order valleys (I and II in the Horton-Strahler system) have, in longitudinal profile, a large slope that requires rapid drainage and accentuation of linear erosion. In the case of higher order valleys, the slope of the riverbed decreases, thus allowing the manifestation of lateral erosion. In the transversal profile, the slopes of the elementary valleys are flared and have a small slope, so that in the case of higher order valleys there are steep and convex slopes.

Most of the tributaries in the Subcarpathian sector originate in the mountain area of Parâng massif. At the exit of this area, when the rivers meet less hard rocks, there is a widening of the riverbeds and the production of the most dynamic riverbed processes within them. The alluvium transported from the mountain area is found in the form of boulders, coarse and large gravels, large-grained sands, etc. At the exit from the mountains, the longitudinal profile of the river changes substantially with the decrease of the slope so that most of the coarse alluviums are deposited in the riverbed in the sectors of the contact depressions at the mountain borders. The bed of the riverbeds rises; for a while, the main component of the erosion becomes the lateral erosion and the rivers make meanders strongly forming specific riverbed relief.

The river with the strongest transport in the studied area is the Gilort, which at the exit from the mountains on a distance of 8 km, south of Pociovaliştea, deposited a layer of coarse gravel which is the most important source of ballast - the material being used a lot in construction activity.

At the contact between the mountains and the Subcarpathian Depression, against the background of a pronounced decrease of the riverbed, the phenomenon of aggradation appears (raising the surface of the relief by depositing new materials, resulting from fluvial processes, Fig. 6). This phenomenon is very visible along the road from the Gilort valley from Novăcei to Novaci II micro-hydropower plant. The Gilort River and its tributaries have the characteristic riverbeds in the hill and depression sector, where the meadow (major riverbed) and the minor riverbed appear, and in the valley corridor sector.

Fig. 6 Aggradation of the Gilort riverbed in the upper sector

The modeling of alluvial riverbeds (alluvial riverbeds) is done by redistributing mobile or easily mobilized materials and takes into account the dynamics of alluvium, which is why they are also called *mobile riverbeds* (Grecu & Palmentola, 2003). The sediments transported and deposited by the river are the result of the processes of surface erosion and linear erosion (Fig. 7).

Fig. 7 Alluvial Gilort riverbed at Tg. Cărbuneşti, in the middle sector (low meadow terrace dug in its own alluvium)

The Gilort valley corridor in the Piedmont area and, to a much lesser extent, in the Subcarpathian area presents the widest alluvial riverbeds in the whole studied basin. These, depending on the overall morphology of the meanders and on the corridor sector which they belong to, are slightly meandering, meandering and strongly meandering riverbeds. The meandering process is due to the lateral erosion of the river that attacks the banks, imprinting a concave shape on them, while the opposite banks acquire a convex shape due to the lateral accumulations (Fig. 8). Subsequent evolution is influenced by the process of self-capture of meanders.

Meanders have the greatest development for the Gilort basin in the Piedmont area, where the riverbed sectors are close to the equilibrium profile, when lateral erosion dominates to the detriment of linear erosion. Locally, in the parts where the Gilort River undermines the right bank (between Jupâneşti and Socu) there are collapses and landslides whose frontal wave pushes the water course to the opposite bank, favoring the appearance of meanders. Also locally, meanders appear at the confluences of the tributaries of the Gilort (the Câlnic, the Blahniţa, the Hârnea) with lower hydrographic organisms by forming alluvial fans that change the position of the riverbed.

Fig. 8 River beaches and fluvial islets in the Gilort riverbed at Turburea, in the lower sector

In the piedmont sector, excessive meandering leads to a reduction of the slope and the ability of the watercourse to carry the load of materials. Thus, the water current looks for another track that allows the evacuation of the transported materials (Fig. 9). By narrowing the space between the meanders, it becomes narrow enough for the Gilort water to flow directly from one meander to another, taking place the self-capture (straightening of the watercourse). The old meander remains an abandoned course along which areas with excess moisture are kept and hygrophilous vegetation appears.

In the morphology of the minor riverbed, the old meanders can be reconstructed (abandoned meanders, hooks, meander loops, and oxbow lakes). We frequently find such chute cutoffs in the valley corridor of the Gilort (Rogojeni, the confluence with the Tudorese stream, in the perimeter of the villages of Socu, Vierşani, Petreşti). Inside the old meanders, there can be found outliers called *popine* or *gradiste*, which in the Gilort basin have suggestive names (*La Matcă, La Ocol, Şesul Generalului, Şesul Popii*). The morphology of the bed sometimes has depressions and thresholds and, on some parts, gravel and sand banks.

Fig. 9 Cocorovei riverbed (left slope of the Gilort) drowned in its own alluvium

Apart from the forms of erosion and the deposition forms created in the riverbeds by the action of deep erosion, lateral erosion and transport carried out by permanent waters, there are also forms on the bed of torrential valleys, resulting from the processes carried out by temporary waters.

Taking into account the quantities of alluvium temporarily accumulated in the riverbeds, we can analyze the share they have in the sectors covered by the Gilort (mountainous, Subcarpathian and piedmont) and the way in which these materials will be reintegrated in motion.

The sediments in the riverbeds and in the alluvial fans present at the base of the slopes are represented by alluvium and proluvial materials periodically subjected to movement. These materials are unevenly distributed in the longitudinal profile of the valleys and they move periodically (at floods), being transported out of the basins.

4. CONCLUSIONS

The processes of erosion and accumulation produced by the action of watercourses, become important especially for floods taking into account the surface of the river basins and the multitude of tributaries, as well as the climate characterized by torrential rains from spring to autumn with a maximum in June-July.

These processes are amplified by the high degree of fragmentation, the presence of springs that feed the hydrographic network and the important rainfall that contribute to the formation of river flows in the Subcarpathian and piedmont sectors. The Gilort River discharges through Turburea section on average a significant amount of alluvium of about 468,300 tons/year.

Considering the complexity of the basin and the importance of comparative studies on morphohydrographic basins in which the control variables of the morphodynamics of the slopes and riverbeds to be systemically reported, it is necessary to set up a hydrometric station at the river basin closure, upstream of the confluence from Capu Dealului, to Ţânţăreni. This station would be highly important because a geomorphological study on the basin offers the possibility of making precise models and quantifications, due to the clear delimitation that can be made for a hydrographic basin. The establishment of this hydrometric station is also justified for socio-economic reasons.

The mountain sector of the Gilort river holds 15-20% of the total amount of alluvium transported. Boulders predominate, which can only be transported at high floods and the accumulations formed at these floods behind the natural dams, due to the blockage with uprooted trees or collapses (The Gilort Gorges). Also, in this mountain sector, four large debris flows (Setea Mică, Ieșu, Gruiu and Mândra glacial cirques) were identified to be mapped. These were triggered and activated by the torrential rains and historical floods from the 26^{th} – the 29^{th} of July, 2014. At the exit of the river from the mountain area, there is a strong phenomenon of riverbed aggradation.

In the Subcarpathian sector, between 30 and 40% of the quantities of alluvium are circulated, which are deposited in a discontinuous cover thickened at confluences and downstream. The largest amount of alluvium is circulated in the piedmont sector (about 40-55%) being justified by the nature of the friable rocks, by the contribution of the torrential valleys situated south of the confluence with the Blahniţa river, by the intense erosion phenomena of the banks, and by the periodic moving of materials at floods. If we also add the older proluvial materials, we can say that the alluvium in the piedmont sector stands for the largest share of the total quantities of existing materials in the riverbed.

At present, against the climate change background and the cumulative effect of converting land from subalpine shrubs to subalpine meadows, the increasing trend of the amount of proluvial materials removed from small basins is maintained and even accentuated.

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