Geogr. Fis. Dinam. Quat.
32 (2009), 95-102, 5 figg., 5 tabb.

LILIANA ZAHARIA (*) & GABRIELA IOANA-TOROIMAC (**)

EROSION DYNAMICS - PRECIPITATION RELATIONSHIP IN THE CARPATHIANS' CURVATURE REGION (ROMANIA) (***)

ABSTRACT: ZAHARIA L. & IOANA-TOROIMAC G., *Erosion dynamics - precipitation relationship in the Carpathians' Curvature region (Romania).* (IT ISSN 0391-9838, 2009).

The present paper analyses the relationship between the variability of precipitation and suspended sediment load (expressed as specific suspended sediment yield) during 1961-2000 period, in order to establish the role of precipitation in erosion processes and to identify the tendencies of their dynamics, in perspective of climatic changes. The scientific approach has employed the pluviometric and hydrological data (from the national hydro-meteorological network) for 7 catchments lying in the external Carpathian's Curvature region, which is the area with the highest erosion rate in Romania. The analysis has been undertaken for each catchment, as well as for the entire region. For each catchment graphs of interannual variability of the annual precipitation and of the mean annual specific suspended sediment yield have been accomplished, on which the linear tendencies and the moving averages of the two parameters during a 10 years period have been represented. The statistic significance of linear tendencies has been established by applying the Mann - Kendall test. At regional scale, two synthetic indexes (determined through Principal Component Analysis) have been taken into account, namely the synthetic index of the mean specific suspended sediment yield and the synthetic index of precipitation. The results of the accomplished analyses show that the suspended sediment load in the external Carpathians' Curvature during the 1961-2000 period has a general descending trend, similar to that of the precipitation, which indicate the important role played by the climatic conditions in the erosion processes. This is also emphasized by the value of the linear correlation coefficient between the mean multiannual specific suspended sediment yields and the mean multiannual precipitation of the 7 study catchments (0.57), which is higher than the correlation coefficients between the suspended sediment load and other features of the river basins (mean altitude, mean slope, forest ratio). Thus, in the perspective of climatic changes, erosion processes will reflect directly the alterations of the precipitation regime. However, one must not loose sight of the fact that, apart from the precipitation amount, the erosion dynamics is influenced by other factors as well (the geological, morphological and hydrological conditions, the land use, etc.). This fact is emphasized at regional scale by the relatively low correlation between the synthetic index of the specific suspended sediment yield and that of the precipitations (R^2 = 0.45), even though the correlation is statistically significant (r = 0.66) (according to the Bravais - Pearson test, for α = 0.05 risk error). At the scale of the river basins there are relatively important correlations, statistically significant (according to the Bravais - Pearson test, for the α = 0.05 risk error), between the mean specific suspended sediment yield and the maximum liquid discharges (linear correlation coefficients ranging from 0.54 to 0.81), as well as between the mean suspended sediment yield and the mean liquid discharges (linear correlation coefficients from 0.62 to 0.83), which shows the important role played by the hydrological factor in sediment transport. A more thoroughly analysis of the relationship between precipitation and erosion (expressed as the solid discharge) must take into account not only the amount of precipitation fallen during a given period of time, but also the intensity and the frequency of rainfalls, aspects that we intend to approach in the future.

KEY WORDS: Erosion, Suspended sediment yield, Precipitation, Carpathians' Curvature region, Romania.

INTRODUCTION

The erosion dynamics is the result of the cumulated interaction between the natural and human factors, at both local and regional scale. One of the main roles is played by the climatic factors, the precipitation firstly. The amount, the duration and the intensity of the precipitation interfere directly (erosion on slopes) and indirectly (fluvial erosion) in the erosion processes. A parameter witch reflects the intensity of the erosion processes is the suspended sediment load of the rivers draining an area. The goal of this paper is the analysis of the erosion dynamics (expressed by the specific suspended sediment yield) in correlation with the temporal variability of precipitations, in order to identify their eventual tendencies and to establish the role of precipitation in the formation of the sediment load, in the context of the official acceptance of the global climatic changes by the Intergovernmental Panel on Climate Change

(*) *Faculty of Geography, University of Bucharest, 1 Nicolae Bălcescu Blv., Sector 1 - 010041 Bucharest, Romania* - e-mail: zaharialil@yahoo.com.
(**) *Universités des Sciences et Technologies de Lille, Avenue Paul Langevin, 59655, Villeneuve d'Ascq, cedex, France* - g.ioana-toroimac@ed.univ-lille1.fr.
(***) *12th Belgium-France-Italy-Romania Geomorphological Meeting - IAG. «Climatic Change and Related Landscapes», Savona 26-29 September 2007.*

(IPCC), and by the Climate Convention (Rio, 1992) (Juvanon du Vachat, 2006).

The study area covers, on the whole, the External Carpathians' Curvature region. The natural and socio-economical characteristics of this area generally provide favourable conditions for the erosion processes. This fact is reflected by the high rate of erosion (over 20-25 t ha^{-1} year^{-1}), the highest of the country, i.e. 10 times the average value of erosion rate in Romania (Mociorniţă & Birtu, 1987). By applying statistical, correlative and comparative analysis on the data series (annual mean suspended sediment yield and annual precipitation) for a period of 40 years (1961-2000), we have tried to identify the trends in the inter-annual variability of these two parameters, and the intensity of their interaction. At the same time, we have analyzed the relationships between the suspended load, on the one hand, and the hydrological (mean and maximum liquid discharges) and morphometric (mean altitude, mean slope, forest ratio) features of the catchments, on the other hand, in order to identify the role of other factors as well in the dynamics of erosion processes.

THE EXTERNAL CARPATHIANS' CURVATURE REGION: MAIN GEOGRAPHICAL FEATURES

The External Carpathians' Curvature area includes two distinct morphological units: the Carpathians (occupying the North-Northwest area) and the Subcarpathians (in the East-Southeast part of the Carpathian area) (fig. 1). The natural and socio-economical features of these areas favour, generally, the erosion processes.

Morphological and geological features. The Carpathian area is highly fragmented by valleys and small depressions. The altitudes range between 1600 and 1800 m a.s.l., in the central and northern part, and are over 1900 m in West. Toward the contact with the Subcarpathian area the altitudes values decrease gradually, reaching 600-800 m a.s.l. The tectonics is complex, and the lithology is very diverse. Specific are the Cretaceous and Palaeogene flysch formations, consisting of a mosaic of rocks: sandstones, marls, limestones, conglomerates, marly-sandy schist etc. (Mutihac & *alii*, 2007).

The Subcarpathian area includes an alternation of hilly ridges (with heights typically between 600 and 700 m a.s.l.,

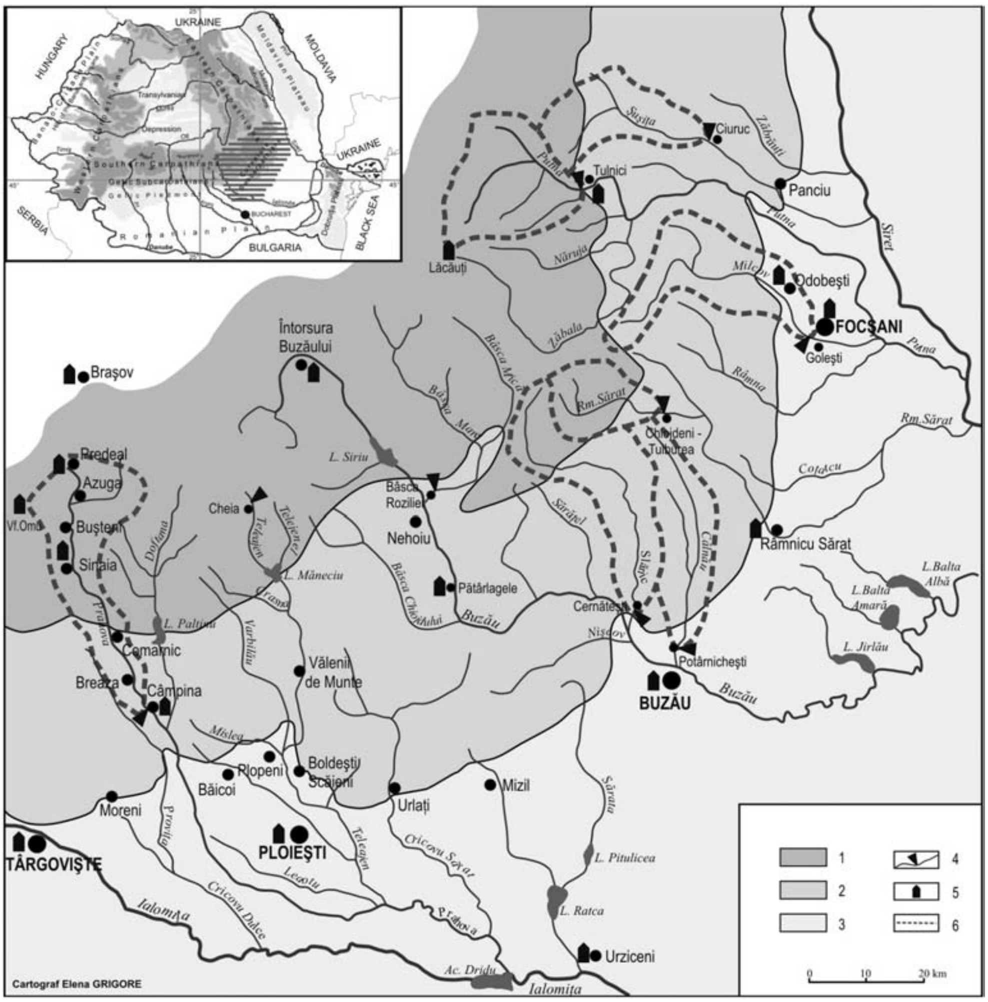

FIG. 1 - Study catchements and meteorological stations location map: 1. Carpathian area 2. Subcarpathian area; 3. Plain area; 4. Hydrometric station; 5. Meteorological station; 6. Watershed boundary.

which sometimes overpass 900-1000 m a.s.l.), depressions with diverse widths, and valleys with a transvers and a longitudinal orientation with respect to the general direction of the hills. Concerning the lithology, generally friable and very favourable to erosion deposits are specific of this area. Mostly, they belong to the Miocene and Sarmathian-Pliocene molasse (Sarmathian is the equivalent of Serravallian), including different lithologies such as clay, marls, sandstones, gravels, conglomerates, gypsum, marly limestone, marly-clays, limestone, salt, tuff etc. There are also Paleogene formations from the Carpathian area which breaks-in in the molasse part under the form of flysch spurs (Mutihac & *alii*, 2007). The lithology of the Subcarpathian eastern area is represented mainly by quaternary (mostly Pleistocene) deposits, consisting of gravels, sands, clay and loess deposits (Geografia României, 1987).

The *main climatic parameters* vary spatially with the altitudes and with the relief orientation. Whilst for the mountainous area, the yearly mean temperatures range between below 0°C and 4-5 °C, in the Subcarpathian area the temperatures increase to 8-10°C. This area is affected by the foehn phenomenon in the context of a western atmospheric circulation (Bordei-Ion, 1971). This is the reason that causes the precipitation to be less than in other areas with similar heights (except the eastern margin of the area, less affected by the foehn). The annual precipitation amounts to 700-1000 mm in the mountainous area, and 600-700 mm in the Subcarpathian area (Zaharia, 2005). The rainfalls regime is characterized by abundant precipitation during May-July period, and low quantities over autumn and winter. Characteristic for the summer are the heavy rains, favourable to surface erosion and river flooding.

In the Carpathian area, the *vegetation cover* is dominated by coniferous and mixed forests and by primary and secondary meadows. In the Subcarpathian area, the natural vegetation, initially represented by the foliage forests (beech and oak trees) and by meadows, has been strongly modified by man and replaced by large surfaces of secondary grasses, orchards, vineyards, and croplands. Massive deforestations took place at the beginning of the second half of the XIX century, and continued until the third decade of the XX century. The results of these actions were the acceleration of the erosion in the area. After 1976, with the implementation of a national program to combat soil erosion, an important reforestation associated with anti-erosion practices were realized in the area (Zaharia, 1998). The forests repossession to the landowners after 1989 was followed by uncontrolled deforestations.

Hydrological features. The mean density of the drainage network in the study area is 0.4-0.5 km km^{-2} (0.6-1.0 km km^{-2} in the mountainous area and 0.3-0.6 km km^{-2} in the plain area). In the Carpathian area, the mean specific discharge varies between 10 and 16 l s^{-1} km^{-2}, and between 3 and 12 l s^{-1} km^{-2} in the Subcharpathian area. The variation of the mean annual discharge, expressed by the variation coefficient, is lower in the mountainous area (C_V = 0.3-0.4) and higher in the hilly part (C_V = 0.4-0.6). The flow regime is characterized by high discharges in spring (41-43% of the annual mean water volume) and summer (24-30%), whilst over the winter and autumn the flow is lower (less than 15% of the annual mean water volume). The floods and the peaks of the annual discharge have mainly pluvial causes, occur most commonly over the summer and spring, and the rivers have a high erosive and transport capacity (Zaharia, 2005), with turbidity mean values of 2,500-5,000 g m^{-3}. In some sectors of the Subcarpathian area, the turbidity values overpass 25,000 g m^{-3} (Geografia României, 1987).

Socio-economical aspects. The External Carpathians' Curvature region is well populated, and hosts diverse economic, though their features differ from one area to another. In the mountainous area, the population mean density is 40 inhab. km^{-2}, and the urbanization index is 42% (at the country level, the population mean density is 95 inhab. km^{-2}, and the mean urbanization index is 54%, according to Anuarul Statistic al României, 2002). The main economical activities are forestry, farming and tourism. The Subcarpathian area is more densely populated (98 inhab. km^{-2}), but with a lower degree of urbanization (25%), and the economic activities are more diverse: farming, plant growing, local industry activities (Zaharia, 2005).

The natural and human impact conditions in the external Carpathians' Curvature cause a high erosion rate, particularly in the Subcarpathian area, where degraded lands (as far as bad-lands stage) occupy important areas (fig. 2). The intense erosion rate is also reflected by the high values of specific suspended sediment yield that in some sectors exceeds 20-25 t ha^{-1} year^{-1}, i.e. much than the country mean, only 2 t ha^{-1} year^{-1} (Mociorniţă & Birtu, 1987).

DATA AND METHODOLOGY

The analysis is based on the rainfalls data (annual precipitation) from 24 meteorological stations of the Meteorological National Administration (MNA) and on hydrological data (mean annual suspended sediment yields, mean annual discharge, maximum annual discharge) from 7 hydrometric stations of the National Institute of Hydrology and Water Management (NIHWM). The pluviometric and the hydrological data were validated by the two mentioned institutes. The period covered in the study is 1961-2000, long enough for a pertinent analysis. In the table 1 and table 2 the morphometrical and hydro-meteorological characteristics of the study catchments are synthesized. The morphometrical parameters correspond to the watersheds limits determined on the basis of the hydrographical maps, scale 1:100,000, from Atlasul Cadastrului Apelor din România (1992). The catchments mean altitudes and mean slopes were calculated based on the NOAA's numerical land-model GLOBE, using the MapInfo soft (version 6.5.), and its module, Vertical Mapper (version 3.0.). The forest ratio was determined on the basis of Eurasia Land Cover Database (EDC), with 1 km spatial resolution, using the *International Geosphere Biosphere Programme's* (IGBP), according to Zaharia, 2005.

The rivers analyzed are characterized by catchments with areas varying between 172 and 484 km^{2}, with mean

FIG. 2 - Bad-lands in the Subcarpathian's Curvature region.

TABLE 1 - Morphometrical characteristics of the study catchments

River	Hydrometric station	A (km^2)	H_m (m.a.s.l.)	S_m (degrees)	FR (%)
Şuşiţa	Ciuruc	172	556	2.6	74
Putna	Tulnici	365	1014	5.6	54
Milcov	Goleşti	406	422	3.1	55
Rm. Sărat	Chiojdeni-Tulburea	177	790	4.5	58
Câlnău	Potârnicheşti	194	338	2.2	27
Slănic	Cernăteşti	422	524	3.8	47
Prahova	Câmpina	484	1124	5.5	58

A = catchment's area; H_m = catchment's mean altitude; S_m = catchment's mean slope; FR = forest ratio.

TABLE 2 - Hydro-meteorological characteristics of the study catchments

River	Hydrometric station	Q_m* (1961-2000)		R (1961-2000)		CMP (1961-2000)**
		(m^3 s^{-1})	(l s^{-1} km^{-2})	(kg s^{-1}) *	(t ha^{-1} $year^{-1}$)	(mm)
Şuşiţa	Ciuruc	1.39	8.08	3.33	6.1	634.7
Putna	Tulnici	4.75	13.0	3.92	3.38	713.5
Milcov	Goleşti	1.50	3.69	18.4	14.3	630
Rm. Sărat	Chiojdeni-Tulburea	1.51	8.53	9.19	16.4	571.3
Câlnău	Potârnicheşti	0.392	2.02	8.27	13.4	544.2
Slănic	Cernăteşti	1.38	3.27	15.4	11.5	569.4
Prahova	Câmpina	8.27	17.1	10.9	7.1	926.4

Q_m = multiannual mean discharge; R = multiannual mean suspended sediment yield; CMP = catchment's mean precipitation.
* Data from NIHWM.
** Based on the data from MNA.

altitudes ranging between 338 and 1124 m a.s.l. The mean discharge varies between 0.392 m^3 s^{-1} and 8.27 m^3 s^{-1} (or between 2.02 l s^{-1} km^{-2} and 17.1 l s^{-1} km^{-2}). Generally the rivers have relatively high values of suspended sediment yield, reaching even 18.4 kg s^{-1}, corresponding to 14.3 t ha^{-1} $year^{-1}$ (Milcov River at Goleşti). The mean specific suspended sediment yield (calculated as ratio of suspended sediment yield, in t $year^{-1}$, and the catchment's area, in ha) is higher than 10 t ha^{-1} $year^{-1}$ in Milcov, Rm. Sărat, Câlnău and Slănic catchments (tab. 2).

The interpolation method (using the Natural Neighbour method from Vertical Mapper module) on the annual precipitation for the 24 meteorological stations was applied in order to estimate the annual mean catchment's precipitation. These vary between 544 and 926 mm (table 2).

For each catchment we analyzed, at an annual temporal scale, the variability of mean specific suspended sediment yield and of mean precipitation and also the relationship between the two parameters. The interannual variability of the two parameters, the linear trends and the 10 years moving averages are reported on plots. For establishing the statistical consistency of the temporal variability tendencies of precipitations and of specific suspended sediment yield, the Mann Kendall test has been applied (using MAKENSES 10. soft).

In order to identify regional trends of sediment yield and precipitation variability (at annual scale), we used the statistical method of Principal Component Analysis (PCA), applied without turnover, using Xlstat 5.1. soft. The PCA is a technique of factorial analysis allowing to summarize the information of a set of quantitative data. The basic principle of this method consists in the fact that the main part of the information is retained by the factorial axes (Principal Components) grouping together information common to several variables (Chadule, 1997).

Firstly, we determined the annual regional synthetic indexes for the specific suspended sediment yield (PC1r) and for the catchments' mean precipitation (PC1P). These indexes correspond to the information retained by the fist principal component. Secondly, we carried out the comparative analysis of the annual variation graphics for the two synthetic indexes, for their linear trends and for the 10 years moving averages. The Mann-Kendall test was applied to establish the statistical significance of the temporal variability trends of the two regional synthetic indexes (PC1r and PC1P). In order to identify the intensity of the relationship between the erosion's rate and the precipitations variability on regional scale, we have carried out the linear correlation between the two indexes, and we have analyzed the correlation and the determination coefficients. The statistical relevance of the correlations was established on the Bravais-Pearson test basis (Chadule, 1997).

TRENDS IN THE SUSPENDED SEDIMENT YIELD AND PRECIPITATION VARIABILITY

The analysis of the graphics realized for each catchment revealed a generally linear decreasing trend of suspended sediment yield between 1961 and 2000. This decrease is partially explained by the diminution of annual precipitation for each catchment, as shown by the similar general decreasing trend of precipitation (fig. 3). Even though the graphs show the existence of a decreasing linear tendency both of the annual precipitations and of the suspended sediment yield for all the study catchments, the Mann-Kendall test has shown that these tendencies are statistically consistent in the Putna catchment (at $\alpha = 0.01$ level of significance), in the Prahova catchment (at $\alpha = 0.05$ level of significance) and in the Milcov catchment (at $\alpha = 0.1$ level of significance). As regards the diminution tendency of suspended sediment yields, this is statistically significant for the Câlnău catchment (at $\alpha = 0.001$ level of significance), the Rm. Sărat catchment (at $\alpha = 0.05$ level of significance) and the Milcov catchment (at $\alpha = 0.1$ level of significance). The only basin where both the precipitations and the suspended load tendencies are statistically significant is the Milcov's, but the risk error is rather high ($\alpha = 0.1$ level of significance). The important decreasing tendencies of the two analyzed parameters are also highlighted by the «a» term of the equation corresponding to the linear tendency, of the form $y = ax + b$ (tab. 3).

In the case of the Câlnău catchment the existence of a strong decreasing tendency of the suspended sediment load to a low error risk ($\alpha = 0.001$ level of significance) and the lack of a considerable diminution of precipitations tendency could be put to the account of the application, beginning with 1976, of erosion control measures, within the framework of the National Program of Fighting against Soil Erosion (Zaharia, 1998).

TABLE 3 - Equations of linear trend of precipitations and suspended sediment yield for the study catchements

River	Hydrometric station	Equation of precipitation trend	Equation of suspended sediment yield trend
Şuşiţa	Ciuruc	–6,384x +845,64	–0,0937x +5,3369
Putna	Tulnici	–2,9271x +693,35	–0,1208x +8,3544
Milcov	Goleşti	–2,794x +692,89	–0,3159x +21,205
Rm. Sărat	Chiojdeni-Tulburea	–2,2314x +681,29	–0,3413x +24,051
Câlnău	Potârnicheşti	–1,4957x +588,03	–0,7924x +29,693
Slănic	Cernăteşti	–1,8791x +647,09	–0,0869x +13,359
Prahova	Câmpina	–5,0852x +1015,8	–0,0111x +7,4644

Important suspended sediment yield growths are noticeable in the graphics for the years with large floods, which generated substantial amounts of alluvium through their erosive and transport capacity. At a regional scale, these events occur in 1970, 1972, 1975, 1988, and 1991. These growths show the important role played by the flow for the suspended sediment load, as shown by the relatively high correlation coefficients (tab. 4) between the suspended sediment yield and the flow parameters (mean and maximum discharge).

TABLE 4 - Coefficients of determination (CD) and correlation coefficients (CC) of the relationships between the suspended sediment yield and hydro-meteorological characteristics of the study catchments (1961-2000)

River	Hydrometric station	Q_{max}		Q_m		CMP	
		CD	CC	CD	CC	CD	CC
Şuşiţa	Ciuruc	0.61	0.78	0.48	0.69	0.41	0.64
Putna	Tulnici	0.5	0.72	0.38	0.62	0.39	0.62
Milcov	Goleşti	0.66	0.81	0.65	0.8	0.18	0.42
Rm. Sărat	Chiojdeni-Tulburea	0.32	0.56	0.60	0.78	0.21	0.46
Câlnău	Potârnicheşti	0.29	0.54	0.69	0.83	0.29	0.54
Slănic	Cernăteşti	0.29	0.54	0.54	0.74	0.31	0.56
Prahova	Câmpina	0.39	0.62	0.40	0.64	0.30	0.55

Q_{max} = annual maximum discharge
Q_m = annual mean discharge
CMP = catchment's mean annual precipitation

The analysis of the 10 years moving averages reveals a relative cyclic variability of the suspended sediment yield, quite similar to the precipitation variability. Therefore, we can identify a cycle of 9-12 years for high suspended sediment yield and precipitations (1969-1981; 1991-1999). This alternates with lower values (1961-1968; 1982-1990). A statistically significant break (on the Petitt test basis), partially due to the North-Atlantic Oscillation, was revealed by the precipitation data series for 1961-1998 at the beginning of the 8th decade of the XXth century (Zaharia & *alii*, 2002). This break can also be visually identified in the variability of the annual suspended sediment yield, as well as in the moving averages graphics.

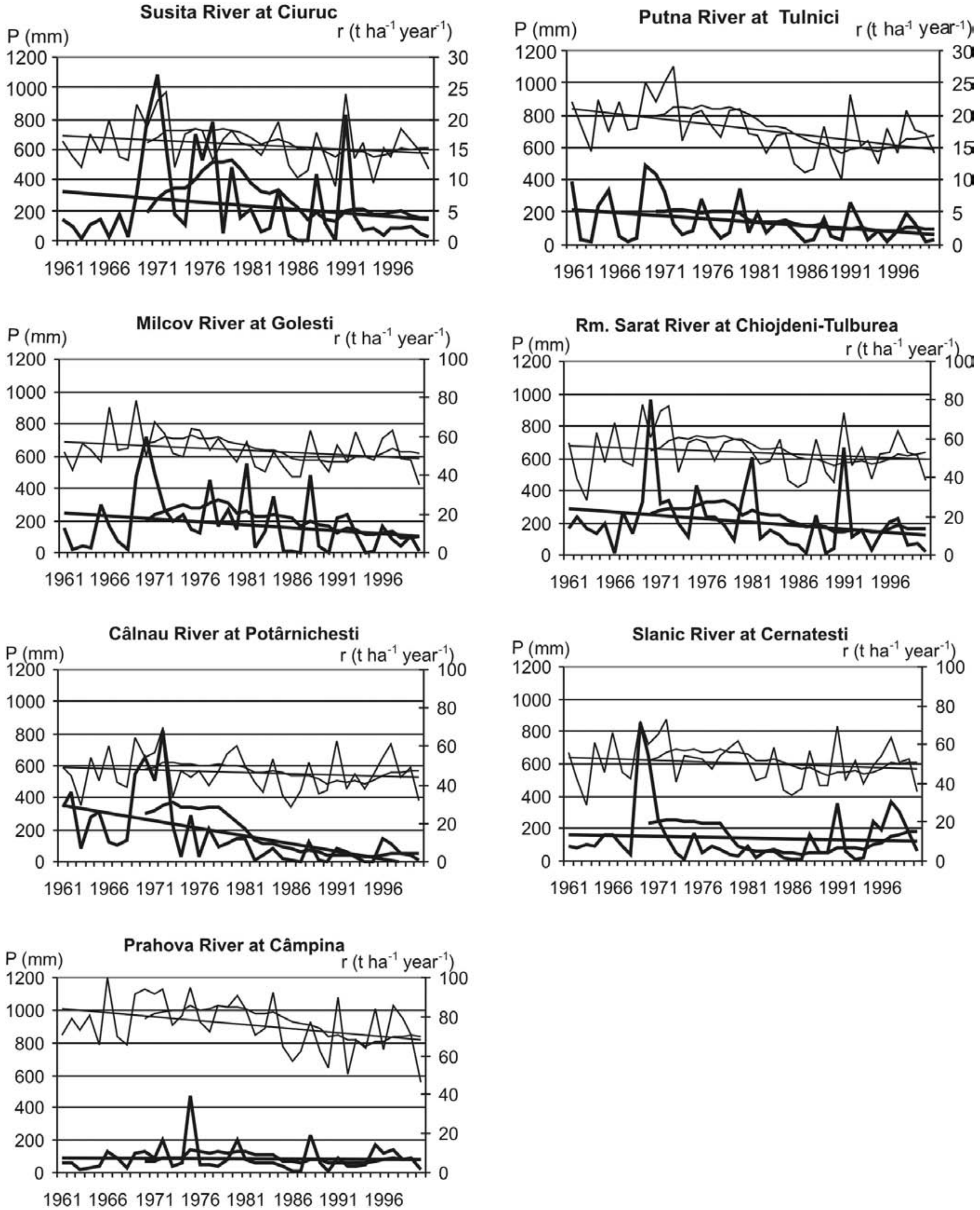

FIG. 3 - The interannual variability, the linear trends and the 10 years moving averages for mean specific suspended sediment yield (r - thick line) and annual precipitation (P - thin line) for the study catchments.

In order to emphasize the trends of the annual suspended sediment yield and precipitation variability at the scale of the whole Carpathians' Curvature external area, we carried out and analyzed the graphic of the interannual variability of the two parameters' synthesis indexes - PC1r and PC1P, and also their linear trend and 10 years moving averages (fig. 4). The graphic shows a general linear decreasing trend of the specific suspended sediment yield and of the precipitation in the Carpathians' Curvature region. The decreasing tendency of the suspended sediment load is statistically significant at $\alpha = 0.05$ level of significance, while the precipitations diminution is not consistent at all, which points at the importance of some other regional factors in the erosion processes.

PRECIPITATION ROLE IN THE EROSION DYNAMICS

The analysis carried out in chapter 3 emphasizes that at annual time scale, there is a certain correlation between suspended sediment yield and precipitation in the study area. The intensity of the relationship between the two parameters is emphasized by the values of the correlation coefficients. In the case of the study catchments these coefficients range from 0.42 to 0.64 (tab. 4). Even though they correspond to statistically consistent correlations (according to Bravais-Pearson test, for $\alpha = 0.05$ risk error), the generally low values of the determination coefficients (0.18-0.41) highlight the low quality of the correlations. This happens because of the influence of some local factors, such as lithology, morphology, land use, human activities, etc.

To estimate the intensity of the relationship at regional scale, the linear correlation between the annual synthetic index of specific suspended sediment yield (PC1r) and the annual synthetic index of precipitation (PC1P) was carried out (fig. 5). According to Bravais-Pearson statistical test, for $\alpha = 0.05$ level of significance, the correlation coefficient value (r = 0.66) is superior to the 0.308 threshold, which

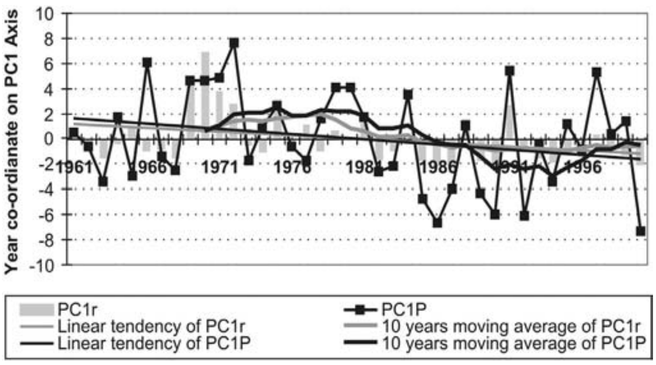

FIG. 4 - Interannual variability of the regional index for the annual precipitation (PC1P) and of the regional index for the annual specific suspended sediment yield (PC1r) in the Carpathians' Curvature region.

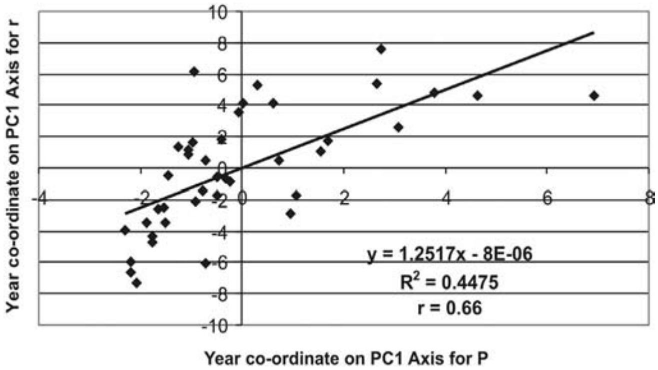

FIG. 5 - Linear correlation between the regional index for the annual precipitation (year co-ordinate on PC1 Axis for P) and the regional index for the annual specific suspended sediment yield (year co-ordinate on PC1 Axis for r) in the Carpathians' Curvature region.

indicates a statistically significant correlation between the analyzed parameters. However, the value of the determination coefficient ($R^2 = 0.45$) shows a low quality of the correlation. As mentioned previously, this is the consequence of the action of other regional and local factors that affect the erosion processes. The accomplished correlations between suspended sediment yield (for the 1961-2000 period) and the different catchments' characteristics (mean altitude, mean slope, forest ratio, mean precipitation) show that the most important role in the erosion processes is still played by the precipitation (with a correlation coefficient of 0.57), followed by the catchments' mean altitude (correlation coefficient = 0.52). Catchments' mean slope and the forest ratio have a lower influence (tab. 5).

TABLE 5 - Correlation coefficients and coefficients of determination of the relationships between the suspended sediment yield and catchment's characteristics

Relationship	Correlation coefficient	Coefficient of determination
r - H_m	0,52	0,28
r - S_m	0,38	0,15
r - CMP	0,57	0,32
r - Fr	0,37	0,14

r = multiannual mean specific suspended sediment yield (t ha^{-1} $year^{-1}$; 1961 - 2000)
H_m = catchment's mean altitude (m.a.s.l.)
S_m = catchment's mean slope (degrees)
CMP = catchment's mean precipitation (mm; 1961-2000)
Fr = forest ratio

CONCLUSIONS AND PROSPECTS

The erosion dynamics in the external Carpathians' Curvature region, expressed by specific suspended sediment yield, has a general decreasing trend for the period 1961-2000, mainly due to the precipitation reducing trend. This fact was emphasized for each catchment (through the comparative and correlative analysis of interannual variability of mean suspended sediment yield and mean precipitation), and at the whole external Carpathians' Curvature area, based on the analysis of the interannual variability of the synthesis indexes of the two parameters (indexes calculated based on the Principal Component Analysis method).

The linear correlation between the two synthesis indexes, through the value of the correlation coefficient, indicates a statistically significant correlation between the sediment yield and the precipitation amount. This shows the important role of the climatic conditions on the erosion processes, which reflect directly the changes in the precipitation variability. However, the low value of the determination coefficient shows that in the erosion processes interfere other local and regional factors (lithology, morphology, hydrological characteristics, human activities). Therefore, it is necessary to apply an integrated analysis of the possible determinant factors assembly, in order to better understand and manage the erosion processes in the studied area. The land use changes should be considered. A more rigorous analysis of the relationship between the erosion dynamics and precipitation variability should take into consideration not only the precipitation amount (considerate also on more detailed temporal scale), but the intensity and the frequency of precipitation, too. These aspects we intend to approach in a further research.

REFERENCES

BORDEI-ION N. (1971) - *Problèmes de la circulation de l'air dans la zone des Carpates de la Courbure*, La V-ème Conférence de Météorologie des Carpates, Bucureşti, 57-65.

CHADULE (group) (1997) - *Initiation aux pratiques statistiques en géographie*, Masson, Paris, 203 pp.

JUVANON DU VACHAT R. (2006) - *L'adaptation au Changement Climatique en France. Evaluation des vulnérabilités et stratégies*, Actes du XIX^{e} Colloque International de Climatologie, Epernay, 21-26.

MOCIORNAIŢĂ C. & BIRTU E. (1987) - *Unele aspecte privind scurgerea de aluviuni în suspensie în România*, Hidrotehnica, 7, Bucureşti, 241-245.

MUTIHAC V., STRATULAT M.I. & FECHET R.M. (2007) - *Geologia României*, Didactică şi Pedagogică, Bucureşti, 249 pp.

ZAHARIA L. (1998) - *Tendances dans l'évolution des transferts de matières en suspension dans les Subcarpates de Courbure, en relation avec les modifications du milieu naturel.* Géomorphologie, 3-15.

ZAHARIA L., BELTRANDO G., BIGOT S., OSZWALD J. & PETRACHE R. (2002) - *Pluviométrie extrême, en période chaude, dans le bassin-versant de la Putna (Roumanie) et circulation atmosphérique sur l'Europe Centrale,* Publications de l'Association Internationale de Climatologie, Volume 14, Aix-en-Provence, 236-242.

ZAHARIA L. (2005) - *Studiul resurselor de apă din Carpaţii şi Subcarpaţii Curburii*, Lucrări şi rapoarte de cercetare, Universităţii Bucureşti, 137-171.

*** (1987) - *Geografia României*, vol. III, Academiei Române, Bucureşti, 655 pp.

*** (1992) - *Atlasul Cadastrului apelor din România*, AQUAPROIECT, Bucureşti.

*** (2002) - *Anuarul Statistic al României*, http://www.insse.ro/download/anuar_2002/asr2002.htm

(Ms. presented 30 September 2007; accepted 30 December 2008)