DISCRIMINANT DESCRIPTORS AND STABILITY OF THE RIVER FLOW REGIME; A METHODOLOGICAL ATTEMPT

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Abstract. The stability of the river flow regimes is of a tremendous importance in the hydroecological judgment of the river life. The hydrological regime is defined by six descriptors meaning the first, the second and the third maximum and minimum values of the mean monthly discharges during the year. The stability is defined as the degree of regularity of the occurrence of a specific flow regime phase (maximum or minimum) in a given period indicated by the above-mentioned descriptors. According to this newly proposed method, the first component of the stability coefficient stability is the frequency of occurrence of certain descriptor in an as short as possible period of the year. The second component CR is a distribution coefficient computed as a function of the length of the period. It should take into account the fact that as shorter the period as higher is the stability. Thus on the one hand the frequency increases as the period is longer and on the other the stability is greater as the period is shorter. Taking into account these considerations a second component factor has been considered together with the frequency of occurrence.

The advantage of this method stands in the fact that for several combinations of subsequent months, the maximization of the stability coefficient leads to the assessment of the characteristic period itself of a distinct regime phase (maximum or minimum).

An application of the proposed methodology for some Danube countries and maps of regionalization of the river flow regimes are presented in the work.
Keywords: River regime, Stability coefficient, Entropy, probability

Zusammenfassung: Die Stabilität des Hydrologischen Regimes eines Wasserlaufes ist von ausserordlichen Bedeutung für seine hydroecologische Einschätzung. Erstens ist das Hydrologische Regime durch sechs Beschreiber bestimmt wie folgend: das erste, das zweite und das dritte Höchst, und Mindestmasswert des mittleren monatlichen Durchfluss Wertes eines Jahres (MAX1, MAX2, MAX3 für die Maximal-Phasen und MIN1, MIN2, MIN3 für die Minimal-Phasen.

Die Stabilität des Regimes bestimmt den regularitäts Grad der Erzengung, während eines Jahres, der Maximal und Minimal-Phasen in den dürch die Beschreiber angegeben Zeitspannen. Der erste Bestandteil des Stabilitäts Koeffizient ist die Frequentz der Erscheinung eines Beschreibers in eine so Kurz wie möglich Zeitspanne des Yahres. Der zweite Bestandteil zeigt dass je kürzer die Zeitspanne, in der ein Beschreiber des Regimes erscheint, desto grösser die Stabilität des Regimes ist. Der Vorteil der Anwendung dieser Methode besteht derin dass für mannigfaltige Kombinationen der nacheinander folgenden Monaten in welchen je ein Regime-Beschreiber erscheinen kann, die Maximisirung des vorgeschlagenen Stabilitäts-Koeffizient zur korrektesten Bestimmung der charakteristischen Zeitspanne für jede Regimephase führen kann (die drei Monate mit den höchsten beziehungsweise kleinsten mittleren monatlichen Durchflusswerten).

Eine Anwerdung der vorgeschlagenen Methode für manche Donau- Länder und eine Regionalisirung der Hydrologischen Regime dieser Länder werden in dem Vortrag vorgestellt.
Schlüsselworte: *Wasserlauf-Regime,* Stabilität-Koeffizient, Entropie, Wahrscheinlichkeit

1. Introduction

The stability of a river flow regime is of a paramount importance in the management of the fresh water aquatic ecosystems. Both the high and low waters exert a stress on the river life. The developing phases of the aquatic plants as well as of the vegetation along the flood prone areas might be sensitively disturbed while the high waters produced in the periods which are not “recognized “by the vegetation ecosystem. The same severe situation could be created during the periods of low waters that occur in other season than unusually.

The absorbing capacity of the ecosystems that ensure the “river health” Zalewski, 2000) against both the natural and made - man stress depends on the river regime stability. The state of the river means three things, namely:

- Hydrological regime;
- Water quality;
- Habitat.

The last can be seriously affected by the river flow stability in some periods of the year, as the fish reproduction for example needs favoring conditions of habitat.

The stability of a certain flow regime may be quantitatively expressed by the the entropies of the occurrence of the regime descriptors (the first three maximum MAX1, MAX2, MAX3 and minimum MIN1, MIN2, MIN3 values of monthly flows) in the discriminating periods (Shannon and Weaver, 1941), (Krasovskaia, 1995). The production of such an event in a certain considered period of subsequent months represents one of the descriptor of the flow regime pattern.

The occurrence of a certain pattern of flow during individual years in a series is considered as an event E_i, the probability of which is $p_i = p(E_i)$ and $\sum_{1}^{n} p_i = 1$.

The index H, measuring the entropy as defined by (Shannon and Weaver, 1941), is the sum $H=\Sigma H(E_j)$ of the index $H(E_j)$ characterizing the individual stability of the six hydrological events listed above, as defined by the following equation:

$$H(E_i) = p_i \ln p_i + (1 - p_i)\ln(1 - p_i) \qquad (1)$$

where p_i is the probability of occurrence of the given hydrological event within the selected descriptor (discriminant period of the year and $(1 - p_i)$ is the probability of occurrence of the same event within the complementary period. The function (1) is symmetrical, that is $H(p_i)=H(1-p_i)$. Thus the stability index H can be used only within the interval p_i>0.5.

The entropy has the maximum value when $p_1 = p_2 = \ldots = p_n$ (complete incertitude or instability of the regime) and minimum value when $p_i = 1$ (complete certitude or stability).

Thus if the entropy is determined for each of the six discriminant periods (MAX1, MAX2, MAX3, MIN1, MIN2, MIN3) which define a specific regime all along the year, the sum of the all entropies represents the measure of the regime stability for the whole year.

Using property of additivity of the entropy the sum of the entropies of each characteristic (total entropy) expresses the entropy of the flow pattern and therefore the degree of its stability.

The advantage of the use of entropy to measure the degree of stability of the river flow regimes consists in the property of additivity of the entropy. The great disadvantage of the entropy consists in the fact that it depends on the length of the discriminant period that has been chosen for a certain phase of regime (for example for MAX1). Moreover, if the probability is less than 0.5 the method cannot be used.

2. Derivation of the stability coefficient

These shortcomings in applying the entropy as a measure of the stability has resulted in searching of an index that would be able to take into account both of the frequency of occurrence of a certain event and concomitantly to consider that a high stability of this event is reached in an as short period as possible. This fact led to propose another alternative that considers that the discriminant periods occur with a high frequency in a characteristic period formed of *subsequent* months (for example a descriptor occurs in the period April-June). Therefore, the sum of the frequencies of the occurrence in each of the months of the year, belonging to the selected characteristic period would indicate a numerical indicator of the stability of a considered discriminant characteristic. The greater is the number of events, which fall in a certain discriminant period the higher is the stability. However, on the other hand, if only this indicator is considered, it would mean that the stability would have been greater as the discriminant period is longer (the number of occurrences in a long period of subsequent years is greater). In other words, chances that a certain flow regime characteristic (MAX1, MAX2 etc.) would be found in a longer period increase and consequently the frequency that is great. This is in conflict with idea that, in reality, as the period is longer, the occurrence of the descriptor has a more unstable character. At the limit, if it is admitted that for a certain descriptor, the length of the period is the entire year (months January to December) the frequency is 100%. In spite of this, the regime is very unstable as the occurrence of the descriptor is produced in any month of the year. That is why, while establishing a numerical indicator of the stability of the river flow regime, both one component expressing the frequency and another one that deems the length of the period are necessary to be taken into consideration. Thus, the frequency of the occurrence of a certain discriminant value is higher and the length of the period within which the value is found, the regime is more stable.

Relied upon this concept the coefficient of stability is determined as follows:

$$CS = FA * CR \quad (2)$$

where:

FA is the frequency of the occurrence of the discriminant value in *m* subsequent month ($m = 1,12$)

CR is the distribution coefficient along the period, given by:

$$CR = \left[\frac{13 - m}{12}\right]^2 \quad (3)$$

In the table 1 the degree of stability of the river regime, function of the ranges of the stability coefficient is presented.

Table 1. The character type of the river regime function of the stability coefficient

FA	CR		CS	Regime character type
	m	$CR=f(m)$		
0.9-1.0	1-2	0.69-1.00	0.62-1.00	Very stable
0.8-0.9	2-3	0.56-0.69	0.45-0.62	Stable
0.7-0.8	3-4	0.44-0.56	0.31-0.45	Relatively stable
0.6-0.7	4-5	0.34-0.44	0.20-0.31	Relatively unstable
0.0-0.6	6-12	0.00-0.34	0.00-0.20	Unstable

In Figure 1 for different lengths of the discriminant period ranging in the interval 1-12 months and for three scenarios of frequencies FA1, FA2, FA3, the curves of stability coefficient are presented. One can see that if the number of months increases (the considered period is longer) the distribution coefficient CR decreases.

On the other hand, if the number of the concomitant months in which the regime characteristic increases, the frequency (in a certain scenario) increases, too. The result is that the product CS will have a maximum value which has the signification of an optimum situation. This led to the idea that the periods that characterize a certain flow regime (i.e. the periods in which the descriptors MAX1, MAX2, MAX3, MIN1, MIN2, MIN3 fall) could be chosen on the bases of maximizing the value of this index.

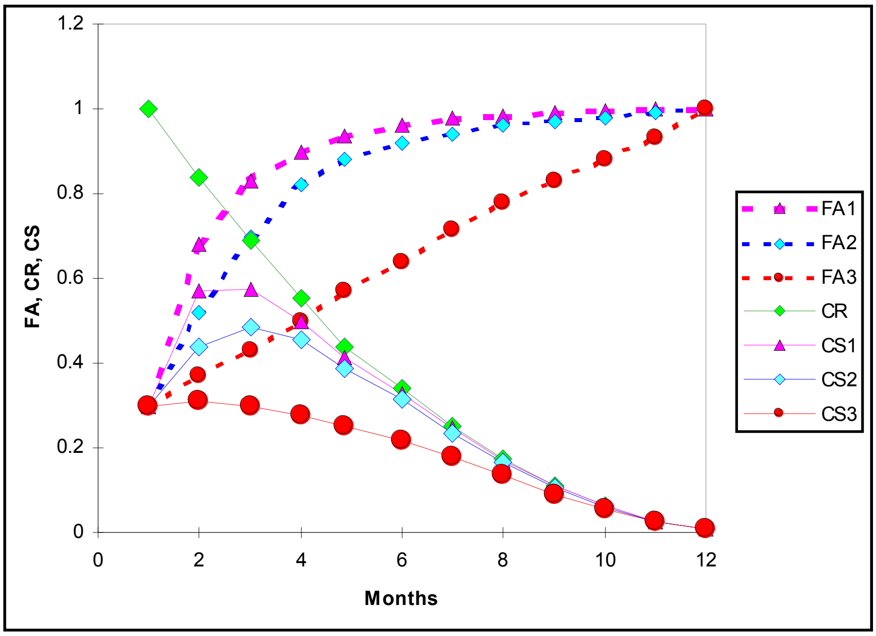

Figure 1. The stability coefficient for different scenarios of the frequencies

An example of the determination of the stability coefficient is given in Figure 2.

Years	Months			
	IV	V	VI	VII
1950		✓		
1951		✓		
1952		✓		
1953		✓		
1954	✓			
1955	✓			
....	....	....	....	....
1990	✓			
1991	✓			
1992	✓			
1993			✓	
1994				✓
1995		✓		
Sum	12	21	9	3

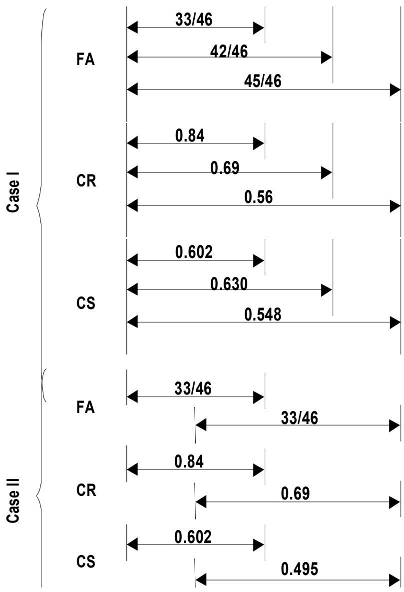

Figure 2. Applying the method of assessing the stability coefficient of the River Flow Regime and the discriminant period

For a certain descriptor, in the case 1 as possible discriminant periods the following ones have been considered: IV-V (April-May), V-VI (May-June) and IV-VII (April-June). Thus, for this case although the frequencies increase as the length of the period becomes longer, the distribution coefficient decreases and the maximum value of the product $CS = FA * CR$ equal to 0.630 correspond to the period IV-VI (April- June).

In the case 2 where the selected periods were IV-V and V-VII the first one (April-May) have the maximum value $CS = FA * CR$=0.84 and therefore expressing the highest stability it is taken as discriminant for the considered descriptor.

3. Method of application

The advantage of this method stands in the fact that for several combinations of subsequent months, the maximization of the stability coefficient leads **to the assessment of the discriminant period for each descriptor**.

An example of application of this method is made for 29 stations in Romania, which are characteristic for the river flow regime type of the mountainous zone. In tables 2 and 3 the stability coefficients have been computed for the discriminant periods of high and low waters. It can be seen that for the first discriminant period in which MAX1 occurs, at the majority of the stations the maximum value of stability coefficient for the shortest period is met in the time interval IV-VI that is marked in the table in bold. At 11 stations the descriptor MAX1 (maximum value of monthly flow in each year) is observed within other selected intervals (V-VI, IV-V, IV-VII) but the values are very closed to those computed for the basic discriminant period IV-VI.

Moreover, at the majority of these stations the characterization of the stability according to the Table 1 is the same. For example, in column of discriminant period MAX1 the values of CS are practically equal: at Pitesti station CS=0.67 in the period V-VI as compared with CS=0.63 in the basic period IV-VI. Also, at Valea lui Stan station CS=0.75 in the period IV-V as compared with CS=0.67 in the basic period IV-VI, etc. Yet, the characterization of the stability is the same (very stable, noted “vs” in the table). The same remarks are made for the discriminant periods of the low waters (MIN1, MIN2) as seen in the Table 3

Thus this method allow not only to numerically representing the stability of the river flow regime by computing this index, but also for determining in an objective manner the discriminant periods.

Table 2. The establishment of the discriminant periods of high waters by applying the stability coefficient CS

STATION	**MAX1**				**MAX2**				**MAX3**		
	IV-VI	V-VI	IV-VII	IV-V	**IV-VII**	IV-VI	III-V	V-VII	**IV-VII**	IV-VI	V-VII
Apa Sarata	0.55(s)	**0.63(vs)**			0.47(s)	**0.55(s)**			**0.46(s)**	0.39(rs)	
Busteni	0.40(rs)		**0.49(s)**		0.46(s)	0.41(rs)		**0.53(s)**	**0.42(rs)**		0.42(rs)
Moroeni	0.57(s)	0.58(s)		**0.61(s)**	0.47(s)	**0.50(s)**			**0.41(rs)**	0.39(rs)	
Pod Dambovita	0.56(s)	**0.64(vs)**			0.54(s)	**0.65(vs)**			**0.43(rs)**	0.41(rs)	
Tunel	0.61(s)	**0.71(vs)**			0.51(s)	**0.60(s)**			**0.49(s)**		
V.lui Stan	0.66(vs)	0.67(vs)		**0.75(vs)**	0.56(s)	**0.68(vs)**			**0.45(s)**		
Pitesti	0.63(vs)	**0.67(vs)**			0.48(s)	**0.55(s)**			0.41(rs)	**0.44(rs)**	
Zarnesti	**0.57(s)**				0.43(s)	**0.46(s)**			0.37(rs)	**0.39(rs)**	
Plaiul Foii	**0.59(s)**				0.46(s)	**0.51(s)**			0.39(rs)		**0.40(rs)**
Fundu Moldovei	**0.52(s)**				0.48(s)	**0.54(s)**			**0.45(s)**	0.44(rs)	
Dorna Giumalau	0.67(vs)			**0.74(vs)**	0.47(s)	**0.52(s)**			0.45(s)	0.39(rs)	**0.48(s)**
Itcani	**0.54(s)**				**0.46(s)**	0.42(rs)			**0.37(rs)**	0.31(ru)	
Nehoiu	**0.54(s)**				0.43(rs)	**0.48(s)**			**0.30(ru)**	0.30(ru)	
R. Sarat	**0.43(rs)**				0.34(rs)	**0.40(rs)**			**0.29(ru)**	0.29(ru)	
Tarlung	**0.54(s)**			0.54(s)	043(rs)	**0.51(s)**			0.36(rs)		**0.39(rs)**
Sancraieni	**0.56(s)**				0.39(rs)	**0.41(rs)**			**0.39(rs)**		
Tomesti	**0.57(s)**				041(rs)	**0.45(s)**			**0.41(rs)**		
Bistrita Bargau	**0.47(s)**				0.34(rs)	0.34(rs)	**0.42(rs)**		0.34(rs)	**0.36(rs)**	
Poiana Mare	0.64(vs)			**0.65(vs)**	0.50(s)	**0.58(s)**			**0.40(rs)**	0.38(rs)	
Iscroni	**0.52(s)**				0.44(rs)	**0.55(s)**			0.34(rs)	**0.40(rs)**	
Fata Motru	**0.40(rs)**				0.34(rs)		**0.40(rs)**		0.31(rs)	**0.37(rs)**	
Filiasi	**0.47(s)**				0.39(rs)	0.45(s)	**0.48(rs)**		0.35(rs)	**0.40(rs)**	
Podari	**0.41(rs)**				040(rs)	**0.47(s)**			0.30(ru)	**0.33(rs)**	
Tg. Carbunesti	**0.60(s)**				0.47(s)	**0.56(s)**			**0.37(rs)**	0.34(rs)	
Caransebes	**0.56(s)**				0.37(rs)	**0.44(rs)**			0.31(rs)		**0.39(rs)**

Lugoj	**0.49(s)**				0.35(rs)	**0.42(rs)**			**0.28(ru)**		
Pietroasa	0.54(s)			**0.59(s)**		**0.37(rs)**	**0.39(rs)**		0.31(rs)		
V. Dragan	0.61(s)			**0.65(vs)**	0.42(rs)	**0.49(s)**				**0.49(s)**	0.43(rs)

Legend: (vs)-very stable, (s) –stable, (rs) relatively stable, (ru) relatively unstable

Table 3. The establishment of the discriminant periods of low waters by applying the stability coefficient CS

	M I N 1		**M I N 2**		
	XII - II	VIII - X	**XI - II**	XII - II	IX - XI
Apa Sarata	**0.45(s)**		**0.35(rs)**		
Busteni	**0.57(s)**		**0.48(s)**		
Moroeni	**0.48(s)**		**0.40(rs)**		
Pod Dambov.	**0.53(s)**		0.31(rs)	**0.42(rs)**	
Tunel	**0.57(s)**		0.35(rs)	**0.42(rs)**	
V.lui Stan	**0.49(s)**		**0.38(rs)**		
Pitesti	**0.40(rs)**		**0.31(rs)**		
Zarnesti	**0.47(s)**		**0.40(rs)**		
Plaiul Foii	**0.56(s)**		**0.43(rs)**		
Fundu Moldovei	**0.55(s)**		0.46(s)		
Dorna Giumalau	**0.60(s)**		0.51(s)	**0.55(s)**	
Itcani	**0.55(s)**		**0.41(rs)**		
Nehoiu	**0.45(s)**		**0.31(rs)**		
Tarlung	**0.42(rs)**		**0.39(rs)**		
Sancraieni	**0.55(s)**		**0.43(rs)**	0.43(rs)	
Tomesti	**0.60(s)**		0.34(rs)	**0.42(rs)**	
Bistrita Bargau	**0.36(rs)**		**0.39(rs)**		
Poiana Mare	**0.42(rs)**		**0.31(rs)**		
Iscroni		**0.40(rs)**			**0.31(rs)**
Fata Motru		**0.52(s)**			**0.39(rs)**
Filiasi		**0.45(s)**			**0.45(rs)**
Podari		**0.50(s)**			**0.46(s)**
Tg. Carbunesti		**0.46(s)**			**0.32(rs)**
Caransebes		**0.46(s)**			**0.40(rs)**
Lugoj		**0.43(rs)**			**0.42(rs)**
Pietroasa		**0.40(rs)**			**0.44(rs)**
V. Dragan		**0.32(rs)**	**0.38(rs)**		

Legend: (vs)-very stable, (s) –stable, (rs) relatively stable

This method has been applied for assessing the stability character of different types of the river flow regimes the Romania. For each discriminant periods of the considered river flow regime, the equations (2) and (3) have been applied to compute the stability coefficient. Then, for a given area where there are more than one station the stability coefficient has been computed for each station and furthermore, the average value for each regime phase has been determined. The averaging has been applied provided that the deviation of the computed indexes of stability for all stations in the considered area where it is assumed to have the same flow regime should be small. Anyway, even a small deviation of the stability coefficients from the mean computed for a group of stations give an indication of the membership of these stations to the same type regime. Thus, besides the criteria of similarity of physiographical and climatic conditions of an area, the applying of the method represents a crosschecking of correctness of establishing a certain type regime for a given zone. In compliance with the corresponding characterization of the stability of the regime function of the position of the stability coefficient value in the ranges of variation of CS (as presented in the Table 4) the character of each type of regime has been established.

4. Application for some Danube countries.

For the analysis of the river flow regime in some Danube Countries the following data sources have been used:

- FRIEND-AMHY data base;
- Data on mean monthly discharges at gauging stations published in the hydrological yearbooks of Romania, Hungary and Yugoslavia.

The lengths of the data series concerning the mean monthly discharges are very different ranging from 20-80 years. Nevertheless, the short series of data having at lest 15 years record period have been considered for the assessment of the occurrence of the discriminant discharges as in these periods dry and wet years have been observed so that the selected series have been considered as representatives ones. Where some small gaps in the series of data have been detected they were completed making use of correlation with other stations having similar flow regimes. The range of the series of data is given in Table 4.

Table 4. Available data used for the river flow regime analysis.

Country	Number of stations	Record period (years)
Bulgaria	10	34-54
Serbia & Montenegro	7	40
Slovenia	12	15-45
Romania	80	45 – 65
Hungary	17	33-36
Slovakia	2	40

Relying upon the available data at the stations considered in the countries given above in the Table 1, the discriminating periods, which define a particular river flow regime, have been assessed. The existence of different zones which are quasi-homogeneous from the physiographical properties stand point, especially expressed by their mean altitudes, allows carrying out a hydrological regionalization of the river flow regime types that have been found. Mention is made that in the case of the large catchments of the rivers that encompass two or even three regime types the delineation made by this regionalization refer to the sub-basins located in the area that define a specific type. Thus a “combined” regime for the river basins having areas more than a couple of thousands square kilometers may result as a mixture of the two or three types.

The synthetic description of the river flow regime types in each country considered in the study is given in Table 5. Mention is made that for characterizing the river flow regimes of Slovakia, beside the stations located on Hron River (Brehy Station)and Vah River(Sala Station), data from Hungarian stations located on tributaries of Tisza and Danube River (Hernad-Hornad River at Hisdasnemety Station, Sajo River at Felsözsolca Station, and Bodrog River at Felsöbereki Station as well as Ipoly-Ipel River at Nogradszakal have been used.

The regionalization of the regime types has been performed taking into account both the climatic characteristic features of the zones and the mean elevation of the analyzed basins. The regionalization maps of specific types of river flow regimes and the mean monthly hydrographs (expressed as percentage of the annual volume) at the gauging stations of basins that are representative for each regime type are presented in Figures 3-7.

Table 5. Synthetic characterization of the descriptors, patterns and stability of the river flow regime types of Romania

ROMANIA

No.	Zone	DISCRIMINANT PERIODS					
		MAX1	MAX2	MAX3	MIN1	MIN2	MIN3

1	Southern Plain zone	II-III	II-IV	II-IV	VIII-X	VIII-X	VIII-X
		0.38	0.41	0.34	0.52	0.58	0.41
		R. Stable	R. Stable	R. Stable	Stable	Stable	R. Stable
2	Western Carpathian	IV-VI	III-VI	III-VI	IX-XI	IX-XI	VIII-XI
		0.57	0.41	0.47	0.41	0.41	0.48
		Stable	R. Stable	Stable	R. Stable	R. Stable	Stable
3	Central Plateau	III-IV	III-IV	III-V	IX-XI	VIII-XI	VIII-XI
		0.53	0.41	0.41	0.39	0.4	0.49
		Stable	R. Stable	R. Stable	R. Stable	R. Stable	Stable
4	Moldavian Plateau	III-IV	III-V	III-V	VIII-X	VIII-X	VIII-X
		0.41	0.44	0.26	0.36	0.33	0.35
		R. Stable	R. Stable	R. Unstab.	R. Stable	R. Stable	R. Stable
5	Southern and eastern Carpathian Mountains	IV-VI	IV-VI	IV-VII	XII-II	XI-II	XI-II
		0.56	0.50	0.40	0.50	0.39	0.39
		Stable	Stable	R. Stable	Stable	R. Stable	R. Stable
6	Dobrodgean zone	IV-VI	IV-VII	IV-VII	VIII-X	IX-X	VII-XI
		0.36	0.36	0.30	0.30	0.39	0.35
		R. Stable	R. Stable	R. Unstab.	R. Unstab.	R. Stable	R. Stable
7	South-Western Carpathian	II-V	II-VI	II-VI	VIII-X	IX-XI	IX-XII
		0.51	0.46	0.36	0.50	0.40	0.40
		Stable	Stable	R. Stable	Stable	R. Stable	R. Stable
8	Western Plain and low hilly zone	I-II	I-IV	I-IV	VIII-X	VIII-X	VIII-X
		0.41	0.37	0.33	0.55	0.46	0.46
		Stable	R. Stable	R. Stable	Stable	Stable	Stable

BULGARIA

No.	Zone	DISCRIMINANT PERIODS					
		MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Balkan Mountains and high hilly area	III-VI	III-IV	III-V	VIII-X	VIII-X	VIII-IX
		0.44	0.43	0.41	0.50	0.48	0.41
		R. Stable	R. Stable	R. Stable	Stable	Stable	R. Stable
2	Low hilly and lowland northern Bulgaria	II-V	II-IV	II-IV	VIII-IX	VIII-IX	IX-XII
		0.36	0.31	0.36	0.38	0.36	0.35
		R. Stable	R. Stable	R. Stable	R. Stable	R. Stable	R. Stable

SLOVENIA

No.	Zone	DISCRIMINANT PERIODS					
		MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Northwestern upland zone (Julian Alps, Gorenjka)	IV-V	IV-VI	IV-VI	I-II	VIII-IX	VII-VIII
		0.42	0.34	0.51	0.39	0.42	0.34
		R. Stable	R. Stable	Stable	R. Stable	R. Stable	R. Stable
2	Northern upland zone (Savinjke Alps, Pohorje)	II-IV	II-IV	I-IV	VII-X	VII-IX	VII-X
		0.31	0.29	0.33	0.32	0.39	0.34
		S. Stable	R. Unst.	R. Stable	R. Stable	R. Stable	R. Stable
3	South-western high hilly zone (Notranjska)	II-IV	X-XII	X-XII	VII-X	VII-IX	VII-X
		0.35	0.31	0.35	0.39	0.34	0.34
		R. Stable	R. Stable	R. Stable	R. Stable	R. Stable	R. Stable
4	Central low hilly and lowland zone Dolenjska, Slovenske Gorice	III-V	III-IV	I-IV	VII-IX	VII-VIII	VII-IX
		0.32	0.36	0.29	0.29	0.48	0.33
		R. Stable	R.Stable	R. Unstab.	R. Unstab.	Stable	R. Stable
5	Southern hilly zone (Upper Kupa, Gorjanci)	X-XII	I-IV	I-IV	VII-IX	VII-IX	VII-IX
		0.37	0.35	0.35	0.38	0.55	0.43
		R. Stable	R. Stable	R.Stable	R. Stable	Stable	R. Stable

SERBIA AND MONTENEGRO

No.	Zone	DISCRIMINANT PERIODS					
		MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	North plain - low altitude.	II-IV	II-V	III-V	VIII-X	VIII-IX	VIII-IX
		0.49	0.40	0.46	0.61	0.51	0.45
		Stable	R. Stable	Stable	Stable	Stable	Stable
2	South-eastern zone - South Morava River	II-IV	II-IV	II-V	VIII-IX	VIII-X	VII-X
		0.49	0.51	0.37	0.63	0.54	0.48
		Stable	Stable	R. Stable	V,Stable	Stable	Stable
3	Eastern zone-Balkan Mountains (Nisava and Timok Rivers)	II-IV	III-V	III-V	VIII-X	VIII-X	VII-X
		0.49	0.42	0.49	0.64	0.49	0.40
		Stable	R. Stable	Stable	V,Stable	Stable	R. Stable

4	South-western high elevation zone (Dinaric Alps).	IV-V	III-V	III-V	VIII-IX	VIII-X	VII-VIII
		0.52	0.59	0.32	0.53	0.59	0.45
		Stable	Stable	R. Stable	Stable	Stable	Stable
5	Central zone – West Morava River basin	II-IV	II-IV	II-V	VIII-X	VII-X	VIII-X
		0.47	0.44	0.41	0.63	0.63	0.51
		Stable	R. Stable	R. Stable	V,Stable	V,Stable	Stable
6	Southern zone - high altitude.	IV-V	IV-V	IV-VI	VIII-IX	VII-IX	IX-X
		0.60	0.46	0.38	0.68	0.56	0.54
		Stable	Stable	R. Stable	V,Stable	Stable	Stable

HUNGARY

No.	Zone	DISCRIMINANT PERIODS					
		MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Northern high hilly and low mountains (Börzsöny,Matra, Bukk).	II-IV	II-V	III-V	VIII-X	VIII-XI	VIII-XI
		0.42	0.35	0.36	0.44	0.36	0.33
		R. Stable	R. Stable	R. Stable	R. Stable	R. Stable	R. Stable
2	South - Western zone (Bakony, Mecsek low mountains)	XII-III	I-IV	I-IV	VII-X	VII-X	VIII-X
		R. Stable	R. Stable	R. Stable	Stable	Stable	R. Stable
		0.42	0.36	0.39	0.59	0.50	0.43

SLOVAKIA & Western UKRAINE

No.	Zone	DISCRIMINANT PERIODS					
		MAX1	MAX2	MAX3	MIN1	MIN2	MIN3
1	Western Ukraine-Lisysti Karpaty (Uh River) and South-eastern Slovakia- -Nizke Bezkudy (Ondava River)	III-IV	III-V	III-IV	VIII-X	VIII-XI	VIII-XI
		0.46	0.38	0.55	0.49	0.37	0.42
		Stable	R. Stable	Stable	Stable	R. Stable	R. Stable
2	Slovenské rudohorie (Hornad-Hernad River, and Ipel (Ipoly) Sayo-Rimava, Slano Rivers)	II-IV	III-V	III-V	VIII-X	VIII-XI	VIII-XI
		0.45	0.45	0.38	0.46	0.40	0.37
		R. Stable	R. Stable	R. Stable	Stable	R. Stable	R. Stable
3	High Tatra Mountains-Nizke Tatry (Vah River, Hron River)	III-IV	III-V	III-VI	VIII-X	VIII-X	VIII-X
		0.52	0.48	0.40	0.43	0.40	0.42
		Stable	Stable	R. Stable	R. Stable	R. Stable	R. Stable

Legend: R. Stable=Relatively stable; R. Unstab.=Relatively unstable.

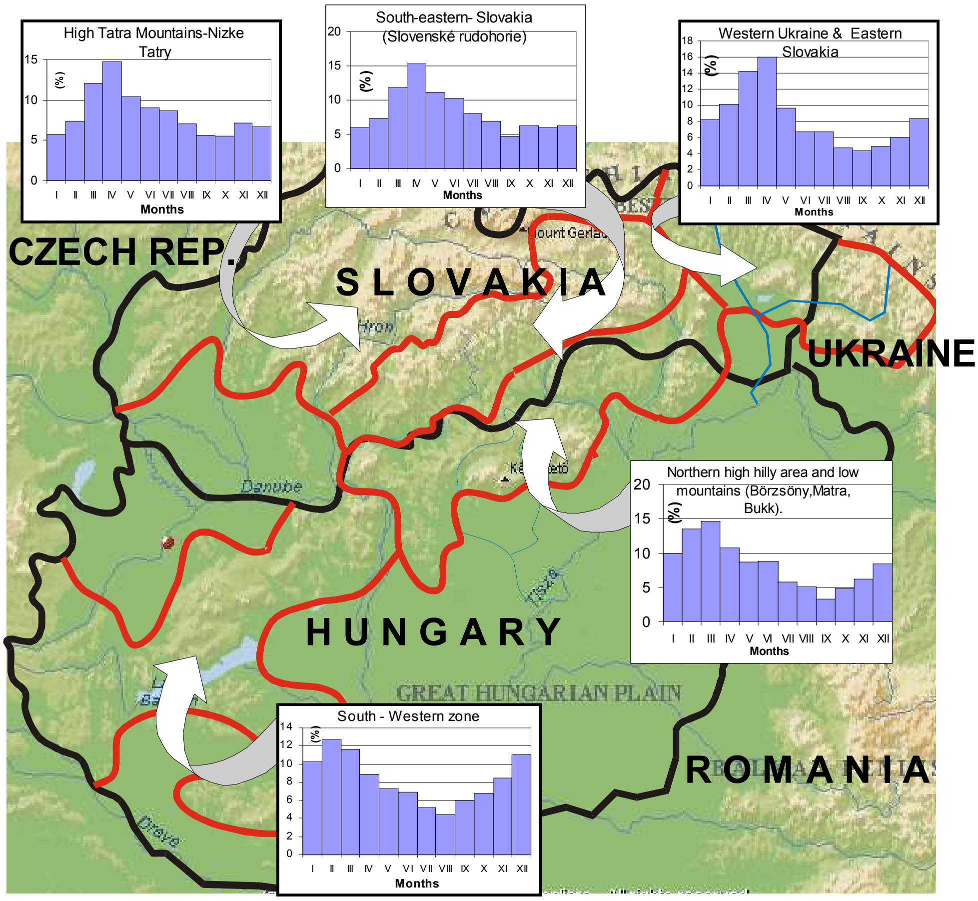

Figure 3. Characteristic river flow regimes in Hungary, Slovakia and Ukraine

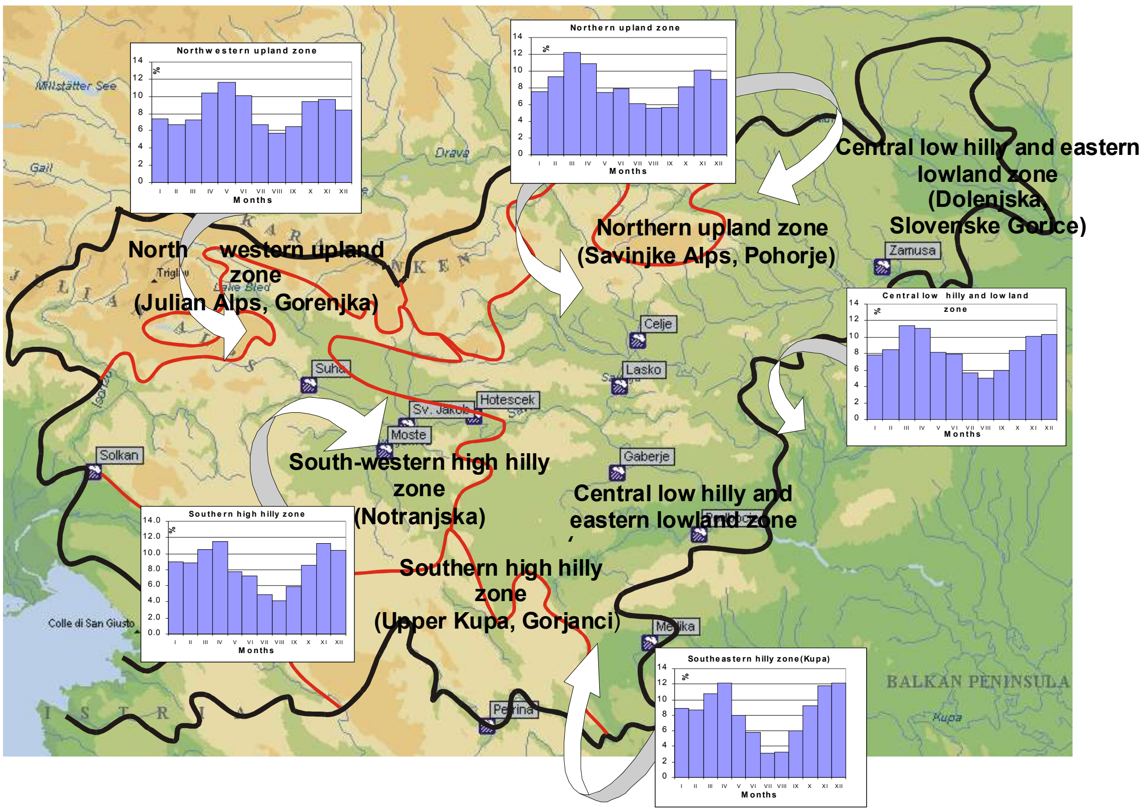

Figure 4. Characteristic river flow regimes in Slovenia

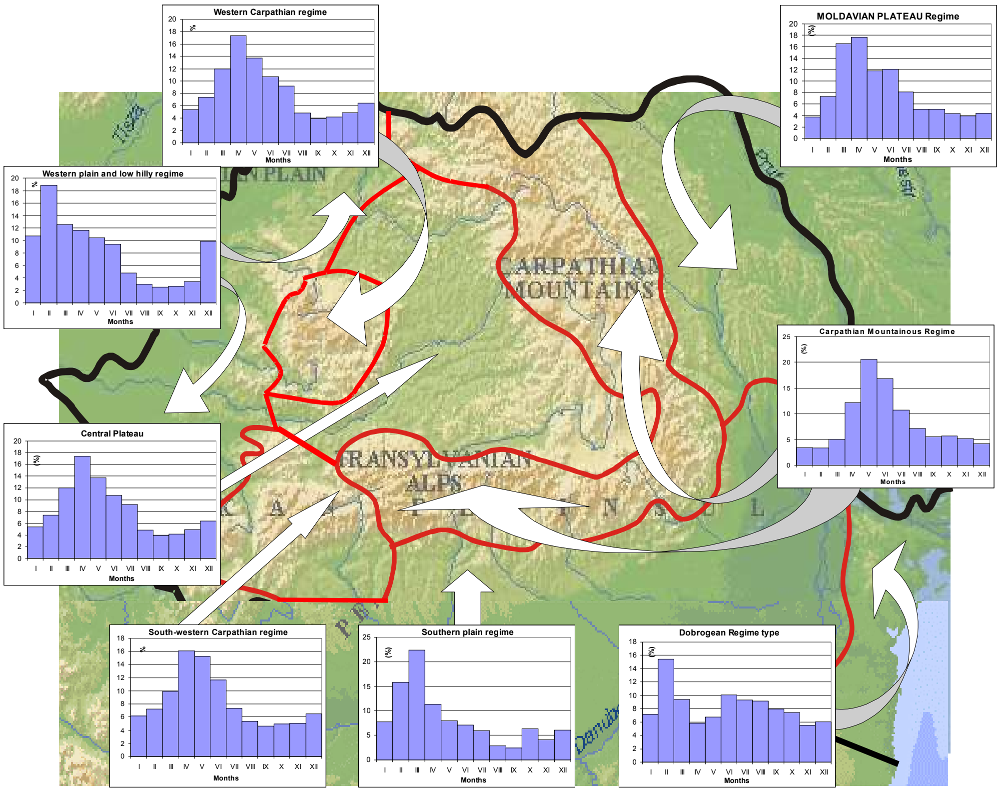

Figure 5. Characteristic river flow regimes in Romania

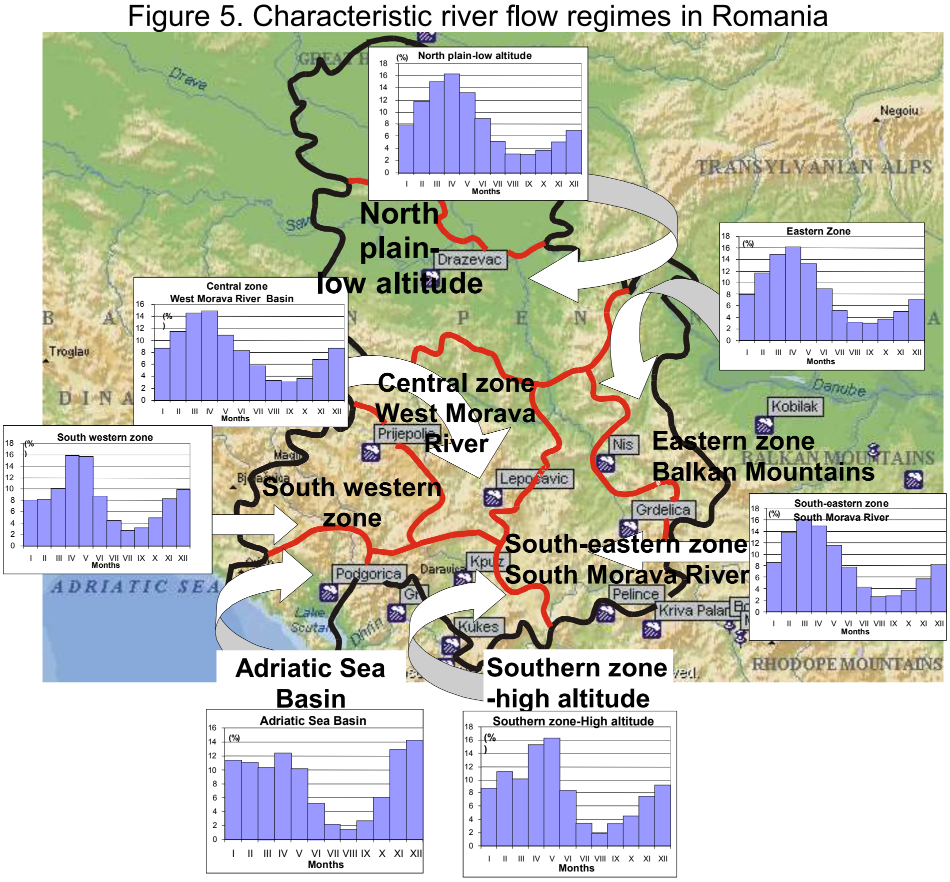

Figure 6. Characteristic river flow regimes in Serbia-Montenegro

Conclusions

- The use of the total entropy of the occurrence of the descriptors of the pattern of a particular flow regime as an index of the stability assumes that the frequency of production of descriptors should have a probability greater than 0.5.
- This shortcoming led to the replacing the entropy by the method of the stability coefficient CS. This allows taking into account both the length of the discriminant period and the probability of occurrence of a certain regime type in this interval of time. Moreover, this coefficient can numerically express the stability character of the river flow regime, but also it is useful for determining in an objective manner the discriminant periods themselves.
- In order to automatically find the maximum value of the stability coefficient and therefore the most appropriate discriminant period a computer program has been derived
- The significant variation in altitude of a zone or basin subject to the influence of a particular climate leads to a differentiation of several micro-types of flow regimes. If a certain large zone is found under the control of the intersection of many atmospheric circulations, the micro-regime is a result of their combination with the altitude influence. The area encompassing the Danube River Basin has a pronounced orography and therefore it shows a great differentiation in the river flow regimes.
- Under the circumstances of a quite "regularity in the manifestation of the climate dictated mainly by the Mediterranean circulation of the atmosphere that induces a mild climate in the south and a "continentalization" towards the northern zones of Danube Basin, the catchment elevation plays a paramount role in modifying (sometimes substantially) the basic influence of the climate.

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