TRENDS IN VARIABILITY OF WATER FLOW OF TELEAJEN RIVER

N. JIPA, L. MEHEDINŢEANU[1]

ABSTRACT. – TRENDS IN VARIABILITY OF WATER FLOW OF TELEAJEN RIVER. In the context of climate change at global and regional scale, this study intends to identify the trends in variability of the annual and monthly flow of Teleajen river. The study is based on processing the series of mean, maximum and minimum flows at Cheia and Moara Domnească hydrometric stations (these data were taken from the National Institute of Meteorology and Hydrology). The period of analysis is 1966-1998, statistical methods beeing mostly used, among which the Mann – Kendall test, that identifies the liniar trend and its statistic significance, comes into focus. The trends in the variability of water annual and monthly flows are highlighted. The results obtained show downward trends for the mean and maximum annual flows, and for the minimum water discharge, a downward trend for Cheia station and an upward trend for Moara Domnească station. Knowing the trends in the variability of the rivers' flow is important empirically in view of taking adequate administration measures of the water resources and managment measures for the risks lead by extreme hidrologic events (floods, low-water), according to the possible identified changes.

Keywords: trends, water discharge, variability, Mann – Kendall test, Teleajen river.

1.INTRODUCTION

In the general context of climate change, modifications and trends of the main climatic parameters with important consequences upon the hydrologic regime of rivers have been observed. These are highlighted in the IPCC reports (IPCC, 2001, 2007). In Romania, the climate change and variability of climatic parameters subjects have been tackled in many studies, both at national (Busuioc *et al.*, 2009) and regional (Croitoru *et al.*, 2010, 2011a, 2011b etc.) level. In view of the adaptation to climate change, in Romania was developted in 2005 *The national strategy of Romania regarding climate change 2005-2007,* and the *National Plan of action regarding climate change* (Ministry of Environment and Forests, 2012 a, b). The impact of climate change upon the water resources was approached in relatively few studies in Romania, among which those developed by Stănescu *et al*. (1999) and Şerban (2006) come into focus. In terms of the studies regarding the trends and variability of flow parameters, we cite the ones carried out by: Neculau

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and Zaharia (2009, 2010) in Trotuş catchment, Zaharia and Beltrando (2009) in the external Carpathians' Curvature region. In the Teleajen catchment the informations regarding the hydrologic aspects are relatively few and exist in synthesis studies on the Romanian territory (Ujvári, 1972) or regional (Nedelcu, 2000). In this context we consider that this article interest through its the contemporaneity and originality of the approached problem at Teleajen catchment level. It aims to identify and analyse the trends in variability of the mean, maximum and minimum water discharge of Teleajen river.

2.STUDY AREA

The hydrographic catchment of Teleajen river is located in the south-central part of Romania between latitude 44º 47' - 45º 32'N and longitude 25º 50' - 26º 05'E. The Teleajen catchment has a surface of 1656 km² and extends on all three major relief levels. The climate of Teleajen catchment, the main factor of the flow, is different from one relief unit to the other. In the superior basin the annual mean temperature is about 4.8°C, in the middle basin it reaches 8.8.°C and in the inferior basin 10.1°C. The annual mean precipitations decrease by amount from the mountain region (950 mm) towards the subcarpathian hills (768 mm), in the plain region reaching 630 mm (source: Nedelcu, 2000).

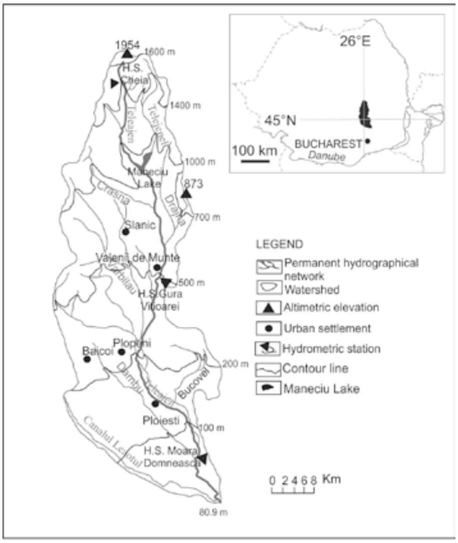

Fig.1. Hypsometric map of Teleajen catchment
Adapted by [9]

The river Teleajen springs from the main two heights of the Ciucaş Mountains (Zăganu and Bratocea) from approximately 1750 m and discharges into Prahova off the Palanca settlement, at an altitude of 80.9 m (in Gherghiţei plain) with a length of 122 km (Fig. 1.). The mean slope of Teleajen river is 13‰ and the sinuosity parameter is 1.54 (source: Nedelcu, 2000). The main tributaries of Teleajen river are: Crasna, Vărbilău and Dâmbu, on the right side, and on the left side Telejenel, Crasna and Bucovel. There are a series of water facilities on the Teleajen river that have contributed to the alteration of the water discharge parameters. The Măneciu dam, situated at approximately 17 km upstream of Vălenii de Munte city, at the contact between the Carpathian and Subcarpathian sector, has the greatest impact on the discharge. The construction of the greatest ballast dam with a central clay core in our country began in 1979 and finished in 1984. The reservoir that formed behind the dam (with a height of 75 m), has a length of 4 km and a surface of more than 100 ha, with an total volume of 60 milioane de m³ (Pop, 1996). The lake is harnessed, mainly, to water supply for the settlements from downstream (including Ploieşti municipality). It also ensures the supply of a power plant with an installed power of 10 MW.

3.DATA AND METHODOLOGY

There are 3 hydrometric stations that operate on the Teleajen river (Cheia, Gura Vitioarei and Moara Domnească) where daily observations upon the variation of the water level and periodically observations upon the water discharge and solid load, upon the dynamic of the river channel, as well as upon the physical, chemical and organoleptic properties of the water are made. The first hydrometric station that came into existence on the river Teleajen was Cheia, in 1951, where the catchment has a mean altitude of 1265 m, followed by Moara Domnească in 1953, where the catchment has a mean altitude of 558 m, an by Gura Vitioarei in 1958, where the catchment has a mean altitude of 896 m. The basin surfaces that the three stations manage are: Cheia (39 km²), Gura Vitioarei (493 km²) and Moara Domnească (1398 km²). The river sectors associated with every hydrometric station have the following lenghts: Cheia (8 km), Gura Vitioarei (48 km) and Moara Domnească (108 km).

In order to realize this study the mean, maximum and minimal, annual and monthly flows, from Cheia and Moara Domnească stations were used. The observation period is 33 years, 1966-1998. While the mean flows are retraced, the maximum and minimal ones are in natural regim. For these data series their temporal variability was analysed and the liniar trends (at interannual, monthly and seasonal scale) for the concerned period were identified. Statistical methods were mainly used. In order to identify the statistic significance of the identified trends the Mann-Kendall test was applied, by means of the MAKENSES programme (according to Salmi *et. al.*, 2002). The statistic significance of the trend is established according to 4 levels of significance, that correspond to the error risk α (level of significance): $\alpha = 0.001$; $\alpha = 0.01$; $\alpha = 0.05$ si $\alpha = 0.1$ (Salmi *et. al.*, 2002). For example, the level of significance of $\alpha = 0.01$, represents a probability of 1% for the trend to be false, which means that the upward and downward trends have a high probability of occurrence (99%).

4.RESULTS

4.1.Variability of mean annual, monthly and seasonal flows

In the analysed period (1966-1998) at Cheia hydrometric station the greatest annual mean flow was recorded in 1991, of 0.69 m³/s, and the lowest in 1987, of 0.37 m³/s, with a multiannual mean value of 0.83 m³/s. At Moara Domnească hydrometric station the greatest annual mean flow was recorded in 1970, of 16.8 m³/s, and the lowest in 1987, of 3.4 m³/s, with a multiannual mean value of 10.7 m³/s (Fig. 2).

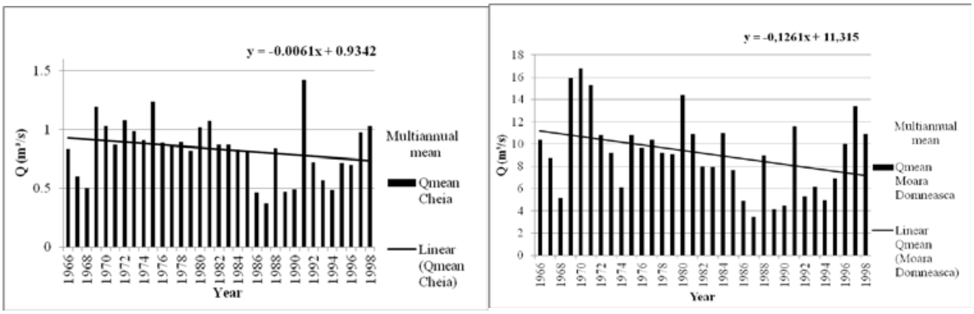

Fig. 2. ***Multiannual variability of the annual mean flow (Q) of Teleajen River at Cheia (at left) and Moara Domneasca (at right) hydrometric stations in 1966-1998***

In order to statistically analyse the multiannual variability of the mean water discharge the variation parameter of the annual discharge (Cv) was used. For the Cheia hydrometric station, in the period 1966-1998, the value of 0.29 was obtained and for the Moara Domnească hydrometric station a value of 0.37, which indicates a more emphasized variability of the mean annual discharge in the plain area than in the mountain area.

The module or flow parameter (Ki), calculated for each year, as a ratio between the mean flow in the concerned year and the multiannual mean flow, was used to indicate the variability of the annual mean water discharge under a relative form. The greatest value of the flow parameter at Cheia station was recorded in 1991, respectively 1.7, and the lowest value in the year 1987, namely 0.4. The flow parameter's values have a downward trend. At the second hydrometric station (Moara Domnească) the maximum value of the flow parameter was recorded in 1970, of 1.6, and the minimum value in 1987, of 0.3. The flow parameter also has a downward trend (Fig. 3).

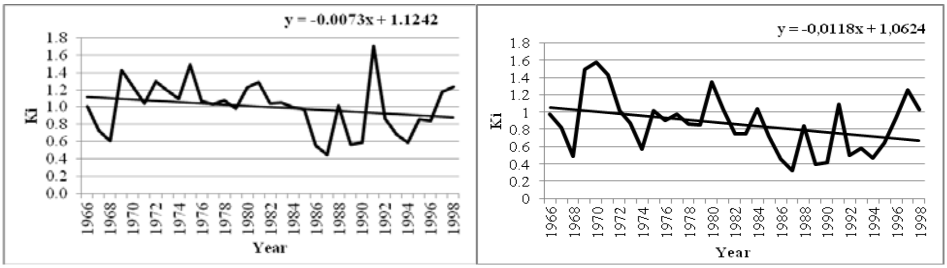

Fig. 3. ***Multiannual variability of the flow parameter (Ki) at Cheia (at left) and Moara Domnească (at right) hydrometric stations in 1966-1998***

The results obtained by applying the Mann-Kendall test on the monthly and annual mean flows of Teleajen river can be observed in Table 1. At Cheia station the following results have been obtained: downward trend in February, with a significance level of α=0.05; downward trend of the annual mean flows at annual level with a significance level of α= 0.1; in the other months the trends have a significance level greater than 0.1, thus the trends are not statistically significant. At Moara Domnească station in February the downward trend has a significance level of α = 0.05 and in the following months (March, July, August) as well as at annual level the downward trends have a significance level of α = 0.1. In the other months due to the significance level greater than 0.1, the trends are not statistically significant.

Table 1. ***Trend and significance level of the monthly and annual mean flow of Teleajen River at Cheia and Moara Domnească hydrometric stations (1966-1998)***

H.S.	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An
Cheia	**Test Z**	-0.9	-2.1	-1.5	-0.6	-0.2	0.0	-1.0	-1.6	-0.4	-0.7	-1.1	-0.1	-1.2
	S.		*											+
Moara Domească	**Test Z**	-0.4	-2.3	-1.7	-1.0	-0.9	-0.6	-1.7	-1.7	-1.6	-1.2	-0.9	0.0	-1.8
	S.		*	+				+	+					+

* if trend at α = 0.05; + if trend at α = 0.1 level of significance; s. = (significance)

As for the trends at seasonal scale, as one can observe in Table 2., these are downward trends in all seasons both for Cheia and Moara Domnească stations. The identified trends are not statistically significant, except for the downward trend in Autumn, at Moara Domnească, with a significance level of α=0.1.

Table 2. ***Trend and significance level of the seasonal mean flow of Teleajen River at Cheia and Moara Domnească hydrometric stations (1966-1998)***

Hydrometric station	Season	Spring	Summer	Autumn	Winter
Cheia	**Test Z**	-1.0	-0.9	-0.9	-0.8
	Significance				
Moara Domnească	**Test Z**	-1.4	-1.0	-1.8	-0.1
	Significance			+	

+ if trend at α = 0.1 level of significance; s. = (significance)

4.2.Variability of maximum annual and monthly flows

At Cheia hydrometric station the maximum maximorum discharge was recorded in the year 1998 (101 m^3/s) and the lowest maximum flow was measured in the year 1968, with the value of 4.03 m^3/s. At Moara Domnească, the maximum maximorum discharge was recorded in the year 1975 (850 m^3/s), and the lowest maximum flow was measured in the year 1968 (26.8 m^3/s).

Whereas at Cheia hydrometric station a trend in the variability of the annual maximum flows cannot be determined, at Moara Domnească an obvious downward trend of these flows can be identified (Fig. 4).

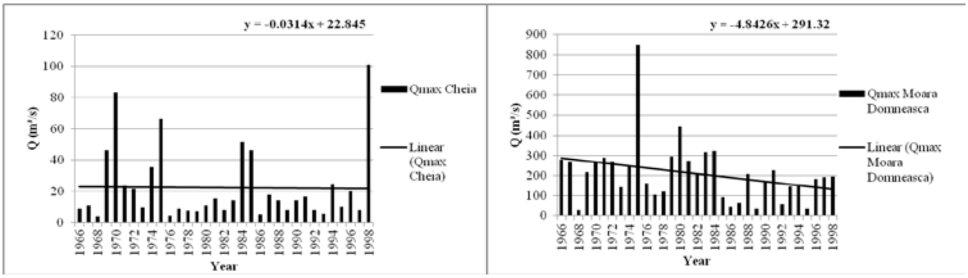

Fig. 4. ***Multiannual variability of the maximum discharges (Q) of Teleajen River at Cheia and Moara Domnească hydrometric stations in 1966-1998***

For the Cheia hydrometric station the downward trends of the maximum flows, obtained after applying the Mann-Kendall test, in January and February have a significance level of α=0.05. In the other months trends have a significance level greater than 0.1, thus they are not statistically significant. Applying the Mann – Kendall test on the series of monthly and annual maximum flow values at Moara Domnească hydrometric station the following results were obtained: in March and at annual level the significance level of the downward trend of the maximum flows is α=0.1; in February and July there is a downward trend with a significance level of α=0.05; in August a downward trend with a significance level of α=0.01 can be noted (Table 3).

Table 3. ***Trend and significance level of the monthly and annual maximum flow of Teleajen River at Cheia and Moara Domnească hydrometric stations in 1966-1998***

H.S.	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An
Cheia	**Test Z**	-2.4	-2.2	-0.7	-0.4	-0.6	1.4	-1.3	-1.2	-0.3	0.7	-1.2	0.5	-0.1
	S.	*	*											
Moara Domească	**Test Z**	-1.1	-2.2	-1.7	-0.9	-0.9	-0.7	-2.5	-2.8	-1.4	0.2	-0.9	0.00	-1.8
	S.		*	+				*	**					+

** if trend at α = 0.01; * if trend at α = 0.05; + if trend at α = 0.1 level of significance;
s. = (significance)

4.3.Variability of minimum annual and monthly flows

In the analysed period the minimum minimorum discharge at Cheia station was 0.001 m³/s, in 1987, and at Moara Domnească station 1.37 m³/s, in 1968. The greatest minimum discharge was 0.46 m³/s (1975) at the first station and 5.4 m³/s (1997) at the second one. At Cheia hydrometric station a liniar downward trend of the annual minimum discharge can be noticed, and at Moara Domnească an upward trend, due to the influence of Măneciu barrier lake that caused a regulation of the minimum water discharge (Fig. 5).

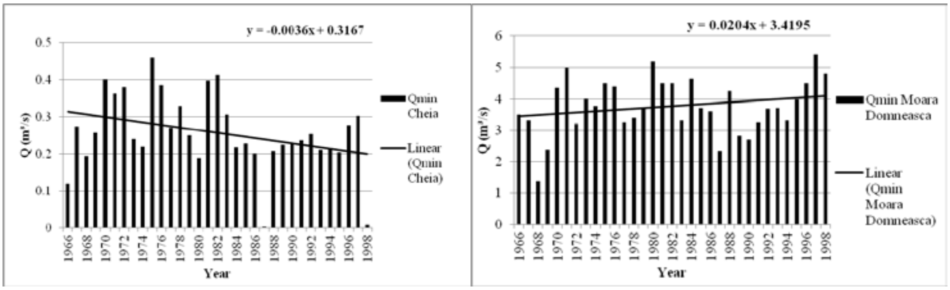

Fig. 5. ***Multiannual variability of the minimum discharge of Teleajen River at Cheia (at left) and Moara Domnească (at right) hydrometric stations in 1966-1998***

At Cheia hydrometric station, the Mann-Kendall test indicated a downward trend in all months (Table 4.). In February and March the significance level of the downward trends of the minimum flows is α=0.05 and in April the the significance level of the downward is α=0.1. The results of the Mann-Kendall test applied after applying the test on the minimum flows (monthly and annual) at the Moara Domnească hydrometric station show a general upward trend in January, February, September, December and at annual scale and a downward trend in the other months. However, due to the fact that the trends have a significance level greater than 0.1, they are not statistically significant.

Table 4. ***Trend and significance level of the monthly and annual minimum flow of Teleajen River at Cheia and Moara Domnească hydrometric stations in 1966-1998***

H.S.	Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	An
Cheia	Test Z	-1.3	-2.3	-2.5	-2.0	-1.2	-0.4	-0.3	-0.7	-1.2	-0.8	-1.5	-1.4	-1.6
	S.		*	*	+									
Moara Domească	Test Z	1.5	0.1	-1.2	-1.4	-0.3	-0.1	-0.7	-0.5	0.12	-0.8	-0.5	0.9	1.0
	S.													

* if trend at α = 0.05; + if trend at α = 0.1 level of significance; s. = (significance)

4.CONCLUSIONS AND PERSPECTIVES

The analysis of the variability of water discharge of Teleajen river at Cheia (in the mountain sector) and Moara Domnească (in the plain sector) hydrometric stations, in the period 1966-1998 have made obvious the following:

- the mean water discharge recorded at multiannual scale general downward linear, both for the annual mean flows and for the monthly and seasonal ones;

- the maximum water discharge recorded in general downward trends; they are, however, more significant at Moara Domnească; at Cheia a relative stationarity in the variability of the annual maximum flows is asserted;
- the minimum water discharge has highlighted downward trends at Cheia and upward trends at Moara Domnească in the case of the annual flows, and in the case of the monthlyy flows, downward trends in most months.

It is ascertained, therefore, the regulatory role of Măneciu barrier lake, which causes downstream (at Moara Domnească) the attenuation of the maximum discharge and the augmentation of the minimum one. Identifying the trends in the variability of the rivers' discharge might be useful for the management work of the water resources, for the adaptation at the possible identified changes.

In the near future we intend, depending on the access to the data, to carry out the analysis of the trends for a greater period of time. Also, we intend a more thoroughly analysis of the impact of the barrier lake on the discharge of Teleajen river.

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