CONSIDERATIONS ON STREAMFLOW DROUGHT IN CENTRAL ROMANIAN PLAIN

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ABSTRACT. – Considerations on Streamflow Drought In Central Romanian Plain. As one of the most important hydrological phenomenon in the area, streamflow drought was identified using daily discharge flow data series for 30 years (1980-2009). The data were recorded in seven observation points located on six rivers, in the central part of the Romanian Plain (between Olt and Argeş rivers). Some aspects of duration and severity of the hydrological drought events were calculated: number, average and maximum duration, daily average discharge flow and streamflow deficit volume of hydrological drought events. Mann-Kendall test and Sen's slope estimation for trends detection were applied in order to analyze trends of those features in the studied region. As main conclusions: most part of the considered rivers show similar behavior with general increasing trends of the most analyzed drought parameters; the only exception is Glavacioc river, with decreasing slopes for the great majority of the parameters. For the mean daily discharge flows, insignificant slopes were calculated.

Keywords: hydrological drought, duration, severity, Mann-Kendall test and Sen's slope, Central Romanian Plain.

1. INTRODUCTION

Drought phenomenon is affecting nowadays, very large areas all over the world. E. Bryant (1992), based on the multicriterial hierarchy, considered it as the most important hazardous phenomenon in the world. Many scientific papers and projects had as their main goal to study the phenomenon in different regions of the globe (Assessment of the Regional Impact of Droughts in Europe, 2001, Sectoral Impacts of Drought and Climate Change, 2008, Evaluation of Arizona Drought Watch: The State's Drought Impacts Reporting System, 2009, State Drought Planning in the Western U.S.: A Multi-RISA-Agency-NIDIS Collaboration, 2010).

Southern and Eastern regions of Romania are considered more and more vulnerable to different kinds of drought: meteorological, hydrological or pedological. The implications become more important because they are considered as main agricultural areas of the country (Croitoru and Toma, 2010). That' why many authors studied the drought from meteorological (Bogdan and Niculescu, 1999, Stângă, 2009) or hydrological perspectives (Ştefan et al., 2004, Ghioca, 2008, Holobâcă, 2010, Sorocovschi, 2010).

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Some of the hydrological analysis of wider regions or for the entire country considered rivers from Central Romanian Plain too (Ujvari, 1972, Zaharia, 1993, 2004, Ştefan, 2004), but no consideration on hydrological drought were made. Because the drought is considered the most important natural hazard affectig the Central Romanian Plain, the main purpose of this paper is to study some issues on the hydrological drought.

2. METHODS AND DATA

2.1. Methods

Hydrological drought in terms of streamflow drought is defined when the flow decreases below a given values. It defines a threshold, q0, below which the river flow is considered as a drought (Yevjevich, 1967). This approach allows simultaneous characterisation of streamflow droughts in terms of duration (d_i), severity (or deficit volme, s_i) and time of occurrence (Hisdal et al., 2001).

Among other types of thresholds (a well-defined flow quantity, a percentage of the mean flow), we decided to use a percentile from the flow duration curve because expressing flows as exceedance values allows flow conditions in different rivers to be compared.

According to European Union Project ARIDE (Demuth and Stahl, 2001), the threshlod may vary from 70% to 90% exceedance probability. Usually, the lower level thresholds (90%) are recommended when short data series are used and higher threshold (70%) are to be used for region where inter-annual droughts are specific (droughts lasting longer than a year). For this study, the 80% excedeence probability of seasonal flow was used for many reasons. The same percentile was successfully used by Holobaca (2010) when studied drought in Transilvania Tableland. In the case of a longer than one season drought event, the threshold changes according the specific flow. High flow season was considered from November till March, while low flow season was from April till October.

A special soft was used to identify drought events. The soft performs finds the intervals with running days with discharge flow under a specified value. Thus, the hydrological drought event begins when the discharge goes under the 80% excedance probability value and ends when the discharge increases over that threshold, depending on the season of the day.

The soft identifies the beginning date, calculates the length (in running days) and the total volume of discharged water in the drought period (and thus permits the calculation of the discharge deficit volume). At the same time, it associates a drought event to that year to which the beginning date belongs. That’s why, sometimes, during the same year, one or more drought events with a total number of days higher than 365 are found. As an example, during 1993, there were four events identified at one station: 35 days long (February, 8), one day long (March 23), three days long (April, 12), 15 days (May, 9) and 409 days (May, 29). In that situaton, the last event ended in July 11, 1994.

To detect and estimate trends in the hydrological drought parameters time series, the Excel template MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), developed by researchers of the Finnish Meteorological Institute (Salmi et al., 2002), was used. In Romania, the same method and software have also been used with good results to identify trends in different data series (temperature, precipitations, fog) (Holobaca et al., 2008, Muresan and Croitoru, 2009, Croitoru and Toma, 2010).

The procedure is based on the nonparametric Mann-Kendall test for the trend and Sen's nonparametric method for the magnitude of the trend (Mann, 1945, Kendall, 1975). Sen's method uses a linear model to estimate the slope of the trend, and the variance of the residuals should be constant in time.

The MAKESENS software performs two types of statistical analyses: first, the presence of a monotonic increasing or decreasing trend is tested with the nonparametric Mann-Kendall test, and then, the slope of a linear trend estimated with Sen's nonparametric method is computed (Gilbert, 1987). In MAKESENS, the tested significance levels α are 0.001, 0.01, 0.05, and 0.1.

Both methods are used here in their basic forms.

2.2. Data

For hydrological drought, daily data of the discharge flows recorded in seven hydrometric stations were employed (fig. 1). Five of the hydrological data sets covered 30 years, from 1980 until 2009. Only two hydrological data series are available for a period of 22 years long (those recorded on Glavacioc and Neajlov).

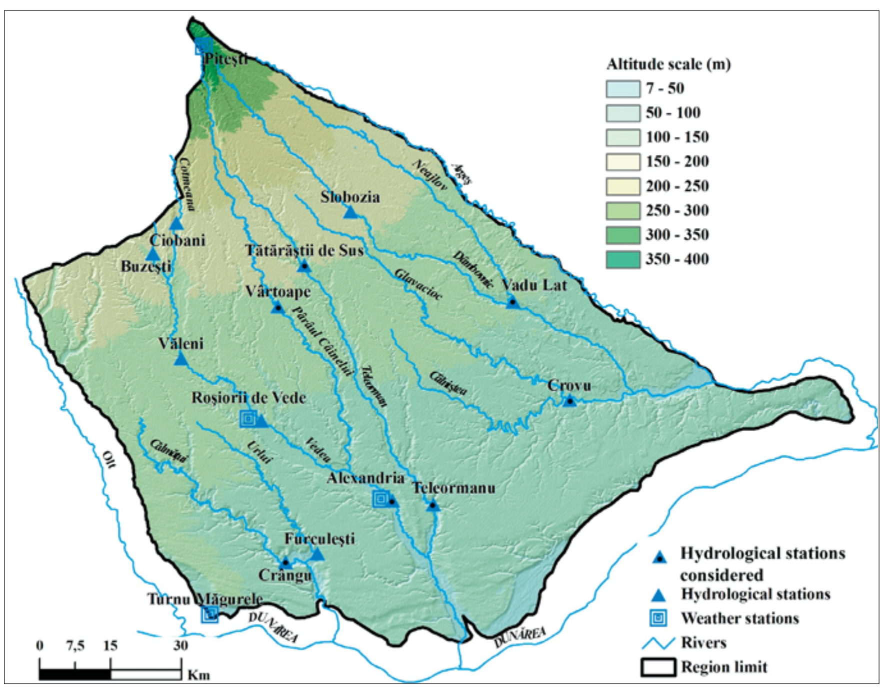

Fig. 2. ***Hydro-meteorological network in Central Romanian Plain***

3. RESULTS AND DISCUSSIONS

3.1. Hydrological drought parameters

To analyse the hydrological drought, first few basic parameters as mean multiannual discharge flow and excedeence probability thresholds were calculated. The values were computed both for the entire year and for different seasons (low water season from April till October and high water season from November till March).

Then, five specific parameters of the hydrological drought (HD) have been analysed: mean multiannual number of the hydrological drought events (HDE), mean multiannual duration of the HDEs, maximum duration of HDEs both in their average and absolute values, mean annual cumulated duration of HDEs, average daily discharge during HDEs and the mean discharge deficit volume (Table 1).

Finally, trends in the specific parameters of HD were identified.

In the Central Romanian Plain (sector between Olt and Argeş rivers), annual discharge flows have their maximum values, for all the rivers considered, in late winter or early spring (February and March), while the minimum values are specific to August and/or September. The multiannual discharge flows varies very much inside the region, depending on the rivers (Table 1). Thus, the highest values were recorded on the main rivers of the region, Vedea and Neajlov (over 5 m^3/s and respectively, 4 m^3/s), while the lowest flows were recorded on tributaries Valea Câinelui and Glavacioc (less than 1 m^3/s).

The hydrological drought parameters also show different values depanding on the rivers size. Thus, the mean annual number of HDEs varies, generally, between three and nine, while the maximum number of events was between 10, in the eastern part of the region, and 25, in central area. Otherwise, the analysis revealed for Teleorman river the highest values both for average and for maximum number of HDEs, for the two hydrometric stations considered. It worth mention that there are two rivers that experienced years without any HDE (Călmăţui and Neajlov) at the end of ‘80s and at the beginning of the ‘90s.

The longest HDEs as average values were recorded on the lowest rivers in terms of discharge flow, Câinelui and Galvacioc, while the lowest values were specific to southern stations: Teleormanu and Crîngu on Teleorman and Călmăţui rivers.

Cumulated duration of HDEs analysis show that dry periods are more longer in Vedea Hydrographic basin than in the others, with more than 140 days/year as average and more than 300 days/year as maximum values.

If the absolute maximum duration of a single HDE is considered, the variation in the area is very large, from less than 200 days, on the most important river, Vedea, up to almost 500 days, on the little Câinelui River.

About the longest HDEs on Câinelui River (492 days), it has to be emphasized that the dry period began on 8 of August 2008 and did not finished until the analyzed period ended (31st of December 2009). This means that it may be even longer, if the considered dataseries would be extended. Otherwise, this river is the only one analysed that dries during summer and autumn. Thus, it experienced 8 dryness events with a cumulated period of 431 days, which the longest was in 1993 and lasted 123 days (from 1st of July till 31st of October).

Table 1. ***The hydrological drought parameters in Central Romanian Plain (1980-2009)***

Hydrographic basin		Vedea				Cal-ma-tui	Argeș	
River / Paramenter		Vedea	Teleorman (Tatarasti HS[1])	Teleorman (Teleormanu HS)	Valea Câinelui	Călmățui	Neajlov[2]	Glavacioc[2]
Basic (reference) parameteres								
Q[3] (cm/s)		5.20	1.29	2.42	0.242	1.26	4.16	0.834
Q[3] for unfreezing season (m^3/s)		6.10	1.06	2.60	0.211	1.25	3.83	0.666
Q[3] for freezing season (m^3/s)		9.41	1.62	4.03	0.577	1.77	4.49	1.07
80% - EPT[4] (m^3/s)		2.94	0.683	1.77	0.050	0.809	3.01	0.482
80%-EPT[4] for unfreezing season (m^3/s)		2.27	0.511	1.48	0.055	0.720	2.52	0.295
80%-EPT[4] for freezing season(m^3/s)		2.39	0.719	2.07	0.099	1.22	2.58	0.399
Hyrological drought parameteres								
Annual number of HDE [5]	m[6]	1	3	3	1	0	0	1
	A[7]	6.8	8.14	11.1	4.3	4.2	3.32	5.82
	M[8]	15	25	18	12	12	12	10
Annual mean HDEs duration (days)	m	3.0	4	1.7	2.5	0	0	3.6
	A	25.8	25.9	15.5	47.7	14.9	18.4	29.6
	M	108	106	40.7	149	53.7	122.5	190
Average cumulated HDEs duration	A	141.6	161.6	158.2	184.6	87.5	77.3	118.5
	M	324	365	300	567	322	252	246
Absolute maximum duration of one HDE (days)	M	198	306	164	492	278	244	190
Multiannual average daily discharge during HDE (m^3/s)	m	1.44	0.373	1.21	0.017	0	0	0.114
	A	1.85	0.5	1.43	0.048	0.6	1.4	0.206
	M	2.31	0.705	1.85	0.093	1.78	2.47	0.391
Multiannual mean streamflow deficit (mil. m^3)	m	1.85	0.9	1.6	0.2	0	0	1.1
	A	67.1	11.4	25.1	6.61	5.5	12.7	5.97
	M	175.5	29.5	51.3	39.6	18.2	50.2	13.4

Note: [1] – Hydrographic Station; [2] – Data available for 1988-2009; [3] –Mean multiannual discharge flow [4] – Exceedance probability threshold; [5] – Hydrological drought event; [6] – minimum value; [7] – mean value; [8] – maximum value; [9] - Hydrological drought.

Actually, considering both mean and absolute maximum values of HDEs, no rule seems to be identified in the area between multiannual discharge flows values and the length of HDEs. Thus, we consider that rather meteorological factors, such as temperature and the intensity of the evaporation, may play the main role in the occurrence of the HDE than hydrological parameters values of the analysed rivers.

As expected, the mean multiannual daily discharge during HDEs, has the highest values on Vedea River and the lowest on Câinelui River.

The highest values of the multiannual streamflow deficit volume were found on the main rivers (Vedea and Neajlov), but the lowest value was not on the less important river in terms of mean multiannual discharge flow (Câinelui river).

Streamflow deficit volume analyses shows the lowest value specific to Galvacioc and not to Câinelui River. Mean multiannual deficit value recorded on Câinelui River ranges this river as the fifth in decreasing order, before Călmăţui and Glavacioc while, if maximum annual values of the deficit volume are considered, the same river can be placed also before upper Teleorman river (Tătărăştii de Sus hydrographic station).

3.2. Trends of hydrological drought parameters

For the same parameters, trends were identified and mean slopes were calculated for the 30 years period considered (table 2).

Mean annual number of HDEs, has different behavior in the area. There are four rivers with decreasing trends, and only one river to which increasing trend is specific (Călmăţui). For Câinelui River and Neajlov, stationary trends was identified.

Table 2. ***The hydrological drought parameters trend in Central Romanian Plain (average slope/decade)***

Hydrographic basin		**Vedea**				**Cal-matui**	**Argeş**	
River / **Paramenter**		Vedea	Teleorman (Tatarasti HS)	Teleorman (Teleormanu HS)	Valea Câinelui	Călmăţui	Neajlov[2]	Glavacioc[2]
Mean annual number of HDE	Q	-0.250	-0.085	-0.231	0.000	0.235	0.000	-0.125
	α	*		*		**		
Mean annual HDE length (days)	Q	0.914	0.722	0.528	1.363	0.731	1.229	0.297
	α	**	*	**	+	**	+	
Mean annual number of HD days	Q	3.235	4.165	2.091	4.933	5.100	4.000	-3.235
	α				+	***	*	
Absolute maximum HDE length	Q	1.905	1.477	1.533	2.636	2.813	2.500	-1.500
	α	+	+	+		***	+	
Mean daily discharge during HDE (m^3/s)	Q	-0.002	0.000	0.004	0.000	0.000	0.000	-0.004
	α							+
Mean annual stream-flow deficit (mil. m^3)	Q	1.484	0.298	0.512	0.110	0.307	0.696	-0.161
	α		+			***	*	

Note: [1] – Statistically significance: + – α= 0.1; * - α=0.05; ** - α=0.01; *** - α=0.001.

For mean annual HDEs lenghs, the positive slopes are generalized in the area and on six of the seven rivers, values show statistically significance. Also, mean annual cumulated duration of HD is increasing with slopes from 2 days/decade to more than 5 days/decade. There is one exception in the area (Glavacioc river), where a negative slope was calculated.

General increasing is also specific to absolute maximum duration of an HDE, with 5 statistically significant situations. The slopes vary between 1-3 days/decade. On Glavacioc rivers, a decreasing trend was found (1.5 days/decade).

Considering mean daily discharge during HDEs, no significant changes seem to be. Only a very slow negative slope was identified on Glavacioc river (0.004 m^3/s/decade).

Mean annual streamflow deficit volume trend indicate positive values for all the rivers, excepting Glavacioc. The slopes are between 0.1 and 1.5 mil. m^3/decade, with highest values for Vedea and Neajlov while the lowest were identified for Câinelui River.

4. CONCLUSIONS

Analysing the hydrological drought parameters there are few main conclusions we reached at.

Thus, there is no direct or reverse correlation between mean multiannual discharge flows and the parameters of the hydrological drought events in the area.

Generally, there is an increasing trend of hydrological drought phenomenon in the area characterized by less events, but which are longer. The most important duration of drought was specific to central area, on Câinelui river, both in terms of mean multiannual value and absolute maximum values of the 1980-2009 period. The most important intensity (given by the streamflow deficit volume) was specific to the main rivers of the area (Vedea and Neajlov). Dryness phenomena were recorded only on one river (Câinelui river).

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