ASSESSMENT OF HYDROLOGICAL DROUGHT IN THE NORTH-EASTERN PART OF ROMANIA. CASE STUDY – BAHLUI CATCHMENT AREA

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ABSTRACT. – Assessment of hydrological drought in the north-eastern part of Romania. On the background of amplification of hydro-climatic drought in the last decades, in this paper we try to evaluate a series of indexes for assessing hydrological droughts. To characterize the hydrological drought, minimum flow parameters are successively analyzed: percentiles from the flow duration curve, mean annual minimum flow, base flow index and recession indeces. Also was used some indices to evaluate the water deficit from streams like thereshold level method and the sequent peak algorithm. Each method was exemplified using data from hydrometric stations from Bahlui drainage basin and associated data from 2012 summer drought. The results show that in the 2002-2014 period, the average drought duration of the cold season is 23 days, but with a low water deficit due to conditions of quartering it in the form of ice and snow layer. In summer season, the average lenght of hydrological drought is 22 days, with a huge water deficit which may exceed 37.5 mil. m^3 as happened in the summer of 2012.

Keywords: hydrological drought, indices, water deficit, Bahlui drainage basin

1. INTRODUCTION

Drought is a complex natural phenomenon caused by climate variability that can turn to a risk factor by exceeding the tolerance limits of natural systems. Drought affects many sectors of economic activity in a region, so that it is necessary to make some methodological approaches as accurate in assessing this phenomenon (Talaksen, van Lannen, 2004). The primary cause of droughts appeareance lies in the lack of rainfall (meteorological drought). The water deficit propagates to water circle, and in time reach a deficit of moisture at ground level (agricultural and pedological drought). In parallel flow values are reduced along the river system (hydrological drought) and gradually charging rate of aquifers is reduced (occurring hydrogeological drought).

The assessement of hydrological drought phenomenon like a risk phenomena involves some objective uncertainties due to natural conditions which generate it, and some subjective uncertainities because of the lack of data series from gauge and meteorological station, that covers optimally the entire analyzed area. In this situation, most often, the hydrological study of droughts is a diagnostic in nature and less than forecast. Studies of hydrological drought are relatively

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sparse in Romania (Adler et al., 1999, Stefan et al. 2004). More detailed analysis is the assessment of atmospheric droughts using various indicators (Paltineanu et al., 2009, Cheval et al., 2014) or various hydrological parameters correlated with climate changes (Paltineanu et al., 2012; Croitoru, Minea, 2015; Minea and Croitoru, 2015). More detailed studies are the hydrological droughts assessments conducted worldwide synthesized by Talaksen and van Lannen (2004), Peters et al. (2005), Fleig et al. (2006), Bloomfield and Marchant (2013) and van Loon and Laaha (2015). In the context of increased of frequency of such hydro-climatic extremes events in the last decades the principal objective of this paper is to evaluate a series of indexes for assessing hydrological droughts.

2. METHODS OF DROUGHT ASSESSEMENT

Having as database just daily average flows, Romanian studies which analyze hydrological droughts uses a minimum of indicators: monthly, annual and multiannual minimum levels and discharges. In this respect the results show only a temporary situation without the possibility of extrapolation to some more detailed forecast or regionalization methods based on G.I.S. tehniques. The present study attempts to fill the deficit of information resulting from the analysis of data series of flows and levels in rivers by applying existing methodologies in international literature to a complex geographic area (north-eastern part of Romania), which overlaps of the Moldavian Plain recognized as being a region at risk in terms of hydrological droughts. To characterize the hydrological drought minimum flow parameters are analyzed successively: percentiles from the flow duration curve, mean annual minimum flow, base flow index and recession indices. Also was used some indices to evaluate the water deficit from streams like thereshold level method and the sequent peak algorithm (Table 1).

Table 1. ***Indices used to evaluate the hydrological drought***

Hydrological drought		
Low flow caracteristics	Percentiles from the flow durations curve	Q_{50} Q80, Q_{90}, Q_{95}
	Mean annual minimum flow	MAM (1), MAM (7) MAM (30)
	Base flow indices	BFI
	Recession indices	Master recession curve
Deficit characteristics	Thereshold level method	
	Sequent peak algorithm	

We mention that hydrological data used in this paper were made available by the Prut-Barlad Water Basin Administration.

3. APLICATIONS

To exemplify the methods described above, Bahlui drainage basin was chosen, situated in the north-east Romania, very well equipped in terms of hydrological natural conditions (because of the frequent droughts and flood waves that required arrangements of ponds and lakes with multiple roles in mitigating of this phenomena). For detailed study of hydrological characteristics of the drought situation was analyzed imposed by the drought produced in summer 2012.

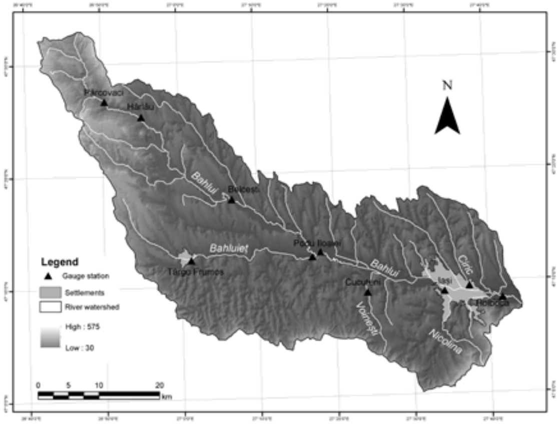

Fig. 1. ***The position of the gauge station in the Bahlui catchment area***

The summer of 2012 was associated with positive anomalies in the field of temperature worldwide (Hanna et al., 2013), being characterized by very warm conditions also in the region of Romania. Here, intense heat waves occured in the middle summer leading to a couple of new record high in the temperature observations. Beside the temperature positive anomaly, arid conditions prevailed througout all summer period. For the territory of Romania it is known that the drought during summer is driven especially by the thermodynamics factors, such as temperature and humidity (Cheval et al., 2012). Although, on the basis of NCEP/NCAR reanalysis maps (Fig 1. left) we can observe that the european continent was dominated by anticyclonic conditions, a ridge of the Azoric High being extended on the central and southern parts of Europe.

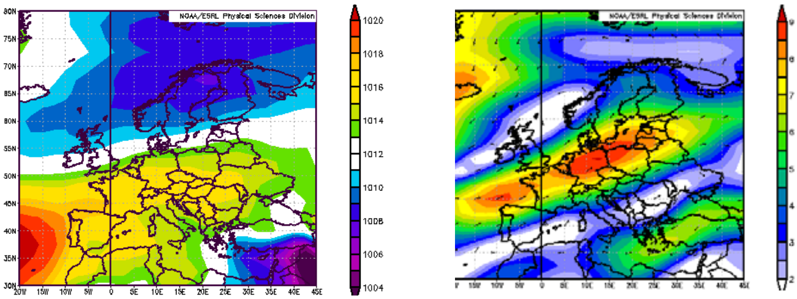

Fig. 1. ***The distribution of the mean sea level pressure (left) and anomaly of the wind speed at 200 hPa (right) in Europe for August-September 2012 (NCEP/NCAR reanalysis)***

These conditions were induced by a the trajectory of the jet streams (Fig. 1. right) imposing a blocking pattern in the field of atmospheric pressure at sea level.

On this background of large scale circulation pattern, the region of Romania was dominated by the action of high pressure ridges avoiding the occurence of precipitation. This induced aridity conditions with less than half of the mean precipitation amount from 1980-2010 (Fig. 2).

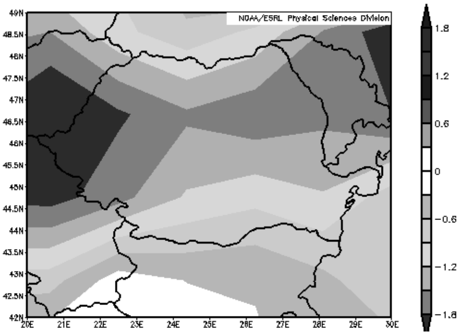

Fig. 2. ***Anomaly of precipitation amount (mm/day) for August-September 2012 (NCEP/NCAR reanalysis)***

For the region of Bahlui drainage basin (at Iași meteorological station) the negative anomaly in the monthly precipitation amount prevailed from March to August with a cummulated precipition deficit of 213 mm (Table 2) compared to the climatic mean from 1980-2010 in the same monthly interval. Additionaly, some 30% of the total amount of precipitation from March to September occured during the maximum daily amount at monthly level. Taking to account their high run-off/infiltration ratio these amounts were not very efficient in reducing the water deficit in the soil. In this manner, these climatic conditions have led to a high water deficit throughout the soil profile at the end of the interval.

Table 2: ***Monthly precipitation amount for January-September 2012, anomaly to the 1980-2010 monthly mean(in brackets) and daily maximum precipitation in 2012 for Iași***

Mounth/Indices	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.
Pp amount	12 (-20)	61 (+30)	22 (-9)	53 (-2)	98 (-36)	16 (-86)	22 (-59)	32 (-23)	50 (+2)
24 h max quantity	3,4	11,8	6,1	13,1	28,8	6,5	9,8	11	28,0

(Source: CPC/NCAR, global summary of the month)

Hydrological drought analysis includes two directions: the minimum flow assessment and water deficit. First direction is based on percentile from the flow duration curve, mean annual minimum flow and base flow indices analysis.

Using a series of temporal data regarding the flow of rivers in Bahlui catchment area for the period 2002-2014 were identified main parameters that characterize minimal leakage (Table 3). Analyzing these parameters we can extract, in brief, some conclusions:

- the corresponding values of Q_{80}, Q_{90} and Q_{95} percentiles are 5-7 times lower than average flows calculated, and 8-10 times higher than the minimum flows recorded in the period considered;

- the relatively small differences between percentiles Q_{80}, Q_{90} and Q_{95} show a low variability in flows induced by anthropic lakes realized along the river system, especially at stations located downstream;

Table 3. ***Flow indices for hydrological drought analysis in Bahlui drainage basin***

No.	Gauge station	River	Qav. (m^3/s)	Q_{50} (m^3/s)	Q_{80} (m^3/s)	Q_{90} (m^3/s)	Q_{95} (m^3/s)	MAM(1) (m^3/s)	MAM(7) (m^3/s)	MAM(30) (m^3/s)	Qmin
1	Targu Frumos	Bahlueț	0.159	0.830	0.050	0.032	0.021	0.024	0.029	0.041	0.006
2	Podu Iloaiei	Bahlueț	0.777	0.250	0.071	0.035	0.022	0.034	0.047	0.087	0.002
3	Parcovaci	Bahlui	0.307	0.044	0.031	0.026	0.019	0.023	0.024	0.026	0.011
4	Harlau	Bahlui	0.427	0.112	0.078	0.064	0.054	0.057	0.060	0.068	0.038
5	Belcesti	Bahlui	0.644	0.136	0.026	0.011	0.040	0.037	0.040	0.046	0.003
6	Podu Iloaiei	Bahlui	0.925	0.437	0.195	0.134	0.099	0.117	0.132	0.166	0.024
7	Holboca	Bahlui	4.693	3.509	2.658	2.360	2.191	2.161	2.301	2.562	1.602
8	Iasi	Ciric	0.060	0.014	0.005	0.004	0.003	0.004	0.004	0.006	0.001
9	Iasi	Nicolina	0.332	0.129	0.075	0.056	0.046	0.041	0.049	0.066	0.010
10	Cucuteni	Voinesti	0.177	0.046	0.016	0.009	0.007	0.011	0.011	0.013	0.001

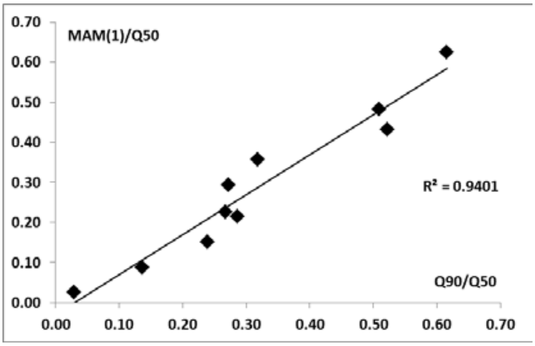

Fig. 3. ***The correlation between MAM(1)/Q_{50} and Q_{95}/Q_{50} indices***

- correlation ratio between MAM(1)/Q_{50} and Q_{95}/Q_{50} indicators (Fig. 3) also express the flashines of the flow stream from this basin.

Another indicator that can characterize minimal leakage is *Base Flow Index* (BFI). It highlights the ratio between of runoff and the contribution that river it has from underground. Applications for different formulas of the BFI for this area were analyzed by Minea et al (2014, 2015) resulting that the best method is that proposed by Eckhardt (2008). Thus for basins developed on porous aquifer with perennial stream, the values of BFI are equal with 0.55 and for basins developed on porous aquifer, but with ephemeral stream, the values of BFI are equal with 0.50.

The Great variability and seasonality of atmospheric input requires a differentiated analysis of parameters that characterize low flow. The *master recession curve* method tries to solve this problem induced by seasonal rainfall by building *reccesion mean curve*. This can be applied for a definite period of time or for individual segments (Fig. 4) showing the dependence of leakege to external inputs (atmospheric or underground).

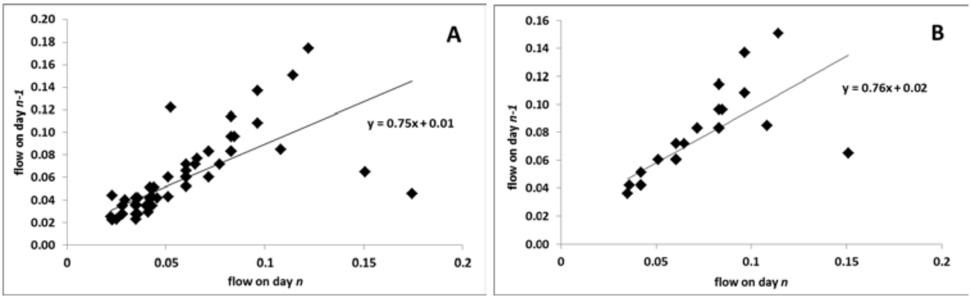

Fig. 4. ***Reccession rate determined by the correlation method for period from 1st August to 1st October 2012 (A) and for perior 1st August 1st September at Targu Frumos gauge station of Bahluet river***

Deficit characteristics can be assessed either by thereshold level method or sequent peak algorithm. Both methods are extremely useful in practical terms. An example of a water scarcity obtained by sequent peak algorithm method is shown in table 4.

More detailed is the threshold level method which allows us to estimate the water deficit volume and actual hydrological drought duration (Table 5). Taking the example of 2012 is observed that there have been 7 deficit periods on the rivers system with an average duration between 5 and 30 days and cumulated deficit water volume over 133 mil. m^3, with an maximum in summer season (over 37 mil.m^3), and an annual average deficite volume for all periods over 0.950 mil. m^3.

Table 4. ***Selection of deficit parameters Qmin and duration at Targu Frumos gauge station Bahluet river (in the period 2006-2013).***

Winter season			**Summer season**		
Qmin (m^3/s)	**Duration days**	**End date**	**Qmin (m^3/s)**	**Duration days**	**End date**
0.001	8	24-Dec-06	0.019	5	8-Jul-07
0.044	4	30-Dec-06	0.005	4	16-Jul-07
0.083	9	9-Feb-07	0.058	8	25-Aug-07
0.045	7	17-Mar-07	0.605	81	18-Sep-12
0.462	47	3-Jan-08	0.035	11	19-Aug-13
0.020	4	12-Mar-08			
1.170	59	22-Jan-09			
1.182	70	6-Feb-10			
0.064	9	31-Dec-11			
0.346	20	29-Jan-12			
0.319	18	1-Jan-13			
0.365	25	4-Feb-13			
Qmin	**0.001**	**24-Dec-06**	**Qmin**	**0.005**	**16-Jul-07**
Qmin av.	**0.341**		**Qmin av.**	**0.144**	
Max duration	**70**		**Max duration**	**81**	
Av.Duration	**23.3**		**Av.Duration**	**21.8**	
Selection criteria: threshold level Q_{90}					

Table 5: ***Drought deficit characteristics at Targu Frumos gauge station Bahluet river in 2012***

Start	End	Def.vo. (1000m^3)	Av.def.vol. (1000m^3/days)	Real duration (days)	Min. flow (m^3/s)	Date min flow	Av.flow (m^3/s)
10.01.2012	29.01.2012	29.911	1.495	20	0.010	25.01.2012	0.014
9.02.2012	24.02.2012	16.459	1.028	16	0.026	24.02.2012	0.020
30.06.2012	4.07.2012	2.445	0.489	5	0.234	1.07.2012	0.026
6.07.2012	15.07.2012	4.700	0.470	10	0.241	12.07.2012	0.026
18.072012	9.08.2012	18.126	0.788	23	0.016	4.08.2012	0.022
20.08.2012	18.09.2012	37.759	1.291	30	0.012	16.09.2012	0.017
11.12.2012	21.12.2012	23.544	1.121	21	0.010	21.12.2012	0.019
Selection criteria: threshold level=Q_{90}, d_{min}= 5 days							

This requires special attention to water resources management in the entire basin, especially in the summer season, when water demand is growing exponentially amid recrudescence droughts and dry.

5. CONCLUSIONS

Detailed analysis of hydrological droughts was based on indices such as percentiles from the flow durations curve (Q_{50} Q_{80}, Q_{90} si Q_{95}), mean annual minum flow (MAM_1, MAM_7, MAM_{30}) and base flow index, to which and quantitative evaluations of hydric deficit in the river system through thereshold level method and sequent peak algorithm. All these indices highlighted a number of important features of these phenomena in the north-eastern part of Romania:

- in the cold season hydrological drought frequency is higher than during the warmer season generated by quartering precipitation as snow and ice lays;
- effective duration of periods of hydrological drought is 22-23 days to both seasons, but the maximum exceed 80 days in summer;
- water scarcity is more pronounced in the warm season of the year exceeding, like in 2012, values of 37.5 mil. m^3, in a single sequence of hydrological drought, or over 133 mil. m^3 at the level of entire year;
- requiring a rigorous management of water resources especially in the warm season of the year when water demand is growing exponentially.

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