ASSESSMENT OF THE IMPACT AND TYPE OF DROUGHT RECORDED IN 2012 IN THE LOWER BASIN OF THE RIVER JIJIA

Dana-Irina Tutunaru[1], Claudiu-Ionuţ Pricop[1], Ioan Crăciun[2], Tudor-Viorel Blidaru[1], Eugen Crăciun[1], Maria-Cristina Timofte[2]

Abstract. This article aims is to analyse droughts in the lower basin of the river Jijia for the year 2012 and determine the type of drought that affected the area, using mathematical methods (functions) and GIS applications. They are based on hydrographical network analysis, geographical features, network piezometrical levels, groundwater level data series, runoff and rainfall. Detailed analysis of meteorological, hydrological and hydrogeological data leads to a hydrological and hydrogeological drought in the lower basin of the river Jijia and to reappraisal of water management aspect.

Keywords: *hydrographical network, geographical characteristics, piezometrical levels, discharge, rainfall regime, drought, climatic changes.*

1.Introduction

A comparative analysis of the hydrographical, meteorological and hydrological parameters has an explorative character intended to identify general patterns in adaptive and integrated water management and to determine its role in coping with the impacts of climate change on floods and droughts. Between this parameters is a strong interdependence of the elements within a water management regime, and as such this interdependence is a stabilizing factor in current management regimes (Huntjens et al., 2010; Teodosiu et al., 2012).

The assessment of climatic change in basin river has been studied by many authors, which highlights the regional importance (Roy and Mazumdar, 2005; Palmer et al., 2009; Crăciun et al., 2009; Huntington, 2010; Simonovic 2010; Gruia, 2010; Crăciun et al., 2011; Ştirbuleac 2011; Minea and Crăciun, 2012).

In most cases the negative impacts regarding the climate change to aquatic ecosystems cannot be mitigated by measures in the river basin management. Ignoring climate change by the Water Framework Directive may have strong implications for the typology and quality assessment systems used for water bodies (Noges et al., 2007; Ungureanu et al., 2010; Vinke-de Kruijf et al. 2009; Rowan et al., 2011; Pepa, 2012).

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[1]Water Basin Administration of Prut Bârlad, Office of Hydrology, Hydrogeology and Basin Forecasts, E-mail: claudiu.pricop@dap.rowater.ro
[2]Technical University Gheorghe Asachi of Iaşi, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering

Drought, as a phenomenon, is one of the most important factors which affect the exploitation of water resources infrastructure. Regarded as a three-dimensional phenomenon, drought can be characterized by intensity, duration and geographic expansion

Several types of drought are to be mentioned, according to their characteristics: meteorological defined as the degree of reduction of rainfall from a mean annual average or "normal" and low rainfall period, hydrological which involve defining the influence of precipitation on hydrologic system components (infiltration, surface runoff, groundwater flow, rivers flows, volumes and water levels in reservoirs, groundwater levels), agricultural that implies analysing climatic elements which influence the size of agricultural production, the volume of runoff from rivers, the water volume accumulated in lakes and aquifers and socio-economic drought which associates the supply and demand of economic goods with meteorological, hydrological and agricultural drought (Teodosiu et al., 2012; Crăciun et al., 2011; Huntjens et al., 2010).

Based on drought consequences, National Drought Mitigation Center USA, identifies four types of droughts: meteorogical, which occurs when rainfall is below normal; pedological (agricultural) drought appears when soil moisture level is below ordinary values, which is caused by rainfall that is insufficient to satisfy the needs of a particular culture on a certain time, which leads to a reduction of biomass and production; hydrological drought refers to lower average level of surface water and groundwater; socioeconomic drought occurs when rainfall is below regular values, affecting all human activities.

So it can be said that there are winter, spring, summer and autumn droughts with different kind of consequences, in regard to crop stage, droughts that influence the quality of life. The increasing intensity of drought is affected by season, phase of vegetation, agro works as well as by complex natural and anthropogenic factors.

To characterize the drought there is a wide range of meteorological or hydrological indices and indicators that can be used.

2. Analysis on the regionalization of hydrological drought in the lower basin of Jijia. Meteorological and hydrological characterization of 2012

Although Prut River collects its springs in the Carpathians, about 80% of its basin area in the silvosteppes and steppes of Podolic-Moldavian Plateau, which is the foundation platform unit represented by the Moldavian Plateau. Prut drainage area falls into the Moldavian Plateau geomorphologic forms, represented by platform units in the northern hills of Moldova, being equated here with Jijia Plateau (figure 1).

Hilly plain of Moldova (Jijia – Bahlui Plateau) has the highest geomorphological erosion unit on river basin (where altitudes reaches approx. 150 - 200 m) due to the parallel positioning of Bahlui, Jijia, Baseu Rivers basins that drain all the area.

Phreatic aquifers from Prut floodplains and terraces as its tributaries (Jijia, Bahlui etc.) are also poorly developed both in extension and granulometry. Phreatic aquifer consists of fine to medium sand, gravel, rare elements 2-10 m thick, bigger elements being found in Prut riverside at Cârniceni, Cristoreşti, Costuleni, Grozeşti.

Dominant climatic variability in the Prut-Barlad watershed is determined by its latitudinal extension and especially the opening to the Great Russian Plain which puts its prints by specific climate characteristics. Air masses with high Eastern continental character impose harsh winters in this geographic area, with strong and dry winds, mostly blizzard snow, torrid and droughty summers.

A feature of this climate regime is a frequent movement of arctic air from the north - west and north into the Romanian Plain, often accompanied by strong winds, resulting in a relatively cold and wet weather with heavy snow falls. The dry component of these air masses generates heavy mixed precipitations and wind intensifications from the north and north-west during the cold semester and rainfalls accompanied by lightning and sometimes hail during the warm semester abundance mixed rainfalls and intensity north north-west winds in cold semester of the year, and on the other hand during the warm semester there are downfalls accompanied by lightning and sometimes hail. The presence of high anticyclones in Eastern Europe during the propagation of tropical air generates dry weather with clear skies and no wind.

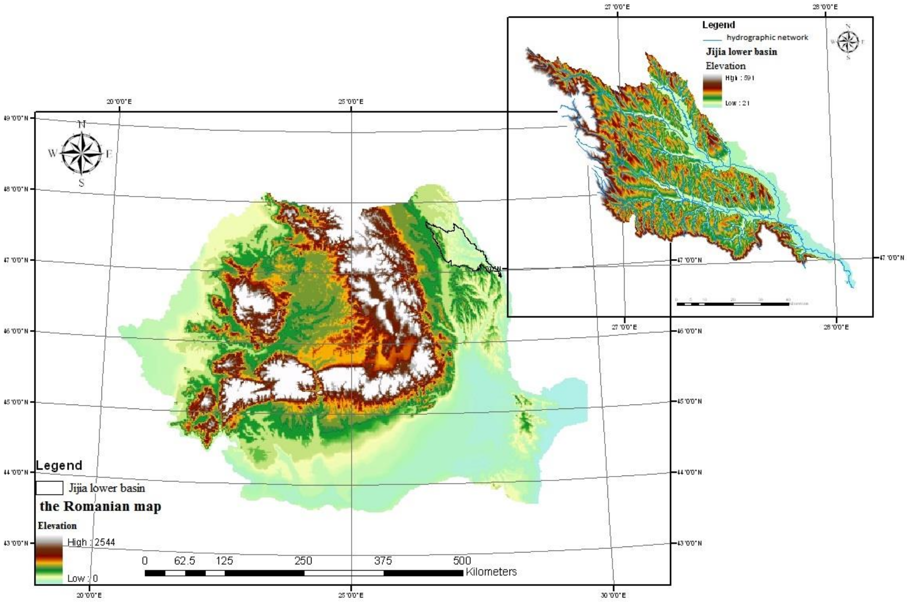

Figure 1: Jijia lower basin Geographical position in Romania country

Rainfall varies with elevation relief ratio which is lower in the plains and higher in the hills.

Among all weather phenomena, the drought and dryness may be considerate complex much as the presence of a lot of other factors such as rainfall, liquid and soil reservoir, moisture and temperature, evapotranspiration, wind speed, soil type etc.

The year 2012, in terms of meteorology, has been characterized as warmer than normal, with a rainfall deficient in the northern half of Prut River basin.

Due to the lack of rainfall and high temperatures the drought phenomena has occurred, which has increased to excessive drought stage since the air temperature values were placed substantially above, with a maximum of 41.3^{0}C at Iași Weather Station. At ground level, temperatures were very high, which lead to an intense evaporation, both on ground level and on lake surfaces.

As of pluviometric data, the studied period was generally showing a deficit. Heavy rainfalls (critical thresholds exceeded) were recorded only on short periods like 1-2. This led to rapid leakage, however, this did not result in regeneration of water resources and mitigating the effects of drought, accompanied by increased wind and hail.

Maximum temperature recorded in this period was 41.3 º C at Iași Weather Station and Hălceni reservoir, the minimum one in the whole basin had the value 6.8^{0}C.

In this period at the rainfall stations placed on area of Iași County, the maximum rainfall of 162.4 l/m^2 was recorded on Boșteni Weather Station and the minimum one at rain-gauge Dobrovăț.

Temperatures on the ground level had very high levels, exceeding the frequency range between 50- 60^0 C.

The weather condition mentioned before lead to a much higher level of water evaporation from the ground surface than normal for this period, which had repercussions both on soil moisture content and water surface levels.

The distribution of the recorded air temperatures in the Prut-Bârlad basin shows normal features which is lower temperatures in the north and higher in the south. The same characteristics occur in the number of summer days, number of tropical days and nights grow from north to south and the number of frosty nights, winter nights is higher in the north of the basin compared to the south.

Table 1: Distribution of local weather phenomena on days and nights

Meteorological Station	Frosty nights	Winter days	Days with ground frost	Summer days	Tropical days	Tropical nights
Botoşani	42	49	105	120	61	6
Iaşi	38	46	107	134	73	9
Galaţi	24	37	95	141	74	36
Negresti	45	50	116	134	67	5
Bârlad	36	48	103	128	63	19
Tecuci	37	41	106	140	71	19

Considering the rainfalls, this period presented a deficit, recording large quantities only for short intervals of 1-2 days per month that led to the rapid discharge without contributing to the water resources regeneration.

Based on the records from the Meteorological National Administration, Regional Meteorological Centre Moldova, soil moisture reserve for plants with the profile 0-100 cm was 334 m^3/ha (extreme pedological drought), the eastern and southern half of the county of Iaşi, the deficit ranged between 1.350 to 1.620 m^3 / ha.

The soil moisture reserve for plants with the profile 0-100 cm was extremely low in most agricultural areas in Iasi as appropriate the pedological drought was exceedingly and strong.

The soil moisture reserve value for plants with the profile 0-50 cm was 86 mc/ha (extreme and acute drought), in the south-east and south part of Iasi county, the deficit has reached values between 650-750 m^3/ha. In the same area of the basin in the 0-50 cm soil layer, the degree of soil water supply was below the limit of wilting coefficient (Co < 350 m^3/ha for heavy and extreme drought).

In the area administered by Iaşi Water Management System, piezometric levels measured weekly in the wells national hydrogeological network (between 1-5 cm), were decreasing, being placed below the annual average and more pronounced towards the end of the interval. This scenario emerged in most hydrogeological sections.

Levels lower then annual average were observed also in the interfluvial areas where there were constant decreases of 1-2 cm, with a different behaviour compared to wells located separately in the alluvial plain.

From the hydrological point of view, the year 2012 has been characterized as a dry year, for all multi-gauging stations in the Prut-Bârlad hydrographical area.

Annual average runoff in most rivers from Prut catchment had module coefficients ranging between 1 and 60% from the multiannual average.

Annual average runoff on the watercourses from Prut basin has the following coefficients:

- Jijia river: hydrometrical station Todireni 0.18 and hydrometrical station Victoria 0.30;
- Bahlui river: hydrometrical station Pârcovaci 0.38, hydrometrical station Hârlău 0.40, hydrometrical station Podu Iloaiei 0.37, hydrometrical station Iaşi 0.41 and hydrometrical station Holboca 0.42;
- Miletin river: hydrometrical station Nicolae Bălcescu 0.16 and hydrometrical station Şipote 0.18.

Reduced runoff flows were recorded, caused by lack of rain which widened in the second half. In 2012 droughts manifested mainly on watercourses that are shorter than 50 km^2 (Table2).

Table 2: The stage of the dried or partial dried during the year 2012 in the Jijia River basin (N.A. "Romanian Waters" 2012)

Nb. crt.	River	Cadastral Code	Length (km)	Length (km) of the sector affected by the drought in the period July-October 2012
1	Glăvăneşti	XIII.1.15.21	7.0	4.0
2	Cracalia	XIII.1.15.21.2	5.0	5.0
3	Gotcoaia	XIII.1.15.21.3	5.0	5.0
4	Iepureni	XIII.1.15.22	10.0	6.0
5	Aluza	XIII.1.15.23	15.0	9.0
6	Hărbărău	XIII.1.15.24	8.0	3.0
7	Miletin	XIII.1.15.25	35.0	15.0
8	Scânteia (Nacu, Mitoc)	XIII.1.15.25.5	9.0	5.0
9	Pârâul lui Vasile	XIII.1.15.25.8	15.0	9.0
10	Recea (Odaia)	XIII.1.15.25.9	12.0	12.0
11	Puturosul	XIII.1.15.26	11.0	5.0
12	Gârla Morii (Jijioara)	XIII.1.15.27	34.0	27.0
13	Boroşoaia	XIII.1.15.27.1	6.0	4.0
14	Catargiu	XIII.1.15.27.1.a	5.0	5.0
15	Paiş	XIII.1.15.27.2	12.0	3.0
16	Barboşica	XIII.1.15.27.2.1	6.0	6.0
17	Lacu Negru	XIII.1.15.27.3	5.0	5.0
18	Sbanţ	XIII.1.15.27.4	10.0	7.0
19	Jirinca	XIII.1.15.29	6.0	6.0
20	Pop	XIII.1.15.30	8.0	8.0
21	Frasin	XIII.1.15.31	25.0	25.0
22	Optoceni	XIII.1.15.31.2	9.0	9.0
23	Tamarca (Tătarca)	XIII.1.15.32.33	11.0	11.0
24	Comarna	XIII.1.15.32.34	8.0	8.0
25	Covasna	XIII.1.15.32.35	9.0	9.0

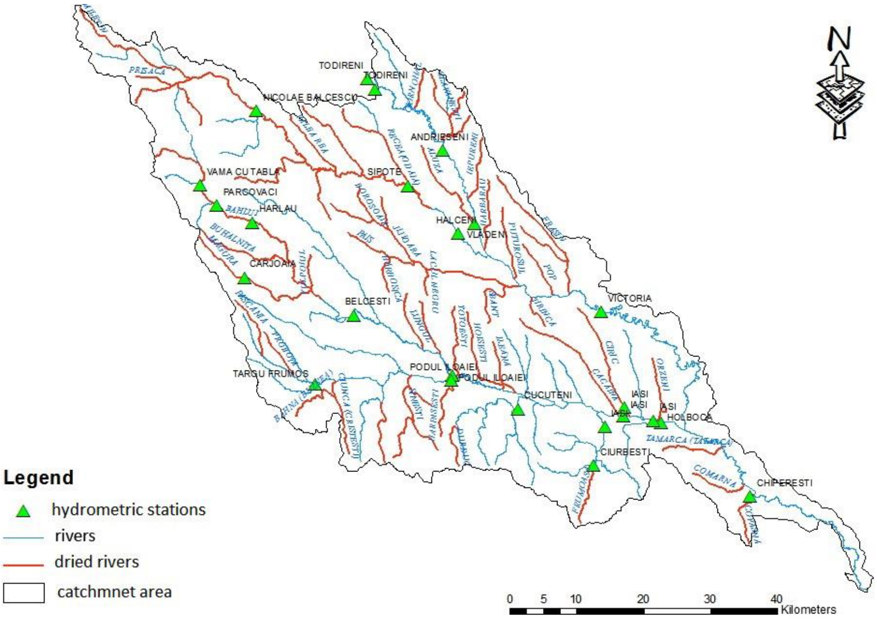

Figure 2: Droughts in the lower basin of the Jijia River in 2012

Starting from the data presented in the tables above and by using ArcGIS software the drought map on the lower Basin of Jijia River was attained. Thus was highlighted much easier area in which runoff was affected.

Table 3: Table with yearly average and multi annual average discharge between 1996 and 2012 at the Vlădeni and Victoria hydrometrical station on the Jijia river

Year	hydrometrical station Vlădeni		hydrometrical station Victoria	
	Yearly average discharge	Multi annual average discharge	Yearly average discharge	Multi annual average discharge
1996	8.43	5.22	11.8	6.91
1997	8.10	5.22	9.73	6.91
1998	12.5	5.22	15.5	6.91
1999	11.1	5.22	15.2	6.91
2000	5.58	5.22	7.29	6.91
2001	4.37	5.22	6.37	6.91
2002	9.00	5.22	12.9	6.91
2003	5.37	5.22	7.71	6.91
2004	3.40	5.22	4.72	6.91
2005	7.66	5.22	8.88	6.91
2006	9.61	5.22	12.3	6.91
2007	2.83	5.22	3.33	6.91
2008	5.68	5.22	7.14	6.91
2009	3.88	5.22	5.12	6.91
2010	8.29	5.22	10.2	6.91
2011	4.30	5.22	5.09	6.91
2012	1.87	5.22	2.10	6.91

3.Results

Average annual flow analysis (Figures 3 and 4) shows decreasing trend values on the last 15 years with a favourable impact on droughts.

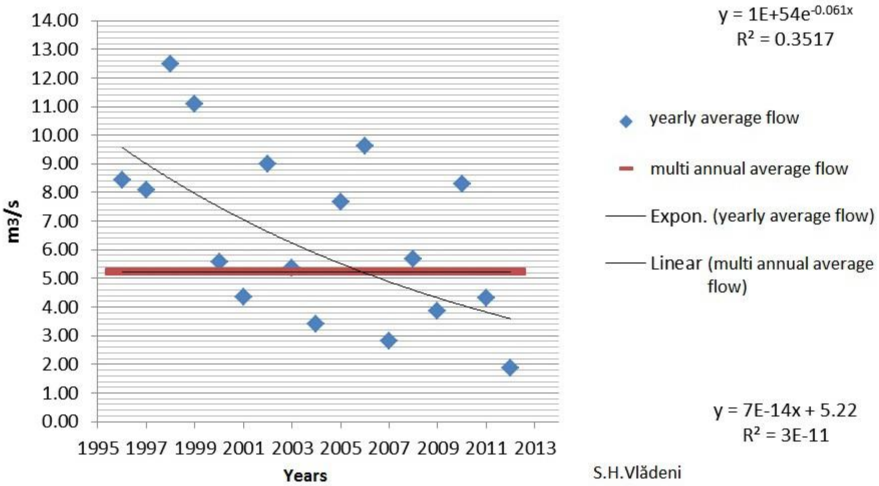

Figure 3: Trendline of the yearly average flow (m^3/s) recorded at Vlădeni hydrometric station between 1996 and 2012

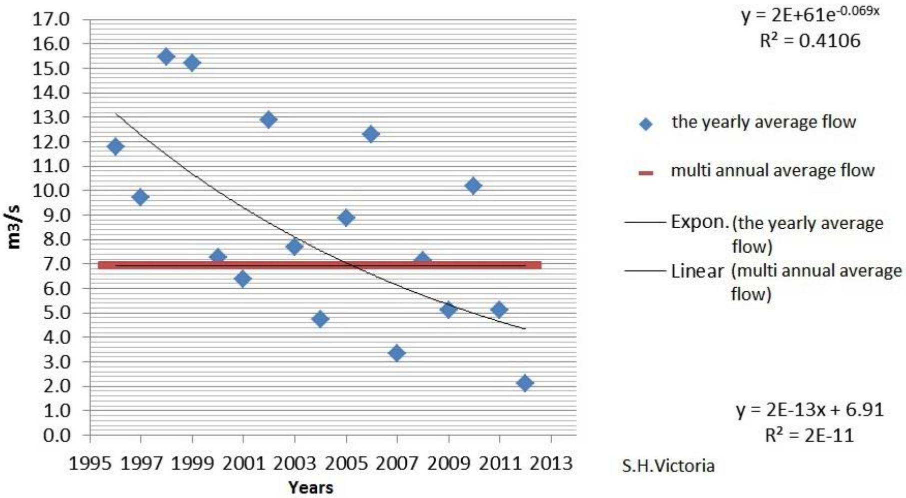

Figure 4: Trendline of the yearly average flow (m^3/s) recorded at Victoria hydrometric station between 1996 and 2012

Figures 5, 6, 7 and 8 are shown the effects observed in the groundwater at the wells Glăvăneşti F2 and Ţigănaşi F3 near the hydrometric stations Vlădeni and Victoria which were taken as an example of downward trend in average annual flow.

Given the piezometric level data sets that are clearly decreasing, multiannual rainfall amounts and average monthly liquid flow from 2012 were also analysed and compared with annual average liquid flow.

Graphical representations clearly show a downward trend in all three analyses made on piezometric level, flow and precipitation.

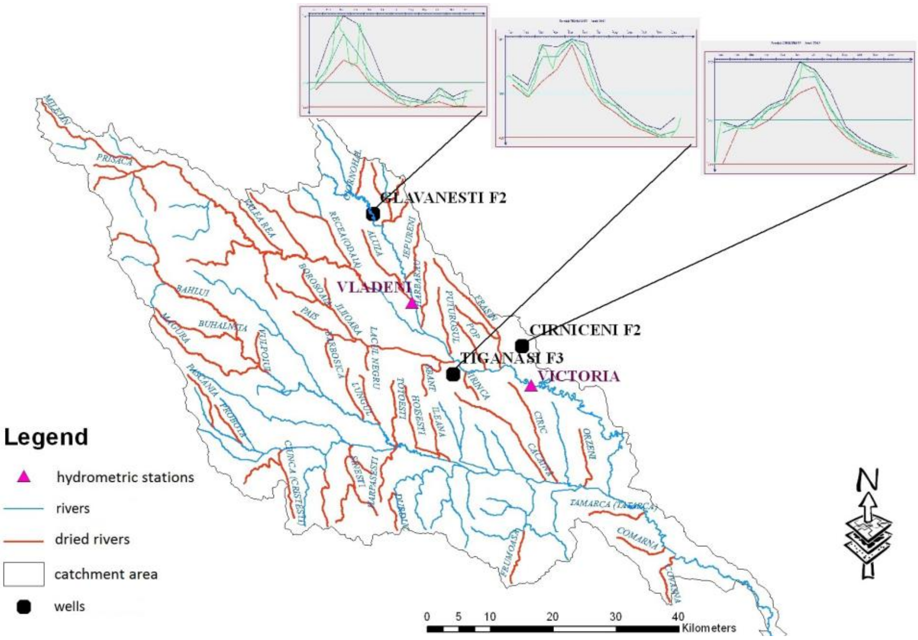

Figure 5: Glăvăneşti F2, Cîrniceni F2 and Ţigănaşi F3 wells location, near the lower River Jijia

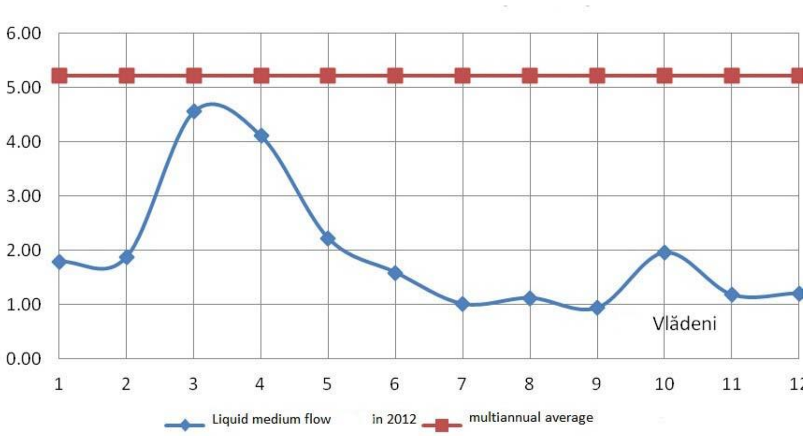

Figure 6: Liquid medium flow during 2012 registered at Vlădeni hydrometrical station compared to the multiannual average flow

Looking at the aquifer position within the lithological profile of the F2 Glăvăneşti well it appears that the level has fallen below the level of the layer roof.

In this case we can speak about the beginning point of a hydrological drought.

Analysis of the aquifer levels recorded in Țigănași F3 well evolution shows that the minimum of 2012 are below minimum multiannual level, but still stands above the roof of the layer.

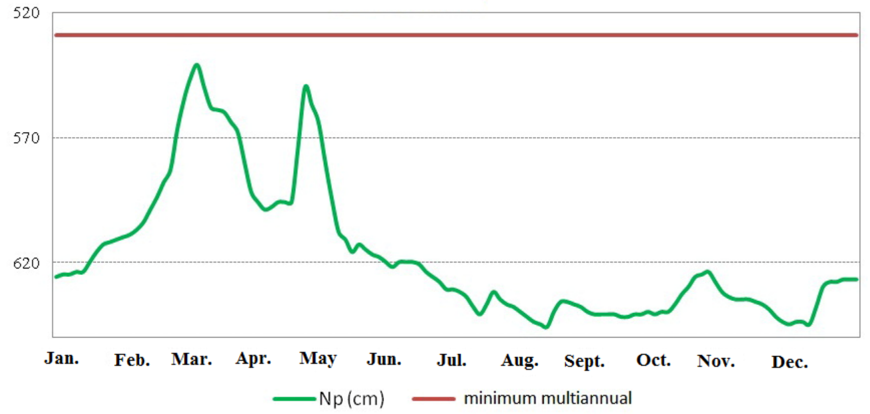

Figure 7: F2 Glăvăneşti, piezometric well level recorded during 2012 compared to the minimum multiannual

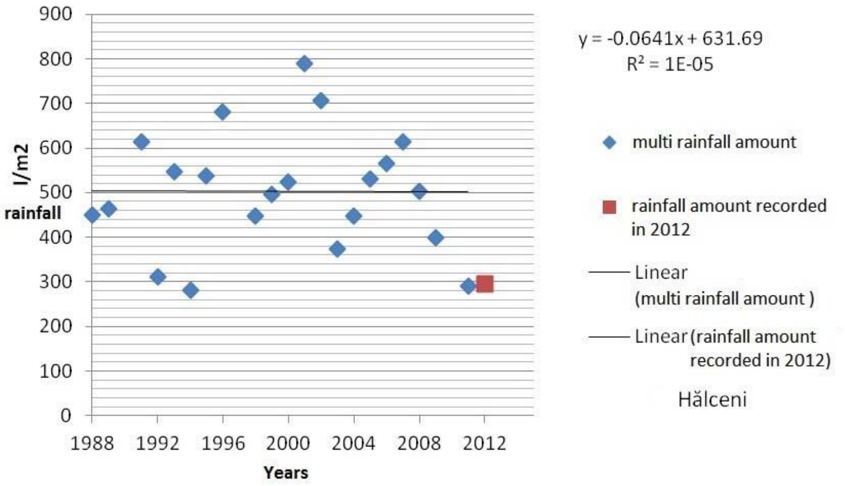

Figure 8: Hălceni, reservoir rainfall amount recorded in 2012, near the hydrometrical station Vlădeni versus multi rainfall amount

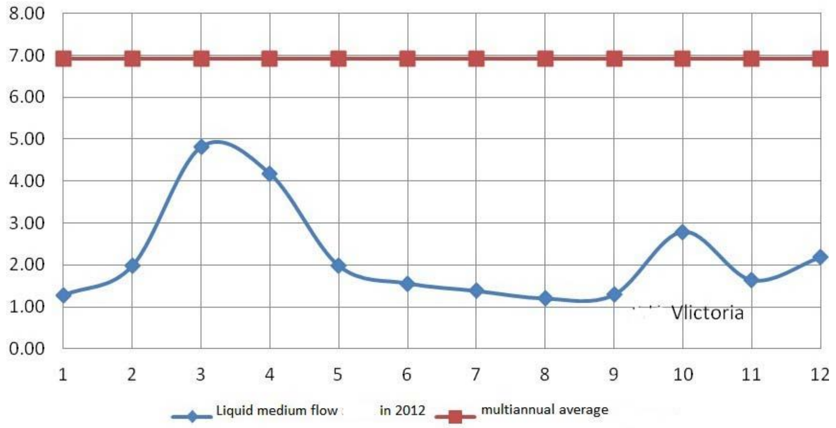

Figure 9: Liquid medium flow during 2012 registered at Victoria hydrometrical station compared to the multiannual average flow

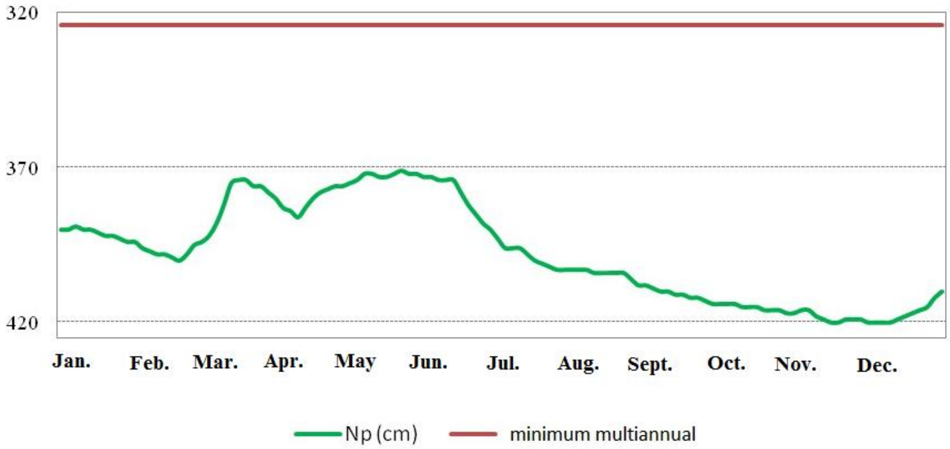

Figure 10: Ţigănaşi F3 well - level recorded during 2012 compared to the minimum multiannual

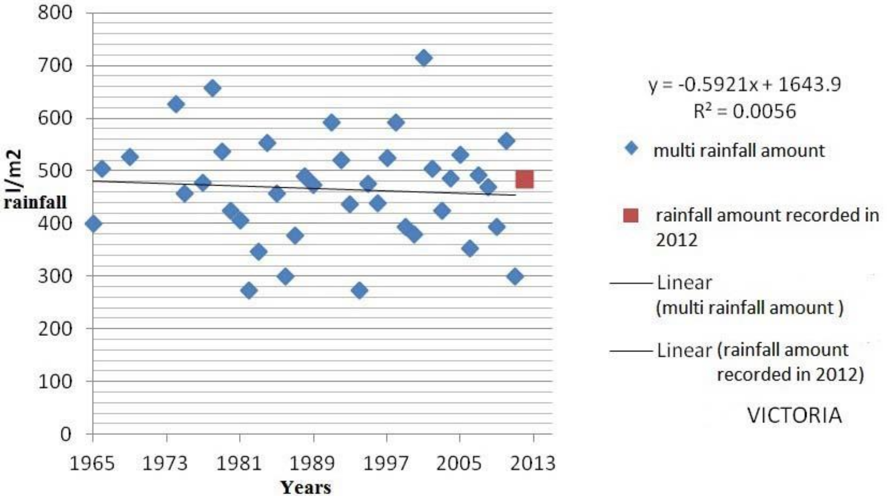

Figure 11: Victoria hydrometrical station - rainfall amount recorded in 2012 versus multi rainfall amount

4. Discussions

The analysed period is characterized by a flowing under normal monthly (average values being between 10 and 30% of normal monthly amount).

On the other hand, hot and dry winds with high speeds also contribute to the increased evapotranspiration and reduce the soil and air moisture.

During the period of drought, soil absorbs approx. 44% of direct solar energy that turns into heat and participates in overheating it and the air. On turn ground and air overheating gradually reduces soil moisture reserve for plants by increasing the evapotranspiration.

Since the lack of precipitation can occur in all months of the year, dry periods and drought can take place in all the seasons with obvious repercussions on agriculture. In most cases droughts are not identified as such in time, therefore when taking suitable prevention no immediate effect is expected. Hence, criteria for defining drought are needed for analysing and applying on time the management measures of the crisis. Unfortunately, the evolution of climate and hydrological behaviour cannot be long-term simulated since a veritable technical and/or informatics support necessary for planning and water management in drought periods does not exist.

The use of increasingly frequent professional softwar's as ArcGIS and technologies which can provide geospatial information more clearly reveals hydrological droughts scenario.

Assessment of infiltration, surface runoff, groundwater flow, flow of rivers, water volumes and levels of reservoirs and groundwater levels are the criteria by which we can classify the 2012 drought in the lower basin of Jijia River as hydrological drought.

Conclusions

In the county of Iaşi, droughts occurred on the entire length or on different watercourse sections. Thus, lowering the water level in wells and drying the overland flow due to lower groundwater levels, flow reduction at source in centralized water supply, decrease of soil moisture reservoir combined with lack of rainfall and high temperatures have led to serious damage to the vegetation of crops, pastures and hayfields, occurrence of fishing mortality in some reservoirs and pounds.

Global climate changes associated with increased pollution, deforestation or landscape changes led to amplification of dryness and aridity process. Thus, areas which are considered having endemic drought tend to be affected by aridity (lower water levels in aquifers).

The impact of geographical and climatic factors on the trends of drought is also closely related to seasonality and duration of short-term season drought and medium-term drought but not the long-term one. Therefore, for an effective management of water resources during droughts, geographical and climatic features of each region must be taken into account.

In extreme cases of drought suitable measures for protection, maintenance and regeneration of water resources have to be taken, due to their fundamental importance for human life and socio-economic development.

All actions of defence against drought must be integrated into sustainable development plans.

Risk assessment associated with potential consequences of drought in various sectors and systems requires the existence of certain methodologies. Drought can affect agriculture, irrigation, drinking and industrial water supply, hydropower and the entire environment. For each of these sectors the risk has to be quantified for every period of drought in appropriate terms (for example in agriculture in the form of lost production). Consequently, each sector exposed to the drought risks has to adopt its own suitable methods for calculating risk associated with drought.

References

1. Crăciun I., Giurma I., Giurma-Handley C.R., Boboc V., 2011. *Evaluating the climatic changes in the hydrological flow regime of the Moldavian areas,* Environmental Engineering and Management Journal, 10(12), 1983-1986
2. Crăciun I., Giurma I., Giurma-Handley C.R., Telişcă M., 2009. *Integrated quantitative and qualitative monitoring system of water resources,* VIth Int. Conf. on the Management of Technological Changes, Sept.3-5, Alexandroupolis, Greece, II, 53-56
3. Gruia R., 2010. *Modular agriculture - paradigm of globalization dynamics within the context of climatic and scientific changes*, Environmental Engineering and Management Journal, 9(12), 1601-1606
4. Huntington T.G., 2010. *Climate warming-induced intensification of the hydrologic cycle: an assessment of the published record and potential impacts on agriculture,* Advances in Agronomy, 109, 1-53
5. Huntjens P., Pahl-Wostl C., Grin J., 2010. *Climate change adaptation in European river basins*, Regional Environmental Change, 10(4), 263-284
6. Minea I., Crăciun I., 2012. *Simulation models to evaluate the groundwater resources in the Bahlui river basin, Romania*, Journal of Environmental Protection and Ecology, 13(2), 756-763
7. Noges P., Van de Bund W., Cardoso A.C., Heiskanen A.S., 2007. *Impact of climatic variability on parameters used in typology and ecological quality assessment of surface waters - implications on the Water Framework Directive,* Hydrobiologia, 584, 373-379
8. Palmer M.A., Lettenmaier D.P., Poff N.L., Postel S.L., Richter B., Warner R., 2009. *Climate change and river ecosystems: protection and adaptation options,* Environmental Management, 44(6), 1053-1068
9. Pepa C.A., 2012. *Assessment of the Water Framework Directive implementation in Romania: case study of Bega catchment,* Environmental Engineering and Management Journal, 11(5), 945-952
10. Roy P.K., Mazumdar A., 2005. *Hydrological impacts of climatic variability on water resources of the Damodar River basin, India,* Regional Hydrological Impacts of Climatic Change - Impact Assessment and Decision Making, IAHS Publication, 295, 147-156
11. Rowan T.S.C., Maier H.R., Connor J., Dandy G.C., 2011. *An integrated dynamic modelling framework for investigating the impact of climate change and variability on irrigated agriculture,* Water Resources Research, 47, W07520
12. Simonovic S.P., 2010. *A new methodology for the assessment of climate change impacts on a watershed scale*, Current Science, 98(8), 1047-1055
13. Ştirbuleac R.S., 2011. *Research on catchment water resources and hydrological extreme weather situations (in Romanian),* Doctoral Thesis, Technical University Gheorghe Asachi of Iaşi
14. Teodosiu C., Bârjoveanu G., Robu B., Ene S.A., 2012. *Sustainability in the water use cycle: challenges in the Romanian context,* Environmental Engineering and Management Journal 11(11), 1987-2000
15. Ungureanu F., Lupu R.G., Stan A., Crăciun I., Teodosiu C., 2010. *Towards real time monitoring of water quality in river basins*, Environmental Engineering and Management Journal, 9(9), 1267-1274
16. Vinke-de Kruijf J., Dinica V., Augustijn D.C.M., 2009. *Reorganization of water and waste water management in Romania: from local to regional water governance*, Environmental Engineering and Management Journal, 8(5), 1061-1071
17. * * * *2011-2012. Operative reports and information on drought and floods Prut River Basin (in Romanian),* National Administration “Romanian Waters”, Water Basin Administration of Prut, Bârlad