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THE ANNUAL AND MULTI-ANNUAL VARIATION OF THE MINIMUM DISCHARGE IN THE MILETIN CATCHMENT (ROMANIA). AN IMPORTANT ISSUE OF WATER CONSERVATION

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Abstract

The Miletin catchment is situated in the central-eastern sector of the Jijia-Bahlui depression, a component of the Moldavian Plateau, which spans Eastern Romania. Climatic conditions feature average multi-annual precipitations of 500–550 mm/year, an average evapotranspiration of 650–700 mm/year, and temperatures often exceeding 30°C during the summer and down to -30°C during the winter. Due to these conditions, the local rivers (such as the Miletin) can only have a permanent discharge if strong underground waters feed them. This situation is only found in the case of large rivers, which never dry up. Data recording was performed for a period of 41 years. The lowest (minimum minimorum) discharge was 0 m^3/s in the upper sector, and it was recorded in 1968, 1969, 1986, and 1987. The lowest discharge in the middle sector was of 0.001 m^3/s, recorded only once in 1990. In the lower sector, downstream from the Halceni pound, the lowest discharge was of 0.002 m^3/s, recorded in 2006 and 2008. These lowest discharge levels occurred during the summer and winter. Dry-spells and water collecting, increasingly more common during the last few years, means that the hydrostatic level of the groundwater regularly drops by 1–2 cm each year.

Keywords: *Drought period; Drying-up; Economic impact; Minimum discharge; Standard deviation.*

Introduction

Droughts, as well as floods, represent hydrologic processes with important negative effects on economic activity. Old documents register numerous droughts that affected the Romanian territory, some of them with long-term repercussions. "Cronica Brasovului" [1] notes, for the year 1710 that "many rivers dried up, the biggest springs and rivers went dry". In his chronicle, Ureche G. (1647) reminds that in 1585 "there was a great drought in the country, and all the springs and ponds went dry; where one could catch fish before, now the plough was used".

During the drought of 1946, several large rivers dried up, such as Buzau, Barlad, Jijia, Baseu, Miletin, etc. The years with the least rain, since the period of regular measurements of

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the Romanian territory, were, depending on the value, 2011, 2003, 1990, 1952, and 1946. After 1960, there was an increase in the frequency of years of drought, and mostly of the severity of the phenomenon during the summer. In January–May 2011, there was a major deficit in the precipitation at the level of Western Europe (20–60% below average). At the same time, the temperatures were 3°C higher in comparison to the multi-annual means. The months of August and September 2011 had the least rain, with thermal means of 3.2°C above the normal means.

The permanent discharge character of the river is given by the interception of phreatic water and by the underground supply [2-9]. If the underground supply brings a major contribution, the river will have an important and relatively constant discharge. A weak underground contribution determines a high rainfall index. During meteorological droughts, only underground waters supply the rivers. This is the main characteristic of the autochthonous rivers in Eastern Romania [10-12].

Small water bodies in Romania, mostly in Moldavia, are specific to summer and autumn, as the rains are rare and there is high evapotranspiration. Winter is also responsible for the existence of small water bodies. In this case, the water is retained in the riverbed or in the basin in solid form. Winter drying-up is rarer in comparison to the summer–autumn one. Winter drying-up is frequent in Moldavia and rarer in the western areas of the country which are influenced by the oceanic climate [3, 13, 14].

Drying-up is specific to small rivers and less to large hydrographic arteries [15]. Human activity may also determine the drying-up of rivers or of sectors of variable sizes [16-18]. In eastern Romania, there are also cases when the permanent streams became ephemeral. This fact occurred because of massive deforestation or because the fields have a dominant agrarian use for corn. Surface erosion caused a strong alluvia transport which aggradated the minor beds of brooks. In this case the brook no longer intercepts the phreatic and it loses, mostly in the upstream sector, its permanent character [19, 20].

The acute lack of water in eastern Romania led to the building of complex anthropic lakes. Most of the ponds were built in the Moldavian Plateau and some of them date back to the 15th century. There are also cases of drying-up because of water use in agriculture. The most eloquent case is that of the Amu Daria and Sir Daria Rivers, which once discharged into the Aral River. These streams disappeared because they were used to irrigate cotton fields.

The most important valorisation of the information regarding rivers drying-up is that of creating maps of stream drying-up. On the river sectors, on which there is information, there are at least two values registered as a connection: for the nominator there is the number of years to which the observations refer; for the numerator there is the number of years when the river dried up: $\frac{5}{10}$ =the river drains every two years, on average.

On the Romanian territory, there are frequent droughts in the Moldavian Plateau, the Romanian Plain, and Dobrudja. This is the reason why the water resources are limited and the economic activity, mostly the agrarian one, has to suffer [21]. For the Romanian territory, within the Carpathian Mountains, the rivers with basins larger than 20 km^2 are ephemeral. The largest catchments, with intermittent discharge, can be found in the Romanian Plain (Sarata – 1,334 km^2) and the Moldavian Plateau (Baseu – 945 km^2, Miletin – 680 km^2, Vaslui – 622 km^2). In the Tisa Plain the basins of intermittent rivers do not exceed 300 km^2, and those within the Transylvanian Plateau 200 km^2 [16, 17, 22].

International and Romanian literature regarding minimum discharges is extremely rich [2, 13, 19, 20, 22-49]. This study aims to systematically analyse the frequency of the minimum discharge rivers of Moldavia, in the Miletin River case study. The data obtained in helping assess water reserves may be contributed to by the local population.

Geographic location

The Miletin catchment has a central southeastern position within the European continent, between parallels 47º20'25" and 47º43'11" N latitude and between the meridians of 26º34'26" and 27º21'35" E longitude (Fig. 1). On the Romanian territory, the basin is situated in the northeastern part and crosses two geographic sub-units: the Suceava Plateau (in the upper basin) and the Moldavian Plateau (in the lower basin) [21, 50].

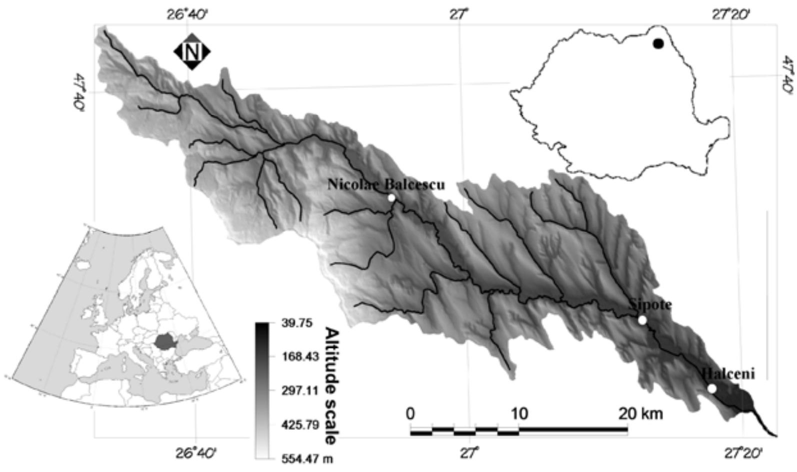

Fig. 1. Geographic position of the Miletin hydrographic basin

The limit of the catchment is given by the watershed which delimits it from the catchments of the rivers of Sitna (to the N), Bahlui, and Jijioara (to the S), Siret (to the W), and Jijia (to the E). The surface of the Miletin catchment (680 km^2) represents 11.72% of the surface of the Jijia River basin (main collector) and 0.08% of the surface of the Danube catchment.

Materials and methods

Statistical data were obtained from the Department of Water from the River Prut, Iasi, the Moldavian Meteorological Centre, Iasi and the National Administration of Romanian Waters, Bucharest. These were processed in the Laboratory of Geo-Archaeology of the Faculty of Geography and Geology, Iasi. Real satellite images were obtained from the Remote Sensing and GIS Laboratory of the National Administration of Meteorology and Hydrology, partially processed or interpreted in the Remote Sensing and GIS Laboratory of the Faculty of Geography and Geology, “Alexandru Ioan Cuza” University and the Geo-Archaeology Laboratory. Most of the satellite images already processed were obtained from the Romanian Space Agency (ROSA – Romanian Space Agency) or the PNCD12 Project on the internet.

Land observations and measurements were taken between the years 2000 and 2010. The major route was the flooded riverbeds of Miletin and Jijia (main collector). Rates were monitored daily at three stations and topographical measurements were made upstream and downstream from it. All data analysed are taken from three hydrological stations (Nicolae Balcescu, Sipote and Halceni-downstream) and from two rainfall stations (Nicolae Balcescu and Halceni). From a statistical viewpoint, 41 and 28 terms respectively were processed. Data from Halceni took place over a period of only 18 years, compared with the other two stations where the period was about 60 years. In order to develop the digital terrain model (DTM), TNTMips (licensed) was used, as well as the topographic maps with a 1:5000 scale. The climatic data of the Meteorological Stations of Botosani, Harlau, Stefanesti, Iasi, and Targu Frumos were also used. For the precipitation, the data from the hydrometric stations with such recordings were also used.

Results

Multi-annual and annual minimum discharges

The data regarding the minimum discharge relates to a period of 41 years at Nicolae Balcescu (1968-2008), of 28 years at Sipote (1981-2008), and of 18 years Halceni-upstream (1991-2008). Unfortunately, these are the oldest hydrologic mentions of areas within the catchment of Miletin. The hydrographic network presents important variations in the discharge and levels over long periods, but also over a calendar year. In the upper basin, there have also been values below the multi-annual mean: 1968–1970, 1971–1978, 1983–1996, 2003–2007 at Nicolae Balcescu; 1983, 1985–1996, 2000–2001, 2003–2008 at Sipote; 1991, 1994–1995, 2000–2008 at Halceni-upstream.

The periods with high values of minimum discharges are shorter. In 1970, 1980–1982, 1997–2002, and 2008, in the lower basin there have been values exceeding 0.018 m^3/s. At the Sipote pluviometric post rich minimum discharges were registered in 1981–1982, 1984, 1997–1999, and 2002. Downstream from Halceni Lake, in 1991–2008 there were two periods with rich minimum discharges: 1992–1993 and 1996–1999 (Fig. 2a,b,c).

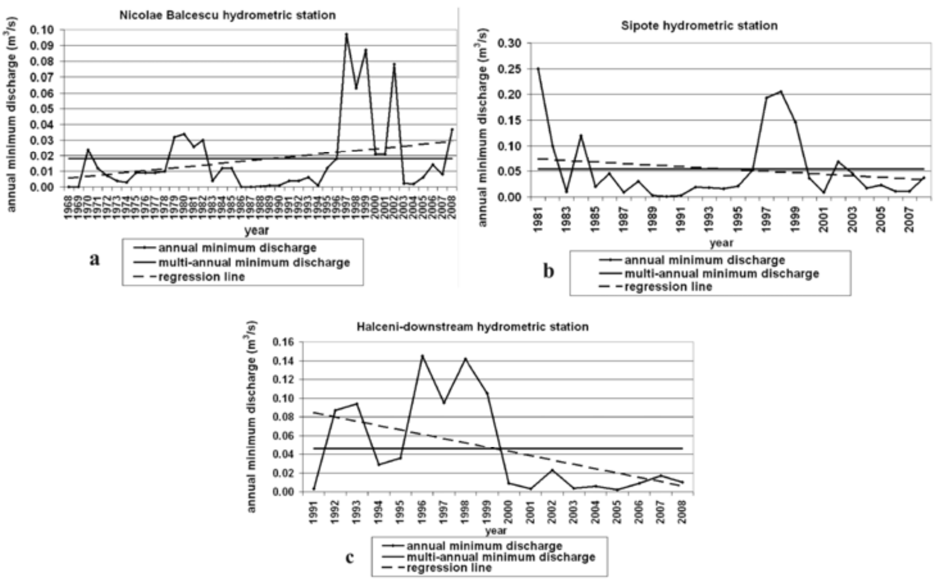

Fig. 2. Multi-annual variation of the minimum discharges:
(a) Nicolae Balcescu hydrometric station during 1968 and 2008;
(b)Sipote hydrometric station during 1981 and 2008;
(c) Halceni-downstream hydrometric station during 1991 and 2008

The minimum minimorum discharge at the Nicolae Balcescu station was of 0 m^3/s (drying-up), on January 28-31, February 1 and 9, May 6–11, June 1 and 24, July 1 and 13, August 6 and 10 1968, January 8 and 12, February 1 and 6 1969, December 29–31 1986, January 1–February 15, July 20–August 4, and September 7–October 19 1987. For the middle sector, the minimum minimorum discharge was 0.001 m^3/s at Sipote, the value registered on August 9 and September 1–14 1990. At Halceni-upstream, the minimum minimorum discharge registered during 1991 and 2008 was of 0.002 m^3/s on January 29, February 14, and November 30–December 1 2005 (Table 1).

Table 1. Values of atmospheric precipitation (mm) at the Nicolae Balcescu and Sipote pluviometric station (1962–2008) during the periods with minimum minimorum discharges (stations with natural discharge regime)

The pluviometric post	Registration periods $Q_{min.\ min.}$ (m^3/s)	Monthly precipitation (mm)	Multi-annual mean of precipitation in the corresponding months (mm)	Annual precipitation (mm)	Multi-annual mean of annual precipitation (mm)
Nicolae Balcescu	May 1968	36.6	57.8	410.3	560.0
	June 1968	85.6	87.5		
	July 1968	57.9	83.2		
	August 1968	28.1	60.3		
	July 1987	23.6	83.2	420.6	
	September 1987	7.9	46.1		
	October 1987	50	34		
Sipote	August 1990	28.1	60.3	106.2	
	September 1990	10.1	46.1		

Over half of the number of years (56.1%) of the Nicolae Balcescu station were characterised by minimum discharges below 0.011 m^3/s, and only in 7.32% of the cases did the annual values exceed 0.04 m^3/s. The probability of maximum discharges below 0.021 m^3/s in the middle basin is lower (46.43% at Sipote). A similar situation is also observed at Halceni-downstream, where half of the year rows analysed present low values of discharges (0–0.021 m^3/s).

At the level of the Miletin catchment, the minimum average discharges were determined with assurances of 80%, 90%, and 95% at the hydrologic stations with a natural discharge regime (Nicolae Balcescu, Sipote), which presents longer data rows, of over 25 years (Table 2). For the Nicolae Balcescu station, the zero value of the minimum discharge, with a 90% and 95% assurance respectively, indicate a relatively high frequency of the drying-up phenomenon. The values of minimum discharges, with different assurances, increase from upstream to downstream, because of the ever growing amount of water, with the increase in the number of tributaries within the middle basin (Fig. 3a,b). The discharge at the Halceni-downstream hydrometric station is influenced by the existence of the Halceni reservoir, located upstream (Figs. 3c, 4).

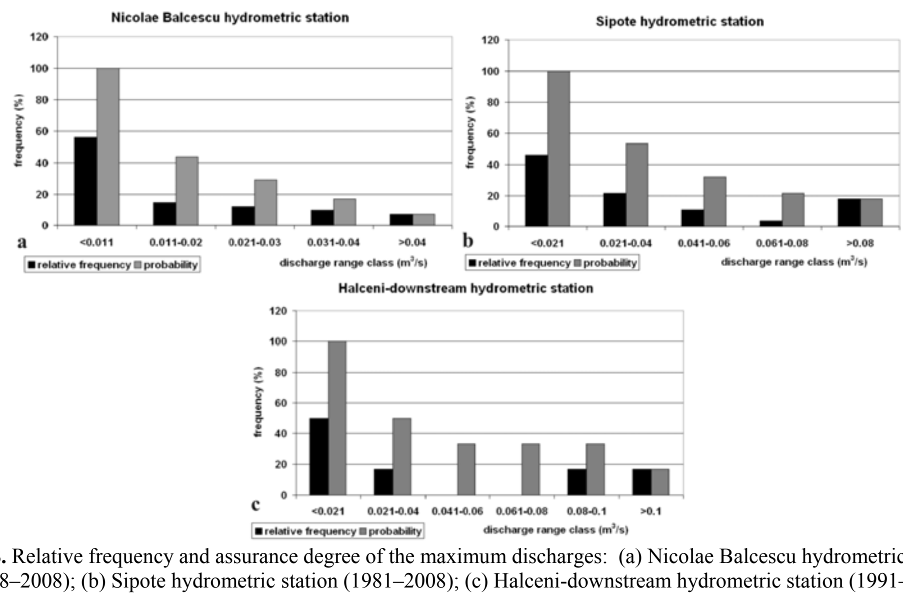

Fig. 3. Relative frequency and assurance degree of the maximum discharges: (a) Nicolae Balcescu hydrometric station (1968–2008); (b) Sipote hydrometric station (1981–2008); (c) Halceni-downstream hydrometric station (1991–2008)

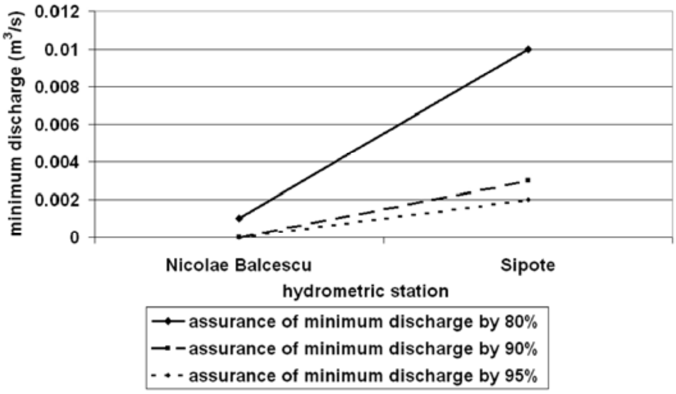

Fig. 4. Variation in minimum discharges (m^3/s) with different assurances, with the increase in the surface of the Miletin River basin, at the stations with natural discharge during the period 1981–2008

Table 2. Minimum average discharges (m^3/s) with various assurances at the Nicolae Balcescu (1981–2008) and Sipote (1981–2008) hydrometric stations

Hydrometric station	Basin surface (km^2)	Minimum average discharges (m^3/s) with the assurances		
		80%	90%	95%
Nicolae Balcescu	223	0.001	0	0
Sipote	620	0.01	0.003	0.002

Minimum seasonal discharges

The seasonal distribution of the minimum water amounts is determined by the synoptic conditions, which generates low quantities of precipitation. The specific of the transitional temperate climate in Eastern Romania gives an irregular aspect to the liquid flow, marked by important differences in the flow between seasons (Table 3). In the winter, the minimum discharges have relatively high values of the multi-annual mean, as the variation coefficient of the air temperatures is very high (Table 4, Fig. 5a). This is why there are years with important positive deviations from the multi-annual mean of minimum discharges. Water is completely froze upstream from Sipote. The phenomenon is favoured by the existence of reduced discharges. At Sipote, where the discharge is higher (because of the water amount brought by a large number of tributaries), the water does not totally freeze and there is an important liquid flow underneath the ice.

Table 3. Multi-annual seasonal mean of minimum discharges (m^3/s) on the Miletin River at the Nicolae Balcescu station (1991–2008)

Hydrometric station	Multi-annual seasonal mean of minimum discharges (m^3/s)			
	Winter	Spring	Summer	Autumn
Nicolae Balcescu	0.049	0.071	0.038	0.05
Sipote	0.198	0.157	0.082	0.125
Halceni-downstream	0.085	0.120	0.138	0.075

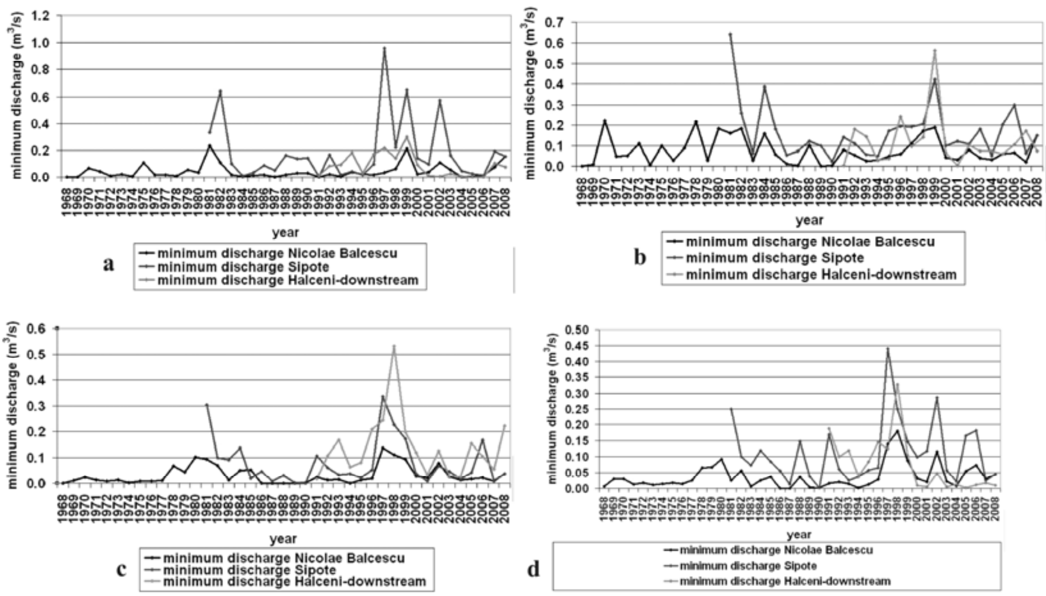

Fig. 5. Multi-annual variation of minimum discharges in: (a) winter (m^3/s) (1968–2008); (b) spring (m^3/s) (1968–2008); (c) summer (m^3/s) (1968–2008); (d) autumn (m^3/s) (1968–2008)

Table 4. Air temperature means in the winter for the periods with very low minimum discharges (1968–2008)

Hydrometric station	Period with very low minimum discharges	Average temperature in winter (˚C)	Period analysed	Average temperature in winter (˚C)
Nicolae Balcescu	1968–1978	-2	1968–2008	-1.5
	1884–1996	-1.6		
Sipote	1984–1995	-1.3	1981–2008	-1.2
Halceni-downstream	2001–2008	-1.1	1991–2008	-1.1

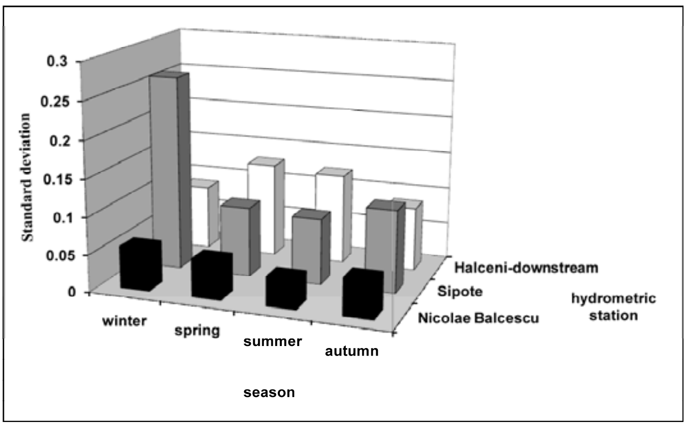

Fig. 6. Seasonal variation in standard deviation for minimum discharges (1991–2008

Snow melting and the increase in precipitation during the spring determine the highest multi-annual means of minimum discharges (Table 5, Fig. 5b). In the summer, the high temperatures determine the increase in evapotranspiration, and the reduction in the amount of rainfall, in July and August, results in low values of the minimum discharge (Fig. 5c). The thermal convection weakens during autumn. Due to reduced evapotranspiration, the values of the minimum discharges are higher (Fig. 5d).

The seasonal variation of the standard deviation for the maximum discharges within the Miletin catchment has greater variations at Sipote. The maximum value in the winter is 0.262 and in the summer is 0.089 (Fig. 6). For the Nicolae Balcescu station, it varies between 0.057 in the winter and 0.039 in the summer. At Halceni-downstream, with a man-controlled flow, there are values between 0.128 in the spring and 0.086 in the autumn. Therefore, at Halceni-downstream there is a different situation than at the two other stations, which function naturally.

Table 5. Frequency of extreme drought months (EDM), very high drought months (VDM), drought months (DM), and low drought months (LDM) from the pluviometric perspective (depending on the Hellmann criterion) during periods of very low minimum discharge (1968-2008)

Seasons	Hydrometric stations	Period with very low minimum discharges	Frequency of EDM, VDM, DM, LDM (%)	Period analysed	Frequency of EDM, VDM, DM, LDM (%)
Spring	Nicolae Balcescu	1986–1990	73.33	1968–2008	53.6
		2000–2007	66.67		
	Sipote	1986–1994	71.42	1981–1994	52.38
	Halceni	2001–2005	50	1991–2008	55.56
Summer	Nicolae Balcescu	1968–1977	63.33		
		1986–1994	62.96	1968–2008	50.4
		2004–2007	50		
	Sipote	1985–1990	44.44	1981–1994	42.85
	Halceni	2001–2007	33.33	1991–2008	40.74
Autumn	Nicolae Balcescu	1968–1976	54.85	1968–2008	52.03
		1986–1994	62.96		
	Sipote	1987–1993	54.76	1981–1994	52.38
	Halceni	2000–2008	48.15	1991–2008	53.7

The monthly minimum discharges

At the Nicolae Balcescu station there is a very high frequency of minimum minimorum discharges in the winter months, when the cold air masses determine the blockage of the flow due to frost (Fig. 7a).

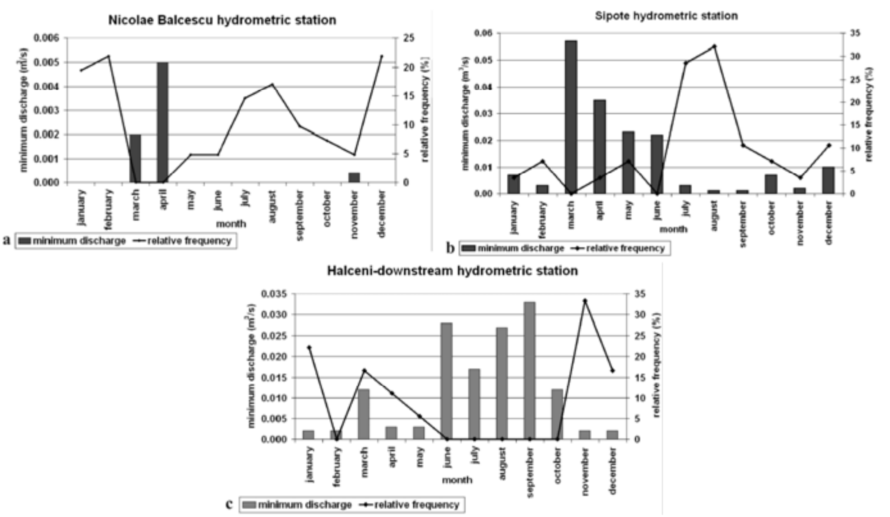

Fig. 7. Monthly probability (%) of annual minimum discharges and monthly minimum minimorum discharges (m^3/s): (a) Nicolae Balcescu hydrometric station (1968–2008); (b) Sipote hydrometric station (1981–2008); (c) Halceni-downstream hydrometric station (1991–2008)

The second maximum is registered in July–August, when the monthly rainfall decreases and evapotranspiration is intense. The main maximum at the Sipote station is registered in July–August (Fig. 7b). The secondary maximum for the annual minimum minimorum discharges occur in the winter (Fig. 7c). The lower frequency of annual minimum discharges during the winter is determined by the rich flow of the middle Miletin, with relatively rich waters introduced by a larger number of tributaries.

The high frequency of the annual minimums at the Halceni-downstream station occurs in the period November–March when the lake waters are frozen. The monthly minimum minimorum discharges at the Nicolae Balcescu station occur in the period March–April and at Sipote in March–June. They correspond to the maximum precipitations specific to the transitional temperate climate. The lowest values of the minimum discharge are registered at the end of the summer and the beginning of autumn. In this case precipitation is minimal. The highest minimum flows at Halceni-downstream are registered in June–September, when a part of the lake water is freed to compensate for the deficit registered during this period.

The drying-up periods

The river drying-up phenomenon clearly has negative social-economic net consequences. Knowing the particularities of this period provides the specialists with the opportunity to adopt the most favourable solutions to reduce the negative effects [11]. The drying-up phenomenon occurs in the upper basin of the Miletin River and on the first, second, and third order main tributaries within the Horton-Strahler order. It is determined by two limiting factors: climate and geology. The fact that the Miletin basin is situated in the NE part of Romania, in the transitional temperate continental climate, determines the frequent drying-up phenomena. The presence of air masses, pulsated by the Russo-Siberian anticyclone in the winter, generates very low atmospheric temperatures. In this way, the drying-up phenomenon appears because of the total frost.

The geologic structure of the upper basin is made of Sarmatian layers, with clayey marls and sandy intercalations, on top of which clayish-sandy soils have formed [50]. The presence of friable rocks (sands) determines a rich infiltration favouring a decrease in surface discharge and the appearance of the drying-up phenomenon during the warm periods of the year (Fig. 8).

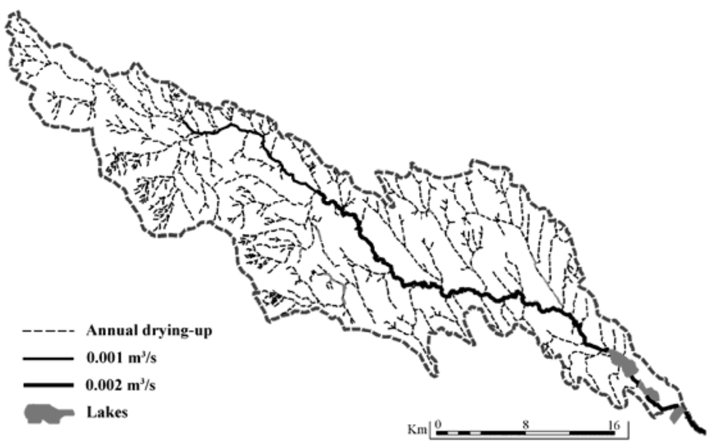

Fig. 8. Hydrographic network of the Miletin basin and the river sectors affected by drying-up

Depending on the monthly minimum discharges, the most numerous months with drying-up phenomena occur at the Nicolae Balcescu station (7), while the other two (Sipote, Halceni-downstream) do not register this phenomenon (Fig. 9a,b,c). During the summer, because of the variability in the atmospheric precipitations and of the high temperatures, nine cases of drought were registered at the Nicolae Balcescu hydrometric station: May 6-11 1968; June 1 and 24 1968; July 1 and 13 1968; August 6 and 10 1968; July 20-August 4 1987; and September 7–October 19 1987. During the cold season, there have been relatively frequent cases of total frost: January 28–31 1968; February 1 and 9 1968; January 8 and 12 1969; February 1 and 6 1969; December 29–31 1986; and January 1–February 15 1987. The longest drying-up periods during the summer occurred on July 20–August 4 1987 and September 7–October 19 1987.

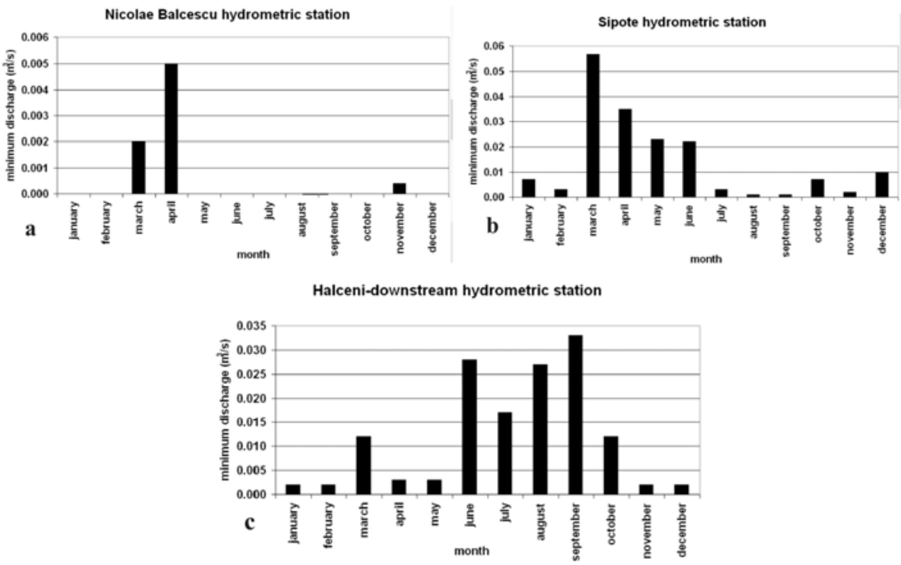

Fig. 9. Monthly minimum discharges: (a) Nicolae Balcescu hydrometric station; (b) Sipote hydrometric station; (c) Halceni-downstream hydrometric station

The year 1987 was excessively droughty (according to the Hellmann classification criterion). Atmospheric precipitation of 420.6 mm was registered at the Nicolae Balcescu station (an important negative deviation from the multi-annual mean of 560 mm, in the period 1962–2008) (Table 6). At Botosani, in June, July, and September, there were positive deviations from the multi-annual mean, as well as an increase in evapotranspiration (for the period 1970–2008) (Fig. 10). In 1987, the highest monthly average temperature was of 22.7°C, in comparison with the multi-annual average temperature of 20.5°C. Thus, the deviation equals 2.2°C. The lowest value in 1987 was of 8.3°C, compared to the multi-annual mean of 9.4°C. In this case the deviation equals -1.1°C.

Table 6. Values of the monthly and annual atmospheric precipitations and monthly pluviometric qualifiers of the year 1987, according to the Hellmann criterion, at the Nicolae Balcescu pluviometric station (1962–2008)

Year 1987	Ian.	Feb.	Mar.	April	Mai	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Sums of precipitation (mm)	25.8	10.8	6.2	29.3	44.9	42.5	23.6	95.9	7.9	50.0	41.9	41.8	420.6
Pluviometric qualifier	NM	EDM	EDM	EDM	EDM	EDM	EDM	ERM	EDM	ERM	ERM	ERM	EDY

NM = normal months; EDM= extremely droughty month; ERM = extremely rainy month; EDY= extremely droughty year

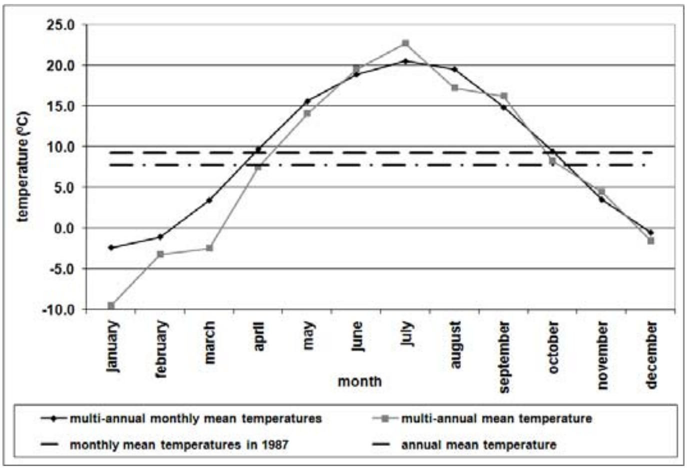

Fig. 10. Monthly average temperatures (°C) in 1987 and the multi-annual average temperatures (°C) in the period 1970–2008 at the Botosani meteorological station

The longest period of total frost in case of the Miletin River was registered in 1987, in the period January 1–February 15, when important negative deviations of the air temperature were registered in Botosani. The month with the lowest average temperature during the period 1970–2008 was January (1987), when a value of -9.5°C was registered. The low temperatures determined a long-term total frost of the upper basin (Fig. 11). The most important years with drying-up phenomena – in the period 1968–2008 – were 1968, 1969, 1986 and 1987. The frequency of such a phenomenon is 9.76%.

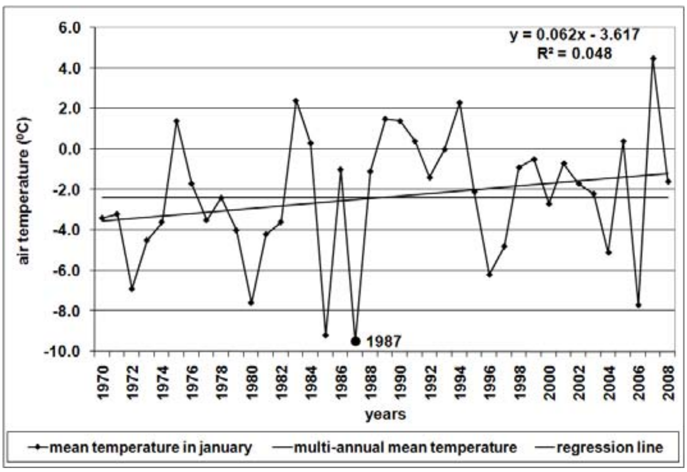

Fig. 11. Multi-annual variation of the air temperature in January in Botosani, during the period 1970–2008

At a monthly level, the highest number of days with a hydrologic drought is January (37), with frequently low temperatures. The very low amount of precipitation and the very high temperatures of the summer months determine the increase in evapotranspiration and reduction in the discharge in September. In this case, the second monthly maximum is formed (24). At the beginning of spring, there is no drying-up phenomenon as the air temperature increases, as well as the total amount of precipitation. At the same time the snow melts (Fig. 12).

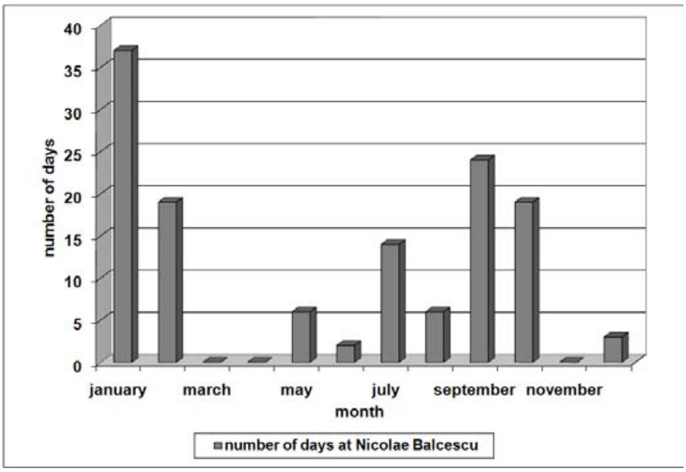

Fig. 12. The monthly number of days with a drying-up phenomenon at the Nicolae Balcescu hydrometric station in the period 1968–2008

Discussions

The Moldavian Plateau and the Miletin catchment, implicitly, have a transitional temperate continental climate. The average amount of precipitation is between 500–600 mm, and evapotranspiration exceeds 650–700 mm. Therefore, the surface discharge can only be maintained if it rains. If it does not, streams only have a ephemeral discharge. The Miletin River is part of the autochthonous streams. Nevertheless, its flow is permanent over more than 50% of its length. This is due to the high underground supply (30–40%), favoured by the existence of a relatively thick permeable substrate. Despite this, most autochthonous rivers, over most of their length, are affected by drying-up: Barlad, Vaslui, Elan, Jijia, Baseu, Miletin, etc. The only hydrographic arteries with important and relatively constant flows are the allochthonous ones, springing from the mountain areas and then crossing the plateau unit: Siret, Prut, Suceava, etc.

The Miletin River has an annual average discharge from upstream to downstream which increases the discharge from 0.472 m^3/s (Nicolae Balcescu station) to 1.258 m^3/s (Sipote station). After leaving Halceni Lake, the multi-annual discharge recorded a lower value (1.088 m^3/s), as part of the lake water is retained and used mainly in agriculture [51].

It is worth mentioning that the autochthonous rivers are also affected by flooding, besides drying-up. These are specific expressions of the climate in Eastern Romania, because of the area-specific heavy rains [11, 12, 15, 52]. The continentality index specific to the streams is extremely high, it includes the Miletin River in the regional normality of the transitional continental climate. The maximum historical discharge is 226 m^3/s at the Nicolae Balcescu station and 204 m^3/s at the Sipote station.

Within the last 20 years (1990–2010), the average amount of precipitation in Eastern Romania has increased. Nevertheless, drought has been present more and more. Unfortunately, the global climatic changes reflect on the uniform distribution of the precipitation, through an increase in the intensity and frequency of heavy rains.

Deforestation and flooding have led to significant mutations in the characteristics of the general climate of the catchment Siret, by increasing the degree of torrentiality and the aridization tendency (Fig. 13). The frequency of precipitation with values over 100 mm/24 hours has risen from 7.7 before 1990 to 35.9 between 1981 and 2000. After data homogenisation (adjusting the values due to the increasing number of hydrometric points), the percentages changed as follows: 7.7 before 1900 to 35.9 between 1981 and 200. After the year 2000, values of 200 mm/24 hours registered frequently especially during the floods of 2004, 2005, 2006, 2008 and 2010 [16, 17, 53].

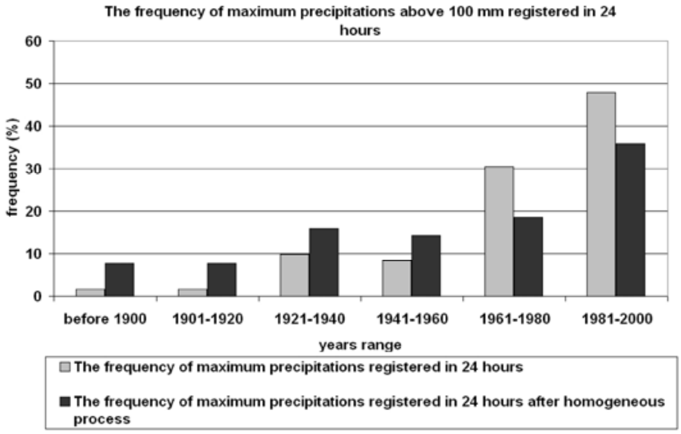

Fig. 13. Frequency of maximum precipitation exceeding 100 mm registered in 24 hours (Moldavian Plateau)

The abovementioned phenomenon can also be supported by the data regarding the Hellmann criterion, showing significant increases during the last few years. Two main causes determine the occurrence of an instantaneous minimum discharge:

1. In the winter, the low values of the flows are due to the mostly solid precipitation and they accumulate at the surface of the soil. At the same time, the very low air temperatures determine the retention in the circuit, under various ice shapes, of a significant amount of water. During total frost, the discharge does not occur at all – also called winter drying-up.

The winters of 1968, 1969, 1986, 1987 and 2005 registered very low temperatures, because of the development of anticyclone formations in Northern Europe or in Siberia (the Eurasian anticyclone) which directed extremely cold air masses toward the Southeast part of the continent. These synoptic phenomena determined the appearance of winter drying-up in the upper course of the Miletin River.

2. In the summer-autumn period, the discharge is reduced because of the small amounts of precipitation that has fallen on a long-term basis, as well as due to the high temperatures favouring evapotranspiration. The low discharge values within the upper basin, on January 28–31 1968, were determined by the formation of a depression couloir crossing Europe from north to south. Extremely cold air masses, coming from the NE of Europe, produced accentuated decreases in the air temperature (below -12˚C), determining the appearance of winter drying-up, and leading to no discharge at all at Nicolae Balcescu.

The periods with positive air temperatures, with minimum minimorum discharges at the stations with natural discharge, registered low values of atmospheric precipitation. The deviations from the monthly and annual multi-annual means are negative. In order to project and exploit the water resources, it is necessary to know the assurance degree of minimum discharges. The high values of the upper flow classes are a consequence of the torrentiality, which determines an accentuated increase in the annual minimum discharges.

The water resources within the Miletin catchment are limited. Because of the friability of the substrate, the Miletin waters are heavily loaded with alluvia in suspension and dragged. This is why only the water within the floodplain phreatic or within the Halceni reservoir can be used, as it ensures cleaning. The high amount of calcium carbonate makes the waters hard or extremely hard. Hydrologic drought, with a low water level on the minor riverbed, makes the phreatic level of the floodplain drop. In this case, the phreatic is affected and the pastures dry out in the middle of the summer.

During the last few years, the hydrometric stations with natural discharge have registered a general increase in the values of minimum discharges, mostly in the period 1991–2008. The cause is the highly accentuated increase in the values of maximum discharges in 1996, 1998 and 2008. Downpours generated by atmospheric fronts crossing the Northeastern part of Romania determine these very high values.

By analysing the multi-annual variation in the maximum discharge in the winter, one can notice a period with low flows since 1968 until 1978 and in the interval 1983–1996 at Nicolae Balcescu. At Sipote and at Halceni-downstream the periods with low values of minimum discharges are 1984–1995 and 2001–2008, respectively. During these periods, the average temperatures of the winters are, generally, lower than the multi-annual mean.

During the spring, there is high variability in minimum discharges. In the summer and autumn there is higher frequency in the periods of drought in the intervals characterised by low minimum flows in most of the cases at Nicolae Balcescu and at Sipote. At Halceni-downstream, due to stream regularisation, the correlations between these hydro-meteorological parameters are very weak. The average squared deviation registers important variations from one season to another and from one hydrometric station to another.

The instability degree of the fluctuation regarding the minimum winter discharge is very high. During frosty winters, the underground discharge reduces significantly because of the very weak supply. The precipitations are only solid, which eliminates infiltration. During milder winters, the snow layer melts and the liquid precipitations determine a rich underground supply. In this case significant minimum flows are registered.

The high values of the standard deviation during the spring are determined by a rich pluvial supply, as well as by snow melting. At the end of warm springs, evapotranspiration is intense and it causes high instability of the discharge variation. The high temperatures during the summer determine an accentuated decrease in the values of the minimum discharge. There is high probability of very low values of the amounts of water carried. At the same time, there is an accentuated stability in the flow variation. The instability degree of the minimum discharge variation during the autumn increases because the annual pluviometric minimum is registered. The variations in the winter and autumn flows at the Halceni-downstream station are attenuated by stream regularisation. At the other stations, there is a normal rhythm – that of the discharge specific to Eastern Romania.

Massive deforestations throughout the entire basin and the intense agrarian use of the slopes determined high soil erosion and a rapid aggradation of the minor riverbed [54-66]. The accentuation of riverbed drying-up, in the upstream sector and on the tributaries, is also due to the dislodgement of the thalweg from the phreatic, because the alluvia is deposed directly on the discharge bed.

Conclusions

Drying-up often affects autochthonous rivers in Eastern Romania. The fact that the underground supply is relatively high (30–50%) means that the large rivers have a permanent character. Drying-up also affects, on an annual basis, the first, second, and third-order main tributaries within the Horton-Strahler order. The downstream sectors, even though they have extremely low minimums ($0.001m^3/s$ and $0.002m^3/s$), are permanent. The water resource within the Miletin catchment, though reduced, has been overexploited by agriculture, domestic use, and pisciculture. The lowest flows and the riverbed drying-up occur at the end of the summer and the beginning of autumn or in the winter. The first period coincides with reduced rainfall, and the second one with the total frost phenomenon (favoured by a reduced flow).

There are only minor anthropic alterations in the basin. The exception is its terminal part, that with the Halceni reservoir, with a complex role: pisciculture, animal drinking, and irrigation. The lower sector, downstream from the Halceni reservoir, is man-controlled; therefore the discharge is not included in the natural course.

The increase in precipitation intensity and in heavy rain frequency leads to an accentuation of the drought phenomenon and of stream drying-up, mostly in case of the autochthonous ones. At the same time, one can notice an alarming increase in the aggradation of minor riverbeds and the dislodgement of the thalweg from the supplying phreatic. This phenomenon, accelerated by human activity, invariably leads to a change in the character of rivers from permanent to intermittent.

The lack of water is even more acute, because in the summer, when there is a need for more water, the Miletin flow is minimal; sometimes it even dries up completely. The Miletin catchment, though important locally, has low water resources, the reason for which is its exploitation has led to an accentuated lowering of the phreatic and to the intensification of the drying-up phenomenon.

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