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THE INFLUENCE OF CLIMATE AND PEDOLOGICAL DROUGHTS ON THE HYDROLOGICAL DROUGHT OF THE SMALL HYDROGRAPHIC BASINS FROM THE NORTHEN PART OF CODRU-MOMA MOUNTAINS, BIHOR COUNTY

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Abstract

The main way to mitigate the effects of pedological droughts and avoid production losses is to supplement the precipitation and to supplement the soil water reserve by administering of some irrigation norms.

The main objective of this paper is to study the connections between the hydrological droughts of small river basins (Finişului Valley, Tărcăiţa Valley and Văratec Valley) from the Beiuş Depression, Crişul Negru river basin and climate droughts and pedological droughts, respectively. The hydrological droughts was monitored with Streamflow Drought Index (SDI) climate droughts with the Standardized Precipitation Index (SPI) and pedological droughts with the standardized Reconnaissance Drought Index (RDIst), using meteorological records from Ştei Meteorological Station, Bihor County, for 19 hydrological years, the period 1991-2010.

The most dry hydrological year, during the 19 years analyzed was, after SPI and RDIst Ştei, 1991-1992 (SPI = -1.29 and RDIst = -1.37), characterized as "moderately dry". The annual hydrological droughts were characterized: on the Finişului Valley "extremely dry" in 1998-1999 (SDI = -2.37); on the Tărcăiţa Valley, 1996-1997 (SDI = -1.59) and Văratec Valley, 2009-2010 (SDI = -1.91) as "severely dry".

The maximum drought duration is six consecutive months for climate drought, 8 consecutive months for pedological drought (soil drought) and 12 consecutive months for hydrologic droughts, respectively.

The hydrological year with climatic and pedological droughts with maximum intensities (1995-1996) presents in the 3 analyzed hydrographic basins: 3 months characterized "near normal" drought on Finişului Valley; 3 months "near normal" drought and 1 month "moderate dry" on Tărcăiţa Valley; 3 months "moderate dry" on Văratec Valley. These occur after climatic and pedological droughts with a delay of 0-3 months.

Because the months from warm season (Apr-Sep), with the exception of April, are characterized as humid, from point of view climatic and pedologic, makes it possible to natural restore of the soil water reserve, during the vegetation season of crops.

Key words: Climate drought, Standardized Precipitation Index (SPI), pedological drought, standardized Reconnaissance Drought Index (RDIst), hydrological drought, Streamflow Drought Index (SDI)

INTRODUCTION

Extreme weather events increasingly attracting more and more the public attention, which notice that there is an increasing probability and ask them what their causes are (Editorial Nature, 2018).

An analysis of the effects of 31 natural hazards from the last century, (1900-2001) using nine criteria has shown that, among the top ten most dangerous, six are climate disasters, among which is included the drought (Bryant, 2005).

The analysis of the works and scientific reports published in Carbon Breaf from the period 2004-2018 highlights that they were over 170, referring to over 190 extreme weather events around the world. It is highlighted that about 2/3 of the extreme meteorological phenomena studied were much more probable or more severe.

Among extreme events due to human-induced climate change stands out: the extreme values of temperature over 43 % of cases, droughts with 18 % and exceeding rains accompanied by flooding in 17 % of cases (Schiermeier, 2018).

It is obvious that climatic disasters linked to extreme temperatures and precipitation, caused by climate change, will become more frequent due to the accumulation of greenhouse gases in the atmosphere.

Drought has many definitions in the literature, but the simplest is that which emphasizes that it is beginning when water supply to a particular economic sector or water reserve in the soil becomes less than the necessary, producing economic losses (Nicholson, 2011).

Depending on the affected environment (atmosphere, soil, water), the economic sectors that suffer (agriculture, industry, tourism, health, etc.) and the specific conditions of the regions, Man et al., 2010 mention several types of drought: atmospheric or climatic (due to lack of rainfall); pedological (high temperatures increase evapotranspiration and reduce the water reserve in the soil); agricultural (reducing the water reserve in the soil causes the reduction or loss of agricultural yields); hydrological (reduction of surface water flows and groundwater flow); ecological (lack of water causes damage to ecosystems); socio-economic (assessed by the economic effects of the water lack).

The large diversity of drought types, their characteristics, their duration, intensity, frequency, magnitude, spatial extent make it very difficult to define the unitary indices needed to characterize the phenomenon. Drought monitoring calls for a very broad category of climatic, pedological, agricultural, ecological, hydrological and socio-economic indicators (Vicente-Serrano et al., 2012).

Because it is calculated on account of precipitation recorded at a given location, a meteorological station, the input data being accessible, over the last decades, the Standardized Precipitation Index (SPI) is used worldwide for the monitoring and forecasting of droughts (McKee et al., 1993).

SPI highlights the precipitation anomalies, surplus or deficit, for different periods of time, using the cumulative frequency of events, normalized and modeled with the help of probability functions, Gamma or Log normal (Tigkas et al., 2013).

Although it presents a complicated calculus method, the use of SPI has been imposed both globally (Costa, 2011; Karavitis et al., 2011; Du et al., 2013) and in Romania (Şerban, 2010; Dragotă et al., 2012; Hălbac-Cotora, 2013; Sabău, Brejea, 2016) due to the existing free computing programs (Sabau, 2014).

Agricultural droughts, the direct consequence of the lack of precipitation, which leads to the reduction of the soil water reserve pedological droughts), can be highlighted by the recorded production losses compared to those obtained under irrigation conditions. For the Crişului Plain conditions, statistical correlated relations between the agricultural yields and the values of some aridity indices (de Martone Index, Donciu Index, Domuţa Hydroheliothermal Index, Palfai Aridity Index) used in Romania, were determined, using the rainfall and irrigation norms, recorded in Oradea (Sabău et al., 2002; Sabău et al., 2015).

The pedological drought was defined by the period in which the soil water reserve decreases in such a way that it produces yield losses of crops, due to water stress. Thus, the number of days in which the soil humidity falls below the minimum moisture content is pedological drought. The number of days in which the soil humidity falls below the wilting coefficient evidence the period of extremely pedological drought (Cenușă, 2016; Domuţa et al., 2016).

Considering that, the soil water reserve recovers through precipitation and irrigation, and the main forms of reduction are surface leakage, evaporation and perspiration (water consumption of crops), the indices used to monitor pedological droughts are based on the balance of water in the soil (Nistor, Brejea, 2017).

In the case of relatively flat land, when water leakage to the surface of the land can be neglected, the simplest form of water balance in soil is the difference between precipitation and different forms of evapotranspiration: potential (PET), of reference (ETo) or real (Čadro et al., 2017).

The modern indices used for monitoring pedological droughts: Palmer Drought Severity Index, PDSI (Wells et al., 2004), Reconnaissance Drought Index, RDI (Tsakiris et al., 2007) Standardized Precipitation Evapotranspiration Index, SPEI (Vicente-Serrano et al., 2012) is calculated similar as SPI, using precipitation P and evapotranspiration ETP.

As noted above, the main possibility of mitigating the effects of pedological droughts and avoiding production losses is to supplement the precipitation in order to complete the water supply of the soil by administering irrigation norms.

The main sources of water for irrigation are the surface and underground waters, which during the same period can be affected by hydrological drought, which is manifested by the decrease of the flows below the water requirements for different uses. Under these circumstances, some restrictions may arise, giving priority the supplying water to the population and only then covering the water demand for irrigation (Chelcea, Adler, 2013).

One of the most popular indices used to monitor and predict surface water sources is the Streamflow Drought Index (SDI), which has the advantage of processing flows (m^3/s) having the same mathematical structure with SPI, and multiple processing possibilities of durations, intensity and frequency of hydrological droughts (Nalbantis, Tsakiris, 2009; Vincente-Serrano et al., 2012).

The investigations carried out in the mountain area of the Crişul Negru river basin, aimed to establish some correlations between SPI, determined using the precipitations from the nearby Stâna de Vale and Ştei Meteorological Station and SDI, respectively, calculated using the flows recorded in the Galbena Valley control section. They showed that there is no link between the SDI Galbena Valley and the SPI Stâna de Vale or Ştei (Sabău, Iovan, 2017).

The main objective of this paper is to study the links between the hydrological droughts of small hydrographic basins (Finisului Valley, Tărcăiţa Valley, Văratec Valley) from Beiuş Depression, Crişul Negru river basin, monitored with the help of SDI and the climatic drought indices, SPI and pedological RDIst, determined using the records at the Meteorological Station of Ştei, Bihor County, for periods of drought with maximum duration and intensity.

MATERIAL AND METHOD

The small river basins Finişului Valley, Ţărcăiţa Valley and Văratec Valley have areas less than 100 km^2 (Table 1), being located in the western part of the Beiuş Depression, in the mountain area of the Crisul Negru Basin.

Table 1

Characteristics of river basins

Hydrographic basin	Surface (S) (km^2)	Hydrographic network length (km)	Average elevation (m)	Average slope (%)	Degree of afforestation (% of S)
Finișului Valley	85.86	112.5	480	3.3	70.76
Tărcăița Valley	52.12	54.56	577	2.9	69.54
Văratec Valley	58.09	62.14	486	2.8	66.35

The main characteristics of the basins were determined using the digital terrain model achieved using the Surfer program (Fig. 1). These are: average elevations of more than 480 m, the length of the hydrographic network over 50 km, the average slope of the watercourse over 2.8 %, the degree of forest over 65 % of the surface.

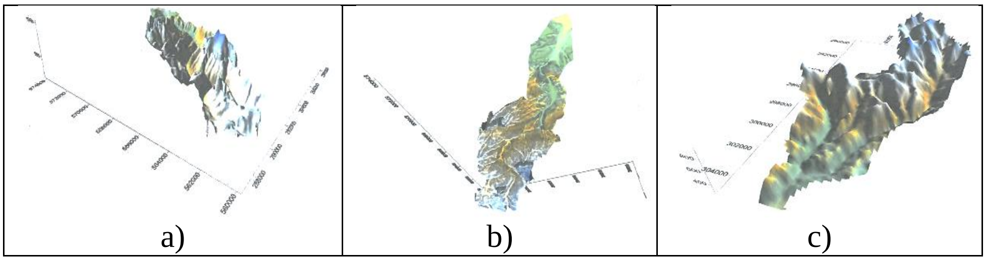


Fig. 1. Digital terrain model for river basins: a) Finișului Valley; b) Tărcăița Valley; c) Văratec Valley (after Iovan, 2012)

The monthly flows from 1991-2010 used to determine the SDI values for the three hydrographic basins analyzed were measured by the National Agency "Apele Române", the Crisuri Waters Department, Oradea, Bihor County (National Agency “Romanian Waters”).

To determine the values of the climatic drought index, SPI and pedological drought index, RDIst, the monthly precipitation and average monthly air temperatures recorded at the Ștei Meteorological Station, during the period 1985-2010 was used. The Meteorological Station is located at 5-20 km southeast from the three analyzed basins (ANM).

Calculation of annual values - 6 months: cold season (Oct-Mar) and warm season (Apr-Sep); - 3 months: autumn (Oct-Dec); winter (Jan-Mar); spring (Apr-Jun) and summer (Jul-Sep) and monthly SPI and RDSst, for the hydrological years 1985-2010 and SDI respectively, for the period 1991-2010, was done with the specialized program DrinC, using for standardization the Gamma probability function (Tigkas et al., 2015).

The PET (potential evapotranspiration) required to determine RDIst values, which is the normalized and standardized ratio between precipitation and evapotranspiration, was calculated using the Thornthwaite, 1948 relationship (PET_{Th}).

For the comparisons between the duration and the intensity of the analyzed drought types, the drought magnitude (DM), which represents the modulus of the sum of the negative values of the monthly indices (SPI, RDIst and SDI) with uninterrupted drought, was used. Thus, the longest droughts, in the number of months and the most intense, were highlighted by their maximum magnitude.

RESULTS AND DISCUSSION

The average multiannual climatic values recorded at Ștei Meteorological Station (1985-2010) are: the sum of precipitation 689.0 mm, the rainy month being July with 81.7 mm and the poorest February with 31.5 mm and the air temperature of 10.0 ° C , with a maximum of 20.3 ˚C in July and a minimum of -0.6 ˚C in January (Table 2).

Table 2

Climate and hydrological characteristics at Meteorological Station Ştei and on the Finişului, Tărcăiţa and Văratec Valley

Month	Meteorological Station Ştei 1985 - 2010			Flow rate (m^3/s) 1991-2010		
	Precipitation (mm)	Temperature (˚C)	ETP_{Th} (mm)	Finişului Valley	Tărcăiţa Valley	Văratec Valley
Oct	43.2	10.2	40.3	0.587	0.390	0.361
Nov	43.4	5.4	16.3	0.604	0.442	0.398
Dec	50.7	0.7	2.9	0.608	0.459	0.403
Ian	37.3	-0.6	1.2	0.597	0.442	0.355
Feb	31.5	0.7	3.8	0.594	0.439	0.359
Mar	45.9	4.2	16.3	0.610	0.463	0.370
Apr	72.4	10.4	50.2	0.625	0.498	0.396
May	73.0	15.2	89.9	0.606	0.447	0.370
Jun	76.6	18.4	114.2	0.571	0.386	0.331
Jul	81.7	20.3	129.9	0.546	0.363	0.298
Aug	67.9	20.0	116.8	0.549	0.342	0.283
Sep	65.4	15.0	71.2	0.557	0.346	0.307
Average	689.0	10.0	653.2	0.588	0.418	0.353

The multiannual average flows (1991-2010) recorded in the control sections of Finişului, Tarcaiţa and Văratec Valleys are 0.557, 0.346 and 0.283 m^3/s respectively, the minimum flows being in the month: July on Finişului Valley (0.546 m^3/s) and August on Tărcăiţa Valley (0.342 m^3/s) and Văratec Valley (0.283 m^3/s).

Hydrological year, 12 months (Oct-Sep)

The analysis of drought periods of one hydrological year using SPI, RDIst and SDI for the period 1991-2010 indicates different years affected by different types of drought (Fig. 2).

The hydrological years with the most intense climatic droughts, designated by the SPI values calculated from the Ştei data are: 1991-92 (SPI = -1.29), 2007-08 (SPI = -1.08) and 2008-09 (SPI = -1.03) all characterized as "moderately dry".

After RDIst the pedological droughts in the analyzed interval are highlighted in the first year, 1991-92 (RDIst = -1.37) and in the years 2001-02 (RDIst = -1.12) and respectively 2007-08 (RDIst = -1.22), years characterized as "moderately dry".

The hydrological drought on the Finnish Valley monitored with SDI indicates that the 1998-99 hydrological year is "extremely dry" (SDI = -2.37) followed by the first year of the analyzed interval, 1991-92, "severely dry" (SDI = -1.80).

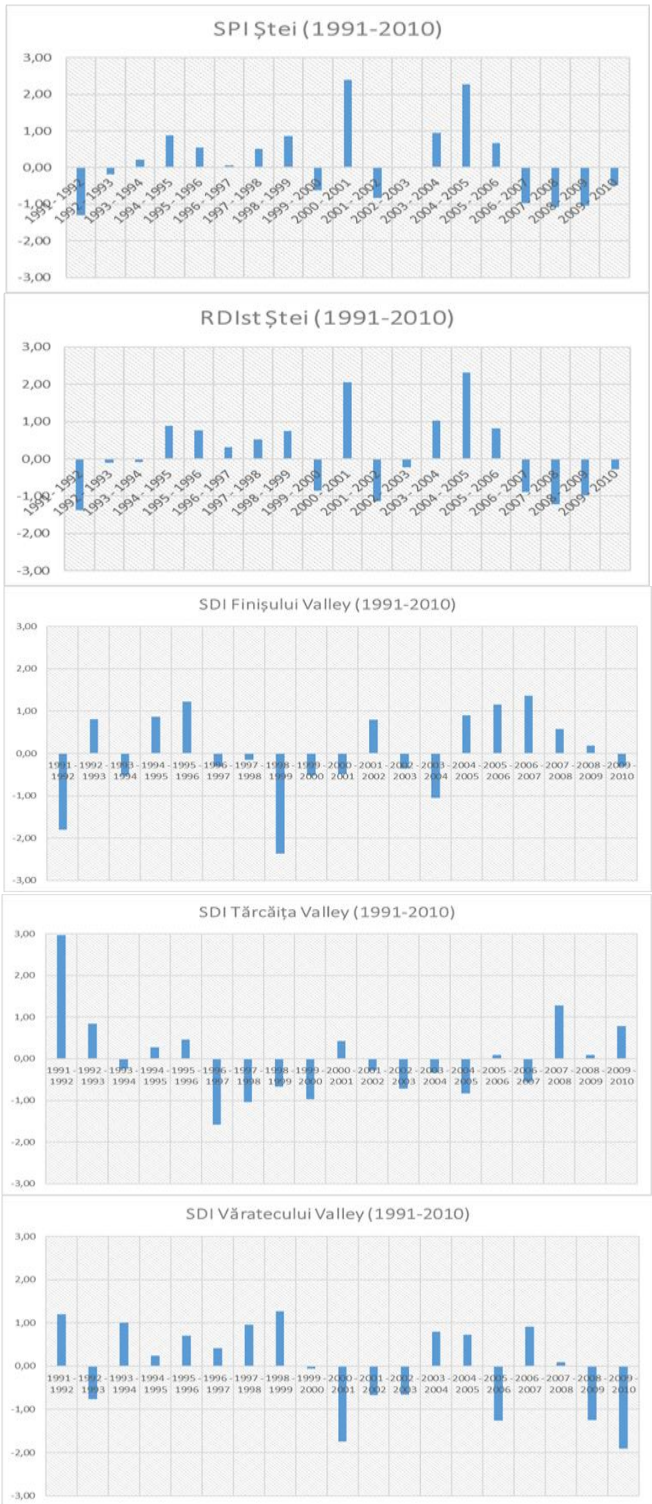


Fig. 2. The SPI and RDIst values in Ştei and SDI values on the Finis, Tarcăiţa and Văratec Valleys for periods of one hydrological year

If the hydrological year 1991-92 coincides with the climatic drought indicated by SPI Ștei and the pedological drought highlighted by RDIst Ștei, the year 1998-99 is the third from a series of four years with hydrological drought.

On the Tărcăiţa Valley, SDI values show the year 1996-97 as "severely dry" (SDI = -1.59), this being the second from a series of 4 years with hydrological drought (1996-2000). It can be noticed that from of climate and pedological point of view, this year is characterized as "near normal wet".

The SDI analysis on Văratec Valley highlights two years characterized "severely dry", 2009-10 (SDI = -1.91) and 2000-01 (SDI = -1.74). The last year of the analyzed time interval is the consequence of the last 4 years with climatic and pedological drought in Ştei.

The study of the possibilities of correlating the SDI values recorded in the hydrographic basins with SPI and RDIst Ştei values for the 19 hydrological years (1991-2010) showed that correlations with statistical significance could not be established.

The frequencies of the different types of droughts of the hydrological years are 15.79% of the analyzed cases for climatic droughts, both for SPI Ştei and for the pedological droughts analyzed with RDIst Ştei. In the case of the hydrological droughts, the dry years have a lower frequency on Tărcăiţa Valley (10.53 %) and are more frequent on Văratec Valley (21.05 %) with the smallest area of the basin and the lowest multiannual average flow (Table 3).

Table 3

Frequency of droughts (%) with durations of 12, 6 and 3 months

Period	Climate drought	Pedological drought	Hydrological drought		
	SPI Ștei	RDIst Ștei	Finișului Valley	Tărcăița Valley	Văratec Valley
Annual	15.79	15.79	15.79	10.53	21.05
Cold season	10.53	5.26	15.79	15.79	15.79
Warm season	10.53	15.79	10.53	15.79	21.05
Average 6 months	10.53	10.53	13.16	15.79	18.42
Autumn	26.32	15.79	10.53	15.79	10.53
Winter	31.58	0.00	15.79	10.53	26.32
Spring	21.05	21.05	10.53	15.79	15.79
Summer	36.84	26.32	10.53	15.79	21.05
Average 3 months	28.95	15.79	11.85	14.78	18.42

Seasons, 6 months, cold season (Oct-Mar) and warm season (Apr-Sep)

The intensity of climate drought, analyzed with SPI Ştei, for the 1991-2010 hydrological years shows that 2 cold seasons were "moderate dry" while in the warm season the season, the year 1999-00 was "extremely dray" and the season from 1991-92 "moderate dray".

The RDIst Ştei values indicate that in the cold season, only in one case, a moderate dry drought was recorded, while in the warm season, there are 3 intervals, of which in 1999-2000 it is "severely dry", the other two being characterized as "moderately dry".

Taking in consideration that the warm season overlaps the vegetation period of crops (Apr-Sep) and in the year 1999-2000 both the climatic and the pedological droughts have been extreme, there is the problem of supplementing the soil water reserve through irrigation.

Hydrologic drought from cold season highlighted by SDI values on the Finișului Valley indicates: an "extremely dry" year in 1998-99, one "severely dry" (1991-92) and one "moderate dry" (2003-2004) In the warm season the hydrological drought occurs only in two years, characterized as "severely dry", 1991-92 and 1998-99. It can be noticed that the climatic and pedological droughts of the 1999-2000 warm season do not coincide with the hydrological drought in Finișului Valley, where the 1998-1999 season was characterized as "moderate dry".

In the Tărcăiţa Valley the hydrological droughts are noted during the cold season, two years being "severely dry" (1997-98 and 2002-03) and one "moderate dry" (1996-97), while the warm season is recorded for 4 years "moderate dry".

The hydrological droughts in Văratecului Valley during the cold season are two years "moderate dry" and the last year is characterized as "extremely dry" (SDI = -2.36). The warm season is three years "moderate dry" and one year, 2000-01, "severely dry" (SDI = -1.78), which is the next after 1999-00, characterized by extreme climatic and pedological droughts.

If the average frequency of climatic and pedological seasonal droughts is the same (10.53 %), hydrological droughts differ, being more frequent on Vǎratec Valley (18.42 %) where they record a frequency of 21.05 % during the warm season. The most frequent seasons, with climatic and pedological droughts characterized as "extremely dry" are present in the warm season, with a frequency of 5.26 % (Fig. 3).

Periods, 3 months, Autumn (Oct-Dec) Winter (Jan-Mar) Spring (Apr-Jun) and Summer (Jul-Sep)

The highest frequency for 3 months is registered by SPI of 28.95 % from the analyzed years, while the RDIst show a frequency of 15.79 %. In the case of hydrological droughts, the highest frequency is highlighted (SDI) in Vǎratec Valley, which has the lowest average flow rate, of 18.42% and the lowest of 11.85 % on the Finișului Valley, characterized by the highest average flow (Table 3).

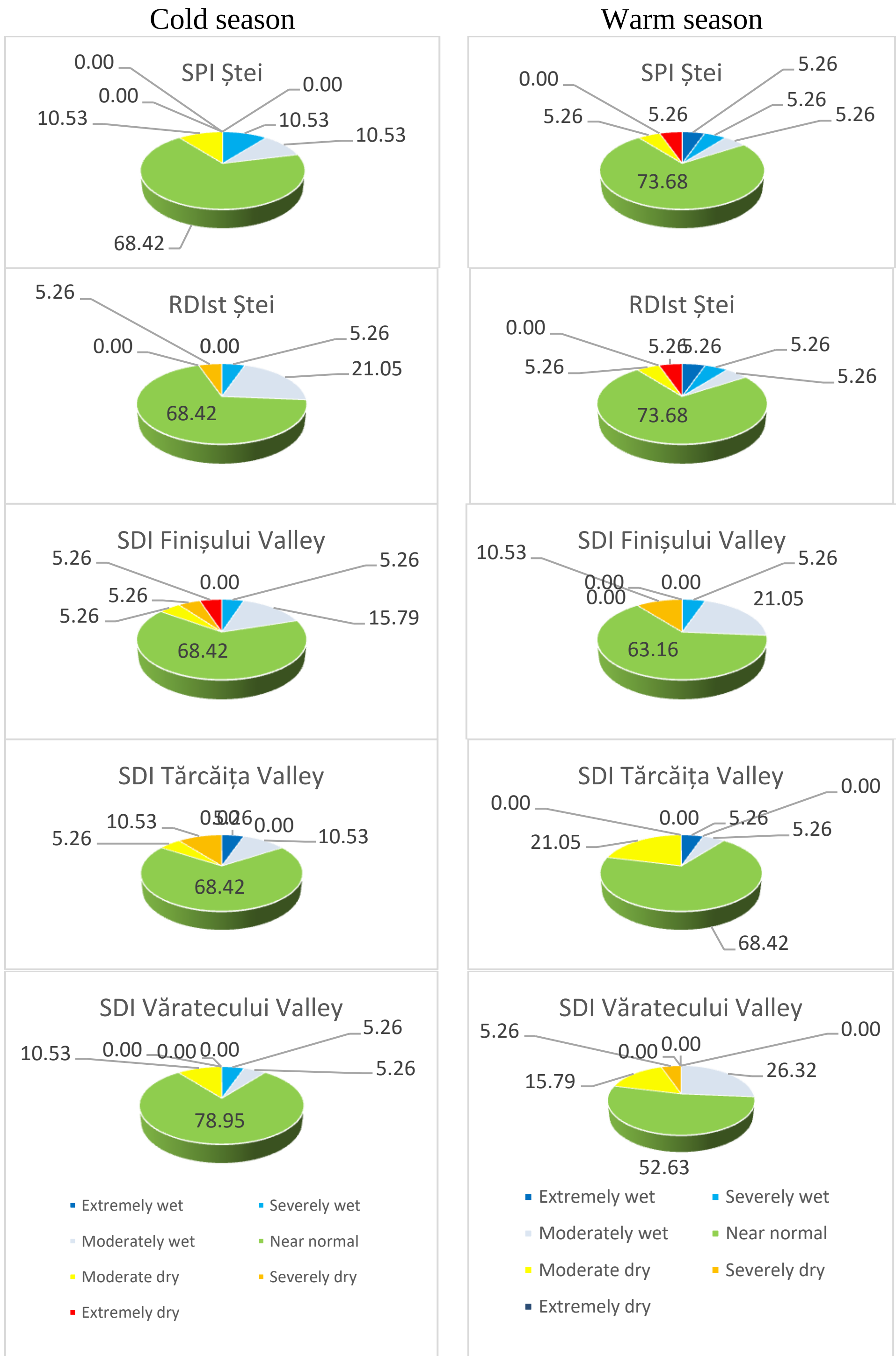


Fig. 3. Characterization of droughts during the cold season and the warm season

The most frequent climatic droughts (36.84 %) and pedological (26.34 %) occur in the summer, while the hydrological ones, mainly in winter, with the exception of the Tărcăiţa Valley, with the minimum winter drought (10.53 %) under the equal frequencies of the other seasons (15.79 %).

The intensity of climatic drought, assessed by SPI and pedological, indicated by RDIst at Ştei for 3 months, shows that they are characterized as "extremely dry" in the spring: SPI = -2.74 and RDIst = -2.69 of year 2001-02 (Fig. 4).

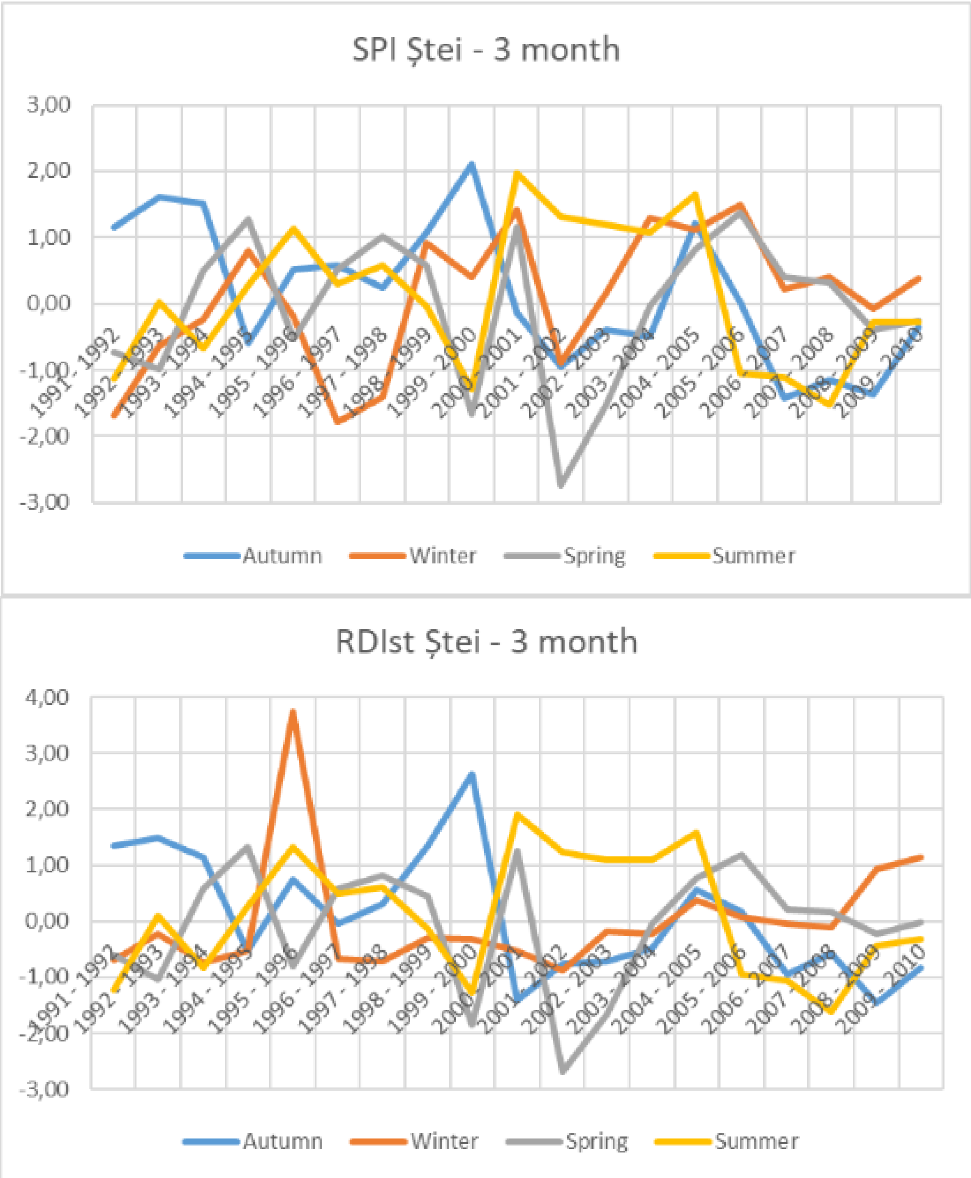


Fig. 4. SPI și RDIst values at Ștei for 3 months (1991-2010)

In the case of SDI assessed droughts, the three-month periods, characterized as “extremely dry” vary from one river basin to another: on the Finnişului Valley, in the spring of 1998-99 (SDI = -2.19); on the Tărcăiţa Valley in the winter of 2002-03 (SDI = -2.15); on Văratec Valley in autumn 2009-10 (SDI = -2.56).

Months, 1 month

The most intense climatic droughts with one-month periods, characterized as “extremely dry”, occur in August 1991-92, (SPI = -3.03) April (SPI = -2.50) and October of the hydrological year 1995-96. Monthly pedological droughts coincide with climatic ones, producing in the same months and the same years.

One-month hydrological droughts, characterized as “extremely dry”, the most intense in small river basins, are produced: Finişului Valley in May of 1999-00, (SDI = -2.36); Tărcăiţa Valley in February 2003-04, (SDI = -2.28) and Văratec Valley, November 2009-10 (SDI = -2.49) (Fig. 5).

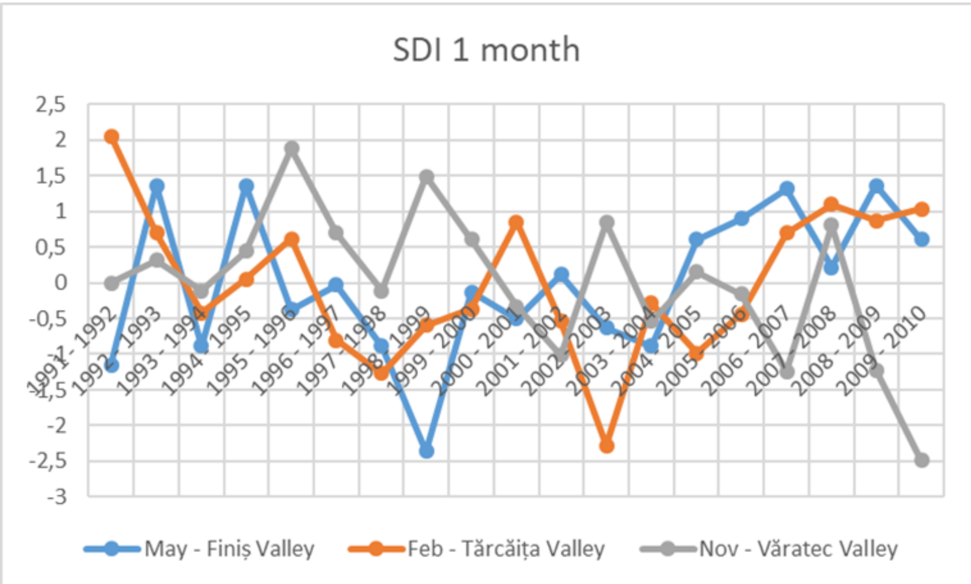


Fig. 5. SDI Values on Finişului Valley in May, on Tărcăița Valley in February and on Văratec Valley in November (1991-2010)

The analysis of the different types of droughts analyzed shows that hydrological droughts with maximum intensity do not occur in the same months with climatic and pedological droughts.

The maximum frequency of one-month climatic droughts is met in the months of May and June, and the pedological drought in February and June. The most frequent hydrological droughts occurred in June (26.32 %) in the hydrographic basins of the Finişului and Văratec Valleys and December on the Tărcăiţa Valley (Table 4).

Table 4

Frequency (%) of monthly droughts (1 month)

Month	Climate droughts	Pedological droughts	Hydrological drought		
	SPI Ștei	RDIst Ștei	Finișului Valley	Tărcăița Valley	Văratec Valley
Oct	10.53	10.53	10.53	21.05	15.79
Nov	15.79	0.00	10.53	21.05	21.05
Dec	21.05	10.53	15.79	26.32	15.79
Ian	15.79	15.79	15.79	15.79	21.05
Feb	21.05	26.32	15.79	10.53	21.05
Mar	21.05	0.00	21.05	15.79	21.05
Apr	10.53	10.53	10.53	15.79	10.53
May	26.32	21.05	10.53	21.05	15.79
Jun	26.32	26.32	26.32	21.05	26.32
Jul	21.05	10.57	15.79	21.05	21.05
Aug	15.79	15.79	15.79	21.05	21.05
Sep	0.00	0.00	15.79	10.53	15.79
Average	17.11	12.29	15.35	18.42	18.86

Droughts Magnitude (DM)

The maximum drought duration in months was identified with DM, considering the consecutive monthly negative values of the drought indices. Thus, the average duration of the climatic droughts in the analyzed period (1991-1992) is 3.1 months and the pedological droughts of 3.5 months. The average duration of hydrological droughts is higher, ranging from 4.8 months on the Văratec Valley and 5.7 months on the Finișului Valley (Table 5).

The average DM of climatic droughts is 2.78 and of the pedological drought 2.94, while in the case of hydrologic drought it is higher, between 4.57 and 4.71, lower on watercourses with lower multiannual average flows.

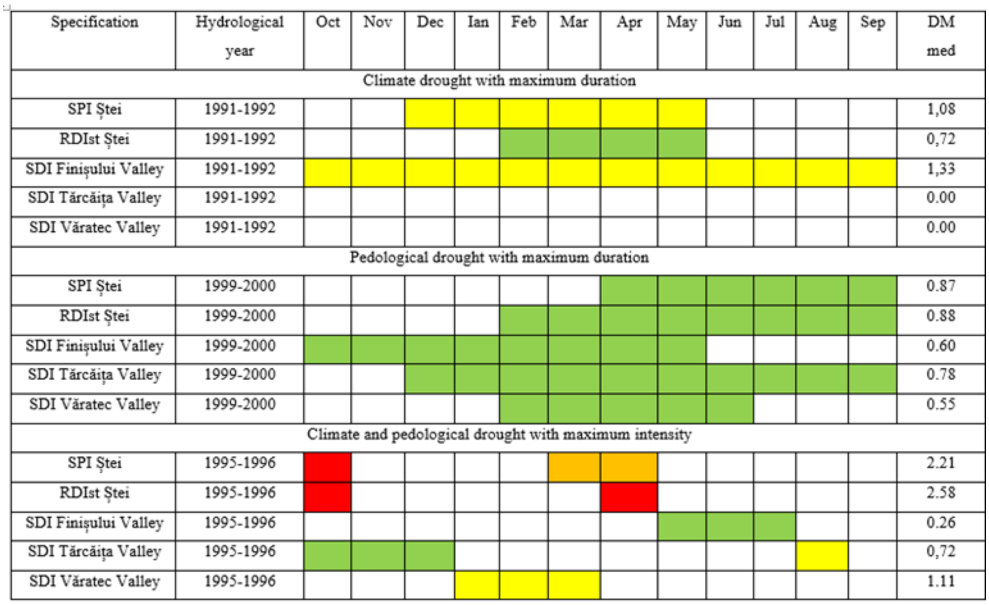
The longest and most intense period of climatic drought in the analyzed period is encountered in the hydrological year 1991-1992, being 6 months, from December to May, with a DM = 6.46, which corresponds to a 4-month with pedological drought, from February to May and DM = 2.86. It can be noticed that, in this year, there are no months with negative values of SDI in Tărcăiţa and Văratec Valleys, while in the Finișului Valley basin, there is all dry year (12 months), the magnitude being DM = 16.0.

Climate Drought (SPI) with the highest duration of rainfall recorded in the hydrological year 1991-92, during the months of Dec-May, characterized after DM_{med} as “moderate dry”. In the same year, at a two months difference, start the pedological drought (RDIst) with a duration of four months, characterized as “near normal” (DM_{med} = 0.72). The hydrological drought occurred in this year, only in the hydrographic basin of the Finișului Valley, on all the hydrological year, being characterized, after DM_{med} = 1.33 as “moderate dry” (Fig. 6).

Table 5

Maximum duration (months) and Droughts Magnitude (DM)

Year	SPI Ștei		RDIst Ștei		SDI Finișului Valley		SDI Tărcăița Valley		SDI Văratecului Valley	
	months	DM	months	DM	months	DM	months	DM	months	DM
1991-92	6	6,46	4	2,86	12	16,00	0	0	0	0
1992-93	3	4,25	2	2,08	3	4,00	2	0,72	8	8,28
1993-94	2	1,05	4	4,23	9	6,11	8	4,45	2	0,23
1994-95	2	1,79	2	1,62	2	1,16	2	1,17	3	1,69
1995-96	2	3,51	1	2,58	3	0,79	3	2,17	3	3,32
1996-97	3	3,36	3	1,84	5	3,89	12	12,03	2	0,88
1997-98	3	3,75	6	5,28	9	5,47	6	7,18	3	0,54
1998-99	2	1,35	2	0,90	12	21,25	7	5,92	0	0
1999-00	6	5,23	8	7,02	8	4,79	10	7,81	5	2,73
2000-01	1	1,00	6	4,93	9	4,35	3	2,33	12	14,57
2001-02	4	5,52	6	6,90	1	0,13	7	5,55	5	3,37
2002-03	4	3,67	4	3,36	10	3,10	7	9,99	8	7,94
2003-04	2	0,99	2	1,44	12	9,50	9	4,96	3	2,21
2004-05	1	0,82	1	0,66	3	1,09	10	7,00	2	0,42
2005-06	2	1,70	3	1,41	0	0	7	4,42	12	10,28
2006-07	4	2,98	4	2,87	0	0	5	5,78	2	1,80
2007-08	4	2,98	4	4,39	3	1,97	1	1,67	4	6,44
2008-09	3	1,78	3	0,99	3	2,19	4	4,39	6	6,94
2009-10	2	0,72	2	0,66	4	3,61	2	0.,89	12	15,14
Sum	56	52,91	67	56,02	108	89,4	105	88,43	92	86,78
Average	3,1	2,78	3,5	2,94	5,7	4,71	5,5	4,65	4,8	4,57



Specification	Hydrological year	Oct	Nov	Dec	Ian	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	DM med
Climate drought with maximum duration														
SPI Ștei	1991-1992													1,08
RDIst Ștei	1991-1992													0,72
SDI Finișului Valley	1991-1992													1,33
SDI Tărcăița Valley	1991-1992													0.00
SDI Vărătec Valley	1991-1992													0.00
Pedological drought with maximum duration														
SPI Ștei	1999-2000													0.87
RDIst Ștei	1999-2000													0.88
SDI Finișului Valley	1999-2000													0.60
SDI Tărcăița Valley	1999-2000													0.78
SDI Vărătec Valley	1999-2000													0.55
Climate and pedological drought with maximum intensity														
SPI Ștei	1995-1996													2.21
RDIst Ștei	1995-1996													2.58
SDI Finișului Valley	1995-1996													0.26
SDI Tărcăița Valley	1995-1996													0,72
SDI Vărătec Valley	1995-1996													1.11

Fig. 6. Durations and intensity (after DMmed) of climatic, pedological (Ștei) and hydrological droughts (Finișului, Tărcăița and Vărătec Valleys)

The pedological drought (RDIst) had the longest duration of 8 months in the February-Sep 1999-00 period, the DMmed value of 0.88 indicating the “near normal” characterization. It can be noted that it started with two months before the six-month climatic drought (Apr-Sep), which has a DMmed = 0.87. In addition, the hydrological droughts on the three watercourses overtake the pedological drought by 4 months on Finișului Valley and with 2 months on Tărcăiţa Valley, being also characterized as “near normal”. Only in Văratec Valley the hydrological drought begins in the same month, but ends 3 months faster than the pedological drought.

Climatic (SPI) and pedological (RDIst) droughts, with maximum intensities (DMmed) occur for short time periods, being signaled in the hydrological year 1995-96. The SPI values, indicate in this year the month Oct, that is “extremely dry” (SPI = -2.21) and Mar and Apr, characterized as “severely dry”.

The influence of climatic and pedological droughts on hydrologic droughts is manifested differently on the analyzed watercourses.

On the Finișului Valley, with the highest average flow rate between the analyzed courses, the first month with climatic and pedological drought (Oct) does not lead to the occurrence of hydrological drought periods, while the droughts from Mar and Apr cause a period of 3 months (DMmed = 0.26) characterized “near normal”.

In the Tărcăiţa Valley basin, the effect is seen in the first 3 months (Oct-Dec) with “near normal” hydrological drought and after 3 months, when after the second climatic and pedological drought series, the hydrological drought in August is “moderate dry”.

Văratecului Valley, closest to Ştei, and with the lowest average flow rate, have a 3-month period (Ian-Mar) with moderate hydrological drought (DMmed = 1.11), at 2 months after the first month with climate and pedological drought and respectively, before with 2 months of the second interval.

CONCLUSIONS

The most dry hydrological year during the 19 years analyzed was, after SPI and RDIst Ştei, 1991-92 (SPI = -1.29 and RDIst = -1.37), characterized as “moderately dry”. The annual hydrological droughts were characterized: “extremely dry” on the Finişului Valley in 1998-99 (SDI = -2.37); on the Tărcăiţa Valley, 1996-97 (SDI = -1.59) and Văratec Valley, 2009-10 (SDI = -1.91) as being “severely dry”.

Extreme climatic and pedological droughts occur during the warm season, overlapping the vegetation period of the main agricultural crops, making it necessary to fill the soil water reserve by applying irrigation. Since the hydrological droughts identified in the warm season, occur in other hydrological years than those with extreme climatic and pedological droughts and are only “severely dry” and “moderate dry”, they can provide the water needed for irrigation.

The most frequent droughts with 3 months duration, climatic (36.84 %) and pedological (26.34 %) occur in the summer, while the hydrological ones, mostly in winter, with the exception of the Tărcăiţa Valley, where the frequency of winter drought is minimum (10.53 %) under the conditions of equal frequencies of other seasons (15.79 %).

The most intense climatic and pedological monthly droughts, characterized as “extremely dry”, occur during the same months: Aug 1991-92, Apr and Oct of the year 1995-96, but extreme monthly hydrologic droughts occur on different hydrological years and different months, on the three natural watercourses.

The maximum duration of droughts: is 6 consecutive months in the case of climate droughts, 8 consecutive months for pedological drought and 12 consecutive months, respectively, for hydrological droughts.

The hydrological year 1995-96 characterized by climatic (DMmed = 2.21) and pedological (DMmed = 2.58) droughts with maximum intensities, presents in the analyzed hydrographic basins: 3-month droughts, characterized as “near normal”, on the Finișului Valley (DMmed = 0.26); 3 months “near normal” and 1 month “moderate dry” (DMmed = 0.72) on Tărcăiţa valley; 3 months “moderate dry” (DMmed = 1.11) on Văratec Valley. They start after the climatic and pedological droughts with 0-3 months.

The fact that, in the warm season of year 1995-96, after April, the months are wet (after SPI and RDIst) and hydrological droughts are “near normal” or “moderate dry”, it makes it possible to restore the water reserve of soil by administering of irrigation.

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