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ASSESSMENT REGARDING THE EVOLUTION IN TIME (1980-2014) OF DROUGHT ON THE BASIS OF SEVERAL COMPUTATION INDEXES CASE STUDY: STRASENI COUNTY, MOLDOVA

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Abstract: Drought is a major issue that humanity confronts with and due to its vast ramifications it is also most difficult to solve. Being a natural phenomenon it has various manifestations which scolars have categorized into meteorological, agricultural, hydrological, environmental and others, in order to better define and understand this phenomenon. Several drought indices have been proposed by different scholars for measuring it which take rainfall, temperature, sun shining and other features into account. This of course, led to a variety of interpretations which makes the phenomenon even more difficult to size up and quantify its devastating effects on a long term scale. The seven indexes this paper makes use of, for calculating drought are: N. Topor index, De Martonne index, Domuta hydroheliothermal index, Selianinov hydrothermal index, Palfai drought index and Lang rain index. In this paper, the case study conducted for Straseni County in the 1980-2014 period reveals alternating wet and dry periods which do not pose any threat of aridisation or desertification in the near future. However, a constant monitoring is imposed in order for these phenomena not to occur, made by the authorized law enforcement together with specialists from various fields.

Keywords: drought indices, rainfall, temperature, sun shining, climate changes

1. INTRODUCTION

The drought phenomenon and its two recurrent phenomena, aridity and desertification represent according to the United Nations Organization the second largest problem with global implications that humankind confronts with, after environmental pollution. Due to the negative effects that are induced by it, drought is part of the dangerous phenomena category.

Published literature made use of various terms (extreme phenomena, dangerous phenomena, hazard, risk, calamity, disaster, catastrophe, cataclysm, etc) to size up and quantify the amplitude of some natural or special anthropogenic events and material losses produced [1].

According to the environment or the hydrological cycle stages in which it exercises its effects and also according to the phenomenon`s duration and magnitude, drought can be observed from multiple perspectives:

-meteorological drought

-agricultural or pedological drought

-hydrological drought.

As a direct consequence of drought types` manifestation, with its afferent negative effects overlaid with a region`s social and economic activities, a new type of drought can be defined, that is, the socio-economic drought.

The numerous definitions of the drought phenomenon can be split into two large classes, according to the phenomenon`s approach mode and their utility:

-conceptual definitions of the drought phenomenon;

-operational definitions of the drought phenomenon;

As a direct result of the increase in drought frequency, severity and duration, and the narrowing of the gap between water supply and demand, there has been a remarkable increase in the impacts associated with drought in both developing and developed countries [13].

The drought phenomenon manifests itself throughout the entire hydrological cycle, in essence, drought can be regarded as a consequence of temporary abnormal deterioration of the normal hydrologic cycle [6].

Drought phenomena are specific to all climates, because of this there is an extremely high diversity concerning the characteristics of such phenomena, especially influenced by local conditions of the area on which the phenomenon manifests itself. For instance, absence of rainfall can occur in all the months of a year [10].

General conditions of the drought phenomena are:

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-occurrence frequency
-intensity
-temporal delimitation
-the area on which it manifests itself
Among these general characteristics, to every drought phenomenon aspect, be it meteorological, pedological, hydrological or socio-economical, a series of features are attributed specific to the environment in which it manifests itself.

As stated previously in this paper, the drought phenomenon cannot be dealt just as a physical phenomenon, most of the times drought is increasingly seen through the negative effects that are produced on the ecosystems and humanities` social-economic activities [3].

To better summarize the negative impact of drought phenomena, it shall be grouped on the predominantly and direct affected areas. It needs to be mentioned that these negative effects are most of the times interdependent and with a direct impact in other fields.

The negative effect of drought phenomena on ecosystems refers mainly to unwanted effects on environmental factors in general and on biodiversity in particular. The plant kingdom is much more vulnerable to drought`s negative effects in comparison to the animal kingdom especially because of its reduced mobility. "The lack of rainfall for a sufficiently long period of time, accompanied by high air temperatures cause high moisture deficit in the air, that is characteristic for atmospheric or climatic drought" [9]. The best way for analysing drought is through "meteorological data for which there is long-term information" [11].

Taking into consideration Republic of Moldova`s position on the globe, half the distance between the pole and the equator, being crossed by the 45° parallel, as well as its geographical position on the continent at approximately 2.000 km from the Atlantic ocean, 1.000 km from the Baltic sea, 400 km from the Adriatic sea and riparian with the Black sea, the air masses directed towards Moldova in different synoptic contexts, evolve in a wide range heading towards the tropical ones. The instability relation between main baric centers lead to recordings of both important periods with an anticyclone regime specific to drought phenomenon, and rapid transitions from the anticyclone regime to cyclone circulation and the opposite with extreme phenomena like storms, hail or tornadoes [2].

From the point of view of aridity index, which is on average 0,20, Moldova`s territory fits on the semi-arid areas, dry-sub humid, and humid.

2. MATERIAL AND METHOD

Calculations on the climatic indexes: Hellman criterion, N. Topor index, De Martonne index, Domuta hydroheliothermal index, Selianinov hydrothermal index, Palfai drought index, Lang rain index.

Hellman criterion introduces the dry period notion, which is considered the interval of at least 10 consecutive days in the months April-September and at least 14 consecutive days in the months October-March, in which no measurable precipitations had fallen (< 0,1 mm);

The pluviometric characterization of a month is made by comparing rainfall quantities in the respective month with the multiannual average, being split in 9 categories:
-excessively rainy months (ERM): in which precipitation quantities exceed with over 50% the multiannual average;
-very rainy months (VRM): in which precipitation quantities exceeds with 30-50% the multiannual average;
-rainy months (RM): in which precipitation quantity exceeds with 20-30% the multiannual average;
-less rainy months (LRM): in which precipitation quantity exceeds with 10-20% the multiannual average;
-normal months (NM): in which precipitation quantity vary with ± 10% of the multiannual average;
-less drought months (LDM): in which precipitation quantity is 10-20% reduced as compared to multiannual average;
-drought months (DM): in which precipitation quantity is 20-30% reduced as compared to multiannual average;
-very drought months (VDM): in which precipitation quantity is 30-50% reduced as compared to multiannual average;
-excessively drought months (EDM): in which precipitation quantity is over 50% reduced as compared to multiannual average;

N. Topor index: introduces for the pluviometric characterization of a year from a given interval, the pluviometric index I_a with the expression [12]:

$$I_a = \frac{N+2P}{N+2S} \quad (1)$$

Where, N= number of normal months (NM + LRM + LDM)

P= number of rainy months (LM + VRM + ERM)

S= number of drought months (EDM + VDM + DM)

Pluviometric year mark is given as such:
-for $I_a < 0,33$ an exceptional drought year (ExcepDY)
-for $0,33 < I_a < 0,41$ an excessively drought year (ExcesDY)
-for $0,41 < I_a < 0,70$ a very drought year (VDY)
-for $0,71 < I_a < 0,84$ a drought year (DY)
-for $0,85 < I_a < 1,0$ a less drought year (LDY)
-for $1,01 < I_a < 1,17$ a normal year (NY)
-for $I_a > 1,18$ a less rainy year (LRY)

De Martonne index: can be calculated for diferent periods according to precipitation and temperatures:
-for the annual period:

$$I = \frac{P}{T+10} \quad (2)$$

-for the vegetation period:

$$I = \frac{2P}{T+10} \quad (3)$$

-for the annual period:

$$I = \frac{12P}{T+10} \quad (4)$$

Where P – sum of precipitation from the analyzed period (mm);

T – average air temperature on the analyzed period (°C);

Drought assessment is made:

I < 10 – very arid period

I = 10-20 – arid period

I = 20-30 – semiarid period

I > 30 – humid

Domuta hydroheliothermic index: takes into consideration the shining duration of the sun, calculating with the relation:

$$I_{hst} = \frac{100P + 12{,}9A}{\sum t + D.s.s.}; \quad (5)$$

In which: P – precipitation and watering from the considered period (mm);

Σt – sum of biological active temperatures (°C);

D.s.s – sun shining duration (hours);

A – air humidity (%)

Using the hydroheliothermic index the following interpretations can be made:

<3,0 – excessively drought; (ED)

3,1 – 5,0 – very drought; (VD)

5,1 - 7,0 – drought; (D)

7,1 – 9,0 – middle drought; (MD)

9,1 – 12,0 – middle humid; (MH)

12,1 – 15,0 – humid I; (H1)

15,1 – 18,0 – humid II; (H2)

18,1 – 25,0 – humid III; (H3)

> 25,0 – excessively humid; (EH)

Selianinov hydrothermal index is determined monthly with the relation:

$$k = \frac{P}{(t^{'}/10)} \quad (6)$$

In which: P – total precipitation from the considered month

t` - average monthly temperature multiplied with the number of days in the month;

Assessment of drought intensity is made:

k < 1 – aridity conditions

1 < k < 1,7 – normal conditions (of equilibrium of hydric balance)

k > 1,7 – hydric excess conditions.

Palfai (PAI) drought index: the basis (uncorrected) value of this PAI_0 index can be calculated for the April-August period with the relation:

$$PAI_0 = \frac{t_{IV-VIII}}{P_{X-VIII}} 100; \; (^{\circ}C/100\,mm) \quad (7)$$

Where: $t_{IV-VIII}$ – the average of monthly averages of air temperatures from April till August (°C);

Px –VIII –sum of monthly precipitations starting from October until August (mm);

A more precise index value is obtained through correcting the base value with three factors:

-for excessive temperatures (t > 30°C):

$$K_t = \sqrt[6]{\frac{n+1}{\bar{n}+1}} \quad (8)$$

Where, n – number of heat days (t > 30°C) in June-August period;

$\bar{n}$ – multiannual average of n;

-for rainfall $$K_P = \sqrt[4]{\frac{\tau_{max}}{\bar{\tau}_{max}}} \quad (9)$$

Where, τ_{max} – duration of the longest period without precipitation (or with a sum of precipitation in consecutive days under 5-6 mm) between 15 June and 15 August;

$\bar{\tau}_{max}$ – multiannual average of τ_{max};

-for groundwater:

$$K_{gw} = \sqrt{\frac{H}{\bar{H}}} \quad (10)$$

Where H – average deepness of groundwater in November – August;

$\bar{H}$ – the average multiannual value for H;

This last correction factor is used for areas from riverside areas [8].

Therefore, the corrected value for the Palfai index is:

PAI = 6-8 – moderate drought; (ModD)

PAI = 8-10 – medium drought; (MedD)

PAI = 10-12 – strong drought; (SD)

PAI > 12 – extreme drought; (ED)

Lang rain index:

$$L = \frac{P}{T} \quad (11)$$

P – total monthly precipitation

T – monthly average temperature

3. RESULTS AND DISCUSSIONS

From over 20 indexes for drought evaluation calculus known in the specialized technical literature, 7 were used for Straseni County for processing climatic data (rainfall and temperatures) on a period of 35 years (1980-2014).

The study case was conducted for Straseni County for the period 1980-2014. The entry data for the study is rainfall and monthly average temperatures from the period 1980-2014 presented in Figures 1 and 2.

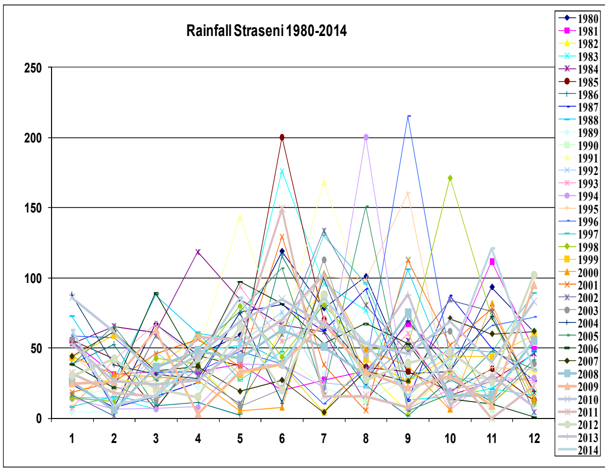

Figure 1. Monthly average rainfall

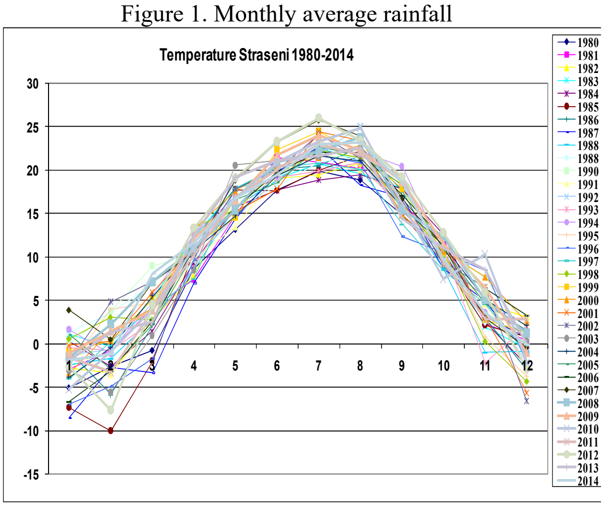

Figure 2. Monthly average temperatures

After processing the data drought indexes according to the criteria presented in paragraph 2 were obtained. They are presented in Figures 3 through 9.

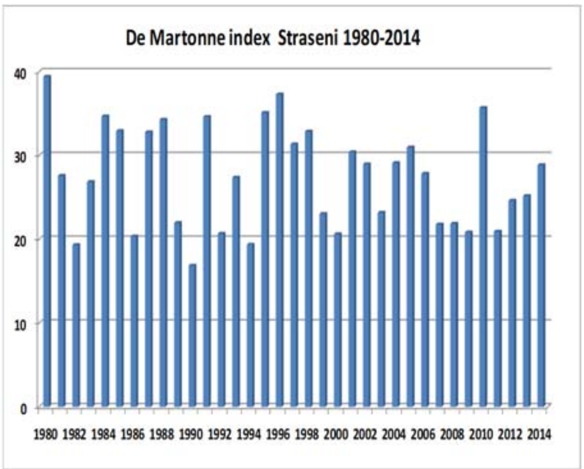

Figure 3. De Martonne drought index

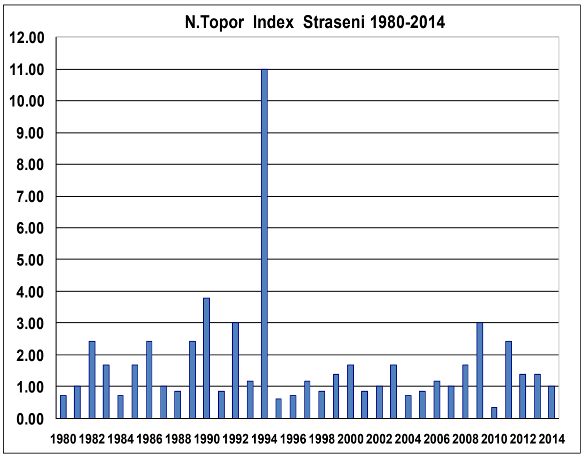

Figure 4. Pluviometric N.Topor index

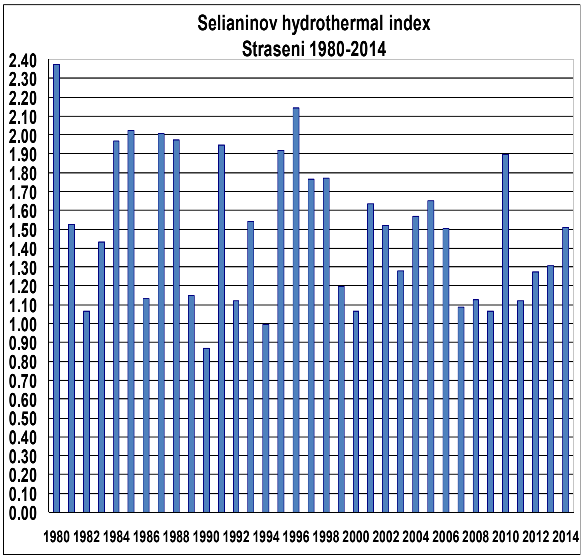

Figure 5. Selianinov hidrothermic index

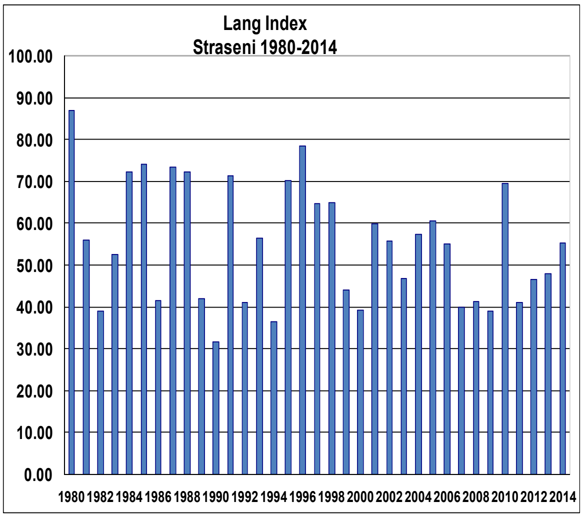

Figure 6. Pluviometric Lang index

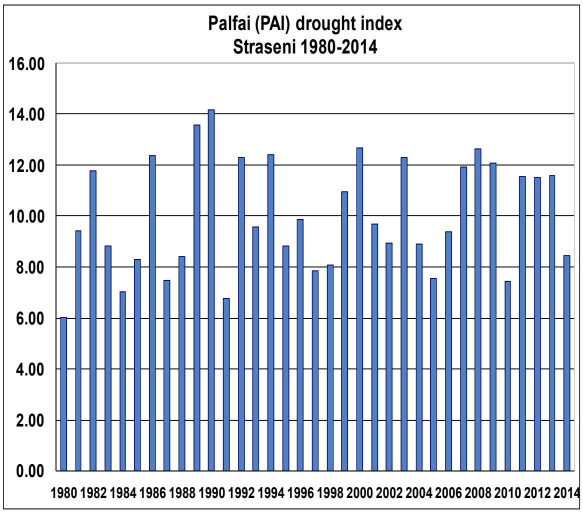

Figure 7. Palfai drought index

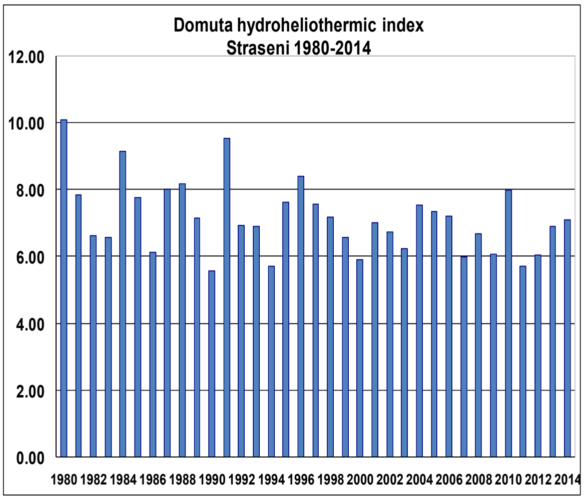

Figure 8. Domuta hydroheliothermic index

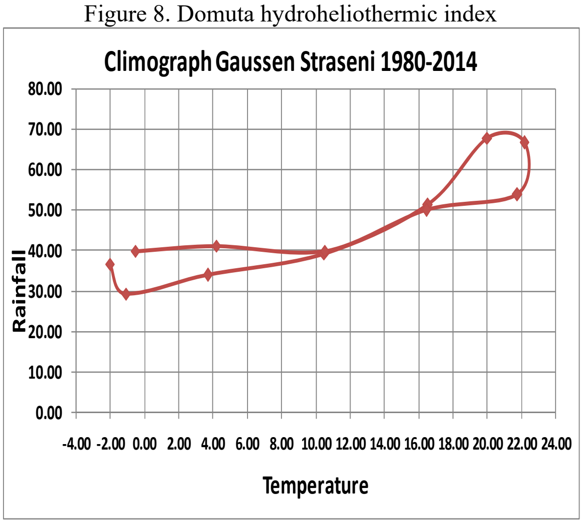

Figure 9. Gaussen climograph

The results gathered from the drought index calculus after the criteria presented in paragraph 2 are presented in Figure 10.

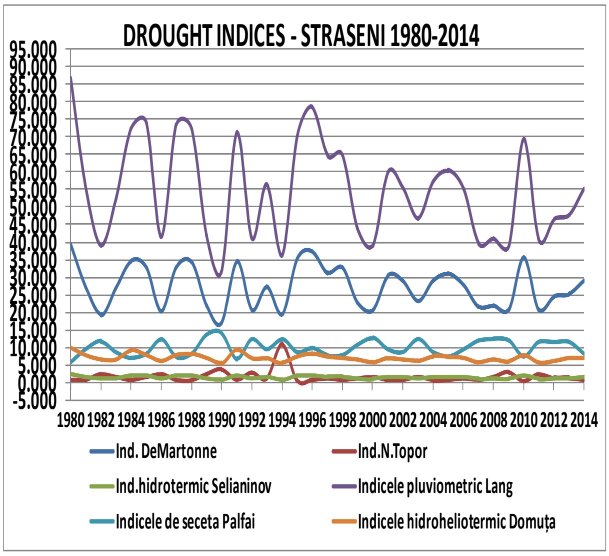

Figure 10. Comparison between calculus methods for drought indexes

4. CONCLUSIONS

The ability to manage climate risk is fundamental to disaster prevention and preparedness [5]. The drought phenomenon represents, according to United Nation Organization the second largest problem of global implications which mankind confronts with, after environmental pollution. Due to the negative effects it has, drought is part of the dangerous phenomenon.

Climatic data from the last century reveal progressive atmospheric warmth and a reduction of rainfall quantities as well as strong land degradation [4].

The proceedings program for establishing a National Strategy for reducing drought effects on short, medium and long term is made of the following principles:

a) Protection and conservation of existent water resources and performing of new water accumulations
b) Protection and conservation of soil resources
c) Protection and conservation of ecosystems
d) Durable development of agriculture and silviculture
e) Reconstruction of damaged areas as effects of drought
f) Public involvement in proceedings implementation for the reduction of drought effects

A national commission regarding this issue has already been made which consists of the Minister of the Environment -the commission`s president, three State secretaries which act as vice presidents, members of other ministries, academies, boards, institutes, agencies and universities [7].

Through data processing by the presented methods drought maps for Straseni can result. A wet period has been recorded in the studied years resulted from calculations with all the methods.

At the moment, in the analyzed area there is not a strong drought, but the phenomenon must be studied in order not to reach aridisation and respectively desertification in the near future.

The analysis of monthly average rainfall evolution chart on a period of 35 years (1980-2014) presented in figure 1, shows that the maximum value of annual average rainfall sum from this period was in the year 2010 at 734 mm, the minimum value in the year 1990 at 360,1 mm, and the average multiannual value for the whole period was 549,1 mm.

Analysis of monthly average temperature evolution chart on a 35 years period presented in Figure 2 shows that the maximum value of annual average temperature sum from this period was in the year 2009 equal with 136,9 °C, the minimum value in the year 1985 is 96 °C and the average multiannual for the whole period was 122,27 °C. Values of calculated indexes are presented in charts 3,4,5,6,7,8,9.

Correlations and or comparisons between calculated indexes values are presented in Figure 10 and Table 1.

Table 1. Correlations between calculated indexes

No.	Year	DeMartonne		Topor		Selianinov		Lang		Palfai		Domuța	
		I	Type	Ia	Type	k	Type	L	Type	PAI	Type	Ihst	Type
1	1980	39.415	H	0.714	DY	2.374	HEC	86.90	HC	6.01	ModD	10.09	MH
2	1981	27.584	SP	1.000	LRY	1.529	NC	55.95	SC	9.43	MedD	7.85	MD
3	1982	19.329	AP	2.429	LRY	1.068	NC	39.09	MC	11.77	SD	6.62	D
4	1983	26.845	SP	1.667	LRY	1.435	NC	52.51	SC	8.83	MedD	6.56	D
5	1984	34.681	H	0.714	DY	1.972	HEC	72.17	HC	7.02	ModD	9.15	MH
6	1985	32.928	H	1.667	LRY	2.024	HEC	74.09	HC	8.30	MedD	7.76	MD
7	1986	20.357	SP	2.429	LRY	1.134	NC	41.51	SC	12.38	ED	6.14	D
8	1987	32.786	H	1.000	LRY	2.005	HEC	73.39	HC	7.49	ModD	8.01	MD
9	1988	34.292	H	0.846	LDY	1.975	HEC	72.29	HC	8.42	MedD	8.18	MD
10	1989	21.955	SP	2.429	LRY	1.149	NC	42.04	SC	13.58	ED	7.16	MD
11	1990	16.873	AP	3.800	LRY	0.867	AC	31.75	MC	14.17	ED	5.58	D
12	1991	34.621	H	0.846	LDY	1.949	HEC	71.32	HC	6.77	ModD	9.52	MH
13	1992	20.679	SP	3.000	LRY	1.124	NC	41.12	SC	12.31	ED	6.94	D
14	1993	27.385	SP	1.182	LRY	1.544	NC	56.49	SC	9.59	MedD	6.91	D
15	1994	19.380	AP	11.000	LRY	0.996	AC	36.47	MC	12.41	ED	5.71	D
16	1995	35.121	H	0.600	VDY	1.918	HEC	70.18	HC	8.82	MedD	7.63	MD
17	1996	37.302	H	0.714	DY	2.145	HEC	78.52	HC	9.88	MedD	8.38	MD
18	1997	31.351	H	1.182	LRY	1.768	HEC	64.70	SC	7.86	ModD	7.56	MD
19	1998	32.869	H	0.846	LDY	1.774	HEC	64.94	SC	8.06	MedD	7.18	MD
20	1999	23.039	SP	1.400	LRY	1.200	NC	43.94	SC	10.96	SD	6.57	D
21	2000	20.629	SP	1.667	LRY	1.069	NC	39.13	MC	12.68	ED	5.91	D
22	2001	30.401	H	0.846	LDY	1.636	NC	59.89	SC	9.67	MedD	7.00	MD
23	2002	28.980	SP	1.000	LRY	1.522	NC	55.71	SC	8.92	MedD	6.73	D
24	2003	23.192	SP	1.667	LRY	1.280	NC	46.86	SC	12.28	ED	6.23	D
25	2004	29.118	SP	0.714	DY	1.568	NC	57.39	SC	8.90	MedD	7.54	MD
26	2005	30.974	H	0.846	LDY	1.653	NC	60.50	SC	7.56	ModD	7.35	MD
27	2006	27.830	SP	1.182	LRY	1.505	NC	55.09	SC	9.39	MedD	7.20	MD
28	2007	21.777	SP	1.000	LRY	1.089	NC	39.86	MC	11.92	SD	5.99	D
29	2008	21.869	SP	1.667	LRY	1.126	NC	41.21	SC	12.62	ED	6.68	D
30	2009	20.833	SP	3.000	LRY	1.068	NC	39.09	MC	12.06	ED	6.08	D
31	2010	35.703	H	0.333	Exces.DY	1.899	HEC	69.52	SC	7.45	ModD	7.98	MD
32	2011	20.929	SP	2.429	LRY	1.119	NC	40.96	SC	11.56	SD	5.70	D
33	2012	24.623	SP	1.400	LRY	1.273	NC	46.61	SC	11.50	SD	6.04	D
34	2013	25.186	SP	1.400	LRY	1.309	NC	47.91	SC	11.59	SD	6.91	D
35	2014	28.876	SP	1.000	LRY	1.512	NC	55.33	SC	8.46	MedD	7.08	MD

From the 35 studied years the cumulated statistics resulted regarding drought indexes assessment corresponding to each calculation method, presented in table 2. However, drought indexes calculated with diverse methods, through interpretation converge in general to the same drought assessment.

Table 2. Drought indexes

DeMartone			
VAP	AP	SP	H
0	3	19	13

Topor						
ExcpDY	ExcsDY	VDY	DY	LDY	NY	LRY
0	1	1	4	5	0	24

Selianinov		
AC	NC	HEC
2	22	11

Lang			
AC	MC	SC	HC
0	6	21	8

Palfai			
7	13	6	9
ModD	MedD	SD	ED

Domuta								
ED	VD	D	MD	MH	H1	H2	H3	EH
0	0	17	15	3	0	0	0	0

Abbreviations list:

De Martonne index
very arid period (VAP)
arid period (AP)
semiarid period (SP)
humid (H)
Topor pluviometric index
an exceptional drought year (ExcepDY)
an excessively drought year (ExcesDY)
a very drought year (VDY)
a drought year (DY)
a less drought year (LDY)
a normal year (NY)
a less rainy year (LRY)
Selianinov hidrothermic index
aridity conditions (AC)
normal condition (equilibrium of hydric balance) (NC)
hydric excess conditions (HEC)
Lang pluviometric index
Arid climate (AC)
Mediteranean climate (MC)
Semiarid climate (SC)
Humid climate (HC)
Palfai drought index
moderate drought (ModD)
medium drought (MedD)
strong drought (SD)
extreme drought (ED)
Domuța hidroheliothermic index
excessively drought (ED)
very drought (VD)
drought (D)
middle drought (MD)
middle humid (MH)
humid I (H1)
humid II (H2)
humid III (H3)
excessively humid (EH)

REFERENCES

[1] Armas A., Man T.E., Ienciu A. A., Cuzic O.S., Beilicci R. F. (2016). Drought As Climate Risk in Timis County, Romania. 16th International Multidisciplinary Scientific GeoConference, www.sgem.org, SGEM 2016 Conference Proceedings, ISBN 978-619-7105-61-2 / ISSN 1314-2704, June 28 - July 6, 2016, Book 3 Vol. 1, DOI: 10.5593/SGEM2016/B31/ S12.033. pp 2.

[2] Cismaru C., Bartha I., Gabor V., Scripcaru D., - 2004 - Gestiunea secetelor, Ed. Performantica Iasi, ISBN 973-730-032-7

[3] Cismaru C., Gabor V. – 2004 - Irigatii: amenajari, reabilitari si modernizari, Ed.Politehnium, Iaşi.

[4] Codreanu, M.M. (ed). (2002). Semicentenar ISPIF. Sesiune stiintifica internationala aniversara. Bucuresti, pp 109-120.

[5]Hellmuth M.E., Mason S.J., Vaughan C., van Aalst M.K. and Choularton R. (eds) (2011). A Better Climate for Disaster Risk Management. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.

[6] Man T. E., Sabău N. C., Cîmpan G., Bodog M., (2007) Hidroamelioraţii, Vol II, Editura Aprilia Print, Timisoara, (Red. 2008).

[7]Ordinul nr. 503/2005 privind componența Comitetului Național pentru Combaterea Secetei, a Degradării Terenurilor şi a Deşertificării. http://lege5.ro/Gratuit/g4zdmmjq/ordinul-nr-503-2005-privind-componenta-comitetului-national-pentru-combaterea-secetei-a-degradarii-terenurilor-si-a-desertificarii

[8] Palfai I., et all. (1995) "Some methodological questions of the European drought sensivity map", Drought in the Carpathians Region, Budapest – Alsogod.

[9] Sabău N C, Man T E, Armaş A, Balaj C, Giru M (2015) "Characterization of agricultural droughts using standardized precipitation index (SPI) and Bhalme-Mooley Drought Index (BDMI)" June 2015, Vol.14, No. 6, pp. 1441-1454, ISSN: 1582-9596, eISSN: 1843-3707 of the Enviromental Engineering And Management Journal.

[10] Stanciu, E. (2005). Precipitatiile atmosferice din Banat. Editura Eurostampa. Timisoara p 142-161.

[11] Şmuleac L., Oncia S., Ienciu A. (2012). The study of potential evapotranspiration in the Banat plain in 1897- 2011, Research Journal of Agricultural Science, ISSN 2066-1843, vol.44 (3), 288-292 Timisoara.

[12] Topor, A. (1964) „Ani ploioşi şi ani secetoşi în România", Bucureşti. United Nations Organization http://www.unwater.org/activities/multi-agency-featured-projects/drought-management/en/

[13] Wilhite D, Sivakumar M, Pulwarty R, (2014) Managing drought risk in a changing climate: The role of national drought policy. Weather and Climate Extremes.Volume 3, June 2014, Pages 4–13.