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VARIABILITY OF RAINFALL REGIME IN ROMANIA ON THE GROUND OF STANDARDIZED INDEX OF PRECIPITATIONS (SPI), IN THE PERIOD 1961-2000

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Summary

Using the standardised index of precipitations (SPI) proposed by McKee (1993)

$$SPI = \frac{Pi - Pm}{\frac{Pm}{s\%}}$$

in which :

Pi = rainfall in a period (... month, season, year etc.)
Pm = mean rainfall (minimum 30 years) in the same period (month, season, year)
s% = coefficient of variation of Pm

and the significance of his values (Barbu & Popa, 2003), the authors computed and mapped the values of SPI_3 (SPI for three months back from curently) for every season (winter, sprig, summers and autumn), from the real data of rainfall, measured in 36 weather stations by the National Meteorological Institute in the period 1961-2000. The results allow an evaluation of the frequency of drought and of the wet seasons in the last 40 years and the trends concerning the dryness or wetness of the seasons and growing season in the same period. Some statistics emphsize the frequencies of the drought at different intensities, and also the succession of excessively dry winter, springs and summers - i.e. 1990, 1992 and 2000. The frequency of wet seasons and successions of wet seasons, like 1969, 1970, 1975, 1991 and 1997, are presented too.

In the analysed period, 70% of springs were near normal, 9% moderately wet, 3% wet, 1% excessively wet, 12% moderately dry, 4% very dry and 2% excessively dry (1986, 2000). Concerning the rainfall regime in the summer, in the period 1961-2000 were registered 12% moderately dry summers, 2% very dry, 8% moderately wet, 4% very wet (1975, 1984) and 2% extremely wet (1970); 72% of summers were near normal. Concerning

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the autumns, in the same period 17% of autumns were moderately dry and 3% very dry, 5% moderately wet, 6% very wet and 2% excessively wet. 70% of autumns were near the normal regime of precipitations (SPI = -1 to +1). From the 40 analysed winters, 70% of these was near normal, 15% moderately dry, 3% very dry, 7% moderately wet, 2% extremely wet and 1% very wet. Concerning the trends of rainfall regime of different seasons, the winters became increasingly much moredry, mainly in the period 1970-1980 and 1990-2003. In the spring, the trend is not significant, while in the summer exists a significant trend to be increasingly much more dryer, especially in the period 1973-2003.

The autumns show significant oscillatory trends, alternating wetter periods (19611975, 1985-2003), with dryer periods, like 1976-1985. In the last 20 years, the summers are dryer than the normal and the autumns wetter than the normal. In the first half of the year, the rainfall shows an interesting trends which become much more less, from a SPI value of 0,5 in 1961 to a value of -0,8 in 2000. Also, the trends of rainfall in the second half of the year (summer and autumn) show to be increasingly from SPI = -0,2 in 1960 to values of + 0,3 in 2000.

Introduction

The variability of rainfall in the continental-temperate climate is very high at the latitude of Romania (44-47°). In the last years alternations of the very drought years (2000, 2002, 2003) and very wet years (1997-1999), or alternation of the very dry spring and summers with very wet autumns (2002, 2003) has conducted to severe impacts on the agriculture and forest management, but also for the social and economic activities. The alternation of dry and wet periods is known from the ancient time, being related in the Holy Bible ("the Flood", or the "7 weak cows and 7 fat cow") or in the registers from old church books in many of Romanian regions (Dudaş, 1992).

The scientific analysis of the frequency and periodicity of drought and wet episodes for the period 1881-1961 has conducted to the conclusion that this phenomena represents the major disturbant natural factor, with important damages on the natural and artificial ecosystems (Topor 1963).

Recent researches has emphasised that the main factors which influence the occurring and the persistence of the drought periods are the interactions air-ocean and land-ocean, the soil moisture, the land topography and the past dynamics of the atmosphere-ocean-land system. The capacity of modelling of this processes and the forecast on the long periods are limited. In Romania, for the forest ecosystems has been developed a modern drought monitoring network which estimates the actual moisture regime and

forecasts the evolution of the dryness in the next month using the GIS and geostatistics facilities. The results are presented monthly on web site http://www.icassv.ro/seceta/, as maps showing the main indices for the rainfall regime in the last 1, 2, 3, ...12 months and the forecast for the next month in five hypothesis.

The paper tries to investigate the frequency of dry and wet periods for the interval 1961-2000, with the aim to construct a model for the forecast of the rainfall regime in the next 20-50 years.

Material and methods

On the basis of the monthly rainfall data registered in the period 1961-2000 by the meteorological stations, were computed the standardised index of precipitation (SPI). The SPI was formulated by McKee, Doesken and Kleist (1993) on the Colorado Climate Centre in 1993. The purpose is to assign a single numerical value to the precipitations, which can compare different regions or different periods. The SPI measures how much the real rainfall (for the last 1 to 12 month) is far from the mean value (of the same period), in standard deviation units (SD)(fig. 1).

The original method for the calculation of SPI use the long-term precipitation records, which are fitted to a gamma probability distribution, and than transformed into a normal distribution. This purpose limit the use of SPI only for the long-term precipitation sites, and limit the big advantage of the index to assess the rainfall regime for other sites, like in the new Network for the Drought Risk Monitoring in the Romanian Forests.

Advantages and disadvantages of SPI to characterise the drought severity can be summarised. For example, from advantages we present:

- simply to use because is based only on the measured precipitations and the long-term mean and their statistics;
- permit to describe the cumulative effect of deficit/excess of rainfall;
- standardisation of SPI permits the estimation of the frequencies of different level of deficit/excess of precipitations;

Disadvantages are:

- the original method of computing (Mc Kee et al., 1993) is quite difficult and limits the results only for the stations with long term measurements (30 years) also for persons who have computer skills;
- the standardisation means that the frequency of deficits/excesses have the same frequency in all locations, the real data being very rare normally distributed;
- in regions with low rainfall or in periods with low rainfall can be computed large positive or negative values of SPI, without

significance for the soil moisture status (i.e. autumn and winter months for the Romanian territory).

Significance of the SPI index

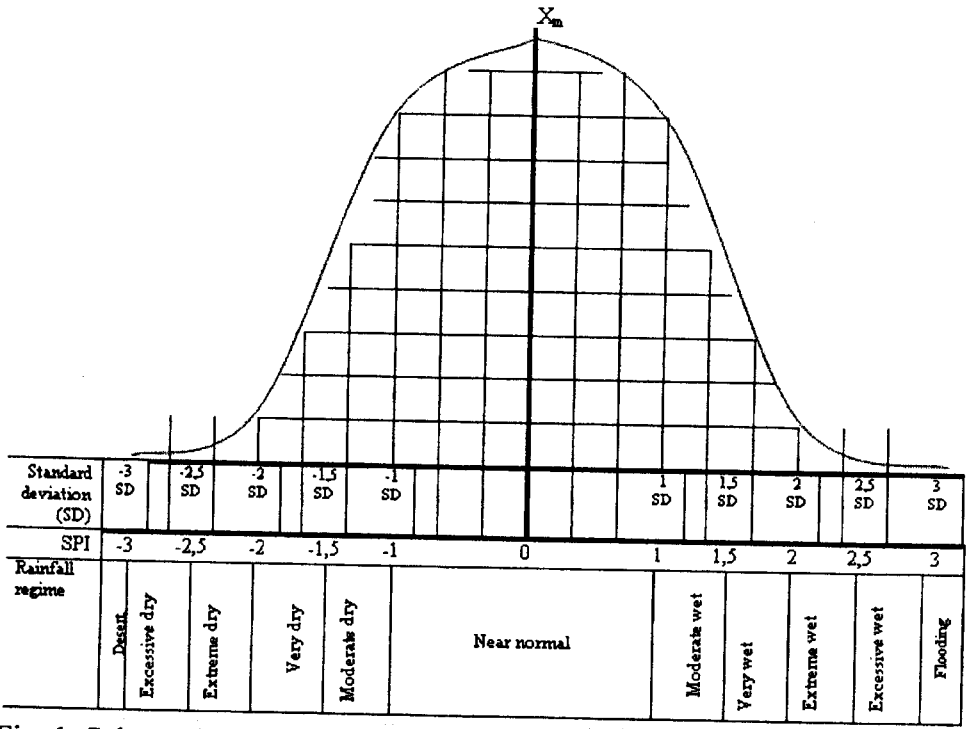

Fig. 1. Schematically representation of the standardised precipitation index (SPI) as measure of the number of standard deviations (SD) from the mean (X m), assuming that the distribution of the rainfall tends toward a normal distribution

For the European area, Lloyd Hughes (2002) made an analysis of the capability of different distributions (gamma, log-normal, normal) to describe the real data set, comparing the empirical cumulative probability distribution with the corresponding theoretical cumulative probability distribution, using Kolmogorov-Smirnov test (K-S).

$D_N = \max |F_N(x)-F(x)|$,

where:

$F_N(x)$ is the empirical cumulative probability $F_N(x_i)=i/N$

$F(x)$ is theoretical cumulative probability distribution evaluate at x.

Under the null hypothesis, that the data are drawn from the theoretical distribution, D_N is compared to tabulated values, appropriated to the sample size and to the assumed distribution. If D_N exceeds the critical value, the null hypothesis is rejected at a given level of significance.

The results (Lloyd 2002) shows that gamma distribution is a good fit for all months, with a failure lee than 15% of grid cells.

The failure of normal distribution for the whole Europe is 20-30%; the zones in which D_N indicate rejection of the null hypothesis are located in the extreme northern and southern regions of Europe. The normal distribution improves how long the scale of the time of interest is extended (more than three months).

For the Romanian area, the normal distribution gives good results, and the null hypothesis is not rejected, for the first eight months of the year and less good for the last, but only for the southern regions outside of Carpathians.

Generally lower performances of the normal distribution were registered at the south of 45° parallel, especially in the Mediterranean climate (Spain, Italy, Balkan Peninsula, Turkey and south of Ukraine) and north of 60° parallel (Scandinavia). But for this regions the author note that "none of the distribution tested could adequately model precipitations over Turkey or across northwest of Spain".

For the Romanian territory, we assume that the distribution of rainfall in 1, 2, 3 ... 12 months tends towards the normal distribution when the shape parameter α of Gamma distribution tends to infinity. Previous researches (Barbu & Popa, 2003) show that if the length of the period for which the data are fitted is longer than 60 years, the distribution tends to normal, and contrary, for a shorter period (30-40 years), it fitted better a Gamma distribution. Assuming a normal distribution of the periodic rainfall (1 to 12 months), we propose a more efficient way to standardise the data from a fitted normal distribution. We have used the mean values of precipitations (computed and mapped for the Romanian territory), calculated as an arithmetic mean (Climatological Athlas of Romnaia, 1965)(only for the normal distribution the arithmetic mean is equal with median value) and the statistic parameters of precipitation (standard deviation, coefficient of variation etc.) computed and mapped for the whole country (Barbu, Popa 2003).

Assuming the normal distribution of precipitations, for the computing of SPI it was used the relation:

$$SPI = \frac{P_i - P_m}{SD_i},$$

in which:

P_i = precipitation registered in the period i (1 to 12 months)

P_m = mean of precipitation in the period i

SD_i = standard deviation of mean precipitations in the period i

Transforming the SD in coefficient of variation (*s*)

$$s\% = \frac{SD}{P_m} * 100$$

The SPI can be computed by the formula:

$$SPI = \frac{\frac{P_i - P_{mi}}{P_{mi}}}{s_i}$$

Using this simply formula it is possible to estimate the SPI for each point of the land on the ground of measured precipitations in the period *i*, the multianual mean values of precipitations (P_{mi}) and the coefficient of variation estimated for the territory, mapped for different periods (Barbu & Popa, 2003). The significance of SPI values are presented in fig.1

SPI 3(II) computed for 3 months back from February (February, January and December) permit the characterisation of the winter, SPI 3(V) from May (May, April and March) for the characterisation of the spring, SPI 3(VIII) from August for the characterisation of the summer and SPI 3(XI) from November for the autumn rainfall regime.

$$SPI3_{II} = \frac{\frac{(P_{II} + P_I + P_{XII}) - (P_{mI} + P_{mII} + P_{mXII})}{P_{mII} + P_{mI} + P_{mXII}}}{s_{\%}3_{(II)}}$$

$P_{I..XII}$ = precipitation registered in January ... December

$P_{mI..XII}$ = mean multianual precipitation registered in January December

$s_{3\ X(II)}$ = coefficient of variation of mean rainfall in the last three months back from February

$$s^2 = \frac{\sum_{1}^{n}[(P_{II} + P_I + P_{XII}) - (P_{mI} + P_{mII} + P_{mXII})]^2}{n-1}$$

$$s = \sqrt{s^2}$$

$$s_{\%} = \frac{s}{P_{mII} + P_{mI} + P_{mXII}} \cdot 100$$

The values of SPI 3 were computed for 36 meteorological stations, distributed on the entire Romanian. Using geostatistics techniques, the values of SPI3 were mapped through isolines on the ground of geographical co-ordinates of the stations (lat., long., alt.). 159 maps of SPI for each season in the period 1961-2000 are analysed below, for the study of the frequency of seasons in relation with the rainfall regime, in 7 regions of the

country (Moldova, Dobrogea, Baragan, Muntenia, Oltenia, Banat, Bihor-Maramures and Ardeal).

Results and discussions

The rainfall regime in the winters (period 1961-2000)

The data summarised in the table 1 show that at country level from 40 winters, 70% were near normal, 12%were wet and 18 % dry. 7% of winters were moderately wet, 2 very wet, 2 extremely wet and 1 excessively wet. From 18% of dry winters 15%were moderately dry and 3%very dry. At the of the regions, the most frequent dry winters were registered on the south-west and western regions (Oltenia, Banat, Bihor), with 2-3 winters very dry (1973, 1989, 1993) and 6 winters moderately dry (1969,1972, 1974, 1984, 1990,1992). The most rich winters in snow were registered in 1966, 1968 and 1970 - when in the whole country were exceeding precipitations - but also in 1963,1969, 1984 when in the area outside of the Carpathians wet regime were registered in the winter.

Table 1. Distribution of the winters in relation with the rainfall regime, estimated through SPI_3 values, for the period 1961-2000, in different regions of Romania

Region	U.M.	Class of SPI values								
		-2,5--3	-2--2,5	-1,5--2	-1--1,5	-0,9-1	1-1,5	1,5-2	2-2,5	2,5-3
		excessive dry	extreme dry	Very dry	moderate dry	near normal	moderate wet	very wet	extreme wet	excessive wet
Moldova	N				7	28	2	1	1	
	%				*18*	*72*	*6*	*2*	*2*	
Dobrogea	N				5	29	3			2
	%				*13*	*74*	*8*			*5*
Bărăgan	N				5	29	3		1	1
	%				*13*	*75*	*8*		*2*	*2*
Oltenia	N			2	7	23	3	3	1	
	%			*5*	*18*	*59*	*8*	*8*	*2*	
Banat	N			3	4	28	2		2	
	%			*8*	*10*	*72*	*5*		*5*	
Bihor - Maramures	N			2	6	28	2	1		
	%			*5*	*15*	*72*	*6*	*2*		
Ardeal	N			1	6	27	3	2		
	%			*2*	*15*	*70*	*8*	*5*		
Romania	Σ			**8**	**40**	**192**	**18**	**7**	**5**	**3**
	%			*3*	*15*	*70*	*7*	*2*	*2*	*1*

The decade with the richest winters in snow were 1961-1970, with five years with wet winters and five years near normal. Practically, no dry

winter were registered in this time. The decade with the most dry winters were 1971-1980, with three consecutive winters (1971-1974) were very dry to moderately dry. Another period with drought winters were 1989-1994. Near normal winters were registered in the interval 1977-1988 and 1995-2000.

Rainfall regime in springs (period 1961-2000)

According with the rainfall regime on regions, the frequency of the springs is presented in the table 2. From 40 analysed springs, 70% has had a near normal regime, 9% moderately wet, 3% very wet and 1% excessively dry. The driest springs were registered in the central part of Romania (1961,1990,1992) and in the eastern regions (1968, 1985, 1986 and 2000). Very wet spring were registered in 1970 (Transilvania and Moldova) 1975, 1980, 1987 (Banat), 1991 (Moldova) and 1997 (Baragan and Dobrogea).

Table 2. Distribution of the springs in relation with the rainfall regime, estimated through SPI_3 values, for the period 1961-2000, in different regions of Romania

Region	U.M.	Class of SPI values								
		-2,5--3	-2--2,5	-1,5--2	-1--1,5	-0,9-1	1-1,5	1,5-2	2-2,5	2,5-3
		excessive dry	extreme dry	Very dry	moderate dry	near normal	moderate wet	very wet	extreme wet	excessive wet
Moldova	N			2	6	26	4	1	1	
	%			*5*	*15*	*65*	*10*	*3*	*2*	
Dobrogea	N			2	7	27	3	1		
	%			*5*	*18*	*67*	*8*	*2*		
Bărăgan	N			2	4	27	6	1		
	%			*5*	*10*	*67*	*15*	*3*		
Oltenia	N			3	4	29	3	1		
	%			*8*	*10*	*72*	*8*	*2*		
Banat	N		1	1	1	31	4	1	1	
	%		*2*	*2*	*3*	*78*	*10*	*3*	*2*	
Bihor - Maramures	N		1	2	5	26	3	1	2	
	%		*3*	*5*	*12*	*65*	*7*	*3*	*5*	
Ardeal	N		1		5	29	2	2		1
	%		*3*		*12*	*73*	*5*	*5*		*2*
Romania	Σ		**3**	**12**	**32**	**195**	**25**	**8**	**4**	
	%		***1***	***4***	***12***	***70***	***9***	***3***	***1***	

Successions of the dry winters and springs were registered in 1973, 1974, 1990 and 1992 in the western regions of Romania. Successions of wet winters and spring were registered in 1966, 1970, 1984, 1987, 1991 and 1997.

The rainfall regime in the summers (period 1961-2000)

In table 3 are presented the frequencies of the summers according with the rainfall regime in different regions and on the entire of Romania. From 40 analysed summers, 72%were near normal, 14% were wet and 14% dry; 12% of summers were moderately dry and 2% very dry. From 14% wet summers, 8% were moderately wet, 4% very wet and 2% extremely wet. The driest summers were registered in 2000 in the western and the south-western regions, in 1987 and 1990 in Transylvania and in regions outside of the Carpathians, and in 1994 in the north-eastern regions.

Table 3. Distribution of the summers in relation with the rainfall regime, estimated through SPI_3 values, for the period 1961-2000, in different regions of Romania

Region		Class of SPI values								
		-2,5--3	-2--2,5	-1,5--2	-1--1,5	-0,9-1	1-1,5	1,5-2	2-2,5	2,5-3
		excessive dry	extreme dry	Very dry	moderate dry	near normal	moderate wet	very wet	extreme wet	excessive wet
Moldova	N				5	29	4	1	1	
	%				*12*	*73*	*10*	*3*	*2*	
Dobrogea	N			2	2	32	1	1	2	
	%			*5*	*5*	*80*	*2*	*3*	*5*	
Bărăgan	N				5	28	4	2	1	
	%				*12*	*70*	*10*	*5*	*3*	
Oltenia	N			1	6	27	3	2	1	
	%			*2*	*15*	*68*	*7*	*5*	*3*	
Banat	N		1		5	29	3	1	1	
	%		*3*		*12*	*72*	*7*	*3*	*3*	
Bihor - Maramures	N			1	5	28	5	1		
	%			*3*	*12*	*70*	*12*	*3*		
Ardeal	N			1	5	28	3	2	1	
	%			*2*	*13*	*70*	*8*	*5*	*2*	
Romania	Σ		**1**	**5**	**33**	**200**	**23**	**10**	**7**	
	%			*2*	*12*	*72*	*8*	*4*	*2*	

The most rainy summers were registered in 1969, 1972, 1974, 1978,1991 and 1997. Successions of dry winters, spring and summers were registered in 1990, 1992 (western part), 1994 and 2000. Successions of wet springs and summers were registered in 1969, 1970, 1975, 1991, 1997. Successions of wet winters, springs and summers were registered in 1970, 1975 and 1997.

The rainfall regime in the autumn (period 1961-2000)

In table 4 are presented the frequencies of autumns, according with the rainfall regime on regions and at the level of the entire Romania.

Close to normal rainfall regime were registered in 70% of cases, 13% of autumns were wet and 17% were dry; 14% of autumns were moderately dry and 3% very dry. Concerning the wetness regime, 5% of autumns were moderately wet, 6% very wet and 2% extremely wet. The most wet autumns were registered in 1964, 1972, 1992, 1996 and 1998. The driest autumns were registered in 1961, 1982 (north-eastern part), 1986 (southern part) and 200 (western part of Romania).

Successions of dry summers and autumns were registered in 1961 (northern part) 1990 (southern part) and 2000 (western part). Successions of dry springs, summers and autumns were registered in 1961, 1986, 1990 and 2000 which was the draughty year of the analysed period.

Table 4. Distribution of the autumns in relation with the rainfall regime, estimated through SPI_3 values, for the period 1961-2000, in different regions of Romania

Region		Class of SPI values								
		-2,5--3	-2--2,5	-1,5--2	-1--1,5	-0,9-1	1-1,5	1,5-2	2-2,5	2,5-3
		excessive dry	extreme dry	Very dry	moderate dry	near normal	moderate wet	very wet	extreme wet	excessive wet
Moldova	N			1	8	26	1	3	1	
	%			*2*	*20*	*65*	*3*	*8*	*2*	
Dobrogea	N				8	26	4	1	1	
	%				*20*	*65*	*10*	*3*	*2*	
Bărăgan	N			1	6	29	2	1	1	
	%			*2*	*15*	*73*	*5*	*3*	*2*	
Oltenia	N			2	3	32		2		1
	%			*5*	*8*	*80*		*5*		*2*
Banat	N		1	1	3	29	3	3		
	%		*2*	*2*	*8*	*72*	*8*	*8*		
Bihor - Maramures	N			1	6	27	1	4	1	
	%			*2*	*15*	*68*	*3*	*10*	*2*	
Ardeal	N			1	5	27	4	2	1	
	%			*2*	*13*	*68*	*10*	*5*	*2*	
Romania	Σ		**1**	**7**	**39**	**196**	**15**	**16**	**5**	**1**
	%			*3*	*14*	*70*	*5*	*6*	*2*	

Conclusions

For the four decades analysed, we must note the wet period 1969-1975, with important excess of rainfall, especially in Transylvania (1969-

1970) and in the southern regions (1971-1972). Also, must specify the dry years 1985-1986, 1990, 1992 and 2000, the must driest year of the whole analysed period. In the last 40 years, the most frequent droughts were registered in the central and western regions of Romania (1990, 1992, 2000) and the most frequent periods with an excess of precipitations in the regions outside of Carpathians (1970, 1972, 1997, 1998).

The next step in the evaluation of the frequency and periodicity of dry and wet seasons consist in the unification of indices for the whole period 1881-2000, using standardised precipitation index (SPI), followed by an estimation of the trends and the periodically occurrence of the drought / wet episodes.

References

1. Barbu, I., Popa, I., 2002 : Cartarea teritoriului României în raport cu lungimea medie a perioadelor de secetă şi uscăciune. Bucovina Forestieră, anul X, nr. 1-2

2. Barbu, I., Popa, I., 2003 : Monitoringul secetei în pădurile din România. Ed. Tehnică Silvică, Câmpulung Moldovenesc, 128 p + CD ROM

3. Barbu, I., Popa, I., 2003 : Variabilitatea spaţială a coeficientului de variaţie a precipitaţiilor din România. Sesiunea de Comunicări ştiinţifice INMH, 10-12 iunie 2003.

4. Dudaş, F., 1992. Însemnări pe bătrâne cărţi de cult. Editura Albatros, Bucureşti, 207 p.

5. Lloyd Hughes, B., 2002 : The long Range Predictability of European Drought. Dept. of Space and Climate Physics University College London.

6. Mc Kee, T.B., Doesken, N.,J., Kleist, J., 1993 : The relationship of drought frequency and duration to time scales. 8 – Conference on Applied Climatology. American Meteorological Society, Boston.

7. Topor, N., 1963 : Ani ploioşi şi ani secetoşi în RPR. Editura Institutului Meteorologic, Bucureşti