COMPARATIVE STUDY REGARDING PERFORMANCE OF SOME FREE SOFTWARES FOR THE CALCULATION OF THE STANDARDIZED PRECIPITATION INDEX (SPI)

Sabău Nicu Cornel*

*University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St., 410048 Oradea, Romania, e-mail: nsabau@uoradea.ro

Abstract

Calculating methods of the pluviometric indices have evolved over the years from various ratios between different values of monthly precipitation to the complex methods based on computer analysis of the precipitation evolution in different time intervals by means of statistical functions.

Standardized Precipitation Index (SPI) although it requires for determination computer programs is one of the most used pluviometric indicators to monitor climate hazards, in last decades, all over the world.

Among the computer programs for SPI, which can be free downloaded, were tested SPI _SL_6.exe, the calculation program developed by the Republic Hydrometeorological Service of Serbia (RHMSS) and DinC software produced by the Laboratory of Land Reclamation and Water Resources Management from the National Technical University from Athena.

As a result of comparative analysis follows that the most performant is DrinC software, because it offers the possibility of determining more indices, working with Excel files and facilitates real-time forecast SPI based on rainfall records.

Key words: pluviometric indices; monitoring climate hazards; *Standardized Precipitation Index (SPI)*; free software;

INTRODUCTION

The current global climate change, increasingly apparent in recent decades, are climate hazards which it manifested in particular by changes in the precipitation and temperature evolution, in the upside values and their frequency, with the implication in socio-economic, agricultural and environmental disasters. In order to reduce their negative effects should be monitored the climate phenomena with a view to forecast and prediction of their future evolution.

For this it use a series of climatic indices classified by meteorological elements taken into account: pluviometric indices - precipitation; hydrothermal indices - precipitation and air temperature; hydroheliothermal indices - precipitation, air temperature and sunshine duration; balance sheet indices - evapotranspiration, which is used to determine the water balance in the soil; and so on. (Cheval et al, 2003)

From the category pluviometric indices doing part: Hellman Criterion, Topor index, Rainfall Deciles, Angot index, Standardized Precipitation Index (SPI) and Bhalme - Mooley Drought Index (BMDI).

Methods of calculating the pluviometric indices have evolved over the years, from various ratios between different values of monthly precipitation to the complex methods based on the computer analysis of the evolution of precipitation in different time intervals by means of statistical functions. In the latter category is also part of the Standardized Precipitation Index (SPI) which was proposed by McKee et al, 1993, from University of Colorado.

Although SPI is an index that highlights the rainfall anomalies, excess and deficit rainfall, in recent decades is used all over the world, to monitor dry periods. (Edwards et McKee, 1997; Lloyd-Hughes et Saunders, 2002; Ntale et Gan, 2003; Tsakiris et al, 2007; Costa, 2011; Karavitis et al, 2011)

In Romania the monitoring of dry periods using SPI has been used in several regions of the country: Eastern Plain of Romania (Şerban et Dragotă, 2009) Western Plain lying north of Mureş (Şerban, 2010) Carpathians and Subcarpathians of curvature (Dragotă et al, 2012) Western Romania (Hălbac - Cotora, 2013)

Advantages of SPI using for characterizing droughts are multiple: the use as input data, the monthly rainfall recorded for a number of largest possible years; possibility of using series of calendar, hydrological or agricultural years; possibility of determining the SPI value for different time scales of 1 month, 3 months, 6 months, etc; SPI value for a certain time scale is more suggestive in connection with characterization of drought than rainfall quantity; possibility of spatial analyzes of dry periods; possibility of processing spatial analysis using Geographic Information Systems, so resulting the representations of the intensity of droughts; the possibility of prognosis regarding droughts in a certain region.

Between disadvantages of using this index can be mentioned dependency of value Z (SPI) by the length of the review period, by the amount of precipitation, lower range of 1 month and higher for 12 or 24 months, respectively heavy calculation methodology. (Wu et al, 2005)

The second drawback, related to the complexity of the SPI calculations is overcome by the use of computer software that can be free downloaded. (Smakhtin et Hughes, 2004)

The main objective of this paper is to analyze the advantages and disadvantages of using three free programs for calculation of the SPI.

MATERIAL AND METHOD

To achieve the proposed objectives were tested the performances of programs "SPI _SL_6.exe" which can be downloaded for free from the National Drought Mitigation Site Center, (

http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx); calculation program developed by the Republic Hydrometeorological Service of Serbia (RHMSS) in Excel format, (Krajinović et Radovanović, 2010) and Drought Indices Calculator (DrinC) software, that can be downloaded free from the page of the National Technical University of Athens, Laboratory of Land Reclamation and Water Resources Management. http://www.ewra.net/drinc/ (Tigkas et al, 2013)

Testing the three programs for SPI calculation was done using monthly precipitation records for 20 years (1946-1965) from the Meteorological Station Oradea.

RESULTS AND DISSCUSIONS

The oldest program for SPI calculation is "SPI_SL_6.exe", available both in Windows version and in versions for Fortran users (http://ccc.atmos.colostate.edu/standardizedprecipitation.php) or R. (http://cran.r-project.org/web/packages/spi/)

However, this program presents some inconveniences: input data must be presented in "notepad" format, where rainfall must be submitted on 3 columns, the first for years, the second for months and third with monthly rainfall multiplied by 100 (or20in); the "dat" format of the output file (or20out.dat) in which are listed calculated SPI values, divided into several columns; the graphics processing of calculated SPI values require their transfer from the "dat" format to "xls" format. (Standardized Precipitation Index, User Guide, 2012) (Figure 1.)

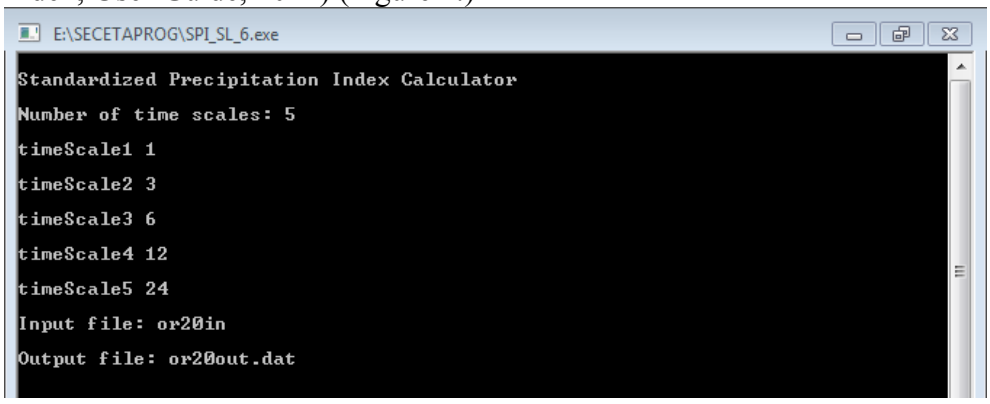

Figure 1. The input (or20in) and output (or20out.dat) files used for SPI calculation with "SPI_SL_6.exe" software.

The output data file, they are divided into several columns, the first of which is the year and the two months. Number of the other columns is equal to the number of processed scales (1 month, 3 months, etc.) each column containing SPI values for 1 month, SPI values for 3 months, etc.

The SPI values of the output file that is missing or that cannot be calculated because the monthly precipitation is zero are marked with -99.00. Lack of rainfall in a month makes for that month of the year, the monthly SPI cannot be calculated because the incomplete gamma function is not defined for zero precipitation. To overcome this drawback is recommended to replace the null value monthly rainfall with 001, which do not essentially modifies SPI values, calculated by the program.

SPI values calculated for different scales and time frames are used to generate thematic maps used to spatial monitor of climatic drought, with programs from GIS category or using special programs.

Calculation program used to implement the SPI in Serbia (RHMSS) in Excel format, compared to the recommended software for conditions from Southeastern Europe, by the Drought Management Centre for Southeastern Europe (DMCSEE) being found that differences between SPI values obtained are minimal. (Krajinović et Radovanović, 2010)

Advantages of RHMSS program consist of fact that is developed on a single spreadsheet for a time scale of 1 month, 3 months, 6 months, etc. and uses the facilities of the statistical functions of Excel.

Thus, after precipitation processing by summation, for monthly scale and years period, it calculate the necessary elements for determining the parameters of distribution function gamma, α and β: Xmed - monthly average rainfall; ln (Xmed) - natural logarithm of the average monthly rainfall; ln x - natural logarithm of monthly precipitation; the term A = ln Xmed - (Σln X / N). With these values are obtained α - slope parameter and β - the scale parameter of the distribution gamma incomplete curve for precipitation. (Figure 2.)

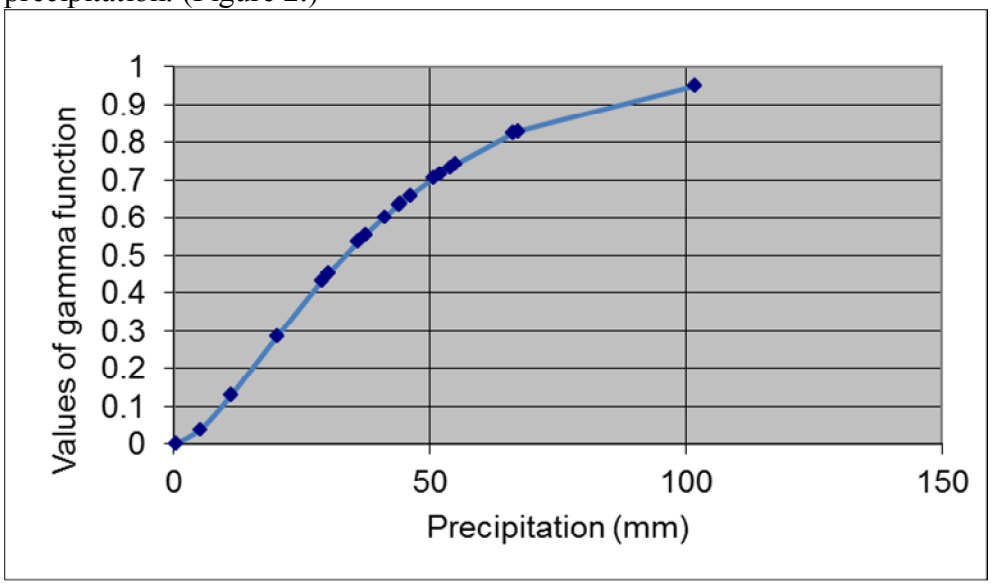

Figure 2. Gamma function of rainfall in February, Oradea (1946-1965)

By knowing the values of gamma distribution curve parameter, it applies GAMMADIST function (X, α, β, TRUE) on rainfall and the choosing the cumulative distribution. To avoid the situation where the incomplete gamma distribution is not defined, ie monthly precipitation null, it is replaced with the value of 0.1 mm.

Monthly values of SPI index are obtained making the normalization of incomplete gamma distribution function by applying the function NORMVINV (GAMMADIST X, α, β, TRUE). (Figure 3.)

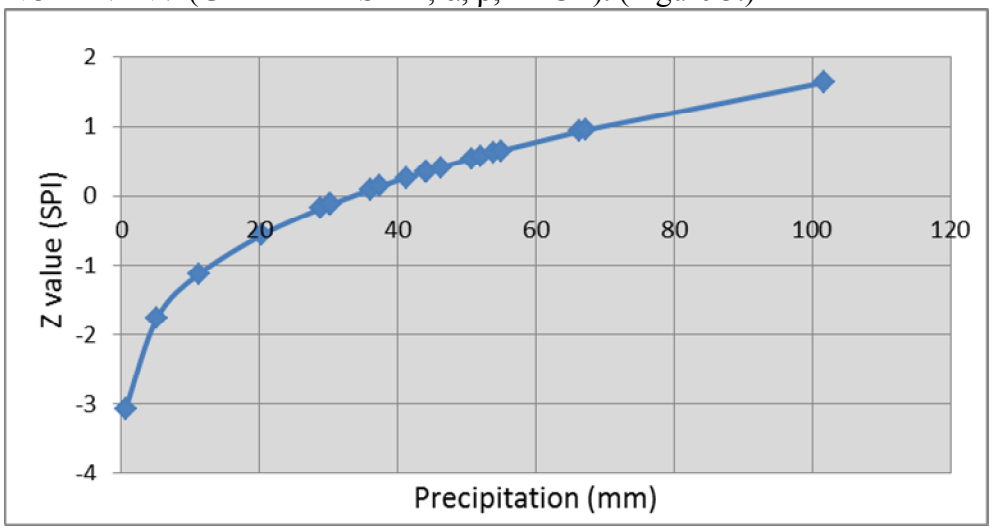

Figure 3. Normalized, standardized distribution of precipitation, Z values (SPI) in February, Oradea (1945-1965)

Precipitation data processing methodology proposed by RHMSS, offer in addition, the advantages of the possibilities to use, outside the Gamma distribution, several distribution functions to model the precipitation, such as Beta, Pearson, Poisson, Exponential, Logarithmic, etc.

One of the latest programs for calculation of indices for monitoring drought is the software Drought Indices Calculator (DrinC) which allows the determination of three indices: Deciles, Standardized Precipitation Index (SPI) and Reconnaissance Drought Index (RDI). (Tigkas et al, 2013)

For the calculation of the SPI values, data input, monthly or annual rainfall (on hydrological or agricultural years) are saved on spreadsheet in Excel 1997-2003, with the ".xls" extension, file name being requested by the program in the "File Management", once with the year of the data series start and the number of years used for calculation. (Figure 4.)

The choice of the index that must to be calculated is done using "Calculate Indices" module, in whose window is selected "Calculate SPI", is inserted the name of output file, the chosen distribution function, gamma or

log normal, computation steps which may be: annual, 6 months, 3 months and monthly and then is pressed the "Calculate" button. (Figure 5.)

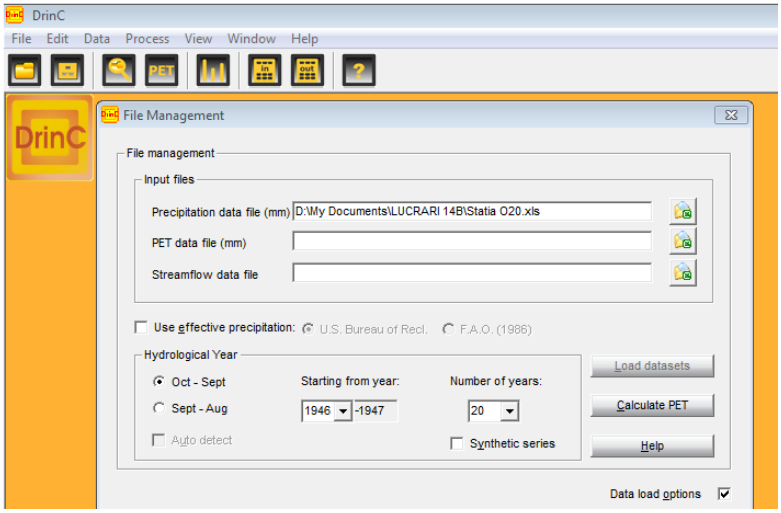

Figure 4. File Management window of DrinC software

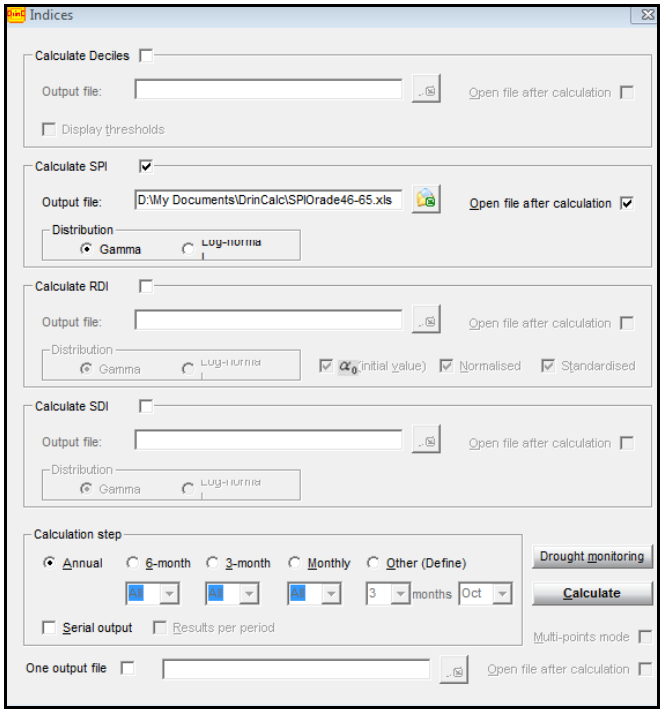

Figure 5. Indices window of DrinC software

When choosing the calculation steps is possible of defining and of other steps in number of months (ex. 2 months, 5 months etc.) with the option of choosing from which month start the summation of rainfall.

Output data are supplied on the table, in indicated file Excel 1997-2003, for the chosen period or in series, on month, specifying the calculation period. Unlike other programs, SPI values calculated are displaying, for many months in the box the start of the period.
Using the same 20 year period, recorded at the meteorological station Oradea (1946-1965) were calculated the monthly SPI values, using SPI_SL_6.exe, RHMS and DrinC programs, these gives very similar results. (Table 1.)

Table 1.

Comparisons between SPI values in November from Oradea (1946-1965) obtained with SPI_SL_6.exe, RHMSS and DrinC programs

No. crt.	Years	Calculation software			Characterization
		SPI_SL_6.exe	RHMSS	DrinC	
1	1946	0.29	0.29	0.29	Easy wet
2	1947	0.47	0.47	0.47	Easy wet
3	1948	0.55	0.55	0.55	Easy wet
4	1949	0.89	0.89	0.89	Easy wet
5	1950	0.49	0.49	0.49	Easy wet
6	1951	-1.99	-1.99	-1.99	Severe dry
7	1952	1.82	1.81	1.82	Severe wet
8	1953	-1.09	-1.09	-1.09	Moderate dry
9	1954	-0.84	-0.84	-0.84	Easy dry
10	1955	-0.64	-0.64	-0.64	Easy dry
11	1956	0.53	0.53	0.53	Easy wet
12	1957	-0.65	-0.65	-0.65	Easy dry
13	1958	-0.16	-0.16	-0.16	Easy dry
14	1959	-0.41	-0.41	-0.41	Easy dry
15	1960	0.94	0.94	0.94	Easy wet
16	1961	-0.06	-0.06	-0.06	Easy dry
17	1962	1.25	1.25	1.25	Moderate wet
18	1963	-1.59	-1.59	-1.59	Severe dry
19	1964	-1.10	-1.10	-1.10	Moderate dry
20	1965	1.33	1.33	1.33	Moderate wet

For SPI values in November, there is a small difference in 1952, to two decimal points, probably due to rounding performed by Excel, but that does not influence climate characterization of the period.

DrinC program also has a monitoring module of droughts (Drought monitoring), which for a sufficiently large data set can calculate SPI using a linear function:

$$SPI = c \cdot \ln(\Sigma P) + b; \quad [1.]$$

With this relationship, using rainfall data recorded in real time are estimated constants c and b and the corresponding SPI value of precipitation.

Using data from Oradea, during 1971-2012 hydrological years, at window opening "Drought Monitoring" by choosing the button "SPI calculation" is displayed values of the coefficients c and b of the straight line equation, SPI = f (ΣP): c = 4 , 767 525 and b = - 30.65095, estimated on account of the years analyzed array.

In this window by pressing the "Apply" button, these values are recorded for use in estimating the SPI. For this longer required amount of the precipitation in the period considered.

For simulation we used monthly rainfall data recorded in Oradea 1970-1971 hydrological year, for which was estimated SPI value = -0.685, indicating an easy dry year. (Figure 6.)

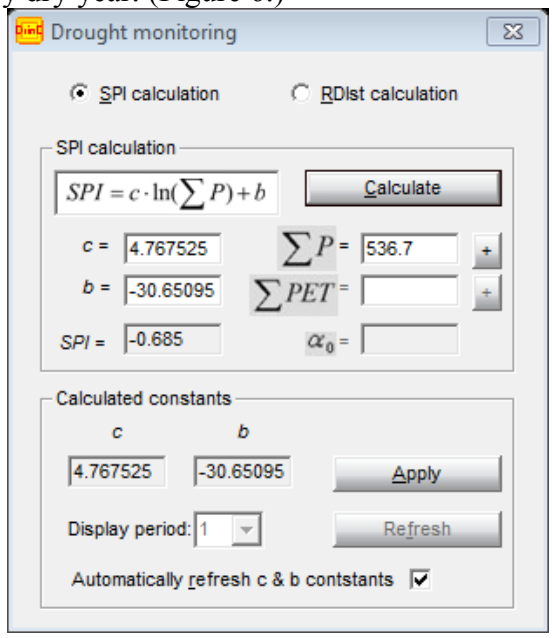

Figure 6. The window "Drought monitoring" of DrinC software and estimated SPI value, in the conditions of 1970-1971 hydrological year in Oradea

The estimated SPI value was compared with the same hydrological year value determined for the interval of records for 50 years (1946-1995), which is -0.65, indicating the same classification in terms of drought characterization.

CONCLUSIONS

The most popular pluviometric indices used to monitor climate hazards are: Criterion Hellman, Topor pluviometric index, rainfall Deciles, Angot pluviometric index, Bhalme-Mooley Drought Index (BMDI) and the Standardized Precipitation Index (SPI).

Because SPI has a complex calculation methodology are used different programs that can be downloaded for free, of which the best known are: SPI_SL_6.exe, RHMSS program and DrinC software.

Given that the incomplete gamma function of cumulative rainfall is not defined in the month without precipitation, all three programs require that for months without rainfall to use a very small amount of them, which does not affect the characteristics of the analyzed period.

The calculation of SPI with the three programs for a period of 20 years (1946-1965) in Oradea leads to very similar values that do not influence climate characterization of the analyzed period.

If the use of SPI_SL_6.exe program is cumbersome, because for graphics processing is necessary to transfer output files in Excel file, than the RHMSS program is directly designed into Excel spreadsheets and show the steps needed to determine the SPI values.

The most recent program conducted, DrinC software are the best because working with input and output files in Excel format, has the possibility of determining several climatic indices to monitor hazards, allows analysis of the predefined time scales, has facilities of graphical representation of calculated values similar to Excel and provides the opportunity of real-time SPI values forecasting, depending on the rainfall records.

REFERENCES

1. Costa A.C., 2011, Local patterns and trends of the Standard Precipitation Index in southern Portugal (1940–1999), Adv. Geosci., 30, pp 11-16;
2. Cheval S., Croitoru Adina, Dragne Dana, Dragotă Carmen, Gaceu O., Patriche C.V., Popa I., Teodoreanu Elena, Voiculescu M., 2003, Indici şi metode cantitative utilizate în climatologie, Edit. Univ. din Oradea, pg. 119;
3. Dragotă Carmen-Sofia, Mărculeț Cătălina, Mic Elena-Loredana, Grofu Andruța, 2012, Mapping dryness time-scales in The Curvature Carpathians and Subcarpathians (Romania) by the Standardized Precipitation Index, Rev. Roum. Géogr./Rom. Journ. Geogr., 56, (2), pp. 137–142, Bucureşti;
4. Edwards, D.C., McKee T.B., 1997, Characteristics of 20th century drought in the United States at multiple time scales. Climatology Report Number 97–2, Colorado State University, Fort Collins, Colorado;
5. Hălbac – Cotora Z.R., 2013, Drought analysis in Western Romania, using DrinC program, In Recent Advances in Energy, Environment and Geology, Antalya, Turkey, october 8-10, Energy, Environmental and Structural Engeenering Series nr.18. pp. 82-87;
6. Karavitis Ch., A., Stavros Al., Tsesmelis D.E., Athanasopoulos G., 2011, Application of the Standardized Precipitation Index (SPI) in Greece, Water, 3, pp. 787-805;
7. Krajinović Z., Radovanović Slavica, 2010, Implementation of Standardized Precipitation Index – SPI, Report, Republic Hydrometeorological Service of Serbia, april 2010, pg., 17;

8. Lloyd-Hughes B, Saunders M.A., 2002, A drought climatology for Europe, Int. J. Climatology, 22, pp. 1571-1592;
9. McKee T.B., Doesken, N.J., Kleist, J., 1993, The relationship of drought frequency and duration to time scales, Preprints, 8th Conference on Applied Climatology, 17-22 January, Anaheim, CA;
10. Ntale H.K., Gan T.Y., 2003, Drought indices and their application to East Africa, Int. J. Climatol. 23, pp. 1335-1357;
11. Smakhtin V.U., Hughes D.A., 2004, Review, Automated Estimation and Analyses of Drought Indices in South Asia. W. P. 83. Colombo, Sri Lanka, International Water Management Institute; (http://www.geospatialworld.net/paper/application/ArticleView.aspx?aid=1048#sthash.Nvscaq5W.dpuf;)
12. Şerban Eugenia, Dragotă Carmen Sofia, 2009, L'anayse du déficit pluviométrique de la Plaine de l'Oest de la Roumanie par l'intermédiaire de l'Indice Standardisé de Précipitations, XXIIème Colloque de L'Association Internationale de Climatologie "Extrêmes climatiques: genèse, modélisation et impacts", Geographia Technica, Numéro spécial dédié au 90ième anniversaire de l'Université Roumaine de Cluj, 1-5 sept, Cluj-Napoca, Romania, pp. 443-448;
13. Şerban Eugenia, 2010, Hazarde climatice generate de precipitaţii în Câmpia de Vest situată la nord de Mureş, Edit. Universităţii din Oradea, pg.395;
14. Tigkas D., Vanghelis H., Pangalou D., 2013, DrinC, Drought Indices Calculator - Getting Started Guide, version 1.5., National Technical University of Athens, Centre for the Assessment of Natural Hazards & Proactive Planning & Lab. of Reclamation Works and Water Resources Management; (http://drinc.ewra.net/DrinC%20-%20GSG.pdf;)
15. Tsakiris G., Loukas A., Pangalou D., Vanghelis H., Tigkas D., Rossi G., Cancelliere A., 2007, Drought characteritzation (Part 1. Components of drought planning. 1.3. Methodological component), In Iglesias A. (ed.) Moneo M. (ed.) López-Francos A. (ed.), Drought management guidelines technical annex, Zaragoza: CIHEM/EC MEDA Water, pp. 85-102 (Options Mèditerranéennes: Série B. Etudes et Researches, no. 58;
16. Wu H., Hayes M.L., Wilhite D.A., Svoboda M.D., 2005, The effect of the length of record on the Standardized Precipitation Index calculation, Int. J. Climatol. 25, pp. 505-520;
17. * * * Standardized Precipitation Index User Guide, World Meteorological Organization, No. 1090, 2012; (http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf; din 08.07.2014)
18. * * * http://ccc.atmos.colostate.edu/standardizedprecipitation.php; din 07.08.2014;
19. * * * http://cran.r-project.org/web/packages/spi/; din 08.07.2014;
20. * * * http://drought.unl.edu/MonitoringTools/ClimateDivisionSPI.aspx; din 05.07.2014;