FORUM GEOGRAFIC

Forum geografic. Studii şi cercetări de geografie şi protecţia mediului
Volume ***XIII****, Issue* ***2*** *(****December*** *2014), pp.* ***147-152***
*http://dx.doi.org/****10.5775/fg. 2067-4635.2014.036.d***

Analysis of precipitation characteristics and trends for the Getic Piedmont and Subcarpathians, Oltenia region, Romania

Alina VLADUT[1]*, Irina ONTEL[2]

[1] University of Craiova, Department of Geography, Romania, e-mail: vladut_alina2005@yahoo.com
[2] University of Bucharest, Faculty of Geography, Romania
* *Corresponding author*, vladut_alina2005@yahoo.com

Received on <15-09-2014>, reviewed on <25-10-2014>, accepted on <01-12-2014>

Abstract

Changes in precipitation characteristics of the hilly area of Oltenia, covering the western parts of the Getic Piedmont and SubCarpathians, were analysed, based on monthly rainfall data, for the timeframe 1961 to 2010. The precipitation trend analysis for the period 1961-2010 shows different results–increasing precipitation in winter half part of the year for most of the Subcarpathian area and a rainfall decrease in summer half of the year for the entire region. The piedmont part of the study area, with dominant agricultural land use, shows the highest spring precipitation decrease, whereas in the Subcarpathian area, summer and autumn precipitation increase is more pronounced. The positive trends are spatially the most homogenous in August, September and October, while the most uniform negative trends were recorded in February, May and November. At annual level, the most significant decrease corresponds to the piedmont, while the rest of the region displays an insignificant positive trend. The SPA emphasized that normal years (deviations oscillating between -1.00 and +1.00) predominate; however, in the eastern part of the region there are lower percentages compared to the western part (70-74% compared to 64-66%). At the same time, in the east, the share of dry weather is double compared to the western part, where rainy weather predominates.

Keywords: *precipitation, trends, SPA, Oltenia, Romania*

Rezumat. Analiza caracteristicilor şi tendinţelor regimului pluviometric din Piemontul şi Subcarpaţii Getici, Regiunea Oltenia, România

Au fost analizate modificările survenite în regimul pluviometric din regiunea deluroasă a Olteniei, care acoperă partea vestică a Podişului Getic şi a Subcarpaţilor Getici, plecând de la cantităţile lunare de precipitaţii înregistrate în perioada 1961 – 2010. Analiza tendinţei de evoluţie a precipitaţiilor pentru perioada menţionată a evidenţiat rezultate diferite – creşterea cantităţilor pentru semestrul rece în cea mai mare parte a zonei subcarpatice şi o scădere a cantităţilor pentru semestrul cald la nivelul întregii regiuni analizate. Zona piemontană, unde terenul este în mare parte utilizat agricol, prezintă cea mai evidentă scădere a cantităţilor înregistrate primăvara, în timp ce la nivelul zonei subcarpatice, cele mai însemnate creşteri se remarcă vara şi toamna. Tendinţele pozitive sunt omogene în lunile august, septembrie şi octombrie, în timp ce cele mai omogene tendinţe negative se înregistrează în lunile februarie, mai şi noiembrie. La nivel annual, cea mai semnificativă scădere a cantităţilor corespunde zonei piemontane, în timp ce în restul regiunii se remarcă o tendiţă pozitivă nesemnificativă din punct de vedere statistic. Valorile ASP au evidenţiat predominarea anilor normali (abateri cuprinse între -1,00 şi +1,00); totuşi, în partea estică a regiunii, ponderile sunt mai reduse decât în cea vestică (64-66%, respectiv 70-74%). În acelaşi timp, în partea estică, ponderea timpului secetos este dublă comparativ cu cel înregistrat în partea vestică, unde predomină timpul ploios.

Cuvinte-cheie: precipitaţii, tendinţe, ASP, Oltenia, Romania

Introduction

Precipitations represent the most variable climatic parameter, because global temperature increase usually triggers changes and variability of rainfall amounts, as well as of their spatial and temporal distribution (IPCC, 2007). In Europe, precipitation variability and trends have been thoroughly studied in the last decades. The results are sometimes contradictory, as they depend on the considered time scale and regions. Thus, Klein Tank and Können (2003) underlines an increasing trend of precipitation amounts, while Mudelsee et al. (2003), on the contrary, emphasized a decreasing trend. Other researchers focused on precipitation variability and trends at a global scale (Diaz et al., 1989; Hulme, 1995; New et al., 2001), regional scale (Norrant and Dougúedroit, 2006), or even local scale (Brunetti et al., 2001a, b, 2006; Rodrìguez-Puebla et al., 1998). In Romania, precipitation variability and trends have been analysed in the last decade, as well. Thus, it resulted that there was registered a significant decreasing trend for winter, especially within the extra-Carpathian region (Tomozeiu et al., 2005). A decreasing trend was also identified for summer and annual precipitation amounts in the central part of the Romanian Plain by Croitoru and Toma (2010), while Piticar and Ristoiu (2013) reached the conclusion that the increasing or decreasing seasonal or annual trends registered in the northeastern part of Romania are generally not statistically significant.

Research Methods

For the present study, there were used monthly precipitation amounts from six meteorological stations (Table 1, Fig. 1). The stations are uniformly distributed, namely two in the piedmont area, west and east of the Jiu River, and four in the

Subcarpathian area. The datasets cover a 50 years period (1961-2010) and they were provided by the Romanian National Meteorology Administration (ANM). There were no missing data.

To calculate trends of the precipitation amounts, there were used 19 data series for each station, namely 12 monthly series, 4 seasonal series, 2 half year series and one annual series.

In order to detect trends in the time series of precipitation amounts, it was used the Excel template MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), developed by the researchers of the Finnish Meteorological Institute (Salmi et al., 2002). Mann-Kendall test is a non-parametric test used for rendering the significance of a linear trend against the null hypothesis of "no trend". The test statistic Z enables the comparison between the absolute value of Z and the standard normal cumulative distribution to detect a certain trend at a certain level of significance α. Consequently, positive values of Z clearly indicate upward trends, while negative values of Z indicate downward trends. Sen's method enables the estimation of the magnitude of a trend. In the present study, the trends are considered to be statistically significant at ɑ level of 0.05. The same method was successfully applied also in temperature data series by Micu and Micu (2006), Piticar and Ristoiu (2012), Croitoru et al. (2011a), Vladut and Ontel (2013), sunshine duration (Croitoru et al., 2011b), snow cover (Micu, 2009), etc.

Table 1 Geographical coordinates of the considered meteorological stations

Meteorological station	Latitude (N)	Longitude (E)	Height (m)
Bâcleș	44°29`	44°29`	313
Târgu Logrești	23°07`	23°07`	265
Apa Neagră	44°53`	44°53`	258
Târgu Jiu	23°42`	23°42`	203
Polovragi	45°00`	45°00`	531
Râmnicu Vâlcea	22°52`	22°52`	237

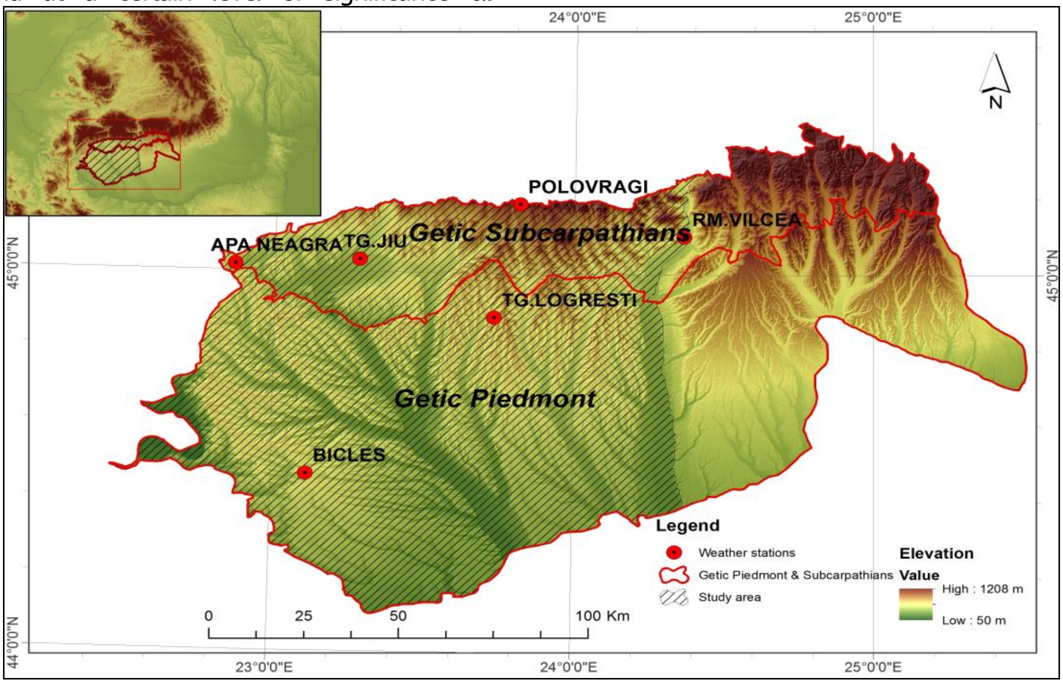


Fig. 1 Location of the meteorological stations within the Getic Piedmont and Subcarpathians

Standardized Precipitation Anomaly (SPA) represents a greatly used method in Romania (Dumitraşcu et al., 2001; Cheval et al., 2003; Croitoru and Toma, 2010). It is calculated as follows:

$$SPA = \frac{x_i - \bar{x}}{\sigma}, \text{ where}$$

SPA – Standardized Precipitation Anomaly;
xi – precipitation amount for *i* month/year;
$\bar{x}$ - multiannual average amount of precipitations;
σ - standard deviation

The standard deviation is computed by extracting the square root of the variance (σ^2). Dispersion is a synthetic indicator, respectively the square mean of the deviations of parameter individual values from the average of the entire string (Cheval et al., 2003). The formula for calculating the dispersion (σ^2) is:

$$\sigma^2 = \frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2}{n},$$

where *n* represents the number of years

Thus, standard deviation (σ) is calculated according to the formula:

$$\sigma = \sqrt{\sigma^2} = \sqrt{\frac{\sum_{i=n}^{n} \left(x_i - \bar{x}\right)2}{n}}$$

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XIII**, Issue **2** (**December 2014**), pp. **147-152***
*http://dx.doi.org/**10.5775/fg. 2067-4635.2014.036.d***

When the data string is longer than 30 years, *n* is replaced by *n-1*; however, the results does not substantially modify.

According to the obtained values, the years can be classified in nine categories, from exceptionally rainy to exceptionally dry (Table 2).

Table 2 Pluviometric characteristics of months and years according to the SPA values

Characteristic	SPA
Exceptionally rainy	> 2.5
Excessively rainy	2 … 2.5
Very rainy	1.5 … 2
Rainy	1 … 1.5
Normal	1 … -1
Dry	-1 … -1.5
Very dry	-1.5 … -2.0
Excessively dry	-2.0 … -2.5
Exceptionally dry	< -2.5

Source: Gaceu, 2002

Results

Spatial distribution and characteristics of precipitation amounts

The mean annual amount of precipitation in the analysed region undergoes certain patterns in terms of spatial distribution. Generally, it slowly decreases from west to east, at least in the Subcarpathians, and from north to south, due to altitude differences, distance from the mountains and frequency of either moist Atlantic or dry tropical air masses. Thus, the highest amount is registered in the northwestern part, at Apa Neagra (917.2 mm), while the lowest at Bacles, in the south-west (609.7 mm).

The seasonal precipitation amounts enable us to highlight a more detailed assessment of the precipitation patterns in the region. Thus, even if the highest amounts correspond to summer, in the western part, there are reduced differences between seasons, especially between summer and spring (less than 25 mm), each of the seasons representing between 25 and 29% of the annual amount. In the eastern part, due to the reduction of the frequency of humid tropical air masses and increased penetration of dry continental polar air masses, summer represents between 33 and 36% of the annual amount. The lowest amounts are registered in winter and they vary between 118.5 mm in the eastern piedmont area and 204.3 mm in the western Subcarpathians. Consequently, the eastern areas of the studied region are more exposed to dry conditions than the western ones.

Dry conditions are well emphasized by the values of the SPA. Thus, it resulted that normal years (deviations oscillating between -1.00 and +1.00) predominate within the entire analysed region; however, in the eastern part, there are lower percentages compared to the western part (70-74% compared to 64-66%). The second category in terms of highest percentage is that of dry years. There is registered a notable difference between the western and eastern parts of the region, namely in the west the share of dry years oscillate between 10% in the piedmont and 4% in the Subcarpathians, while in the east, 20%, respectively 18% (Fig. 2). However, there was registered only one case of exceptionally dry year (Targu Jiu, 2000), while excessively dry years hold only 2% at each station. In terms of rainy years, the categories rainy, very rainy and excessively rainy hold about 20% in the west and 12% in the east. Thus, the risk by deficit is higher in the east and the risk by excess is higher in the west.

The linear tendency as well as the polynomial tendency of the SPA values is clearly downward in the piedmont area, while in the SubCarpathians, the situation is far more complex (Fig. 2). Thus, the linear tendency is generally neutral, except for the north-western extremity (Apa Neagra), where it is upward, and the polynomial tendency is upward in three cases and downward in one case (Targu Jiu). Even if this station is located in the Subcarpathians, it is placed at the lowest altitude, in a depression largely opened southwards, which favours the penetration of drier tropical or polar air masses.

Changes in the precipitation amounts

According to Mann-Kendall test combined with Sen's slope (Table 3), precipitation trends are quite different. For 56% of the analysed data series, there are registered negative trends, but only four of these are statistically significant at 0.01-0.05 level of significance and seven at 0.1.

At annual level (Fig. 3), the piedmont presents a negative trend, while the rest of the region displays a positive trend, but neither of them is statistically significant.

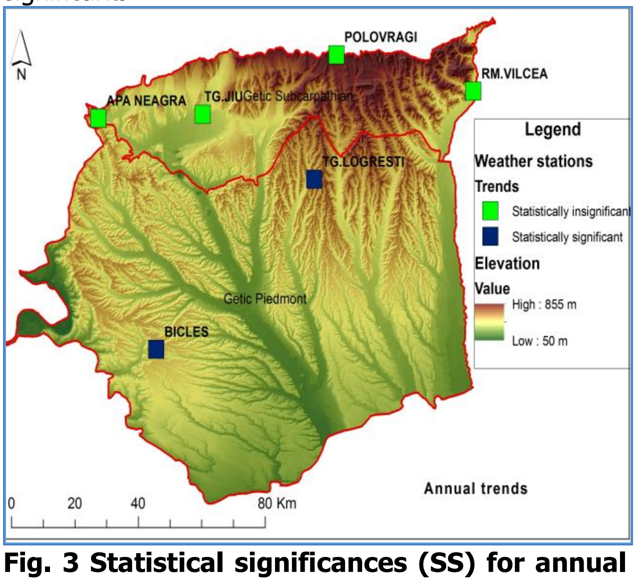
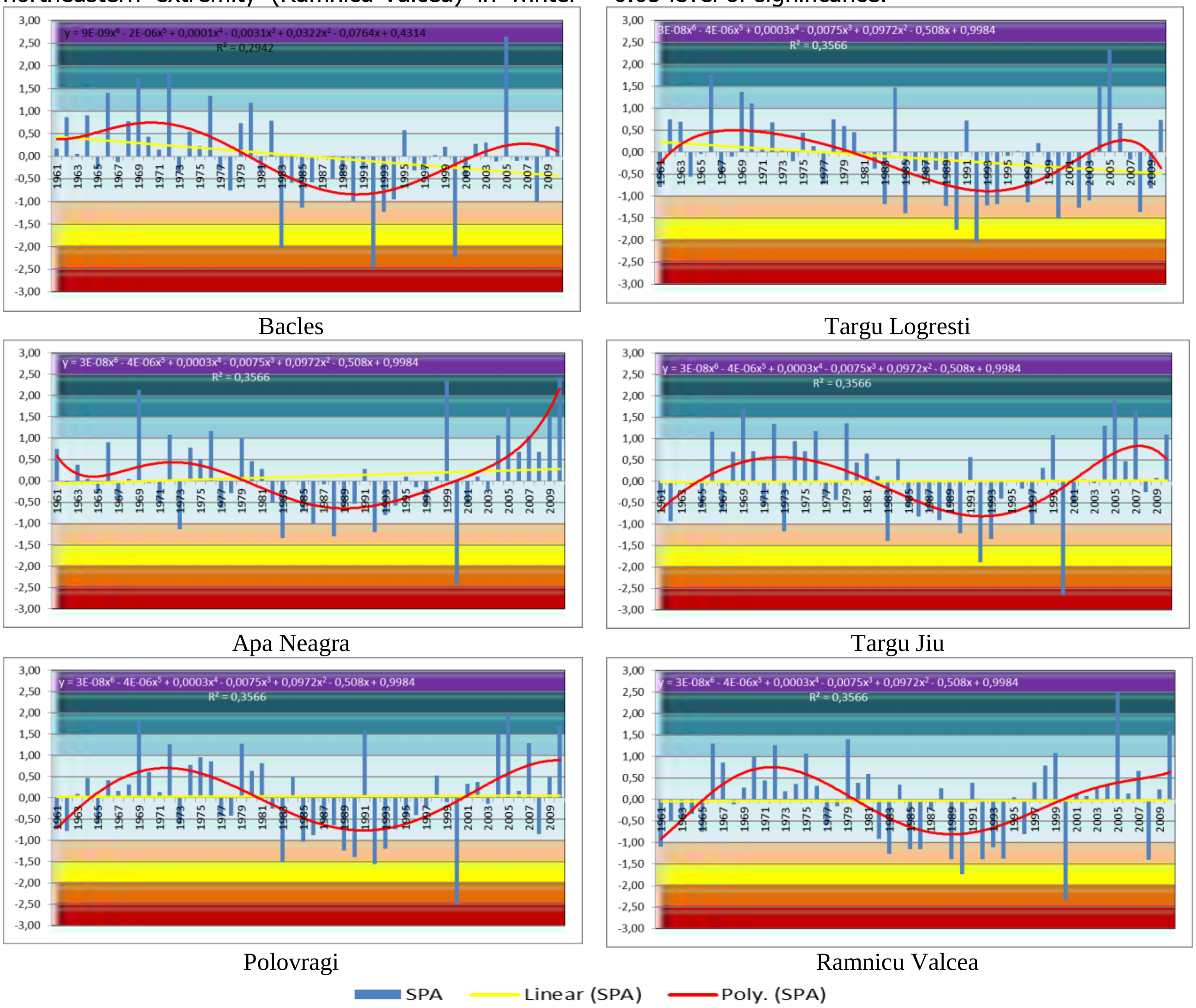


Fig. 3 Statistical significances (SS) for annual precipitation trends within the Getic Piedmont and Subcarpathians, Oltenia Region

In winter half part of the_year, the Subcarpathian area registered an upward trend, while the piedmont area a downward trend (0.1 level of significance). With regard to the summer half of the year, rainfall decrease and downward trends, even though not statistically significant, characterize the entire region.

At seasonal level (Fig. 4), winter and spring display different trends; in the piedmont area, there is a negative trend for both seasons, being more obvious in winter compared to spring, while in the Subcarpathians, trends are downward only in the northeastern extremity (Ramnicu-Valcea) in winter and in the central part for spring (Targu-Jiu). Summer is the season with the most uniform negative trend, which is also statistically significant for the piedmont area (0.01 level of significance), while autumn is the season with the most obvious upward trend, as only the southwestern part of the piedmont undergoes negative values of Sen's slope.

At monthly level, trends are different except for five months. Thus, uniform negative trends are registered in February, May and November, while positive trends in September and October. In the piedmont area, May registers a downward trend at 0.05 level of significance.



SPA values	Categories	Legend
> 2.5	exceptionally rainy	
2 ... 2.5	excessively rainy	
1.5 ... 2	very rainy	
1 ... 1.5	rainy	
1 ... -1	normal	
-1 … -1.5	dry	
-1.5 … -2	very dry	
-2 … -2.5	excessively dry	
< -2.5	exceptionally dry	

Fig. 2 SPA values, the linear and polynomial trend

Forum geografic. Studii și cercetări de geografie și protecția mediului
*Volume **XIII**, Issue **2** (**December 2014**), pp. **147-152***
*http://dx.doi.org/**10.5775/fg. 2067-4635.2014.036.d***

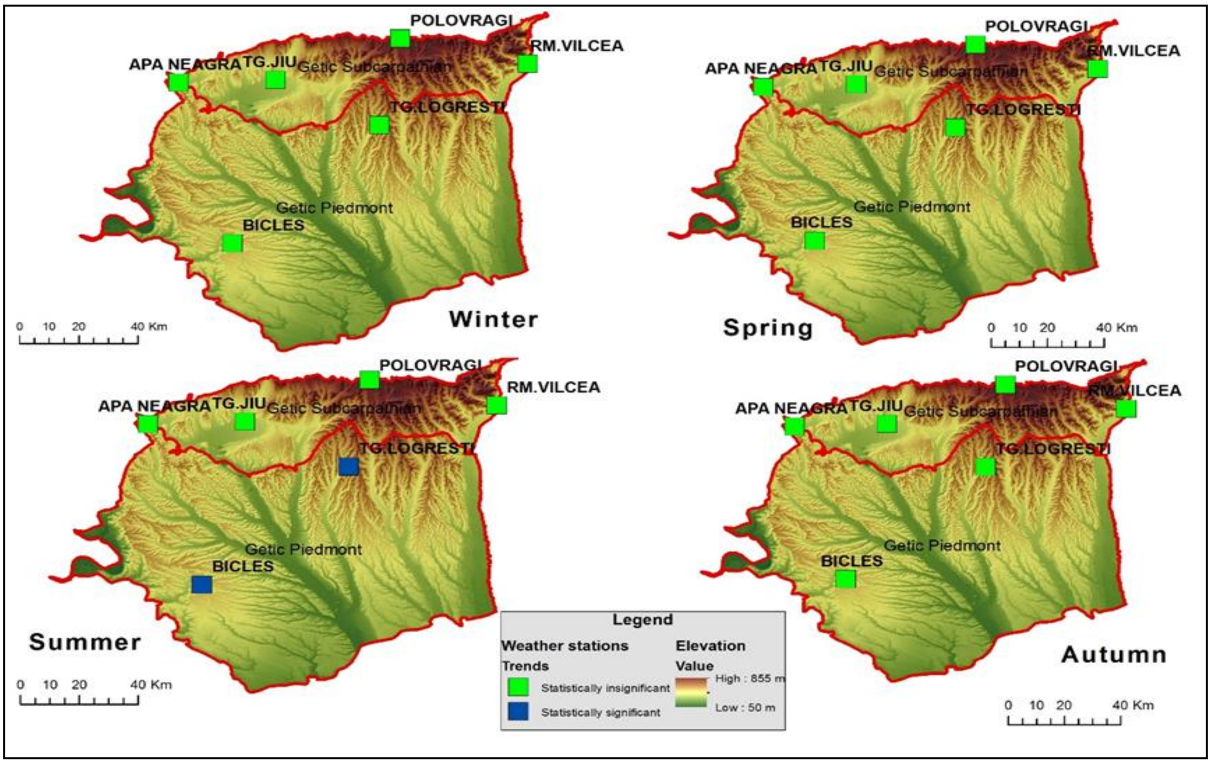


Fig. 4 Statistical significances (SS) for seasonal precipitation trends within Getic Piedmont and Subcarpathians, Oltenia Region

Table 3 Test Z, statistical significances (SS) and Sen's slope estimate (Q) for precipitation trends within the Getic Piedmont and Subcarpathians, for the 1961-2010 period

Period	Bacles			Tg. Logresti			Apa Neagra			Tg. Jiu			Polovragi			Rm. Vilcea		
	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q	Z	SS	Q
J	-0.43		-0.100	0.14		0.052	-0.11		-0.037	-0.10		-0.033	-0.11		-0.037	0.36		0.064
F	-1.64		-0.393	-1.79	+	-0.504	-0.98		-0.435	-1.56		-0.491	-0.98		-0.435	-1.46		-0.304
M	-1.56		-0.373	-0.99		-0.227	0.01		0.010	-0.75		-0.237	0.01		0.010	-0.46		-0.092
A	-1.10		-0.288	-1.47		-0.317	0.42		0.205	-0.45		-0.136	0.42		0.205	0.02		0.003
M	-1.97	*	-0.650	-2.17	*	-0.720	-0.03		-0.018	-1.15		-0.441	-0.03		-0.018	-1.10		-0.469
J	-0.75		-0.288	-0.59		-0.333	0.70		0.380	0.18		0.082	0.70		0.380	0.42		0.237
J	-0.39		-0.222	0.43		0.205	-0.05		-0.024	1.09		0.431	-0.05		-0.024	-1.01		-0.443
A	-0.10		-0.045	1.30		0.497	0.69		0.227	0.54		0.283	0.69		0.227	1.05		0.528
S	1.53		0.483	1.49		0.450	1.48		0.767	1.79	+	0.812	1.48		0.767	1.42		0.591
O	1.25		0.394	0.14		0.052	0.40		0.229	0.87		0.342	0.40		0.229	1.22		0.490
N	-0.92		-0.285	-1.79	+	-0.504	-0.53		-0.247	-0.85		-0.285	-0.53		-0.247	-0.68		-0.260
D	-0.03		-0.010	-0.99		-0.227	0.44		0.311	0.28		0.121	0.44		0.311	0.85		0.322
WH	-1.82	+	-1.855	-1.81	+	-2.967	0.37		0.792	0.17		0.329	0.37		0.792	-0.05		-0.075
SH	-1.24		-1.350	-1.05		-1.123	-0.50		-0.747	-0.99		-1.057	-0.50		-0.747	-0.32		-0.250
W	-1.32		-1.256	-0.82		-0.978	1.01		1.564	0.67		0.830	1.01		1.564	-0.08		-0.125
S	-0.72		-0.450	-1.05		-0.562	0.39		0.414	-0.34		-0.298	0.39		0.414	-0.12		-0.082
S	-2.98	**	-1.533	-2.71	**	-1.489	-0.20		-0.164	-1.64		-0.933	-0.20		-0.164	-1.17		-0.700
A	-0.64		-0.468	0.31		0.333	1.04		1.400	1.05		1.244	1.04		1.400	0.42		0.353
Annual	-1.82	+	-1.855	-1.81	+	-2.967	0.37		0.792	0.17		0.329	0.37		0.792	-0.05		-0.075

*** if trend at α = 0.001 level of significance; ** if trend at α = 0.01 level of significance; * if trend at α = 0.05 level of significance; + if trend at α = 0.1 level of significance

Synthetizing the results, generalized downward trends characterize only four data series and upward trends only two data series. It should be noted that the piedmont area, with dominant agricultural land use, shows the highest summer precipitation decrease. Moreover, February-May interval, when the water reserve in the soil is highly important for plant germination and growing, also presents negative trends, stressing the water deficit characteristic to the summer period.

Conclusion

Climate signals, in this case precipitation signals, related to trends greatly depend on the considered time interval and the density of stations used for the analysis. Thus, the SPA values clearly indicate the predominance of normal years (deviations between -1.0 and + 1.0). However, the piedmont area, as well as the eastern part of the Subcarpathians, registered higher percentages of dry years and seemed to be more exposed to the risk by deficit. In the piedmont area, the linear tendency of both annual precipitation amounts and SPA values is downward, indicating a change of the precipitation regime.

According to Mann-Kendall test combined with Sen's slope, negative trends predominate, but their statistical significance is relevant in only 11 out of the total of 114 datasets, 10 of these in the southern piedmont area. Thus, at annual level, it was emphasized the downward trend for the piedmont area only. At seasonal level, summer underwent a generalized decrease and an obvious negative trend for the entire region; however, the results for the southern piedmont area are also statistically significant. At monthly level, the most significant and generalized negative trend is registered in May and February, while for positive trends we mention September and October.

REFERENCES

Brunetti M., Colacino M., Maugeri M., Nanni, T. (2001a), *Trends in the daily intensity of precipitation in Italy from 1951–1996*, International Journal of Climatology, 21, pp. 299–316

Brunetti M., Maugeri M., Nanni T. (2001b), *Changes in total precipitation, rainy days and extreme events in northeastern Italy*, International Journal of Climatology, 21, pp. 861–871

Brunetti M., Buffoni L., Maugeri M., Nanni T. (2006), *Temperature and precipitation variability in Italy in the last two centuries from homogenised instrumental time series*. International Journal of Climatology, 26, pp. 345–381

Cheval, S., Croitoru, Adina-Eliza, Dragne, Dana, Dragotă, Carmen, Gaceu, O., Patriche, C.-V., Popa, I., Teodoreanu, Elena, Voiculescu, M., (2003), *Indici şi metode cantitative utilizate în climatologie*, Editura Universităţii din Oradea, Oradea;

Croitoru Adina Eliza, Toma Florentina Mariana (2010), *Trends in precipitation and snow cover in central part of Romanian Plain,* Geographia Technica, Volume 05, Issue 1/2010, pp. 1-11

Croitoru, A.E., Drignei, D., Holobaca, I.H., Dragota, C.S. (2011a), *Change-point analysis for serially correlated summit temperatures in the Romanian Carpathian.* Theor. Appl. Climatol.

Croitoru, A.-E., Holobaca, I.-H., Burada, C., Moldovan, F. (2011b). *Sunshine duration in Western Romania Plain.* Collegium Geographicum, 8, Special Edition, Proceeding Book, Energia Transylvaniae, International conference on Solar, Wind and Bioenergy, Abel Publishing House Cluj-University press, 51-57

Diaz H.F., Bradley R.S., Eischeid J.K. (1989), *Precipitation fluctuations over global land areas since the late 1800s*, Journal of Geophysical Research, 94, pp. 1195–1210

Dumitraşcu, Monica, Dumitraşcu, C., Douguédroit, Annick, (2001), *Seceta şi impactul ei asupra mediului în Câmpia Olteniei*, Revista Geografică, T. VII, Serie nouă, Academia Română, Institutul de Geografie, Bucureşti, p. 166-172;

Gaceu, O., (2002), *Elemente de climatologie practică*, Edit. Universităţii din Oradea, Oradea;

Hulme M. (1995), *Estimating global changes in precipitation*, Weather, 50, pp. 34–42

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

Klein Tank A.M.G., Können G.P. (2003), *Trends in indices of daily temperature and precipitation extremes in Europe*. J. Clim., 16, pp. 3665-3680

Micu, D., Micu, M. (2006). *Winter temperature trends in the Romanian Carpathians – a climate variability index.* AUVT-Geogr. XVI, 33-42.

Micu, D. (2009), *Snow pack in the Romanian Carpathians under changing climatic conditions.* Meteorol. Atmos. Phys., 105, 1-16.

Mudelsee M., Börngen M., Tetzlaff G., Grünewald U. (2003), *No upward trends in the occurrence of extreme floods in central Europe*, Nature, 425, pp. 166–169

New M., Todd M., Hulme M., Jones P. (2001), *Precipitation measurements and trends in the twentieth century*, International Journal of Climatology, 21, pp. 1899–1922

Norrant C., Douguedroit A. (2006), *Monthly and daily precipitation trends in the Mediterranean (1950–2000)*, Theoretical and Applied Climatology, 83, pp. 89–106

Piticar A., Ristoiu D. (2012), *Analysis of air temperature evolution in northeastern Romania and evidence of warming trend*, Carpathian Journal of Earth and Environmental Sciences, November 2012, *Vol. 7*, *No. 4*, p. 97 - 106

Piticar A., Ristoiu D. (2013), *Spatial distribution and temporal variability of precipitation in northeastern Romania,* Riscuri si catastrofe, nr. XII, vol. 13, nr. 2/2013, pp. 35-46

Rodrìguez-Puebla C., Encinas A.H., Nieto S., Garmendia J. (1998), *Spatial and temporal patterns of annual precipitation variability over the Iberian Peninsula*, International Journal of Climatology, 18, pp. 299–316

Salmi, T., Määttä, A., Anttila, P., Ruoho-Airola, T. & Ammell, T., 2002. Detecting trends of annual values of atmospheric pollutants by the Mann-Kendall test and Sen's slope estimates – the Excel template application MAKESENS. *Publications of Air Quality No. 31*, Report code FMI-AQ-31, http://www.fmi.fi/kuvat/MAKESENS_MANUAL.pdf.

Tomozeiu R., Stefan S., Busuioc A. (2005), *Winter precipitation variability and large-scale circulation patterns in Romania,* Theor. Appl. Climatol., 81, pp. 193-201

Vlăduț Alina, Onțel Irina (2013), *Summer air temperature variability and trends within Oltenia Plain,* Journal of the Geographical Institute "Jovan Cvijic" SASA, Vol. 63/ no.3 DOI: 10.2298/IJGI1303371V. UDC: 551.524. pp. 371-381