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The Palmer Drought Severity Index (PDSI) as an indicator of soil moisture

J. Mika [a,*], Sz. Horváth [b,1], L. Makra [b], Z. Dunkel [a]

[a] *Hungarian Meteorological Service, Budapest Observatory, P.O.Box 39, H-1675 Budapest, Hungary*
[b] *Department of Climatology and Landscape Ecology, University of Szeged, P.O.Box 653, H-6701 Szeged, Hungary*

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Abstract

Detailed observation of soil moisture time series has of practical importance either in strategic preparing of researches or in professional planning. Meteorological-related spatial and temporal connections of soil moisture were investigated on monthly Palmer Drought Severity Index (PDSI) time series of five meteorological stations in Eastern Hungary (Miskolc, Nyíregyháza, Debrecen, Kecskemét and Szeged) for the period 1901–1999. The calculated PDSI values were compared with the soil moisture content of the upper one meter soil layer. The measured soil moisture time series come from the authors ([Dunkel, Z., 1994; Lambert, K. et al., 1993 (in Hungarian)]). Both the used soil moisture time series and the Pálfai-index, expressing numerically daily hydrological extremes ([Pálfai, I.,1991]), confirmed our result independently of each other according to which PDSI is a good indicator of the soil moisture fluctuations in the upper one meter soil layer of the Great Hungarian Plain. On the basis of the regression coefficients of the linear connection, the index values can be expressed in physical unit of the water content in the upper one meter soil layer, as well. As a result of our examinations, the index has favourable statistical features; namely, the distribution of monthly samples is normal. Analysing spatial and temporal connections of the varied hydrometeorological relations of the selected region, average spatial and strong temporal correlations were established and these results are functions of intra-annual variability of precipitation.

1. Introduction

Significant hydrological extremes are frequently observed in Hungary, especially at the eastern part of the Great Hungarian Plain.

The total area inclined to be flooded by inundation is almost 60% of the cultivated lands of the Great Hungarian Plain (Pálfai, 2000). The other hydrological extreme, drought occurs about as similar frequency as inundation but can afflict several times larger region than that in the Great Hungarian Plain (Pálfai, 2000).

Recently, drought is a threatening global and local problem. Currently, indirect characteristic features of soil moisture time series namely drought indices are widely used, by the help of which spatial and temporal extent and severity of drought can be determined (Palmer, 1965; McKee et al., 1995; Edwards and McKee, 1997; Hayes, 1997; Guttmann, 1998; Hayes et al., 1999; Hayes, 2000). Indices used in Hungarian drought researches are suitable to reveal spatial differences of drought, to compare various years considering drought, to determine probabilities of drought (Pálfai, 1991), to perform relation analyses and to make forecasts, too (Koppány, 1994; Koppány and Csikász, 1994; Koppány and Makra, 1995; Koppány et al., 1996). The various indices represent some aspects of drought adequately.

* Corresponding author. Tel.: +36 1 346 48 05; fax: +36 1 346 48 09.
E-mail addresses: mika.j@met.hu (J. Mika), makra@geo.u-szeged.hu, lupo@geo.u-szeged.hu (L. Makra), dunkel.z@met.hu (Z. Dunkel).
[1] Present address: Ministry of Environment and Water Hungary, Environmental Policy and Impact Assessment Department, 1027 Budapest, 2 Fekete Sas, Hungary.

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However, since the phenomenon is complex, during an analysis use of two or more indices is suggested concurrently (Faragó et al., 1988).

In this study drought is defined as a meteorological anomaly, characterised with a long and abnormal lack of precipitation. In order to study the 20th century spatial and temporal changes of soil moisture content, time series of the palmer drought severity index (PDSI) (Palmer, 1965), which are based on meteorological and soil moisture content data, were analysed by several variable methods.

We are looking for answers for the following questions:

- Is the seasonal and locational independence of the PDSI, originally elaborated for North America, valid in the Great Hungarian Plain, too?
- Can the distributions of the monthly PDSI data sets be considered as normal ones?
- Have the PDSI series got significant correlation to parallel independent estimations of the soil moisture content, according to which the index can be reliably interpreted as a soil moisture indicator?
- Do the PDSI anomalies show regional differences or definite structures in the examined region of Eastern Hungary?
- Until what time-lag is the autocorrelation, coming from the recursive definition of the PDSI, significant?

2. Data and the selected region

2.1. Data

Recently, the most widely used drought index is the drought severity index developed by Palmer in 1965 (Briffa et al., 1994; Scian and Donnari, 1997; Cook et al., 1999) contrary to the fact that some limits of using the index are also realized (Alley, 1984; Kogan, 1995; Guttmann, 1998). PDSI is also suitable for detecting spatial and temporal differences of drought periods in Hungary (Bussay and Szinell, 1996; Mika, 1998; Domonkos et al., 2000, 2001; Horváth, 2002; Makra et al., 2002). Detailed description of the fairly complex calculation the Palmer index consisting of five steps is published in several journals (Palmer, 1965; Alley, 1984; Karl, 1986). PDSI is such an index of meteorological drought, values of which are calculated on the basis of precipitation and temperature data of the actual and preceding periods, as well as the available soil moisture content. According to Palmer (1965), the range of the monthly index time series is between −4 and +4. Negative (positive) PDSI values indicate dry (wet) periods, while those near zero presume a state near the average.

When calculating PDSI values, it is an important step to choose partly the formula of the potential evaporation and partly the reference plant. For calculating the potential evaporation, Palmer used the Thornthwaite-formula in the index (Thornthwaite, 1948); however, later the use of the Blaney–Criddle method gave better assessments (Alley, 1984). Hence, monthly values of the index were calculated with both methods for the investigated five stations in Eastern Hungary (Miskolc, Nyíregyháza, Debrecen, Kecskemét and Szeged) for the period 1901–1999. When applying the Blaney–Criddle method, maize was used as reference plant since, on the one hand, it is characteristic for the investigated region and, on the other hand, on the basis of its quickly growing leaf surface, maize is similar to several other cultivated plants, considering its evaporation.

Input data sets of mean temperature and the monthly precipitation total are inhomogeneous owing to transfer of stations and other factors. Consequently, the Hungarian Meteorological Service performing observations and data storage found it necessary to complete statistical homogenisation of monthly temperature and precipitation data sets (Szentimrey, 1999). The bases of our calculations were the homogenised monthly data sets. When calculating PDSI, basis of determining the humidity anomaly index were the precipitation anomalies for the period 1901–1980. In this period, monthly averages of PDSI values were zero.

For the investigated five stations the water capacity was uniformly supposed to be 150 mm. This value is the lower threshold of water capacity belonging to various soil types found in the examined eastern Hungarian region. This threshold value presumes a soil type of a medium water holding capacity (Stefanovits, 1975).

Results can be influenced by differences in calculating of potential evaporation, similarly to the inhomogeneity of the input meteorological parameters. Hence, before starting detailed analysis, correlation coefficients partly between homogenised monthly PDSI data sets calculated with Thornthwaite- and Blaney–Criddle methods, and those partly between homogenised and non-homogenised monthly PDSI data sets calculated with Blaney–Criddle method were determined (Table 1).

The extremely high and positive correlation coefficients, each significant at the 5% probability level, indicate that neither the different methods nor the homogenisation of the data sets influence the PDSI values. Therefore, the statistical examinations were performed on the basis of the evaporation data calculated with the Blaney–Criddle formula and the PDSI values based on homogenised meteorological parameters.

The calculated PDSI values were compared to the soil moisture content of the upper one meter soil layer. For this reason, soil moisture assessment time series of Dunkel (1901–1990) (Dunkel, 1994) and those of Bussay

Table 1
Correlation coefficients partly between homogenised monthly PDSI data sets calculated with Thornthwaite-(Th) and Blaney–Criddle (BC) methods, and partly between homogenised and non-homogenised monthly PDSI data sets calculated with Blaney–Criddle method, 1901–1999

Method	Settlement				
	Miskolc	Nyíregyháza	Debrecen	Kecskemét	Szeged
Th–BC	0.91	0.91	0.86	0.86	0.89
BC homog–BC non-homog	0.96	0.98	0.98	0.98	0.98

(1901–1988) (Lambert et al., 1993) were analysed for the settlements of Nyíregyháza, Debrecen and Szeged.

In addition to these parameters, such a version of the Pálfai drought index was calculated and used, which can be determined without corrections of the numerically expressed daily extremes, based only on monthly temperature and precipitation data. This index is indicated by the author as PAI_0 (Pálfai, 1991). The PAI_0 index is a favourite tool of agro-hydrological analyses in Hungary. Its mere disadvantage is that it describes each year only by one value relating to the period from October to next August.

2.2. The selected region

The investigated region is the Hungarian catchment area of the Tisza River (Makra et al., 2002) characterised by high proportionality of managed vegetation. Recently, 74% of its area (36,000 km^2) is cultivated (Mika et al., 2001, 1998). The Hungarian catchment area of the Tisza River exhibits the lowest altitude ca. 100 m above sea level, in the Carpathian Basin. Flood situations are often preceded by high soil moisture content, peeking in inundation, too. This region is also inclined to drought, which causes the most damage in agriculture. Selection of the region is also motivated by the concern on natural protection, since the limited spots still covered by natural vegetation, including the Hortobágy National Park (a site of the UNESCO World Heritage), are threatened by degradation of both climatic and non-climatic, moreover of local and maybe global origin.

3. Methods

Many procedures of the classic one variable and several variable methods of the mathematical statistics are applied in the study. The detailed descriptions of the methods are found in the following subsections.

3.1. Seasonal and locational independence

In principle, PDSI is a characteristic feature of the available water capacity, independent of season and location. However, since empirical constants of the computational procedure were determined for other regions (mainly for continental regions of the USA), it is worth to check whether or not statistical parameters of PDSI are really independent of month and the location for the investigated eastern Hungarian region. For this reason, standard deviations of five stations in the examined region (Miskolc, Nyíregyháza, Debrecen, Kecskemét and Szeged) were compared in each month for the whole period, 1901–1999.

It is not worth to perform the same analysis for the averages, since the basic period of calculating PDSI is the time interval of 1901–1980. Because of this, the difference of the averages includes mostly those between the whole and the basic period, which reflects the effect of the last 19 years. Thus, the difference between the averages indicates whether or not PDSI in the given 19-year long period differed uniformly from its values in the basic period for each month and location.

In order to decide on independence of month, it was examined whether or not there is significant difference between standard deviations of homogenised monthly PDSI values in each settlement calculated with the Blaney–Criddle formula. While in order to decide on independence of the location, standard deviations of monthly homogenised PDSI values between the settlements, calculated with the Blaney–Criddle method, were examined. The F-test was applied for both cases. Independence of month and the location is realized if the difference between the examined standard deviations is statistically not significant; namely, the 0-hypothesis of the tests comes true.

3.2. Tests for normality

In order to detect further statistical characteristics of the PDSI data sets, it is important to perform their normality tests. Hence, normality tests are performed for the whole period between 1901–1999 both with the Kolmogorov–Smirnov (K–S) test and the χ^2-test for the 12 months of the 5 stations as well as the contracted samples, respectively. In addition to the analysis and interpretation of the statistical tests, the so called Normal Probability Plot method and the histograms were used, which provided graphic information in connection with the normal distribution of the monthly data sets of the index.

3.3. Correlation and regression analysis

It was examined that how good indicator is the PDSI of the fluctuation of the available soil moisture content in the plant covered upper one meter soil layer. For this reason, on the one hand, correlation coefficients of the PDSI data sets with soil moisture content data sets of Dunkel (1901–1990) and Bussay (1901–1988) and, on the other hand, those between monthly time series of the PDSI and the Pálfai index (1902–1999) were determined. Regression coefficients were determined between the PDSI and the two-monthly soil moisture content data sets, respectively. These analyses were made for the time series of the stations Nyíregyháza, Debrecen and Szeged.

Regression between soil moisture as dependent variable and PDSI as independent variable, especially since they have close correlation, is suitable for transforming the dimensionless Palmer index into physical unit, as well. Empirical multipliers of this transformation into physical unit show clear annual course. This makes it possible to perform further standardization: dividing the regression coefficient by the standard deviation of the soil moisture content of the given month.

Furthermore, in order to determine the competent one of the assessments of the soil moisture content, 12-monthly correlation and regression coefficients between the soil moisture content time series of Dunkel and Bussay were also calculated for the three settlements and the period 1901–1988.

3.4. Spatial and temporal correlations

Within the small region, PDSI values depend of each other at the different stations. The measure of dependence is interpreted by spatial correlations.

It is interesting to study how much is the role of the surplus or deficiency of soil moisture content, accumulating in the former months, in the PDSI values. This was investigated by the two- and six-monthly autocorrelations between the PDSI time series of the selected settlements.

Both the spatial and the temporal correlations were calculated for the PDSI time series of Miskolc, Nyíregyháza, Debrecen, Kecskemét and Szeged for the period 1901–1999.

4. Results

4.1. Seasonal and locational independence of PDSI

Significant differences of the standard deviations of the 66 month-pairs produced of the 12 months for each station were determined with the help of the F-test (Table 2). According to the results, at the 5% probability level in each of the examined stations, while at the 1% probability level only in three stations of the five such month-pairs were found, standard deviation of which differed significantly from each other. Frequency of such month-pairs is several times higher than chance (3.3 and 0.7 cases per station and threshold). However, one member of the pairs is May and June in each case when the annual precipitation maximum gives higher variability to the standard deviation of the monthly PDSI, as well. If May and June are omitted and the differences of the standard deviations are investigated in all of the possible 45 month-pairs made of the rest 10 month, then we receive that standard deviations for no any month-pairs differ significantly.

Table 2
Significant differences of the standard deviations, homogenised monthly PDSI data sets, calculated with the Blaney–Criddle method, F-test, number of cases

Settlement	Each pair of months		Except May and June	
	5%	1%	5%	1%
Miskolc	8	–	–	–
Nyíregyháza	10	–	–	–
Debrecen	14	6	–	–
Kecskemét	4	1	–	–
Szeged	9	1	–	–
Random ratio	3.3	0.7	3.3	0.7

In order to examine spatial distribution of standard deviations, their rank number was determined in the five stations for each month so that standard deviation signed by the lowest (highest) rank number in a given month was considered to be the lowest (highest) one of the five stations. Afterwards, rank numbers of the standard deviations received for each month of the period 1901–1999 were summarized according to the stations and then the frequency values multiplied by the rank numbers as loadings belonging to them were averaged. In this way loaded sums were received according to rank numbers, which sums are characteristics of the standard deviation of PDSI. Fig. 1. indicates that the monthly standard deviation of PDSI has the greatest stability at Kecskemét (namely, the standard deviation here is the lowest), while it has the lowest one at Miskolc (namely, the standard deviation here is the highest). These differences are generally not significant: at the 5% probability level the calculated value of the F-test exceeded the threshold value only in October, while at the 1% probability level there were no significant differences. (The random ratio for the ten station-pairs and the 12 months had been 1.2 cases.)

4.2. Normality of PDSI

Henceforth, results of the normality tests for empirical distributions of the homogenised PDSI time series, calculated with the Blaney–Criddle method, are summarized (Table 3).

Normality of the PDSI time series, according to the Kolmogorov–Smirnov (K–S) test, is realized both for each of the five stations and the 12/,month (60 cases) at the 5% probability level. When using the χ^2-test, which is a stricter one, then in 50 of the examined 60 months the normality is realized for the distribution

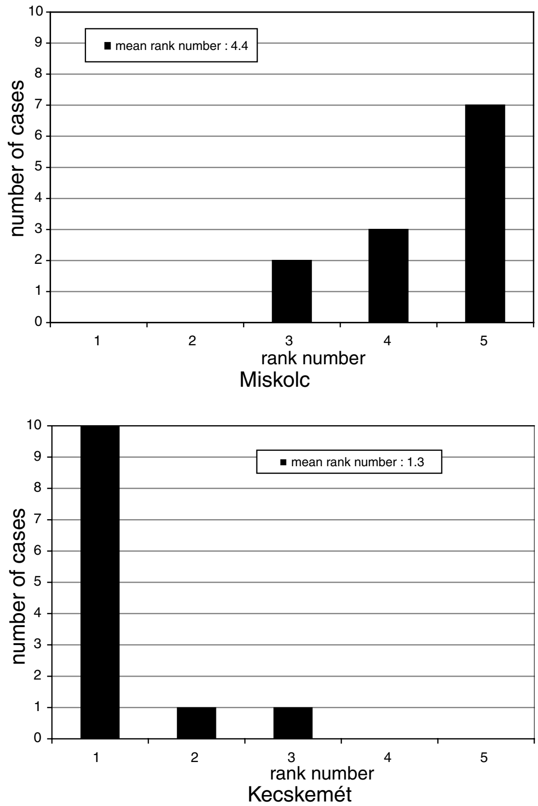

Fig. 1. Distribution of the rank numbers of the standard deviation of the homogenised PDSI data sets, calculated with the Blaney–Criddle method, at Miskolc and Kecskemét. The rank number "1" ("5") indicates the lowest (highest) standard deviation in the given month.

of the PDSI time series at the 5% probability level (Table 3).

In the following, histograms and results of the normality tests performed for partial and whole contraction of stations and months are represented.

Firstly, that case is investigated month by month, where the data sets of all of the five stations are in a joint sample. The reason of it is that there is no significant difference between the standard deviations of the time series. In this contraction, in most cases even the Kolmogorov–Smirnov test, which is not as strict as the χ^2-test, indicates significant differences (namely, the normality of the time series is not realized). On the other hand, the χ^2-test accepts the normality of the distribution only in April. Consequently, though the difference of the standard deviations between the stations is not significant, the contraction basically puts the normality of the joint distribution out of order, however it is mostly realised to the separate distributions of the time series.

If the monthly PDSI values of the investigated 99 years are considered separately at the stations, however they are examined not as monthly but as contracted data sets for the whole year, then normality is realized for none of these data sets. The difference from normality is indicated by the K–S test, while the χ^2-test rejects normality with very high probability.

In addition, if the 99-year 12-monthly PDSI time series of each of the five stations are contracted into one data set, this is neither normally distributed. The reason of the rejection is the same as in the cases before: the very low frequency of values near zero. The degree of rejection is similar according to both tests, as it happened to be in the former case.

4.3. Connection of PDSI with soil moisture content

The homogenised PDSI values, calculated with the Blaney–Criddle method, indicate high correlation with the soil moisture content time series of Nyíregyháza, Debrecen and Szeged computed in two independent ways. The correlation coefficients calculated with the soil moisture content time series of both Dunkel (0.58–0.91), and Bussay (0.27–0.81) are significant at the 5% probability level for each settlement. The correlation coefficients calculated with the soil moisture content time series of Dunkel are higher than those of Bussay for all the investigated stations.

The homogenised PDSI values calculated with the Blaney–Criddle method, are in close correlation not

Table 3
Differences of the distributions of the homogenised PDSI data sets, calculated with the Blaney–Criddle method, from the normal distribution

1901–1999	Test	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Miskolc	K–S	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	χ^2	*7*				*12*					*16*	*10*	
Nyíregyháza	K–S	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	χ^2						**2**	**0.4**	*14*		*8*	**0.5**	*17*
Debrecen	K–S	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	χ^2	**5**	**5**	*6*			**1**	**0.02**	**0.1**	*6*		*8*	*6*
Kecskemét	K–S	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	χ^2			*19*				*11*				*7*	
Szeged	K–S	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	χ^2		*10*					**2**	*6*	**2**			

n.s.: non-significant differences calculated with the K–S (Kolmogorov–Smirnov) test; empty cells: non-significant differences calculated with the χ^2-test; *italics*: the probability of normality $\leqslant$20% and >5%; **bold**: the probability of normality $\leqslant$5%.

only with the soil moisture content time series but with the Pálfai index basic values (PAI_0) in August, too: Nyíregyháza: 0.83; Debrecen: 0.89; Szeged: 0.85.

Original and standardized regression coefficients for the homogenised PDSI values calculated with the Blaney–Criddle method and the soil moisture content time series of Dunkel and Bussay are significant at the 5% probability level. As the original regression coefficients have great variability, the more comparable standardized coefficients are analysed in the following.

The difference in the regression coefficients between, on the one hand, the two soil moisture content time series and, on the other hand, the PDSI reaches its maxima in the summer months, which is especially striking at Szeged (Fig. 2). In April and May the original regression coefficients of Bussay exceed those of Dunkel. However, this difference disappears in the standardized regression coefficients. The reason of it is that the standard deviations of the soil moisture content time series of Bussay differ mostly from those of Dunkel in these months and the Bussay's standard deviations are the higher. The standardized regression coefficients indicate at all of the three stations and the 12 months that for unit change of the homogenised PDSI values calculated with the Blaney–Criddle method the Dunkel's soil moisture content values react more sensitively compared to those of Bussay.

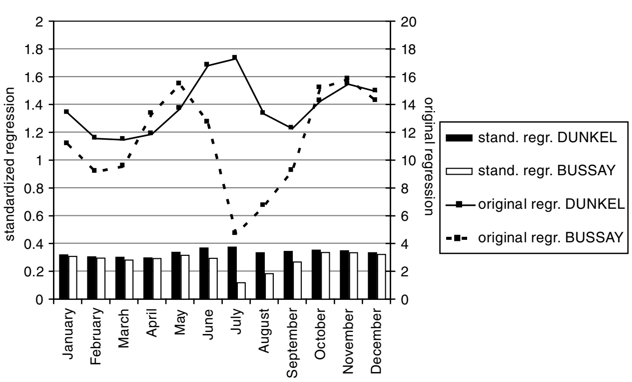

Fig. 2. Original and standardized regression coefficients for the homogenised PDSI values calculated with the Blaney–Criddle method and the soil moisture content time series of Dunkel and Bussay, Szeged.

At Szeged, correlations and regressions between the PDSI and the Bussay's soil moisture content time series are substantially lower in July and August than in the other months (Fig. 2). The question arises, what is the reason of the calculated low values: either the calculating procedure of the PDSI or that of the Bussay's soil moisture content data. In order to answer this, correlation and regression coefficients between the soil moisture content time series of Dunkel and Bussay were determined in each month for the period 1901–1988.

Each of the received correlation and regression coefficients are significant at the 5% probability level. The lowest correlation and regression coefficients were calculated in June, July, August and September for each of the three stations (Nyíregyháza, Debrecen and Szeged). This result indicates that the reason of the strikingly low summer correlations and regressions at Szeged is to be looked for not in the calculating procedure of the PDSI but in the soil moisture content time series of Bussay.

Interpretation of the regression coefficients, lower than one is as follows. The standard deviations of the Dunkel's time series are generally greater than those of Bussay. This is in agreement with the fact that the physical coefficients of the PDSI, calculating with the Dunkel's time series, are larger than those calculating with the Bussay's time series. Since the correlations between the PDSI values and the soil moisture content time series are larger in the most part of the year when using the Dunkel's time series, hereafter the latter one is used as reference time series.

Table 4 represents the calculation method of the homogenised PDSI values computed with the Blaney–Criddle method into physical soil moisture content unit on the basis of the Dunkel's soil moisture content time series. In this way, a clear conversion method is received between the dimensionless PDSI and the physical unit (mm) of the soil moisture content of the upper one meter soil layer. It is evident from Table 4, that unit change of the PDSI indicates different change of the soil moisture content in the different months of the year. The possible interval is between 8 and 19 mm for the Dunkel's time

Table 4
Calculation method of the homogenised PDSI values computed with the Blaney–Criddle method into physical soil moisture content unit on the basis of the Dunkel's soil moisture content time series. $Y = Y_0 + Ky \cdot PDSI$, where Y_0 is the average soil moisture content of the basic period 1901–1980 (the average of the PDSI is zero in each month of the basic period), Ky is the regression coefficient in mm

$Y = Y_0 + Ky \cdot PDSI$	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nyíregyháza: Y_0	155	163	162	158	149	135	107	89	86	97	122	144
Nyíregyháza: K_y	*11.2*	*9.9*	*9.5*	*10.2*	*11.2*	*14.6*	*18.7*	*18.3*	*16.6*	*18.0*	*16.6*	*13.8*
Debrecen: Y_0	154	162	162	158	149	134	103	80	77	89	116	140
Debrecen: K_y	*10.6*	*8.7*	*8.5*	*9.3*	*9.8*	*13.7*	*18.1*	*17.5*	*16.1*	*16.0*	*15.4*	*12.9*
Szeged: Y_0	146	158	161	160	152	134	94	63	58	72	100	129
Szeged: K_y	*13.4*	*11.6*	*11.4*	*11.9*	*13.7*	*16.8*	*17.3*	*13.3*	*12.3*	*14.2*	*15.5*	*14.9*

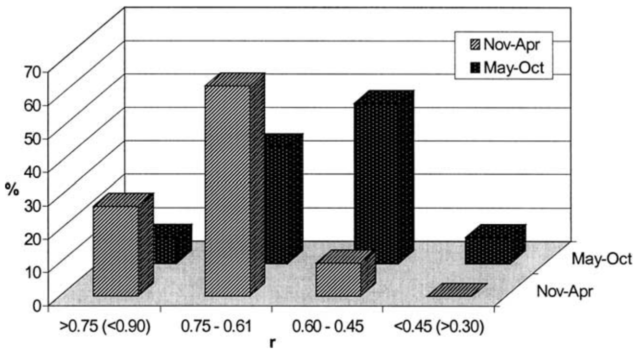

Fig. 3. Ratios of spatial correlations (r) of the homogenised PDSI values calculated with the Blaney–Criddle method, May–October, November–April, five settlements, 1901–1990.

series (and between 5 and 17 mm for the Bussay's time series).

4.4. Spatial and temporal correlations of PDSI

The uniformly positive significant spatial correlations (r = 0.38–0.82) indicate that inclination to drought and inundation in the whole investigated region has spatial variability of meteorological origin. Considering the whole year, correlation coefficients of medium value ($0.45 < r < 0.75$) prevail. Within this interval, the most values in the winter half-year (November-April) are between $0.61 < r < 0.75$, while those in the summer half-year (May–October) are between $0.45 < r < 0.60$ (Fig. 3).

The difference between the winter- and summer half-year spatial correlations is connected by all means with the small spatial extension of convective precipitation in the summer and generally the larger extension of the atmospheric circulation systems in the winter. This result is supported by similar season-dependence of spatial correlations of several other meteorological elements (Czelnai et al., 1976).

Each of both the two- and the six-monthly autocorrelations of the PDSI is significant at the 5% probability level. The great correlation coefficients are consequences of the recursive definition used to the calculation of the PDSI. Namely, soil moisture content both two- and six months earlier influences the actual monthly soil moisture content significantly.

5. Conclusion

Results are summarized as follows.

- Locational independence of PDSI is realised for the monthly values of the five stations in the Great Hungarian Plain. Seasonal independence of PDSI is only partly realised in the Great Plain.
- When putting the index values of both the five stations and the twelve months into one sample, distribution of the PDSI differs significantly from the normal one in all of the three cases. The main reason of this result is the rare occurrence of the near-zero values. On the other hand, when analysing the PDSI sets of each station and month separately, then, according to the Kolmogorov–Smirnov test, distributions of all the $5 \times 12 = 60$ samples are normal; while, according to the χ^2-test, distributions of only ten samples are not normal at the 95% probability level.
- The PDSI, as a standardised index without unit, has a close relation with the two (Dunkel's and Bussay's) calculations of the monthly soil moisture content, as well as with the Pálfai-index. The index values can be expressed in physical unit of the water content of the upper one meter soil layer. Hence, unit increase of the PDSI, corresponds to 8–19 mm surplus according to the Dunkel's, and 5–7 mm surplus concerning the Bussay's soil moisture content, respectively, depending also on season and place.
- The values of the significant spatial correlation coefficients calculated for the 10 station-pairs of the five stations and the 12 months are between 0.38–0.82. From November to April all vales exced 0.6, while from May to October they are lower than the winter values. The results clarify that the inclination to drought and inundation has spatial variability of meteorological origin.
- The high autocorrelation, coming from the recursive definition of the PDSI, remains significant even at the time difference of two (0.7–0.9) and six months (0.3–0.7). Within these ranges, the somewhat lower values of the autocorrelation in the summer half-year come from the higher variability of convective precipitation.

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