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PROBABILISTIC REGIONAL METEOROLOGICAL DROUGHT ANALYSIS WITH STANDARDIZED PRECIPITATION INDEX AND NORMAL PRECIPITATION INDEX METHODS IN GEOGRAPHIC INFORMATION SYSTEMS ENVIRONMENT: A CASE STUDY IN SEYHAN BASIN

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ABSTRACT

Drought indices are useful tools to characterize and monitor drought conditions in a region. Primary objectives of this research were to: 1) develop regional meteorological drought maps of 5- and 10-year return periods by using drought indices of *Standardized Precipitation Index (SPI)* and *Percent of Normal Index (PNI)*, 2) investigate changes in drought classes by the methods used. Long-term (1950-2006) annual and monthly precipitation series of 63 meteorological stations located in the Seyhan River basin of Turkey were utilized in the study. Because the SPI method does not allow missing data in precipitation series, data were completed by regression analysis through utilizing nearby station's data. Frequency analysis was performed on *SPI* series of monthly data calculated for 12-month time-scale and annual total precipitation series. The most suitable probability distribution models for the series were determined by *Kolmogorov-Smirnov* goodness-of-fit test at 5% significance level. *SPI* of 5- and 10-year recurrence intervals and yearly precipitation amounts with 2-, 5- and 10-year return periods for each station were determined from probability distribution models. *PNI* of 5- and 10-year return periods were calculated, too. Maps of *SPI* and *PNI* values with return period of 5- and 10-year were generated by using *Ordinary Co-kriging* interpolation technique. Drought classes of *SPI* with a given return period did not generally match up with *PNI* drought classes. Drought with return period of 10-year or over would be evaluated as potentially risky in Seyhan Basin. Droughts by *SPI* were less influenced from mean precipitation fluctuations compared to *PNI.*

KEYWORDS:
Seyhan Basin, *SPI, PNI*, Recurrence Interval, Drought

INTRODUCTION

According to the assessments of the Intergovernmental Panel on Climate Change (IPCC), hot weather fluctuations, forest fires, drought, extreme precipitations, tropical storms and reductions in agricultural production are among the possible hazards to consider in the 2030s [1]. As the world's average surface temperature increases, the variation of humidity, temperature, and falling precipitation in many areas is considered the largest indicator of climate change [2, 3, 4]. Associated with climate change, the frequency of natural disasters such as floods, droughts, hurricanes etc. tends to increase during observation periods. Drought incidents are considered to be the most primary natural disaster when the criteria such as severity of natural disasters, their duration of occurrence, economic loss, social effect and permanence are taken into account [5, 6].

Total amount of precipitation depth falling during a given period is classified in severe drought for a region although it can be classified in extremely wet for the other area. In regions of high precipitation average, if the average precipitation for a certain period of time is lower than the long-term average precipitation, this natural phenomenon is defined as the drought for that specific region [7, 8]. Although various drought definitions are available in the literature, an ordinary meaning of drought is a natural phenomenon that causes the water resources to be adversely affected and the hydrological balance to be impaired by a significant reduction in the normal levels of precipitation [9]. Due to the fact that the definition of drought depends upon lots of parameters such as duration-intensity-severity-frequency-area etc., it makes difficult to explain the drought identification with one parameter and/or aspect. Therefore, four different types of drought have been described: 1) meteorological or climatological drought which indicates a gradual or

sharp decrease in available water resources of the region because precipitation amounts remain well below the normal precipitation, 2) agricultural drought which is typically evident after long-term meteorological drought resulting in insufficient soil moisture to meet the needs of plant development, 3) hydrological drought which is the result of meteorological and agricultural droughts, causing a reduction in average soil water content, a decrease in stream discharge rates, reservoir volumes, storages of aquifers, runoff volumes etc., 4) socioeconomic drought which is accepted as the final step of meteorological, agricultural and hydrological drought. Accordingly, socioeconomic drought is exposed when the demand for an economic good exceeds supply as a result of a weather-related deficit in the water supply [1, 7, 10, 11, 12].

When annual precipitation changes in recent years are considered in Turkey; the years of 1971-1974, 1983-1984, 1989-1990, 1996, 1998, 2001, 2007-2008 and 2013-2014 were reported as the worst drought incidents prevailed in Turkey [13, 14]. In the coming years, in terms of precipitation, a warmer, drier and more risky climate has been expected in Turkey [1, 15]. Drought risk can be prevented through implementing drought management principles, strategies, policies, required legislation, inter-institutional coordination, and adopting database organization and good management of water resources in arid periods [16, 17]. Drought incidents are unlike natural disasters such as earthquake, flood, etc. Thus, while taking preventive precautions against drought, it should be kept in mind that it is not possible to momentarily monitor the formation of any drought event. This is known as the insidious character of drought, causing rather high damages compared to other natural disasters [18, 19]. Therefore, time of occurrence of drought is uncertain; furthermore, areal extent, duration and severity of any drought event are also important [20] to characterize. So as to provide quantitative information on frequency, duration and severity of droughts, it is necessary to monitor spatial and temporal variations of the climate in a region [10]. More than 100 drought indices have been developed for drought characterization for specific regions. However, each method has the limitation of use under different climatic conditions, strengths as well as weaknesses. With the help of index calculated and threshold values specific for the methods, important information can be derived on the magnitude, severity, frequency and areal extent of the drought [21, 22, 23]. Calculation of *Standardized Precipitation Index (SPI)* and *Percent of Normal Index (PNI)* developed to monitor meteorological drought are based on only precipitation data; these two indices do not consider other variables such as temperature, humidity, evaporation etc. that can influence drought severity [24, 25, 26, 27, 28].

In the southern and western regions in Turkey, mean temperatures are liable to increase, and precipitation amounts are contrarily in a decreasing trend. Projections on climate indicate that drought will probably become a part of our life in our country which is located in semi-arid climate zone [10, 13]. For example, in Seyhan River Basin, one of the important river basins located in the southern parts of Turkey, it has been estimated that there will have been 30-35% decrease in precipitation [29] and 2.0-3.5 ºC increase in air temperature by the year of 2070. As understood from these results, this is a precursor of more severe dry periods in the basin in the near future [7]. This will worsen more and more the living conditions in the basin situated at the mild and moderate boundary of the Mediterranean belt. For this reason, it will be beneficial to estimate as well as to know probabilities of various classes of drought indexes [30]. In fact, delineation of drought-prone areas based on different recurrence intervals in a basin is needed by decision makers and water managing authorities [31] in order to allocate limited water resources to water demanding sectors in drought periods. Studies on PNI and delineation of its areal extent are of paramount importance because PNI has a direct relation with precipitation occurrence in relation to principal crop growth stages in agriculture. For example, threshold precipitation values which are indicative of *"normal and over"* (PNI>85%) and *"emergency situation"* (PNI <65%) were studied and mapped for Seyhan River Basin by [16]. In drought analysis, not only drought severities but also time steps, i.e. 3-, 6-, 9-month etc., must be considered. Drought severity for a determined drought index is an important task to achieve. However, quantification of probability level of any drought is of importance because drought forecast should reflect its inherent uncertainty, too. On the other hand, extent of droughts at different probability levels, therefore inflicted damage due to drought, can be depicted in detail by maps generated with different interpolation techniques in geographical information system platform. These maps may be used by decision makers, practitioners and end users to attain tangible and objective results in relation to drought mitigation measures at the catchment level. The specified objectives of this study are two-fold: (1) to obtain recurrent probable regional meteorological drought maps of 5- and 10-year return periods by using the SPI and PNI methods of the annual precipitation series, (2) to investigate whether there are discernible differences in the spatial distribution of drought categories (or classes) defined by SPI and PNI indices at the same return period.

MATERIALS AND METHODS

Materials. This study was carried out in the Seyhan River Basin in the eastern Mediterranean region, covering a total surface area of 21 470 km². Study area is geographically located between 36°33'-39°12' N latitudes and 34°24'-36°56' E longitudes. Long-term (1950-2006) monthly and annual precipitation series observed in 63 meteorological stations scattered inside and nearby the Seyhan River Basin border were utilized in the study (Figure 1). Precipitation data were officially obtained from Turkish State Meteorological Service (TSMS) and elevation data were obtained through digitizing topographical maps of 1 to 100 000 and 1 to 250 000 scale, then *Digital Elevation Model (DEM)* map of 250 m by 250 m resolution were generated so as to use in co-kriging estimations as a probably secondary-data.

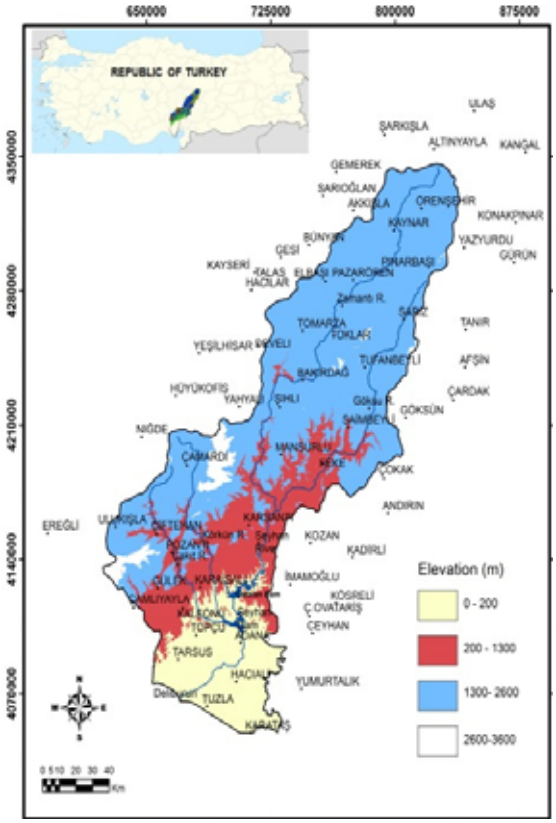


FIGURE 1
Location of the study area

Regression analysis. In order to make reliable estimations from frequency analysis, it is generally accepted that data used in the analysis should involve at least 15 samples of random character [32]. For this reason, the linear, quadratic and cubic polynomial regression models given in Equation 1 were used to extended incomplete monthly precipitation (P) and annual precipitation series. To this end, if there is a missing data in the precipitation series of any meteorological station, then coefficients in Equation 1 have been determined exclusively for the station in question at every turn. As such, correlations between the considered station and nearby stations have been evaluated, and in principle, the station with the highest correlation was chosen in order to estimate missing data. However, location of station, station attitude as well as latitude, concurrence of observations in the stations and distance between stations were taken into consideration in correlation analysis. In order to determine the representative regression model in Equation 1 and corresponding regression coefficients, MINITAB and SPSS statistical package programs were employed and following the method specified by [33, 34]. Determination coefficient (R^2) and ANOVA results of the models were assessed in choosing the best regression model.

$$\left.\begin{aligned} P &= b_0 + b_1 X + e \\ P &= b_0 + b_1 X + b_2 X^2 + e \\ P &= b_0 + b_1 X + b_2 X^2 + b_3 X^3 + e \end{aligned}\right\} \quad (1)$$

Where P is the dependent variable; X is the independent variable; b_i are the regression coefficients; e is the error term.

Standardized precipitation index (SPI). The *Standardized Precipitation Index (SPI)* method, which converts the precipitation amounts into a single numerical value to classify droughts in regions with different climates, was developed by McKee et al. in 1993 [24]. The SPI is able to quantify the precipitation deficits for different timescales, i.e. originally three, six, twelve, twenty-four and fourth-six-month time-scales. In the studies related to meteorological, agricultural and hydrological drought, 3-, 6-, 12-, 24-, 48- and 72-months timescales of drought have been calculated and used for practical purposes. The SPI is, per se, a standardized, i.e. normalized, form of monthly precipitation values based on time-scales considered. In this regard, the SPI series for any timescale can be obtained through using Equation 2. However, details of the SPI computation can be found in [35]. For the hydrological assessments, a time-scale of 12-month has been used in practice. In this study, twelve-month time scale was chosen in order to render SPI results comparable with *Percent of Normal Index (PNI)*, and SPI values for the 12-month period (from January to December) of the long-term monthly precipitation series were calculated by "*SPI_SL_6.exe*" program developed by [36]. Then, only SPI values corresponding to the month of January were chosen for frequency analysis. In so doing, at least 15 SPI values for 12-month time-scale were obtained each station in Figure 1. Drought severities were categorized by [24] as shown in Table 1. The period with consistently negative SPI values is defined as the dry period. The severity of drought is proportional to the value

of SPI as seen in drought classes in Table 1. Positive SPI values is an indication of drought-free periods such as normal or wet [23, 27, 28, 37].

$$SPI_{ij} = \frac{X_{ij} - \mu_j}{\sigma_j} \quad (2)$$

Where X_{ij} is the precipitation values observed at the *"i"* station for the month *"j"*; μ_j is the expected value of the precipitation series for the month *"j"*; σ_j indicates the standard deviation of the series for the month *"j"*. Note that all the variables in Equation 2 are dependent on the time-scale considered.

TABLE 1
SPI drought classifications [24, 38]

Values	Classifications
2.00+	Extremely Wet
1.50 to 1.99	Very Wet
1.00 to 1.49	Moderately Wet
-0.99 to 0.99	Near Normal
-1.00 to -1.49	Moderately Dry
-1.50 to -1.99	Severely Dry
-2.00 and less	Extremely Dry

Percent of normal precipitation index (PNI). *The percent of normal drought index (PNI)* can be easily calculated as defined in Equation 3 and rather suitable to the practitioners, public and weather forecasters. As seen in Equation 3, actual precipitation in the specified time period is divided by the normal precipitation for the period considered and then multiplied by 100 [39] to calculate PNI. However, if the time scale is considered as a year, i.e. annual or water year, then, the normal, i.e. denominator in equation, is typically considered to be a 30-year means, and the numerator will be precipitation in a given year. PNI is used in meteorological and agricultural drought studies with a variety of time scales such as one moth, a specified season, annual or water year [14, 25, 40]. Although PNI is easy to implement, it is inconvenient to use the average of the precipitation series characterized by skewed distributions, indicating non-normal distribution, as a project criteria [38, 39]. Alternatively, instead of using long-term mean values, frequency analysis is done for the yearly precipitation data, then the precipitation amounts with 2 year return periods (Tr= 2-year), put another way yearly precipitation value with the 50% probability level, are used in PNI calculations. Table 2 includes drought categories by PNI for the time-scale of 12-month period from January to December [41].

$$PNI_{iy} = \left(\frac{P_{iTr}}{P_{imean}} \right) 100 \quad (3)$$

Where: *i* stands for the meteorological observation station; *y* is one of the drought category given in Table 2, i.e. *y*=1 for "n*o risk*", *y*=2 for *"watch"*, *y*=3 for *"warning"*, *y*=4 for *"emergency"*; PNI_{iy} is the *y* drought category for station *i*; P_{iTr} is the predicted precipitation amount from frequency model of station *i* for either T_r=5-year or T_r=10-year return periods corresponding to the *y* drought category for *i* station; P_{imean} is expected precipitation (mm) with 2-year return period (50% probability level) at station *i*.

Frequency analysis. In order to include uncertainty into the study, SPI_{iTr} and P_{iTr} are tried to be predicted from probability models of each specified station. To this end, frequency analysis for the long-term annual precipitation series for 63 stations and *SPI* series of 41 stations for the 12-month time-scale were performed through using "*SPI_SL_6.exe*" software [42]. The best-fit probability distribution models for the series were determined by using Kolmogorov-Smirnov goodness-of-fit test at 5% significance level [43]. With the help of "*frequency factor equation*" [44], SPI and PNI values for the exceedance probabilities of 10% (*Tr* = 10-year) and 20% (*Tr* = 5-year) are estimated individually for each station (Equation 4).

$$\left.\begin{aligned} X_{p\%} &= \overline{X} + K_{p\%} S \\ Tr &= \frac{1}{P_{\%}} \end{aligned}\right\} \quad (4)$$

Where: *S* is the standard deviation, and $\overline{x}$ is the mean of the data set subjected to frequency analysis; $X_{p\%}$ is the expected value of the variable at the specified probability level ($P_{\%}$); *Tr* is the return periods of the specified probability level; $K_{p\%}$ is a frequency factor of the probability model, which is a property of the frequency distribution given at the specified probability level ($P_{\%}$).

Ordinary co-kriging. In order to generate a map of the variable at the hand, geostatistical interpolation methods have been used commonly in drought analysis. To that end, the ordinary co-kriging method has been adopted in this study. The method uses theoretical co-variogram model and corresponding parameters estimated from the experimental co-variogram graph. Co-kriging equation system is solved in order to make a best linear unbiased estimation (BLUE) at the un-sampled locations over the sampling domain. While making estimations with co-kriging method, an auxiliary variable is used in addition to the observed values [45]. In this study, Seyhan Basin DEM image (elevation) was used as the secondary (or auxiliary) variable in mapping *SPI* and *PNI* drought indices of 5- and 10-year return periods. Finally, *SPI* and *PNI* maps with the return periods of 5- and 10-year were generated by using the o*rdinary co-kriging* option of geographical information system (GIS). Details of mathematical equations regarding co-variogram analysis as well as co-kriging estimates can be found in [46], or elsewhere.

TABLE 2
PNI drought classifications [18, 41]

Time-scale (Months)	Normal and Over *(No Risk)*	Mild Drought *(Watch)*	Moderate Drought *(Warning)*	Severe Drought *(Emergency)*
12	PNI>%85	%75<PNI≤%85	%65≤PNI≤%75	PNI<%65

RESULTS AND DISCUSSION

Completion of monthly and annual precipitation series. Prior analysis showed that forty-one meteorological observation stations, scattered inside and neighboring the Seyhan River Basin border, have monthly data with the record length of at least 15-year. Nevertheless, monthly data series of Afşin, Çamardı, Feke, Gülek, Hacıali, Kangal, Pozantı, Sarıoğlan, Tarsus, Tufanbeyli, Tuzla and Ulaş were incomplete in some months. Missing observations of the monthly precipitation series of these stations were completed by regression analysis with the help of concordant neighboring station's concurrent monthly data. Hence, forty-one meteorological observation stations were rendered useful for SPI drought analysis regarding monthly data. On the other hand, because percent of normal indicator (PNI) analyses needs annual precipitation data in drought assessment, 63 stations in the Figure 1 were used to calculate PNI. In this regard, data results showed that annual precipitation series of Altınyayla, Andırın, Bünyan, Çukurova Agricultural Enterprises (Ceyhan), Çamlıyayla, Çardak, Elbaşı, Gesi, Hacıali, Hacılar, Kadirli, Örenşehir, Pazarören, Saimbeyli, Tarsus, Tuzla, Yahyalı and Yeşilhisar stations have had missing data in some years, but having record lengths of at least 15-year or over. The missing annual data of these stations have been completed through employing the regression method as done in monthly data completion. There was an exception that Örenşehir station, located in a critically geographical location in the catchment, had only 12-year data, but of complete data. Therefore, only annual series data of this station were extended so as to render data length of 15-year which is a prerequisite for frequency analysis. All the completed data of the stations were used in frequency analysis.

Computation of the SPI series. Monthly data of 41 stations were used to calculate SPI series for 12-month time scale as explained before. Hence, long-term annual SPI series of these stations were obtained through using "*SPI_SL_6.exe*" software. The output of software for each station was filtered and SPI data series corresponding to the month of January was extracted by the stations. Extracted data series for each station were processed so as to be used in frequency analysis.

Fitting probability distributions to SPI series and annual precipitation series. Frequency analysis was performed to the annual precipitation series of 63 stations and SPI series of 41 stations. Consequently, the probability distribution models fitted well to the series were determined accordingly. Frequency analysis results, hence best-fit probability models, of SPI and annual precipitation series were summarized in Table 3.

As seen in Table 3, it is clear and distinct that the probability distributions of the 12-month SPI series and the annual total precipitation series differ each other by 40%. This is probably due to the fact that SPI and annual precipitation series have different random character over the catchment due to some geographical and climatological differences. Furthermore, it may be a logical evidence that this difference might be due to the use of the monthly values in the calculation of SPI series and the calculation method of SPI itself, i.e. transformation of Gamma probabilities into a normal distribution so that the average SPI for the determined time-scale and the location is zero. To make it more clear, data series differ from each other in essence. While the SPI values are dimensionless due to standardization, annual precipitation series are in the unit of *mm*. Alteration of series may cause the probability distributions to be different.

It is of prime importance to highlight that the data sets were first sorted from the smallest to the biggest in ascending order in order to perform frequency analysis, then each one of the ordered data was given an integer rank number, i.e. the smallest data had its rank as 1, whereas the biggest data had the number of record length (viz., as the number of years) of the station considered, finally exceedance probabilities were calculated adopting the same approach in low-flow frequency analysis [47] in hydrology. Therefore, the smallest exceedance probability was attached with the smallest data in the series for the sake of simulation drought conditions in the region. In connection with this, probability distribution models and corresponding parameters for each station were used to predict annual total rainfall and *SPI* values for 2-, 5- and 10-year average occurrence or return periods (*Tr*). Precipitation and SPI values were estimated from probability distribution models by considering different return periods, and results were presented in Table 4 and Table 5.

TABLE 3
Probability distributions of SPI and annual total precipitation series

No	Station Name	Probability Distributions		*No*	Station Name	Probability Distributions	
		Annual Total Precipitation	SPI			Annual Total Precipitation	SPI
1	Kangal	Extreme Val.	Inversegauss	***33***	Şıhlı	Extreme Val.	N/A
2	Konakpınar	Log-Logistic	N/A*	***34***	Yahyalı	Weibull	N/A
3	Yazyurdu	Normal	Normal	***35***	Hüyükofis	Extreme Val.	N/A
4	Ulaş	Lognormal2	Logistic	***36***	Niğde	Logistic	Logistic
5	Altınyayla	Logistic	N/A	***37***	Çamardı	Weibull	Weibull
6	Şarkışla	Logistic	Weibull	***38***	Mansurlu	Normal	Normal
7	Gemerek	Betageneral	Betageneral	***39***	Feke	Betageneral	Betageneral
8	Sarıoğlan	Extreme Val.	Extreme Val.	***40***	Saimbeyli	Pearson5	N/A
9	Akkışla	Rayleigh	Inversegauss	***41***	Çokak	Betageneral	Betageneral
10	Kaynar	Inversegauss	Logistic	***42***	Andırın	Weibull	N/A
11	Örenşehir	Logistic	N/A	***43***	Karsantı	Logistic	Logistic
12	Gürün	Lognormal2	Weibull	***44***	Çiftehan	Logistic	Normal
13	Pınarbaşı	Normal	Normal	***45***	Ulukışla	Normal	Weibull
14	Pazarören	Logistic	N/A	***46***	Ereğli	Logistic	Logistic
15	Elbaşı	Log-Logistic	N/A	***47***	Pozantı	Normal	Normal
16	Bünyan	Logistic	N/A	***48***	Gülek	Normal	Logistic
17	Gesi	Logistic	Logistic	***49***	Çamlıyayla	Logistic	N/A
18	Talas	Logistic	N/A	***50***	Karaisalı	Log-Logistic	Logistic
19	Kayseri	Logistic	Logistic	***51***	Imamoğlu	Logistic	Logistic
20	Hacılar	Logistic	N/A	***52***	Kösreli	Normal	N/A
21	Yeşilhisar	Logistic	N/A	***53***	Ç.Ovatariş	Logistic	N/A
22	Develi	Logistic	Logistic	***54***	Ceyhan	Logistic	Logistic
23	Tomarza	Betageneral	Betageneral	***55***	Yumurtalık	Normal	Weibull
24	Toklar	Log-Logistic	Log-Logistic	***56***	Hacıali	Log-Logistic	Log-Logistic
25	Adana	Inversegauss	Weibull	***57***	Karataş	Weibull	Logistic
26	Sarız	Rayleigh	Weibull	***58***	Tuzla	Log-Logistic	Weibull
27	Tanır	Log-Logistic	N/A	***59***	Tarsus	Logistic	Logistic
28	Afşin	Logistic	Weibull	***60***	Kozan	Logistic	Normal
29	Çardak	Weibull	N/A	***61***	Kadirli	Rayleigh	N/A
30	Göksün	Betageneral	Betageneral	***62***	Kaleönü	Log-Logistic	N/A
31	Tufanbeyli	Logistic	Logistic	***63***	Topçu	Log-Logistic	N/A
32	Bakırdağ	Logistic	Logistic	N/A* : Not Applicable Due To Lack Of Monthly Data			

TABLE 4
Predicted annual total precipitation (mm) and SPI values obtained from probability distribution models for different return periods (Tr, years)

No	Station Name	Annual Total Precipitation Series			SPI Series		*No*	Station Name	Annual Total Precipitation Series			SPI Series	
		Tr=2	*Tr=5*	*Tr=10*	*Tr=5*	*Tr=10*			*Tr=2*	*Tr=5*	*Tr=10*	*Tr=5*	*Tr=10*
1	Kangal	395	333	306	-0.86	-1.23	***33***	Şıhlı	395	345	324	-	-
2	Konakpınar	390	294	257	-	-	***34***	Yahyalı	459	377	331	-	-
3	Yazyurdu	414	332	289	-0.87	-1.32	***35***	Hüyükofis	331	249	215	-	-
4	Ulaş	352	294	273	-0.86	-1.35	***36***	Niğde	332	289	264	-0.71	-1.15
5	Altınyayla	319	285	266	-	-	***37***	Çamardı	370	290	249	-0.78	-1.32
6	Şarkışla	322	269	239	-0.76	-1.32	***38***	Mansurlu	971	775	673	-0.86	-1.31
7	Gemerek	391	342	321	-0.92	-1.33	***39***	Feke	934	676	642	-1.32	-1.49
8	Sarıoğlan	378	329	307	-0.84	-1.11	***40***	Saimbeyli	833	707	659	-	-
9	Akkışla	420	370	349	-0.83	-1.26	***41***	Çokak	1472	1041	964	-1.29	-1.56
10	Kaynar	333	296	277	-0.80	-1.26	***42***	Andırın	1399	1151	1043		
11	Örenşehir	311	240	199	-	-	***43***	Karsantı	1035	805	670	-0.75	-1.19
12	Gürün	305	255	230	-0.84	-1.29	***44***	Çiftehan	493	345	258	-0.86	-1.31
13	Pınarbaşı	410	339	302	-0.86	-1.30	***45***	Ulukışla	321	268	240	-0.76	-1.32
14	Pazarören	391	347	322	-	-	***46***	Ereğli	293	249	222	-0.70	-1.13
15	Elbaşı	381	363	354	-	-	***47***	Pozantı	701	517	420	-0.87	-1.32
16	Bünyan	463	400	364	-	-	***48***	Gülek	868	667	563	-0.81	-1.29
17	Gesi	407	352	320	-0.65	-1.11	***49***	Çamlıyayla	1020	905	838	-	-
18	Talas	369	309	273	-	-	***50***	Karaisalı	898	725	632	-0.81	-1.30
19	Kayseri	394	332	296	-0.79	-1.25	***51***	Imamoğlu	675	548	474	-0.78	-1.22
20	Hacılar	513	449	412	-	-	***52***	Kösreli	661	539	475	-	-
21	Yeşilhisar	274	241	222	-	-	***53***	Ç.Ovatariş	806	685	615	-	-
22	Develi	368	318	289	-0.73	-1.18	***54***	Ceyhan	709	586	514	-0.81	-1.28
23	Tomarza	394	340	316	-0.89	-1.34	***55***	Yumurtalık	825	649	557	-0.86	-1.28
24	Toklar	381	331	310	-0.84	-1.18	***56***	Hacıali	612	530	499	-0.83	-1.11
25	Adana	623	509	468	-0.90	-1.19	***57***	Karataş	765	584	501	-0.77	-1.23
26	Sarız	507	435	405	-0.89	-1.28	***58***	Tuzla	634	501	447	-0.90	-1.21
27	Tanır	303	245	221	-	-	***59***	Tarsus	595	484	419	-0.76	-1.22
28	Afşin	436	371	333	-0.81	-1.28	***60***	Kozan	838	706	629	-0.86	-1.30
29	Çardak	562	493	456	-	-	***61***	Kadirli	709	562	501	-	-
30	Göksün	614	489	440	-0.99	-1.44	***62***	Kaleönü	841	750	708	-	-
31	Tufanbeyli	553	467	417	-0.69	-1.14	***63***	Topçu	646	527	467	-	-
32	Bakırdağ	345	299	272	-0.73	-1.18							

TABLE 5
Estimated annual precipitations (mm) by different return periods (Tr, years) and calculated PNI values for return periods of 5- and 10-year

No	Station Name	Annual Total Precipitation Series			PNI		*No*	Station Name	Annual Total Precipitation Series			PNI	
		Tr=2	*Tr=5*	*Tr=10*	*Tr=5*	*Tr=10*			*Tr=2*	*Tr=5*	*Tr=10*	*Tr=5*	*Tr=10*
1	Kangal	395	333	306	84	77	***33***	Şıhlı	395	345	324	88	82
2	Konakpınar	390	294	257	75	66	***34***	Yahyalı	459	377	331	82	72
3	Yazyurdu	414	332	289	80	70	***35***	Hüyükofis	331	249	215	75	65
4	Ulaş	352	294	273	84	77	***36***	Niğde	332	289	264	87	79
5	Altınyayla	319	285	266	89	83	***37***	Çamardı	370	290	249	79	67
6	Şarkışla	322	269	239	84	74	***38***	Mansurlu	971	775	673	80	69
7	Gemerek	391	342	321	87	82	***39***	Feke	934	676	642	72	69
8	Sarıoğlan	378	329	307	87	81	***40***	Saimbeyli	833	707	659	85	79
9	Akkışla	420	370	349	88	83	***41***	Çokak	1472	1041	964	71	66
10	Kaynar	333	296	277	89	83	***42***	Andırın	1399	1151	1043	82	75
11	Örenşehir	311	240	199	77	64	***43***	Karsantı	1035	805	670	78	64
12	Gürün	305	255	230	84	76	***44***	Çiftehan	493	345	258	70	52
13	Pınarbaşı	410	339	302	83	74	***45***	Ulukışla	321	268	240	83	75
14	Pazarören	391	347	322	89	82	***46***	Ereğli	293	249	222	85	76
15	Elbaşı	381	363	354	95	93	***47***	Pozantı	701	517	420	74	60
16	Bünyan	463	400	364	87	79	***48***	Gülek	868	667	563	77	65
17	Gesi	407	352	320	86	79	***49***	Çamlıyayla	1020	905	838	89	82
18	Talas	369	309	273	84	74	***50***	Karaisalı	898	725	632	81	70
19	Kayseri	394	332	296	84	75	***51***	Imamoğlu	675	548	474	81	70
20	Hacılar	513	449	412	88	80	***52***	Kösreli	661	539	475	82	72
21	Yeşilhisar	274	241	222	88	81	***53***	Ç.Ovatariş	806	685	615	85	76
22	Develi	368	318	289	86	78	***54***	Ceyhan	709	586	514	83	72
23	Tomarza	394	340	316	86	80	***55***	Yumurtalık	825	649	557	79	68
24	Toklar	381	331	310	87	81	***56***	Hacıali	612	530	499	87	82
25	Adana	623	509	468	82	75	***57***	Karataş	765	584	501	76	65
26	Sarız	507	435	405	86	80	***58***	Tuzla	634	501	447	79	70
27	Tanır	303	245	221	81	73	***59***	Tarsus	595	484	419	81	70
28	Afşin	436	371	333	85	76	***60***	Kozan	838	706	629	84	75
29	Çardak	562	493	456	88	81	***61***	Kadirli	709	562	501	79	71
30	Göksün	614	489	440	80	72	***62***	Kaleönü	841	750	708	89	84
31	Tufanbeyli	553	467	417	84	75	***63***	Topçu	646	527	467	82	72
32	Bakırdağ	345	299	272	87	79							

In drought analysis, while the some amount of precipitation depth received at a specific location in a given period is classified in "*severe drought*" category, the same amount of precipitation may be classified in "*extremely wet*" category in another location. This is due to the inherited character of drought phenomena and drought definition [7, 8, 31]. As seen in Table 4, the estimated annual precipitation amounts for the stations differ from each other to some extent at the same return period, indicating spatial variability in precipitation, in turn drought events. For example, the expected total precipitation values of 50% probability level (*Tr*=2 years) are 370 and 971 mm for Çamardı and Mansurlu stations, respectively. However, SPI values with return period of 10-year, in turn, are -1.32 and -1.31. On the other hand, annual precipitations with 10-year recurrence interval were predicted to be 249 and 673 mm for Çamardı and Mansurlu stations, respectively. Put another way, estimated precipitation in Mansurlu station is 2.7 times greater than Çamardı station at the same recurrence interval. Nevertheless, these two stations ranked in the same drought category or class of "m*oderate drought*" according to the SPI drought index. Pozantı-Çamardı, Ulukışla-Kozan, Kangal-Karataş are only a few station pairs, of which there exist great differences in precipitation amounts but located in the same drought category. Therefore, it should be emphasized that long-term annual average precipitation at a specific location has a great impact on determining drought category. For instance, if annual precipitation recorded at any station is less than the precipitation amount of 2-year return period of that station in Table 4, then, there is no doubt that the station has already exposed to the drought event. As seen in Table 4, 673 mm precipitation with return period of 10 years is expected for Mansurlu station. However, it is only 249 mm precipitation for Çamardı station at the same return period. In this case, Çamardı station would be represented by a *"mildly wet"* drought classification. For this reason, long-term annual precipitation averages are one of the major determinants in drought severity categorization.

Calculating PNI index for return periods of 5- and 10-year. Because annual rainfall amounts are not normally distributed due to skewness of data, using average precipitation values in PNI calculation may presumably produce incorrect results. Therefore, annual precipitation values with return periods of *Tr*=2, *Tr*=5 and *Tr*=10 years were estimated by performing frequency analysis, and

used in PNI calculations in this study. In this regard, precipitation value of 2-year return period was substituted for the long-term mean precipitation value in PNI calculation, namely, P_{imean} in Equation 3. Predicted annual precipitations for the predefined returned periods and calculated PNI values of return periods of 5- and 10-year for each station are presented in Table 5.

After examining Table 5, it may be concluded that drought development shows the same spatial behavior like SPI findings shown in Table 4. For example; station pairs of Develi-Saimbeyli, Çamardı-Mansurlu, Bakırdağ-Çamlıyayla, Çiftehan-Karsantı, etc. have the expected total precipitation values with 50% probability level (representing the average of the stations) of 368-833, 370-971, 345-1020 and 493-1035 mm, respectively. If we consider the PNI method in order to assess the spatial extent of drought and interpret jointly Table 2 and Table 5, drought conditions might be determined for the stations. For instance, Develi-Saimbeyli stations are in the category of "*mild drought*", Çamardı-Mansurlu in "*moderate drought*", Bakırdağ-Çamlıyayla in "*mild drought*", and Çiftehan-Karsantı in "s*evere drought*", provided that the estimated annual precipitation of 10- and 2-year return periods of the stations are attached with P_{iTr}, and P_{imean}, respectively, in Equation 3. Although the difference between median precipitations values of stations are 2 to 3 times, these stations have got involved in the same PNI drought category. Once again, long-term precipitation averages, hence the median precipitation, of the meteorological observation stations are one of the most important determinants in drought categorization when percent of normal indicator (PNI) is used as a drought index. However, the use of arithmetic mean is not a representative value when precipitation series are skewed, where the mean value is not equal to the mode or median values as in the normal probability distribution function case. In that case, instead of using average values, precipitation value with 50% probability level should be determined and used in drought assessment studies as done in this study.

Probabilistic drought maps by SPI and PNI methods. There have been a number of studies that the maps regarding hydro-meteorological variables can be improved by introducing a secondary variable in geostatistical analysis [31], i.e. co-kriging interpolation technique. From this viewpoint, elevation data of the catchment have been used as a secondary variable and improved the representativeness of SPI and PNI drought maps, to some extent, in this study. To this end, co-variogram analyzes of SPI and PNI values estimated for the return periods of 5- and 10-year were performed over the Seyhan Basin in GIS media. Geostatistical analysis results indicated that the spherical type theoretical co-variogram model is quite representative for the two variables of SPI and PNI. Thence, the parameters of the spherical co-variogram model for each variable have been determined according to [48]. Analysis results were presented in Table 6. It is important to highlight that range of influence (A) varied from 55 to 69 km over the sampling domain. Furthermore, range of influence was found to be sensitive to the number of observations used in the analysis. The less number of observations is used in the analysis, the less range of influence is determined for the variable in question. In other words, spatial dependency between pairs of stations has been changed in direct proportion to the number of stations used in the calculations. After determining the co-variogram type and corresponding parameters exclusive for the study area, maps for SPI and PNI values with the return periods of 5- and 10-year were generated in GIS media through using *Ordinary Co-kriging* interpolation estimation technique. As a result, the spatial and/or areal extent and continuity of the drought event over the basin could be delineated successfully as seen in Figure 2.

Probabilistic drought maps are useful tools for water managers during drought periods in order to make balance between water supply and demand in the region. Figure 2 shows the spatial extent of probabilistic droughts by SPI and PNI drought indicators. As seen in Figure 2(a), Feke, Çokak and Göksün stations are in the "*moderately dry*" zone

TABLE 6
Covariogram model and ordinary co-kriging estimation parameters

METHODS	The Spherical Type Theoretical Covariogram Model Parameters						Co-kriging Estimation Parameters			
							Sector Information			
							Smoothing factor: 0.2		Neighbors to include	
							Sector Type: 4 Sector			
	Return Period (Tr, years)	Lag Size (m)	Number of lags	Nugget Effect (C_0) (m^2)	Partial Sill (C_1) (m^2)	Range (A) (m)	Semiaxis (m)			
							Minor	Major	Min.	Max.
SPI	*5*	9000	12	0	146	56212	56000	56000	2	5
	10	10700	12	0	51	61861	61000	61000	2	5
PNI	*5*	12000	12	8	15	68510	68500	68500	2	5
	10	12000	12	27	16	68510	68500	68500	2	5

by SPI method when 5-year return period is considered. However, other parts of the basin are classified as "*normal*". On the other hand, when the *PNI* indicator is used with the same return period of 5-year, it is clear from Figure 2(b) that the region encompassed by Akkışla, Develi, Bakırdağ and Kaynar meteorological stations is in the drought category of "*normal*", indication no risk regarding drought. And the remaining areas in the catchment is in the category of "*mild drought*", showing that drought watch is extremely important in the region for taking preventive precautions. However, the most severe droughts has concentrated along Çokak, Feke, Çiftehan zone, approaching to the "*moderate drought*" which shows "w*arning*" situation.

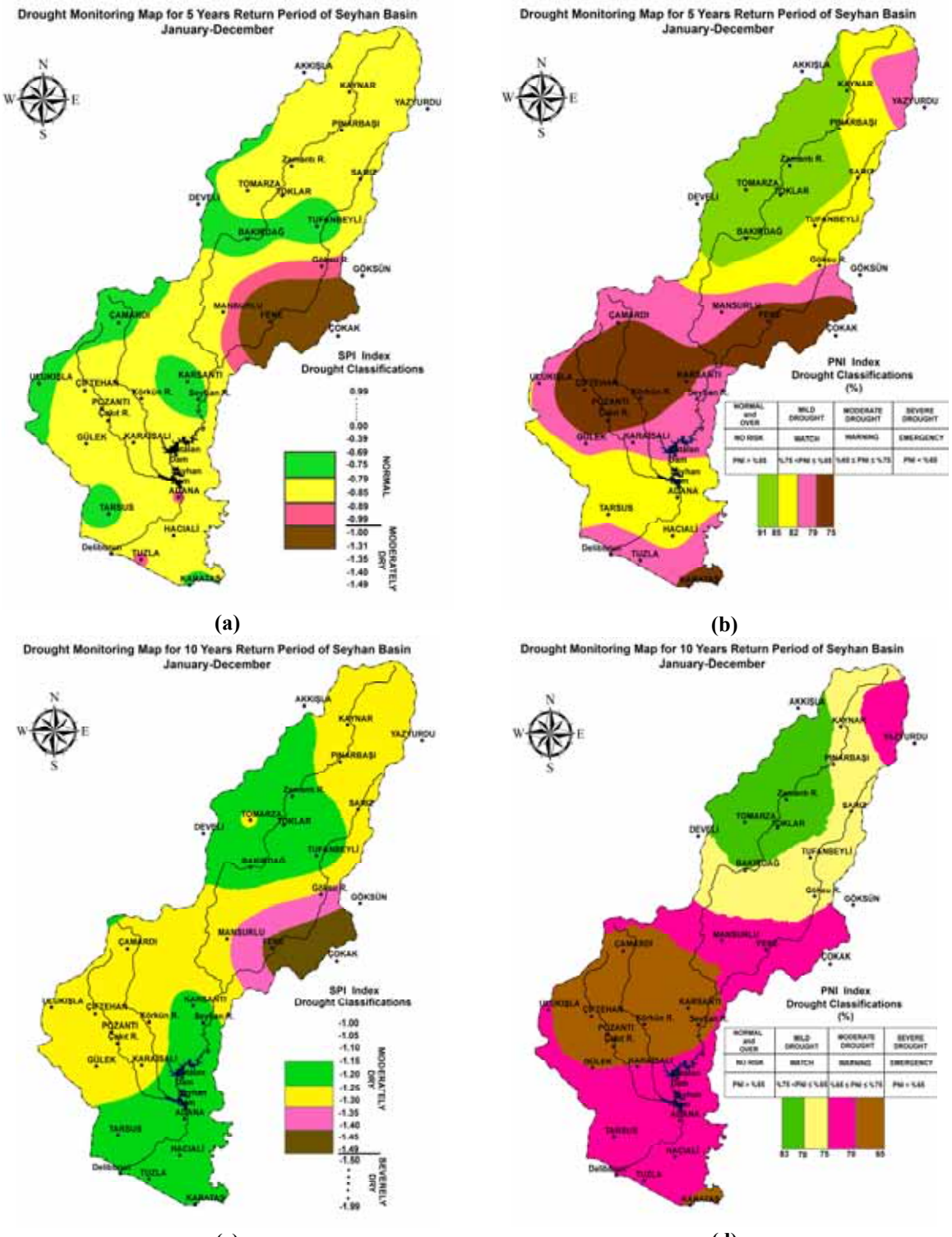


FIGURE 2
Regional meteorological drought maps by SPI and PNI methods for 5 and 10 years return periods

As for expected droughts in a 10-year recurrence interval, it has been determined that the whole of the basin is in the "*moderately dry*" class by *SPI* drought indicator (Figure 2(c). Nevertheless, it is important to know that area encircled by Feke, Çokak and Göksun stations has critical importance because it is the most susceptible to drought events. As for the *PNI* method together with 10-year return period, "*mild drought*" and "*moderate drought*" conditions prevail throughout the basin. However, the area encompassed by Çamardı, Karsantı, Karaisalı, Gülek and Ulukışla stations is more susceptible to drought phenomenon than the other parts of the study area. Figure 2 shows clearly that there exists no areas exposing to "*severe drought*" conditions by the two drought indicators and 10-year recurrence intervals in the basin. Put another way, "*severe drought*" conditions are not supposed to be experienced at any part of the study with the 10% occurrence probability. The higher the recurrence interval is, the more severe drought conditions are expected in the study area with the increasing spatial extent of drought prone areas. In this context, drought events in "*severe drought*" category are potentially expected in the Basin at any time due to the fact that there exist areas very prone to severe droughts with 10-year return period. However, significant differences are observed in dry areas in terms of severity and areal extent of droughts. Drought maps show clearly that drought affects large areas indicating that its impacts may not be structural but nonstructural. Accordingly, spatial and temporal variability of the droughts are important features that must be taken into account in drought management and mitigation studies.

Interpretation of probabilistic drought indices of SPI and PNI led us to conclude that long-term mean precipitation of any station has less impact on drought characterization by SPI in comparison with the PIN method. Calculated SPI and PNI values together with the drought categories were presented in Table 7 and Table 8 for the recurrence intervals of 5 and 10 years, respectively, in order to render comparative assessments.

When Tables 7 and 8 are examined, there is no doubt that the drought categories of the methods for the same recurrence period differ remarkably from each other due to the calculation differences in SPI and PNI methods. As seen in tables, SPI and PNI indices would be able to be calculated for 41 stations. Therefore, drought categories of these stations by the methods can be comparable for the two return periods. Even if the two stations have the same precipitation values for the same recurrence interval, the stations might be probably located in different drought classes because averages and probability distribution models of stations differ from each other. The maps showing spatial extent

TABLE 7
Drought classifications of meteorological stations by SPI and PNI indicators for the recurrence interval of 5-year

No	Stations	Class \PNI	Class \SPI	*No*	Stations	Class \PNI	Class \SPI
1	Kangal	Mild Drought\84	Normal\-0.86	***33***	Şıhlı	Normal\88	N/A
2	Konakpınar	Moderate Drought\75	N/A	***34***	Yahyalı	Mild Drought\82	N/A
3	Yazyurdu	Mild Drought\80	Normal\-0.87	***35***	Hüyükofis	Moderate Drought\75	N/A
4	Ulaş	Mild Drought\84	Normal\-0.86	***36***	Niğde	Normal\87	Normal\-0.71
5	Altınyayla	Normal\89	N/A	***37***	Çamardı	Mild Drought\79	Normal\-0.78
6	Şarkışla	Mild Drought\84	Normal\-0.76	***38***	Mansurlu	Mild Drought\80	Normal\-0.86
7	Gemerek	Normal\87	Normal\-0.92	***39***	Feke	Moderate Drought\72	Moderately Dry\-1.32
8	Sarıoğlan	Normal\87	Normal\-0.84	***40***	Saimbeyli	Mild Drought\85	N/A
9	Akkışla	Normal\88	Normal\-0.83	***41***	Çokak	Moderate Drought\71	Moderately Dry\-1.29
10	Kaynar	Normal\89	Normal\-0.80	***42***	Andırın	Mild Drought\82	N/A
11	Örenşehir	Mild Drought\77	N/A	***43***	Karsantı	Mild Drought\78	Normal\-0.75
12	Gürün	Mild Drought\84	Normal\-0.84	***44***	Çiftehan	Moderate Drought\70	Normal\-0.86
13	Pınarbaşı	Mild Drought\83	Normal\-0.86	***45***	Ulukışla	Mild Drought\83	Normal\-0.76
14	Pazarören	Normal\89	N/A	***46***	Ereğli	Mild Drought\85	Normal\-0.70
15	Elbaşı	Normal\95	N/A	***47***	Pozantı	Moderate Drought\74	Normal\-0.87
16	Bünyan	Normal\87	N/A	***48***	Gülek	Mild Drought\77	Normal\-0.81
17	Gesi	Normal\86	Normal\-0.65	***49***	Çamlıyayla	Normal\89	N/A
18	Talas	Mild Drought\84	N/A	***50***	Karaisalı	Mild Drought\81	Normal\-0.81
19	Kayseri	Mild Drought\84	Normal\-0.79	***51***	Imamoğlu	Mild Drought\81	Normal\-0.78
20	Hacılar	Normal\88	N/A	***52***	Kösreli	Mild Drought\82	N/A
21	Yeşilhisar	Normal\88	N/A	***53***	Ç.Ovatariş	Mild Drought\85	N/A
22	Develi	Normal\86	Normal\-0.73	***54***	Ceyhan	Mild Drought\83	Normal\-0.81
23	Tomarza	Normal\86	Normal\-0.89	***55***	Yumurtalık	Mild Drought\79	Normal\-0.86
24	Toklar	Normal\87	Normal\-0.84	***56***	Hacıali	Normal\87	Normal\-0.83
25	Adana	Mild Drought\82	Normal\-0.90	***57***	Karataş	Mild Drought\76	Normal\-0.77
26	Sarız	Normal\86	Normal\-0.89	***58***	Tuzla	Mild Drought\79	Normal\-0.90
27	Tanır	Mild Drought\81	N/A	***59***	Tarsus	Mild Drought\81	Normal\-0.76
28	Afşin	Mild Drought\85	Normal\-0.81	***60***	Kozan	Mild Drought\84	Normal\-0.86
29	Çardak	Normal\88	N/A	***61***	Kadirli	Mild Drought\79	N/A
30	Göksün	Mild Drought\80	Normal\-0.99	***62***	Kaleönü	Normal\89	N/A
31	Tufanbeyli	Mild Drought\84	Normal\-0.69	***63***	Topçu	Mild Drought\82	N/A
32	Bakırdağ	Normal\87	Normal\-0.73				

TABLE 8
Drought classifications of meteorological stations by SPI and PNI indicators for the recurrence interval of 10-year

No	Stations	Class \PNI	Class \SPI	*No*	Stations	Class \PNI	Class \SPI
1	Kangal	Mild Drought\77	Moderately Dry\-1.23	***33***	Şıhlı	Mild Drought\82	N/A
2	Konakpınar	Moderate Drought\66	N/A	***34***	Yahyalı	Moderate Drought\72	N/A
3	Yazyurdu	Moderate Drought\70	Moderately Dry\-1.32	***35***	Hüyükofis	Moderate Drought\65	N/A
4	Ulaş	Mild Drought\77	Moderately Dry\-1.35	***36***	Niğde	Mild Drought\79	Moderately Dry\-1.15
5	Altınyayla	Mild Drought\83	N/A	***37***	Çamardı	Moderate Drought\67	Moderately Dry\-1.32
6	Şarkışla	Moderate Drought\74	Moderately Dry\-1.32	***38***	Mansurlu	Moderate Drought\69	Moderately Dry\-1.31
7	Gemerek	Mild Drought\82	Moderately Dry\-1.33	***39***	Feke	Moderate Drought\69	Moderately Dry\-1.49
8	Sarıoğlan	Mild Drought\81	Moderately Dry\-1.11	***40***	Saimbeyli	Mild Drought\79	N/A
9	Akkışla	Mild Drought\83	Moderately Dry\-1.26	***41***	Çokak	Moderate Drought\66	Severely Dry\-1.56
10	Kaynar	Mild Drought\83	Moderately Dry\-1.26	***42***	Andırın	Moderate Drought\75	N/A
11	Örenşehir	Severe Drought\64	N/A	***43***	Karsantı	Severe Drought \64	Moderately Dry\-1.19
12	Gürün	Mild Drought\76	Moderately Dry\-1.29	***44***	Çiftehan	Severe Drought\52	Moderately Dry\-1.31
13	Pınarbaşı	Moderate Drought\74	Moderately Dry\-1.30	***45***	Ulukışla	Moderate Drought\75	Moderately Dry\-1.32
14	Pazarören	Mild Drought\82	N/A	***46***	Ereğli	Mild Drought\76	Moderately Dry\-1.13
15	Elbaşı	Normal\93	N/A	***47***	Pozantı	Severe Drought\60	Moderately Dry\-1.32
16	Bünyan	Mild Drought\79	N/A	***48***	Gülek	Moderate Drought \65	Moderately Dry\-1.29
17	Gesi	Mild Drought\79	Moderately Dry\-1.11	***49***	Çamlıyayla	Mild Drought\82	N/A
18	Talas	Moderate Drought\74	N/A	***50***	Karaisalı	Moderate Drought\70	Moderately Dry\-1.30
19	Kayseri	Moderate Drought\75	Moderately Dry\-1.25	***51***	Imamoğlu	Moderate Drought\70	Moderately Dry\-1.22
20	Hacılar	Mild Drought\80	N/A	***52***	Kösreli	Moderate Drought\72	N/A
21	Yeşilhisar	Mild Drought\81	N/A	***53***	Ç.Ovatariş	Mild Drought\76	N/A
22	Develi	Mild Drought\78	Moderately Dry\-1.18	***54***	Ceyhan	Moderate Drought\72	Moderately Dry\-1.28
23	Tomarza	Mild Drought\80	Moderately Dry\-1.34	***55***	Yumurtalık	Moderate Drought\68	Moderately Dry\-1.28
24	Toklar	Mild Drought\81	Moderately Dry\-1.18	***56***	Hacıali	Mild Drought\82	Moderately Dry\-1.11
25	Adana	Moderate Drought\75	Moderately Dry\-1.19	***57***	Karataş	Moderate Drought\65	Moderately Dry\-1.23
26	Sarız	Mild Drought\80	Moderately Dry\-1.28	***58***	Tuzla	Moderate Drought\70	Moderately Dry\-1.21
27	Tanır	Moderate Drought\73	N/A	***59***	Tarsus	Moderate Drought\70	Moderately Dry\-1.22
28	Afşin	Mild Drought\76	Moderately Dry\-1.28	***60***	Kozan	Moderate Drought\75	Moderately Dry\-1.30
29	Çardak	Mild Drought\81	N/A	***61***	Kadirli	Moderate Drought\71	N/A
30	Göksün	Moderate Drought\72	Moderately Dry\-1.44	***62***	Kaleönü	Mild Drought\84	N/A
31	Tufanbeyli	Moderate Drought\75	Moderately Dry\-1.14	***63***	Topçu	Moderate Drought\72	N/A
32	Bakırdağ	Mild Drought\79	Moderately Dry\-1.18				

of SPI method delineated more homogeneous categorical drought distribution with a return period of 5 and 10 years, in comparison to PNI method. In other words, the same drought class with the meaningful drought severity variations from place to place dominated over the basin, indicating no patchy behavior of the drought events (Figure 2). As for the spatial behavior of droughts by PNI method, two distinct drought categories appeared over the study area irrespective of return periods.

This is an indication of transitions between drought classes.

As shown in Figure 2, study area has not experienced with the categories of "*severe drought*" or *"severely dry*" for 10 years return period. However, these drought categories constituted an edge to the nearest drought category, indicating that these categories have rather high potential to experience severe droughts when taken return periods slightly greater than the one used in the study, say 11-year. In fact, both methods have produced drought indices very close to the "*severe drought*" limit for the return period of 10 years, supporting our anticipation on severe drought incidents.

CONCLUSIONS

In this study, SPI with the 12-month time scale and PNI with a year period were used as drought indicators so as to figure out probabilistic drought characteristics in the Seyhan River basin located in the Mediterranean region of Turkey. It may be concluded reliably that PNI method is more sensitive to the average precipitation amounts of observation series than SPI method without regard to recurrence interval.

Areal extent of meteorological drought with a return period of 5 and 10 years were mapped to delineate drought categories by the methods and return periods in the GIS environment. Based on the SPI method, dominant drought class of 5-year recurrence interval was characterized as "*normal"* in the basin. Instead of using mean value, median precipitation was introduced in PNI index calculation. Prevailing drought category in PNI with 5-year frequency was found as "*mild drought*", indicating that PNI made worse drought category in the basin than SPI indicator. Spatial extent of drought classes for a return period of 5 years by SPI method does not match up with drought categories of PNI method. Drought, which is expected every 10-year period, by SPI method was characterized as "*moderately dry*" category over the whole catchment. Contrary to the SPI results, PNI indicator resulted in two drought categories, i.e. "*mild drought*" and *"moderate drought*". Areas of "*moderate drought*" conditions were under the influence of Mediterranean climate, but areas of "*mild drought*" were affected by continental climate. Drought classes of 10-year return period by SPI method have not conformed to drought indicator of PNI. However, although the area has not yet experienced with severe drought events with the return period of 10-year, SPI and PNI maps with 10-year recurrence interval indicated that future droughts in the category of "*severely dry*" or "*severe drought*" might be possible to anticipate in the study area. Water managers, drought mitigation planners as well as practitioners should be aware that there always exists a risk to experience drought events with return period of 10-year or over in the category of "s*evere drought*" throughout the Seyhan basin. A drought event in this kind needs taking urgent measures to provide an immediate emergency response. The higher recurrence interval is, the severer droughts are experienced in the catchment.

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