



## Comparison of the Observed Rainfall with Rainfall Estimated by CLIGEN Climate Model in terms of Drought Analysis<sup>#</sup>

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### ABSTRACT

Standardized Precipitation Index (SPI) is used to determine dry and humid periods according to the cumulative probability method at different time scales. In this study, the rainfall data between the years of 1980-2018 belonging to of Kayseri Meteorology Station was simulated by CLIGEN stochastic climatic data generator. SPI indices calculated by using observed and simulated precipitation were evaluated with the statistical methods at the time scales of 3-, 6-, 9- and 12-months. The SPI values of 3-, 6-, 9- and 12- month which are observed and simulated with CLIGEN are close to each other and the performance of the model is very high in calculating the SPI values of these time series. However, as the time period increased, the model's representative ability decreased.

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## CLIGEN İklim Modeli ile Tahmin Edilen Yağmur ile Gözlenen Yağmurun Kuraklık Analizi Açısından Karşılaştırılması

### MAKALE BİLGİSİ

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### ÖZ

Standart Yağış İndeksi (SYİ) farklı zaman ölçeklerinde, kümülatif olasılık yöntemine göre kurak ve nemli periyodları belirlemek amacıyla uygulanan bir yöntemdir. Bu çalışmada, Kayseri iline ait 1980-2018 yılları arasındaki yağmur verisi CLIGEN iklim modeli ile simüle edilmiştir ve daha sonra her iki veri seti SYİ yöntemine göre 3-, 6-, 9- ve 12- aylık kuraklık ve nemlilik şiddetini ifade eden indeks değerleri elde edilmiştir. Hem gözlenen hem de simüle edilen SPI değerleri karşılaştırılmıştır. 3-, 6-, 9- ve 12- aylık SPI değerleri birbirine yakın olup, modelin bu zaman serilerinin SPI değerlerini hesaplamada performansı oldukça yüksektir. Ancak zaman aralığı arttıkça modelin temsil yeteneği düşüş göstermektedir.

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## Introduction

Natural disasters have an important place in human life from past to present. One of the most important natural disasters is drought. Drought has the greatest impact on life and economy compared to other natural disasters and, it has the property of development under different meteorological and environmental conditions. Drought occurs when rain falls below average rainfall. Because of this water shortage, vital activities are negatively affected. In the literature, there is types of drought categorized with regard to its impacts on sectors (Oğuztürk ve Yıldız, 2014). Shah et al. (2015), were divided into three drought classes in their study. These classes are named as meteorological, hydrological and agricultural drought. Meteorological drought is associated with a long drought period with no rain and snow. Therefore, its definition depends on comparison of the rainfall that occurs in a particular area and year against the average rainfall for many years. Hydrologic drought is related to lack of water amount in streams, reservoirs and lakes resulting from low rainfalls and, hydrological drought occurs when the meteorological drought is prolonged. Agricultural drought is closely related to the various characteristics of meteorological drought. It is defined as the lack of water to meet the need of the plant at soil (Kaplukan, 2013).

Turkey is located in semi-arid – semi-humid middle latitude region. While cyclically in some periods are dominate more dry climatic conditions, in some period is dominated more humid climatic conditions. There have been various drought periods throughout human history. The location of Turkey is a semi-arid climate area of the World and, has faced many drought periods in the past (Turan, 2018). The most severe of drought events in Turkey occurred in 1953-1954, 1956, 1964, 1973, 1977, 1984, 1989-1991, 1999-2000, 2001-2004 ve 2007-2008 years (Türkeş ve Tatlı, 2009; Oğuztürk ve Yıldız, 2014).

The possible effect of drought begins to show itself after a long time. It is therefore difficult to monitor its formation. Many climate studies in the literature, have estimated droughts by using statistical methods in context of its frequency, duration, intensity and the areas influence of drought. These methods are the Palmer Drought Severity Index (PDSI) (Palmer, 1965), Decile Index (DI) (Gibbs and Maher, 1967), China-Z Index (CZI) (Wu et al., 2001), Surface Water Supply Index (SWSI) (Shafer and Dezman, 1982) and Standardized Precipitation Index (SPI) (McKee et al., 1993) Modified Standardized Precipitation Index (Türkeş ve Tatlı, 2009).

The main purpose of this study is to simulate the rainfall data belonging to Kayseri province located in the Central Anatolia with CLIGEN stochastic climatic data generator and, to compare the SPI obtained from the simulated rainfall to SPI calculated from observed data. To reach this targeted mentioned, the SPI values were calculated for 3-, 6-, 9- and 12- time scales.

## Material and Method

Geographical location of Kayseri Province in Turkey selected as the study area is in Figure 1. Kayseri is situated between 37°45' - 38°18' north latitudes and 34°56' - 36°58' east longitudes. The elevation (m) is 1053 m. Kayseri,

which is located in Central Anatolia Region, has a continental climate. Summers are hot and dry; winters are cold and snowy. However, the climate of this province varies depending on the height. In summer, the average temperature is 21.4°C. In winter, temperature change between -1.2 °C and -6.2°C. The average annual rainfall is 399,6 mm. In the study area, occurs the most rainfall in March, April and May, the least precipitation in July, August and September (Meteorological Service, 2019).

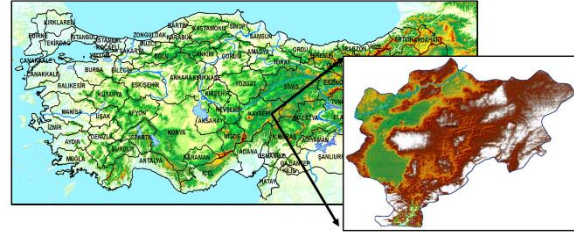


Figure 1 Geographical position to Turkey of Kayseri Province

## Method

In the study, CLIGEN stochastic climatic data generator were used for the simulation of rainfall between 1980-2018 (39 years) for Kayseri. Drought analysis of the observed and simulated data were done by standardized precipitation index method (SPI).

## CLIGEN Climate Model

CLIGEN introduced by Nicks et al. (1995) is a climate model developed by using meteorological data from the centre and south of America. In the simulation of rainfall with CLIGEN, 7 parameters are used, namely daily rainfall, maximum and minimum temperature, dew point, solar radiation, wind speed and direction. Markov chain method is used to predict daily rainfall. In the methodology, the probability of consecutive rainy days and the probability of dry day coming after the rainy day are characterized by the symbols called, P(W/W) and P(W/D), respectively. Normal distribution is used to determine daily rainfall. The probability of precipitation is calculated using the equation given below.

$$P(W) = \frac{P(W/D)}{1 - P(W/W) + P(W/D)} \quad (1)$$

If a random number, which is deduced from a uniform distribution for each day, is less than the precipitation probability for the certain day case, precipitation occurs. In the constitute wet days, a skewed normal distribution is used to constitute the daily precipitation quantities (Nick and Lane, 1989; Al-Mukhtar et al., 2014).

$$x = \left[ \left( \frac{g}{2} \left( \frac{R-u}{s} \right) + 1 \right)^{1/3} - 1 \right] + \frac{g}{6} \quad (2)$$

Where x= standard normal random variable; R= daily precipitation amount; u, s, g= mean, standard deviation and skew coefficient of daily precipitation amount.

During the development of the model, many academicians have made an effort in the analysis of the

parameters used in the model and in changing the incorrect parameters. For example, Nearing et al. (2005) examined errors in the simulation of daily rainfall data. (Yu, 2005) developed a simulation method of calculating rainfall intensity. Demir et al. (2018) evaluated rainfall parameters from CLIGEN climate model for long years in Tokat province. According to the results of the study, it is seen that the model is quite successful in estimating annual and monthly average values but found that the average of seasons were smaller than the observed value.

*Standardized Precipitation Index*

Standardized Precipitation Index (SPI) method was developed by Mckee et al. (1993). The advantage of the methodology is input data which is only the rainfall. The most important advantage of this methodology is to use different time scales in detecting the drought effect based on precipitation on the deficit in underground and surface water resources. Determining the drought classes (Table 1) and probabilities of SPI values calculated from the rainfall data at a given station, important information can be provided for struggle plans with drought.

At least 30 years of rainfall records are used in this method. Daily rainfall depths are summed mathematically to form monthly rainfall series. In its most general form, SPI is calculated by the equation given below;

$$SPI = \frac{X_i - \bar{X}_i}{\sigma} \tag{3}$$

In this equation,  $X_i$  monthly rainfall data;  $\bar{X}_i$  is average of rainfall data set and  $\sigma$  is standard deviation of rainfall. But, if the rainfall data is not normally distributed, the data should be transformed statistically. SPI method is disclosed in the literatures in detail (McKee et al., 1993; Guttman, 1999; Giddings et al., 2005; Wu et al., 2005; Kumar et al., 2009; Belayneh and Adamowski, 2012; Yetmen, 2013; Shah et al., 2015).

Table 1. Drought and Wet Classification by SPI Drought Index (McKee et al., 1993)

SPI Values	Classification
Greater than 2.0	Extraordinary Damp
1.5 to 1.99	Extreme Damp
1 to 1.49	Severe Damp
0.5 to 0.99	Medium Damp
0.0 to 0.49	Light Damp
0.0 to (-0.49)	Light Arid
(-0.5) to (-0.99)	Medium Arid
(-1.0) to (-1.49)	Severe Arid
(-1.50) to (-1.99)	Extreme Arid
Less than (-2.0)	Extraordinary Arid

**Results and Discussion**

The rainfall data from Kayseri Province for the years from 1980 to 2018 was simulated by CLIGEN stochastic climatic data generator. The SPI values at 3-, 6-, 9- and 12-time scales of both observed and simulated rainfall were evaluated in terms of drought. The annual average of the observed and simulated rainfall amounts is 397.8 mm and 346.6 mm, respectively. The highest rainfall among the

observed annual rainfalls was 600.5 mm in 1989 and, the lowest rainfall was 275.7 mm in 1988. The model predicted the annual highest rainfall as 501 mm in 1987 and the lowest rainfall as 230,6 mm in 1988 (Graphic 1, 2 and Table 2). The predicted rainfall heights were lower than the observed rainfalls. This reason for this is probably Cligen methodology. Kayseri is commonly experienced extreme rainfall events especially in spring season. Due to the Cligen stochastic climatic data generator model algorithm, it creates a continuous water budget. Since the continuous precipitation affects the budget negatively, it predicts precipitation below the observed value.

*The Results of Drought Analysis*

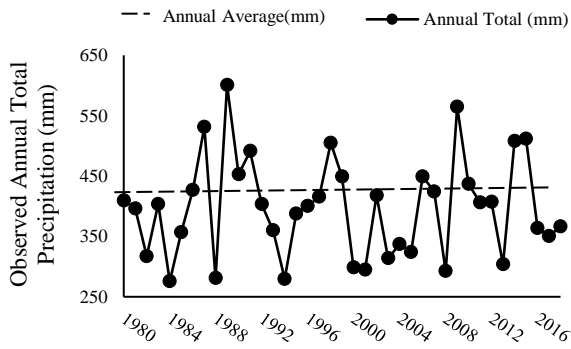
In the study, for the time scales of 3-, 6-, 9- and 12-months, visual graphics of standardized precipitation index (SPI) values are given in Graphic 3, 4, 5, 6, 7, 8, 9, 10. As can be seen from the SPI values of 3 months, it was detected that 292 months were wet at different levels and 174 months were dry at different levels. Extreme dry and extreme wet events were not observed. Based on annual SPI values, 25 and 14 years were found to be humid and dry at different levels, respectively. The 1989 and 2001 years were maximum wet and dry (Graphic 3) respectively. According to the SPI results of 3 months time scale based on CLIGEN, 325 and 141 months were determined as wet and dry at different levels, respectively. Extremely dry and wet events were not observed. Additionally, the annual SPI values showed wet in 33 years and drought in 6 years at different levels. There was maximum wet in 1989 year and severe drought in 2001 year (Graphic 4).

With respect to the SPI values of the 6 months, it was determined that 245 months were wet at different levels and 118 months were dry at different levels. While 11 drought events were observed in extreme conditions, 8 extreme wet events were observed. When looking over SPI data sets from annual rainfall amounts, 20 years and 19 years were found to be wet and dry according to classification given in the Table 1, respectively. Maximum wet in 1989 and, the maximum dry in 2001 were detected (Graphic 5). The SPI values of 6-month from CLIGEN had wet in 220 months and dryness in 243 months at different levels. Excessively dry 11 events were observed while excessive wet 3 events were observed. The annual SPI values were found to be wet in 20 years and dry in 19 years at different levels. There were maximum wet in 2015 and the drought in 2001 (Graphic 6).

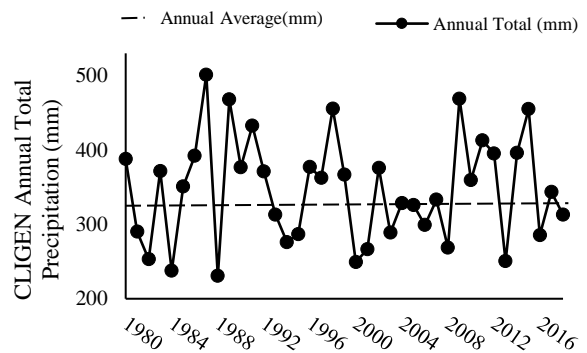
According to the SPI values of 9-month, it was determined that 230 months were wet at different levels and 230 months were dry at different levels. Excessively dry 11 events were detected while excessive wet 13 events were observed. The annual SPI values were found to be wet in 18 years and dry in 21 years at different levels. Maximum wet in 2015 and maximum dry in 2001 (Graphic 7). With respect to the SPI values of the 9-month, it has been determined that 243 months are wet at different levels and 217 months are dry at different levels. Excessively dry 14 events were observed while excessive wet 9 events were observed. The annual SPI values were found to be humid in 18 year and dry in 21 years at different levels. It was seen maximum wet in 2015 and the drought in 2001 (Graphic 8).

Table 2 Observed and predicted annual rainfall amount of Kayseri

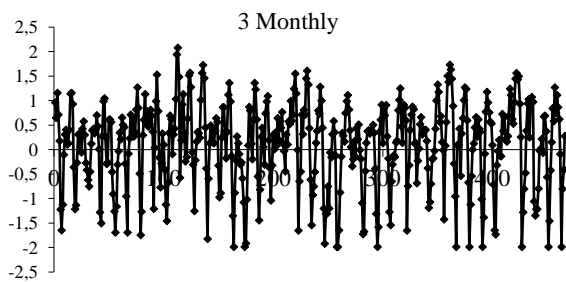
Years	Observed rainfall	CLIGEN rainfall	Years	Observed rainfall	CLIGEN rainfall
1980	409.5	387.9	2000	298.3	249.4
1981	396.3	290.1	2001	294.7	266.5
1982	317.2	253.1	2002	417.9	376.0
1983	403.7	371.7	2003	313.7	288.7
1984	275.7	237.6	2004	337.0	328.6
1985	357	351.0	2005	324.1	326.1
1986	426.6	392.0	2006	449.3	299.1
1987	531.3	501.2	2007	424.2	333.2
1988	281.2	230.6	2008	292.4	268.6
1989	600.5	467.9	2009	564.8	468.9
1990	452.6	376.9	2010	437.0	359.5
1991	491.3	432.7	2011	406.4	412.8
1992	403.4	371.0	2012	407.0	395.3
1993	360	313.1	2013	303.7	250.4
1994	279.5	276.0	2014	507.8	396.1
1995	387.7	286.7	2015	511.5	454.9
1996	400.3	377.1	2016	363.8	285.5
1997	415.7	362.6	2017	350.2	343.5
1998	504.8	455.5	2018	366.3	313.1
1999	449	366.9			



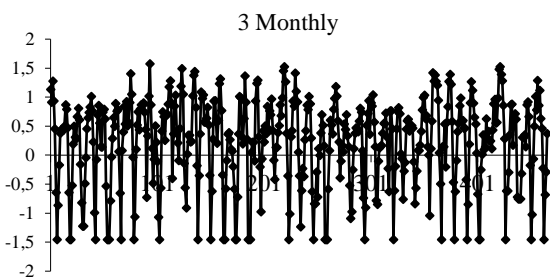
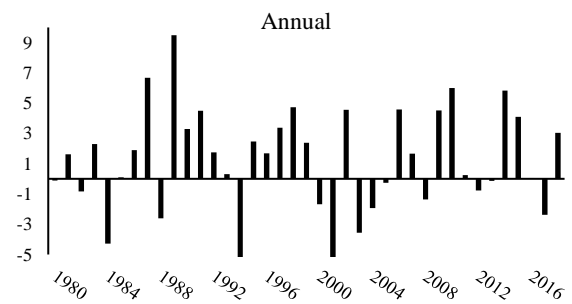
Graphic 1 Kayseri Observed Rainfall Series



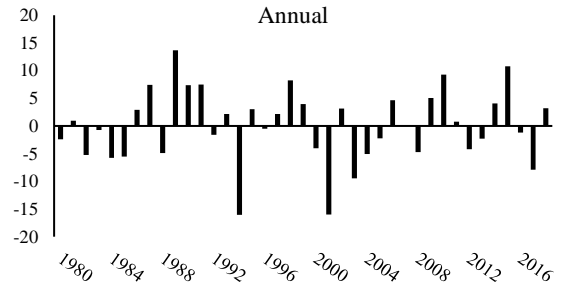
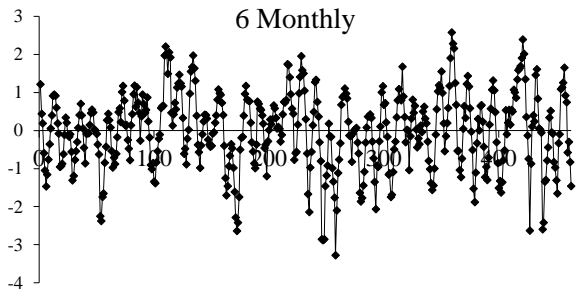
Graphic 2 Kayseri CLIGEN Rainfall Series



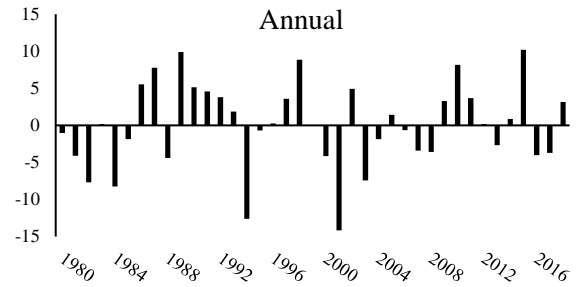
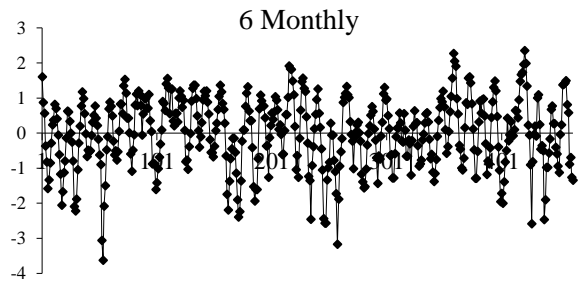
Graphic 3 Three Monthly and Annual SPI data of Observed Rainfall belong to Kayseri



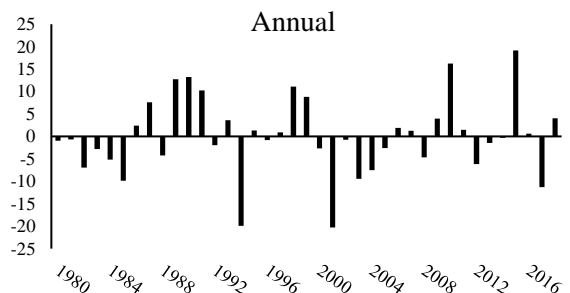
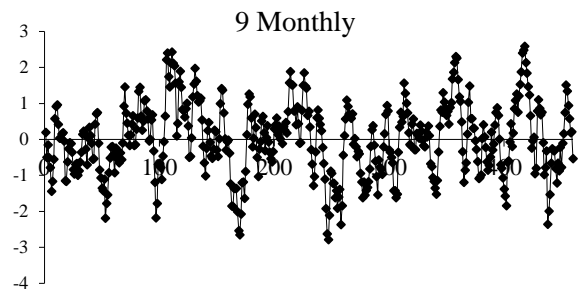
Graphic 4 Three monthly and Annual SPI data of CLIGEN Rainfall belong to Kayseri



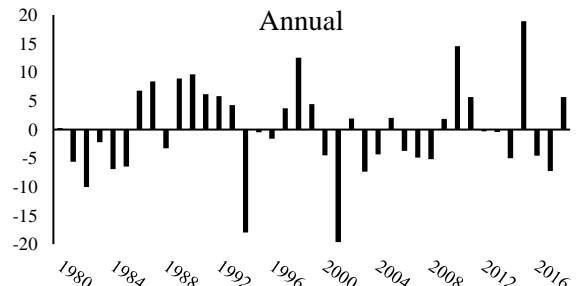
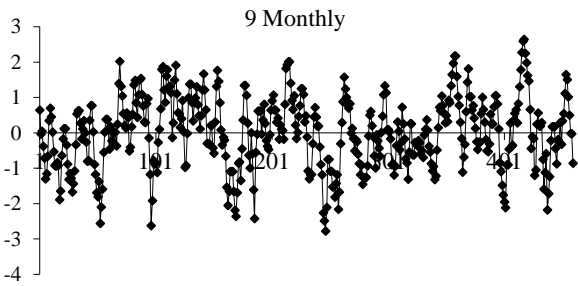
Graphic 5 Six Monthly and Annual SPI data of Observed Rainfall belong to Kayseri



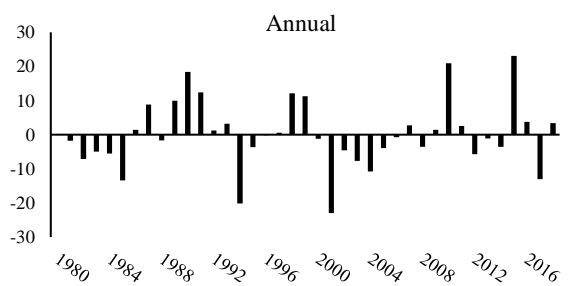
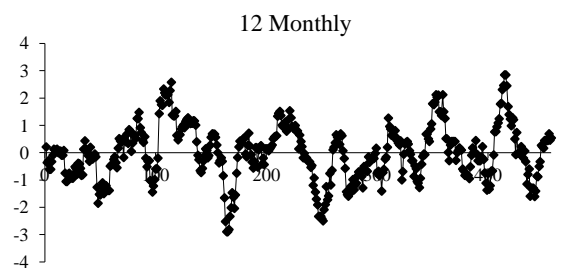
Graphic 6 Six Monthly and Annual SPI data of CLIGEN Rainfall belong to Kayseri



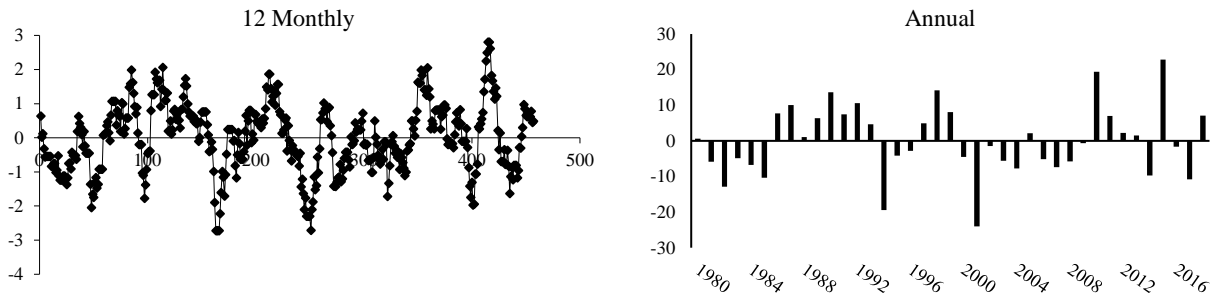
Graphic 7 Nine Monthly and Annual SPI data of Observed Rainfall belong to Kayseri



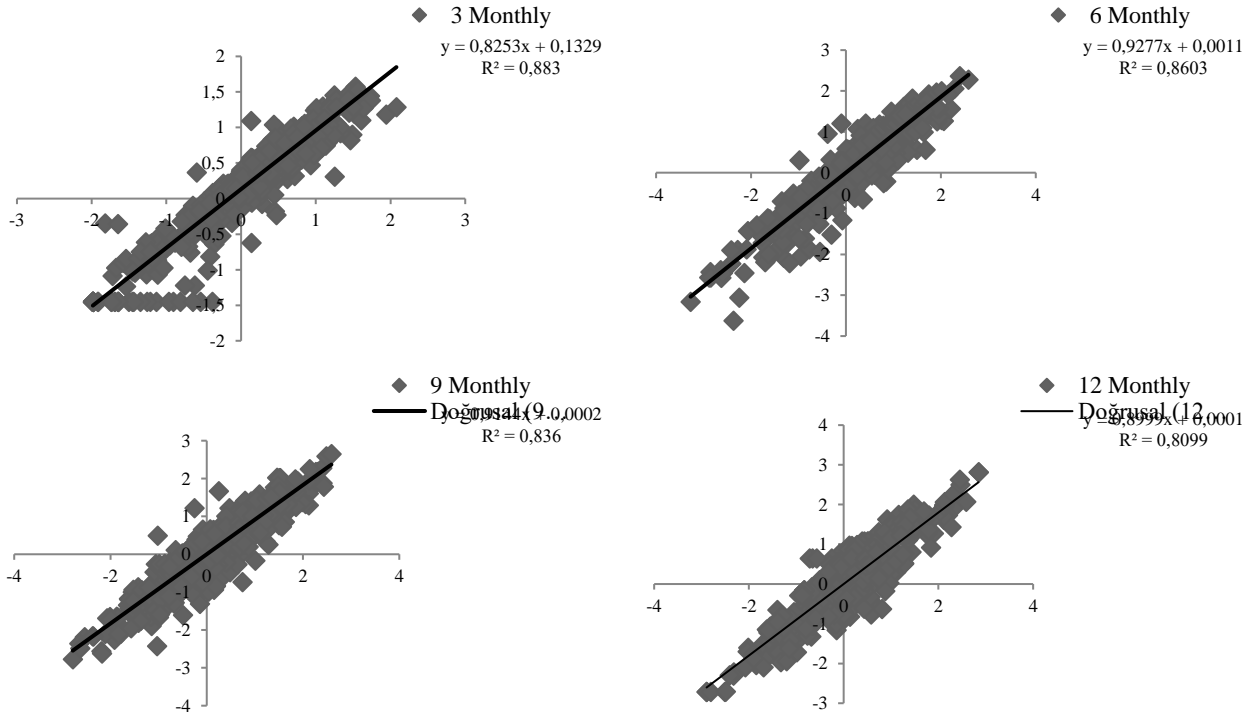
Graphic 8 Nine Monthly and Annual SPI data of CLIGEN Rainfall belong to Kayseri



Graphic 9 Twelve Monthly and Annual SPI data of Observed Rainfall belong to Kayseri



Graphic 10 Twelve Monthly and Annual SPI data of CLIGEN Rainfall belong to Kayseri



Graphic 11 Relationship between observed and simulated SPI values in Kayseri

When the SPI values of 12-month were examined, it was determined that 229 months were wet at different levels and, 228 months were dry at different levels. Excessively dry 13 events were observed while excessive humid 16 events were observed. The annual SPI values were found to be wet in 18 years and dry in 21 years at different levels. It was seen maximum wet in 2015 and the maximum dry in 2001 (Graphic 9). When the SPI value of the 12-month from CLIGEN is examined, it has been determined that 233 months were wet at different levels and 224 months were dry at different levels. Excessively dry 13 events were observed while excessive wet 7 events were observed. The annual SPI values were found to be wet in 19 years and dry in 20 years at different levels. It was seen maximum wet in 2015 and the dry in 2001 (Graphic 10).

The relationship between the observed and simulated SPI values of 3-, 6-, 9- and 12- month is given in Graphic 11. For all-time series,  $R^2$  values was found to be 0.88 - 0.86 - 0.83 - 0.80, respectively. The SPI values of 3-, 6-, 9- and 12- month which are observed and simulated with CLIGEN are close to each other and the performance of the model is very high in calculating the SPI values of these time series. However, as the time period length increased, the model's representative ability decreased.

## Conclusion

In this study, drought analysis based on SPI was performed for various time scales (3-, 6-, 9- and 12- month) in Kayseri Provinces. SPI method was applied to 39 years and the drought characteristics of these values in different time periods were examined. It was observed that the values found according to the SPI analyses represent the climatic conditions of the region. The drought values simulated with CLIGEN were quite similar to the observed data. These show that the performance of the model is quite high in Kayseri climate conditions. As a result stochastic data needs of drought studies can be meet by the CLIGEN data generator for the Kayseri.

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