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Boyabat Yöresi Yıllık Kuraklıklarının Farklı Meteorolojik Kuraklık İndisleri Kullanılarak Araştırılması

Investigation Of Annual Droughts Of Boyabat Region Using Different Meteorological Drought Indices

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ÖZET

Etkilerini her geçen gün artıran bir doğal afet olan kuraklık, önemli zararlar verebilmektedir. Kuraklığı belirlemek için çeşitli kuraklık indeksleri yapılmıştır. Bu endeksler sayesinde kuraklık belirlenebilir ve kuraklığa karşı gerekli önlemler alınabilir. Bu çalışmada, Kızılırmak Havzasında Boyabat meteorolojik gözlem istasyonuna ait 1976-2017 yağış kayıtları kullanılarak yıllık kuraklık araştırması yapılmıştır. Kuraklık analizinde meteorolojik kuraklık endeksleri olan Z-Score Index, China-Z Index ve Modified China-Z Index kullanılmıştır. İstasyonun kurak ve yağışlı dönemleri meteorolojik kuraklık indeksleri aracılığıyla belirlenmiş, ayrıca en kurak ve en yağışlı yıllar da belirlenmiştir. Endeksler arası uyumun da incelendiği çalışmada, MCZI-ZSI ve MCZI-CZI korelasyon katsayısı ZSI-CZI'ye göre daha yüksek olduğu belirlendi. Boyabat bölgesindeki kuraklık olayları farklı endeksler kullanılarak araştırılmalıdır.

Anahtar Kelimeler: Kuraklık, Kuraklık İzleme, Kuraklık Endeksleri, Boyabat

ABSTRACT

Drought, which is a natural disaster that increases its effects day by day, can cause significant damage. Several drought indices were carried out to determine drought. By means of these indices, drought can be determined and necessary precautions can be taken against drought. In this study, an annual drought survey was conducted using the rainfall records of the Boyabat meteorological observation station in the Kizilirmak River Basin in the 1976-2017. In the drought analysis, the meteorological drought indices Z-Score Index, China-Z Index and Modified China-Z Index were used. The dry and wet periods of the station were determined by means of meteorological drought indices, and the driest and wettest years were also determined. In the study, which also examined the compatibility between indices, it was determined that the coefficient of determination values of MCZI-ZSI and MCZI-CZI were higher than the ZSI-CZI. Drought events in Boyabat region should be investigated using different indices.

Keywords: Drought, Drought Monitoring, Drought Indices, Boyabat.

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INTRODUCTION

With the increasing effect of global climate change, the changes in the ecosystem are becoming more evident. The drought disaster, which occurs as a result of these effects, is severe and long-lasting (Mishra & Singh, 2011). It is difficult to cope with the drought disaster because it starts very slowly affecting large areas intensively over years (Sırdaş, 2002; Wilhite, 2000). Although local geographical and climatic characteristics are important in the emergence of this disaster, increased population, urbanization, greenhouse gases, which result from industrial activities, and destruction of nature also contribute to the emergence of it. It should not be forgotten that drought is a national and international problem threatening the entire civilization as a result of its effects on human life as well as natural resources. Various drought indices were developed in the past, and are used today to identify and monitor drought, which is a global issue (Palmer, 1945; Yao & Ding, 1990; McKee, Doesken, & Kleist, 1993; Willeke, Hosking, Wallis & Guttman, 1994; Wu, Hayes, Weiss, & Hu, 2001; Tsakiris, Pangalou, & Vangelis, 2007; Vicente-Serrano, Begueria, & Lopez-Moreno, 2010, Zarei et al., 2017; Tigkas, Vangelis, & Tsakiris, 2019; Bushra et al., 2019).

Turkey, which is located in the middle belt with semi-arid climate characteristics, is struggling with drought. Researchers investigate and determine the effects of drought all over the country (Türkeş, 1996; Kömüşçü, 2001; Yıldız, 2009; Kıymaz, Gunes, & Asar, 2011; Hınış, 2013; Oğuztürk & Yıldız, 2014; Akar, Oguz, & Yurekli, 2015; Gümüş, Başak, & Oruç, 2016; Dikici, 2019; Beden, Demir, & Ülke Keskin, 2020; Boustani & Ülke Keskin, 2020; Karabulut, 2020; Oğuz, Pekin, & Çamalan, 2021). Sırdaş and Şen (2003) reported in their study that was conducted for the 1930-1990 period that the severity of droughts gradually increased in Turkey. Sönmez, Komuscu, Erkan, & Turgu (2005) examined the drought of Turkey and found severe droughts in the Southeastern Anatolia region. Türkeş (2007) reported that large and severe droughts were experienced in Turkey in 1983, 1984, 1989, 1990, 1996, and 2001. Bacanli, Dikbas, and Baran (2011) reported that the Central Anatolian region was in danger of severe drought. Yıldız (2014) reported that the Central Anatolian Region was under the influence of high-frequency droughts in the 1953-2004 period. Arslan (2017), who examined the drought of Niğde between 1950 and 2015, reported that there was an increase in humidity. Zeybekoglu, Alrayess, and Ulke Keskin (2018) examined the drought of Sinop, Boyabat, and Erfelek meteorological stations for the period 1931-2013 by using SPI. Bacanlı and Kargı (2019) examined the droughts of the Bursa region for the period 1969-2015. The authors determined that the study area is prone to drought and stated that the region faces the danger of agricultural and hydrological drought. Yaltı and Aksu (2020), in their study which examined Iğdır plains, reported that the region was at risk of severe drought. Bakanoğulları (2020) examined the severity and frequency of droughts in Istanbul Çamlıdere Basin during the 1982-2006 period. Şener and Şener (2021) analyzed the droughts of the Burdur Lake basin with Geographic Information Systems. They reported that moderate and mild droughts were experienced in the basin in 2019.

This study, which investigated the drought in the Boyabat district of Sinop, consisted of two stages. In the first stage, annual drought status was determined by using the Z-Score Index (ZSI), China Z-Index (CZI), and Modified China Z-Index (MCZI). The relations between drought indices are examined in the second stage of the study.

MATERIAL AND METHOD

Material

Boyabat district of Sinop, which is located in the Kizilirmak Basin, shows terrestrial climate characteristics. The mean annual precipitation for the 1976-2017 period of the precipitation observation station operated by the Turkish State Meteorological Service in the district was 423.4 mm. During the observation period, the highest precipitation measured at the meteorology station was recorded as 919.9 mm in 1996, and the lowest precipitation was recorded as 197.60 mm in 2017. The 1991-1995 period was the longest in which less than average precipitation was recorded. The periods with the longer-than-average precipitation were found to be 1988-1990, 1998-2000, and 2014-2016. The information on the observation station is given in Table 1, and the temporal distribution of rainfall is given in Fig.1.

Table 1. Geographical and statistical details of station

ID	Latitude (N)	Longitude (E)	Elevation (m)	Annual Rainfall (mm/year)			
				Min.	Max.	Ave.	Std. Dev.
17620	41° 28'	34°46'	350	197.6	919.9	423.4	149.1

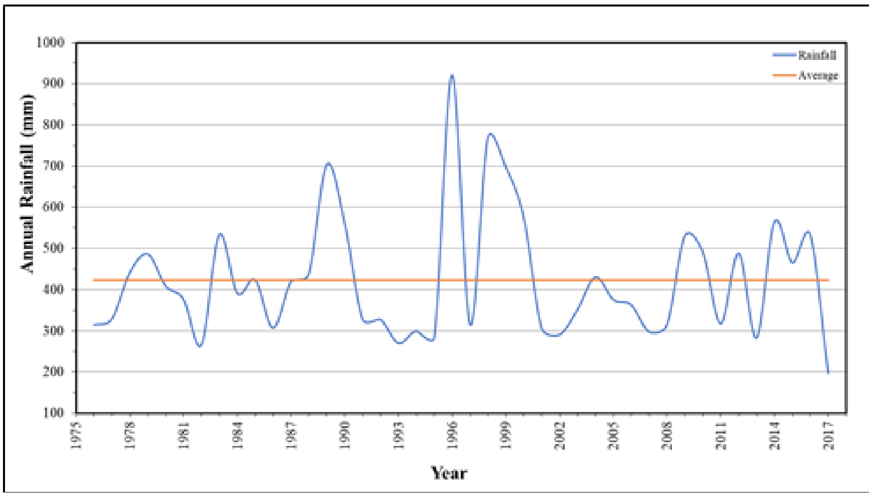

Figure 1. Temporal distribution of rainfall

Drought Indices

The Z-Score Index, China-Z Index, and Modified China-Z Index were used to determine the annual drought scores of the Boyabat in the 1976-2017 period. The advantages of these indices are expressed i) ease of calculation, ii) considers precipitation data only, iii) allowing incomplete data (Wu et al., 2001; Morid, Smakhtin, & Moghaddasi, 2006; Dogan, Berktay, & Singh, 2012; Jain, Pandey, Jain, & Byun, 2015; Kumar, Singh, Bisht, & Kant, 2021). Brief explanations about the drought indices are given in the continuation of the article, and detailed explanations are in the relevant references.

As given in Eq. 1, the Z-Score Index is obtained by dividing the difference between the relevant precipitation value (x_i) in the observation series and the mean of the series ($\overline{x}$) by the Standard Deviation (σ) of the series (Yao & Ding, 1990; Wu et al., 2001; Li, Li, Lu, Zhang, & Kim, 2019).

$$ZSI = \frac{x_i - \bar{x}}{\sigma} \tag{1}$$

The China-Z Index is determined by performing the operation steps given in Eqs. 2-3, based on the assumption that precipitations fit the Pearson Type III distribution (Wu et al., 2001; Morid et al., 2006; Dogan et al., 2012).

$$CZI = \frac{6}{C_s}\left(\frac{C_s}{2} ZSI + 1\right)^{1/3} - \frac{6}{C_s} + \frac{C_s}{6} \tag{2}$$

$$C_s = \frac{\sum_{j=1}^{n}(x_i - \bar{x})^3}{n * \sigma^3} \tag{3}$$

In Eqs. 2-3, C_s given represents the skewness coefficient of the observation series, x_i represents the relevant precipitation, ZSI represents the Z-Score Index value, and n represents the number of observations.

The calculation of the Modified China-Z Index is similar to that of the China-Z Index; however, the median (Ø) value of the series is taken into account rather than the mean value of the series (Morid et al., 2006). The calculation of MCZI is performed with Eqs. 4-6.

$$MCZI = \frac{6}{C_s}\left(\frac{C_s}{2}\varphi + 1\right)^{1/3} - \frac{6}{C_s} + \frac{C_s}{6} \tag{4}$$

$$C_s = \frac{\sum_{j=1}^{n}(x_i - \emptyset)^3}{n * \sigma^3} \quad (5)$$

$$\varphi = \frac{x_i - \emptyset}{\sigma} \quad (6)$$

The draught categories of ZSI, CZI, and MCZI index values are given in Table 2 (McKee, Doesken, & Kleist,1995; Kutiel, Maheras, & Guika, 1996; Morid et al., 2006; Jain et al., 2015; Zarei et al., 2017).

Table 2. Classification of drought indices values

Class	ZSI/CZI/MCZI
Extremely wet	≥2
Severely wet	1.5 ~1.99
Moderately wet	1.0 ~ 1.49
Normal	−0.99 ~ 0.99
Moderately dry	−1.0 ~ −1.49
Very dry	−1.5 ~ −1.99
Extremely dry	≤−2

RESULTS

In the present study, the ZSI, CZI, and MCZI index values were calculated by using the annual total precipitation values of the Boyabat station in the 1976-2017 period. Figs. 2-4 was prepared with the ZSI, CZI, and MCZI indices.

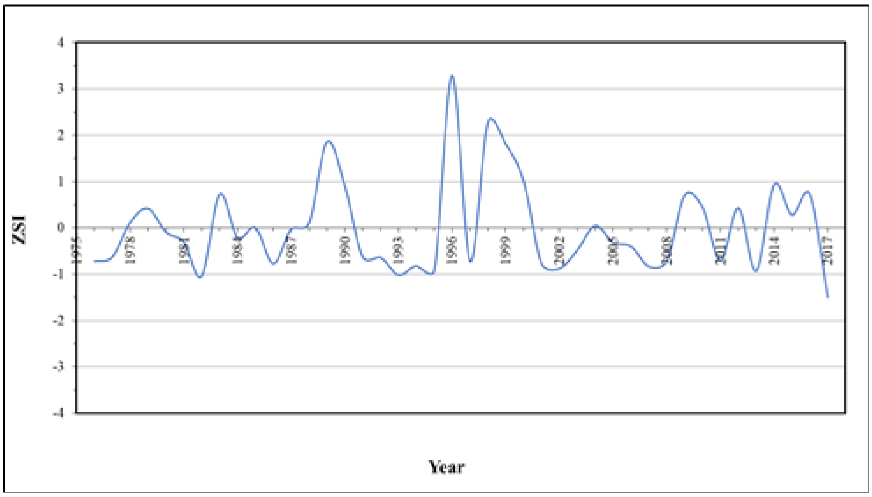

Figure 2. Yearly ZSI values

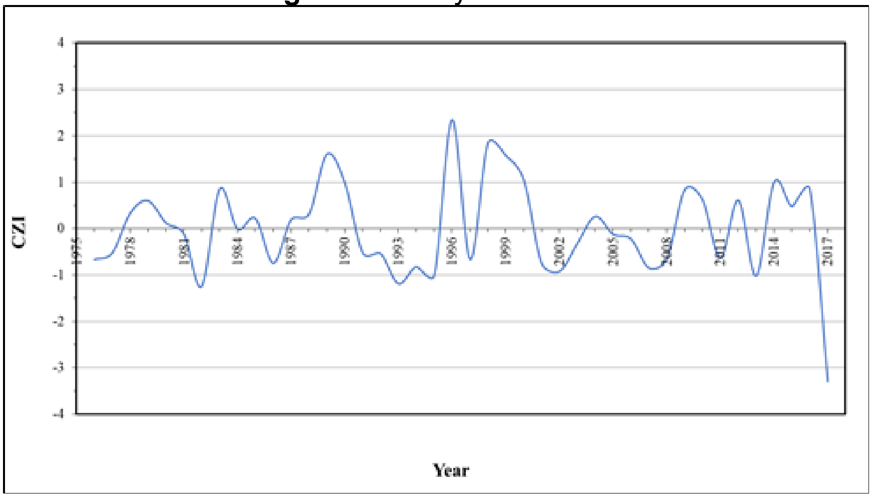

Figure 3. Yearly CZI values

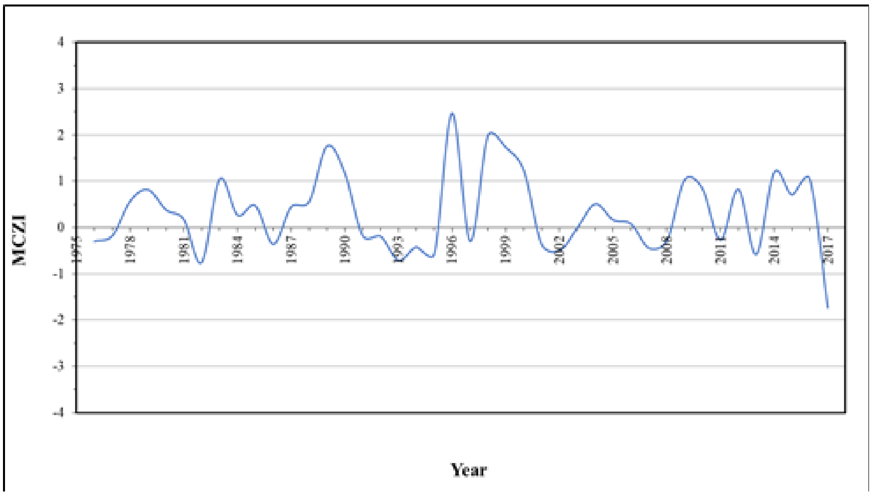

Figure 4. Yearly MCZI values

According to the ZSI method, 1982 and 1993 were determined as moderate drought, and 2017 was determined as severe drought. The year 2000 was moderately humid, 1989 and 1999 were severely humid, and 1996 and 1998 were very humid years. According to the CZI results, although it was determined that there was a moderate drought in 1982, 1993, 1995, and 2003, there was a very severe drought in 2017. When the humid years were evaluated, 2000 and 2014 were determined to be moderately humid, 1989, 1998 and 1999 moderately humid, and 1996 very severe humid. When the MCZI values were evaluated, 2017 was the only year that was dry, and it was determined that there was a severe drought. 1983, 1990, 2000, 2009, 2014, and 2016 moderately humid, 1989, 1998, and 1999 were severely humid, and 1996 was very severely humid. In the normal drought class, 34 years were classified as normal according to the ZSI index, 31 years according to the CZI values, and 32 years were classified as normal according to the MCZI results.

The drought index values of ZSI, CZI, and MCZI for 2017 were determined as the year of the most severe drought. The ZSI, CZI, and MCZI index values for 2017 were -1.50, -3.29, and -1.74, respectively. The year 1996, when the annual total precipitation that was recorded during the observation period was maximum, was also determined to be the year when the humidity reached maximum value. In 1996, ZSI, CZI, and MCZI values were calculated to be 3.29, 2.35, and 2.47, respectively.

Scatter diagrams were prepared and the determination coefficients were calculated to examine the compatibility between the ZSI, CZI, and MCZI indices better. Scatter diagrams prepared with ZSI, CZI and MCZI values are shown in Figs. 5-7.

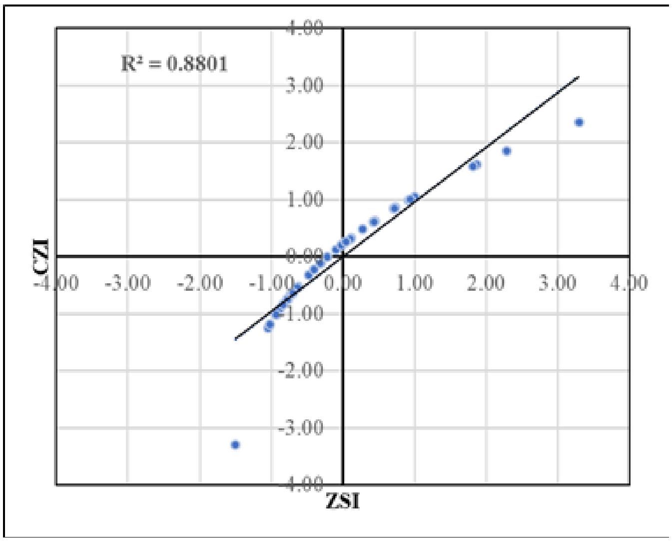

Figure 5. Scattter diagram of ZSI-CZI

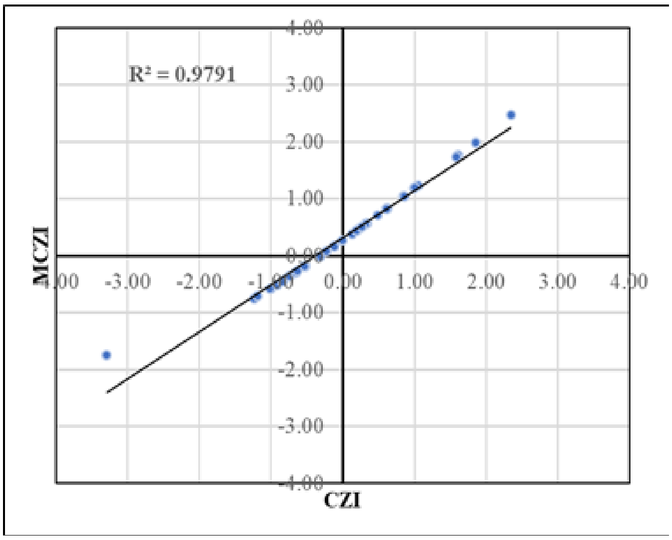

Figure 6. Scatter diagram of CZI-MCZ

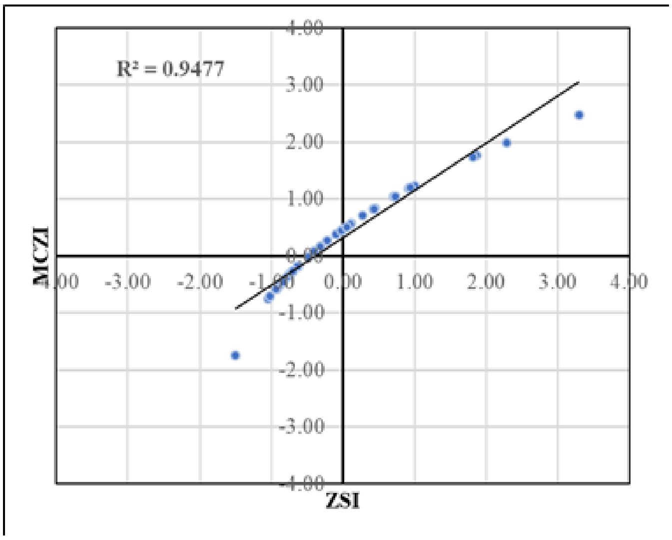

Figure 7. Scatter diagram of ZSI-MCZI

When the scatter diagrams between the indices that are given in Figs. 5-7 are evaluated, it is seen that the indices have a good agreement with each other. The determination coefficient values were determined to be 0.88 for the CZI-ZSI, 0.9477 for the MCZI-ZSI, and 0.9791 for the MCZI-CZI.

CONCLUSION

The annual drought was examined in the present study by using the annual total precipitation values between 1976 and 2017 at the Boyabat meteorological observation station in Sinop. In the study which used ZSI, CZI, and MCZI, the droughts of the years in the observation period were determined. Scatter diagrams were prepared to determine the relations between the indices in the study, and 2017 was determined as the driest year, and 1996 was found to be the wettest year. It was also found that the agreement between MCZI-ZSI and MCZI-CZI was high. In future studies, uncovering the meteorological and hydrological drought in the Kızılırmak Basin, where Boyabat station is located, by using the indices in the literature will provide a better examination and evaluation of the situation in the basin.

REFERENCES

Akar, Ö., Oğuz, İ., & Yürekli, K. (2015). İkikara Havzası'nın kurak ve ıslak dönemlerinin bazı kuraklık indisleri yardımıyla karşılaştırılması. Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi, 32(2), 7-13.

Arslan, O. (2017). Investigation of trends in meteorological droughts in Niğde Province. Anadolu University Journal of Science and Technology A – Applied Sciences and Engineering, 18(5), 919-928. https://doi.org/10.18038/aubtda.293125

Bacanli, Ü, Dİkbas, F., & Baran T. (2011). Meteorological drought analysis case study: Central Anatolia. Desalination and Water Treatment, 26(1-3), 14-23. https://doi.org/10.5004/dwt.2011.2105

Bacanlı, Ü., & Kargı, P. (2019). Uzun ve kısa süreli periyotlarda kuraklık analizi: Bursa örneği. Doğal Afetler ve Çevre Dergisi, 5(1), 166-174. https://doi.org/10.21324/dacd.429391

Bakanoğulları, F. (2020). SPEI ve SPI indisleri kullanılarak İstanbul-Damlıca Deresi Havzasında kuraklık şiddetlerinin analizi. Toprak Su Dergisi, 9(1), 1-10 https://doi.org/10.21657/topraksu.566693

Beden, N., Demir, V., & Ülke Keskin, A. (2020). Samsun İlinde SPI ve PNI Kuraklık İndekslerinin Eğilim Analizi. Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi, 22(64), 107-116. https://doi.org/10.21205/deufmd.2020226411

Boustani, A., & Ulke A. (2020). Investigation of meteorological drought indices for environmental assessment of Yesilirmak Region. Journal of Environmental Treatment Techniques, 8(1), 374-381.

Bushra, N., Rohli, R. V., Lam, N. S. N., Zou, L. L., Mostafiz, R. B., & Mihunov, V. (2019). The relationship between the Normalized Difference Vegetation Index and drought indices in the South Central United States. Nat Hazards, 96(2), 791-808. https://doi.org/10.1007/s11069-019-03569-5

Dikici, M. (2019). Asi Havzası'nda (Türkiye) kuraklık analizi. Doğal Afetler ve Çevre Dergisi, 5(1), 22-40. https://doi.org/10.21324/dacd.426784

Dogan, S., Berktay, A., & Singh, V. P. (2012). Comparison of multi-monthly rainfall-based drought severity indices, with application to semi-arid Konya closed basin, Turkey. Journal of Hydrology, 470-471, 255-268. https://doi.org/10.1016/j.jhydrol.2012.09.003

Gümüş, V., Başak, A., & Oruç, N. (2016). Standartlaştırılmış Yağış İndeksi (SYİ) yöntemi ile Şanlıurfa istasyonunun kuraklık analizi. Harran Üniversitesi Mühendislik Dergisi, 1(1), 36-44

Hınıs, M. (2013). Bütünleşik kuraklık indeksi ile Aksarayda hidrometeorolojik kuraklık analizi. Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 28(4), 711-721.

Jain, V. K., Pandey, R. P., Jain, M. K., & Byun, H. R. (2015). Comparison of drought ındices for appraisal of drought characteristics in the Ken River Basin. Weather and Climate Extremes, 8, 1-11. https://doi.org/10.1016/j.wace.2015.05.002

Karabulut, M. (2020). Standart yağış indeksi kullanılarak Sivas İl'inde kuraklık analizi. Uluslararası Sosyal Araştırmalar Dergisi / The Journal of International Social Research, 13(71), 216-230.

Kiymaz, S., Güneş, V., & Asar, M. (2011). Standartlaştırılmış yağış indeksi ile Seyfe Gölünün kuraklık dönemlerinin belirlenmesi. Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi, 28(1), 91-102.

Komuscu, A. Ü. (2001). An analysis of recent drought conditions in Turkey in relation to circulation patterns. Drought Network News, 13(2-3), 5-6.

Kumar, U., Singh, S., Bisht, J. K., & Kant, L. (2021). Use of meteorological data for identification of agricultural drought in Kumaon region of Uttarakhand. J Earth Syst Sci, 130(3), 1-13. https://doi.org/10.1007/s12040-021-01622-1

Kutiel, H., Maheras, P., & Guika, S. (1996). Circulation and extreme rainfall condition in The Eastern Mediterranean during the last century. International Journal of Climatology, 16(1), 73-92. https://doi.org/10.1002/(SICI)1097-0088(199601)16:1<73::AID-JOC997>3.0.CO;2-G

Li, F., Li, H., Lu, W., Zhang, G., & Kim, J-C. (2019). Meteorological drought monitoring in Northeastern China using multiple indices. Water, 11(1), 1-17. https://doi.org/10.3390/w11010072

McKee, T. B., Doesken, N. J., & Kleist, J. (1993). The relationship of drought frequency and duration of time scales. 8th Conference on Applied Climatology, American Meteorological Society, Anaheim, CA.

McKee, T. B., Doesken, N. J., & Kleist, J. (1995). Drought monitoring with multiple time scales. 9th Conference on Applied Climatology, Dallas, Texas.

Mishra, A. & Singh, V. (2011). A review of drought concepts. Journal of Hydrology, 391(1-2), 202–216. https://doi.org/10.1016/j.jhydrol.2010.07.012

Morid, S., Smakhtin, V., & Moghaddasi, M. (2006). Comparison of seven meteorological indices for drought monitoring in Iran. International Journal of Climatology, 26(7), 971-985. https://doi.org/10.1002/joc.1264

Oğuz, K., Pekin, M., & Çamalan, G. (2021). Muğla ilinde 1960-2018 dönemi kuraklık analizi. Doğal Afetler ve Çevre Dergisi, 7(1), 89-100. https://doi.org/10.21324/dacd.774955

Oğuztürk, G., & Yıldız, O. (2014). Drought analysis for different time periods in the city of Kırıkkale. International Journal of Engineering Research and Development, 6(2), 19-25 https://doi.org/10.29137/umagd.346084

Palmer, W. C. (1945). Meteorological drought. Research paper no. 45. US Weather Bureau, Washington DC.

Şener, E., & Şener, Ş. (2021). GIS based spatiotemporal comparation between SPI and CZI drought index: A case study of Burdur Lake Basin. Journal of Natural Hazards and Environment 7(1), 41-58. https://doi.org/10.21324/dacd.800036

Sırdaş, S., & Şen, Z. (2003). Spatio-temporal drought analysis in the Trakya region, Turkey. Hydrological Sciences Journal, 48(5), 809-820.

Sırdaş, S. (2002). Meteorolojik kuraklık modellemesi ve Türkiye uygulaması. İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, İstanbul.

Sonmez, F. K., Komuscu, A. U., Erkan, A., & Turgu, E. (2005). An analysis of spatial and temporal dimension of drought vulnerability in Turkey using the standardized precipitation index. Nat Hazards, 35(2), 243–264. https://doi.org/10.1007/s11069-004-5704-7

Tigkas, D., Vangelis, H., & Tsakiris, G. (2019). Drought characterisation based on an agriculture oriented standardised precipitation index. Theor Appl Climatol, 135(3-4), 1435–1447. https://doi.org/10.1007/s00704-018-2451-3

Tsakiris, G., Pangalou, D., & Vangelis, H. (2007). Regional drought assessment based on the Reconnaissance Drought Index (RDI). Water Resour Manage, 21(5), 821-833. https://doi.org/10.1007/s11269-006-9105-4

Turkes, M. (1996). Spatial and Temporal analysis of annual rainfall variations in Turkey. International Journal of Climatology, 16, 1057-1076, 1996.

Türkeş, M. (2007). Türkiye'nin kuraklığa, çölleşmeye eğilimi ve iklim değişikliği açısından değerlendirilmesi. Pankobirlik, 91, 38-47.

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index. J. Clim. 23(7), 1696–1718. https://doi.org/10.1175/2009JCLI2909.1

Wilhite, D. A. (2000) Drought: A global assessment. Routledge Press, London and New York, Volume I.

Willeke, G., Hosking, J. R. M., Wallis, J. R., & Guttman N. B. (1994). The national drought atlas. Institute for Water Resources Report 94-NDS-4, U.S. Army Corps of Engineers.

Wu, H., Hayes, M.J., Weiss, A., & Hu, Q. (2001). An evaluation of the Standardized Precipitation Index, the China Z Index and the statistical Z Score. Int J Climatol, 21(6), 745-758. https://doi.org/10.1002/joc.658

Yaltı, S., & Aksu, H. (2019). Drought analysis of Iğdır Turkey. Turkish Journal of Agriculture – Food Science and Technology, 7(12), 2227-2232. https://doi.org/10.24925/turjaf.v7i12.2227 2232.3004

Yao, Z., & Ding, Y. (1990). Climate Statistics. Meteorological Press: Beijing, China (In Chinese).

Yıldız, O. (2014). Spatiotemporal analysis of historical droughts in the Central Anatolia, Turkey. Gazi University Journal of Science, 27(4), 1177-1184.

Yıldız, O. (2009). Assessing temporal and spatial characteristics of droughts in the Hirfanli Dam Basin, Turkey. Scientific Research and Essays, 4(4), 249-255. https://doi.org/10.5897/SRE.9000212

Zarei, A. et al. (2017) Comparison of meteorological indices for spatio-tem-poral analysis of drought in Chahrmahal Bakhtiyari Province in Iran. Hrvatski meteorološki časopis, 52(52),13-26.

Zeybekoğlu, U., Alrayess, H., & Ülke Keskin, A. (2018). Meteorological drought analysis in Sinop Turkey. Proceedings of the 13th International Congress on Advances in Civil Engineering, 1-9.