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Drought monitoring and assessment with different meteorological drought indices in a transitional climate: Amasya and Merzifon, Türkiye

Utku Zeybekoglu

¹ *Boyabat Vocational School of Higher Education,
Sinop University, Sinop, Türkiye*

Author E-mail: Utku Zeybekoglu, utkuz@sinop.edu.tr

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Abstract—The identification, monitoring and prediction of the possible future conditions of drought, a complex disaster, are of significance for decision makers in planning natural-social and human activities and planning, operation, and management of water resources. The present study investigates the meteorological drought experienced by Amasya and Merzifon, located within the transition zone between the Black Sea and continental climates in Türkiye. The analysis employs the standardized precipitation index (SPI), the China-Z index (CZI), and the modified China-Z index (MCZI), utilizing annual time scales to assess the precipitation patterns in these regions. The precipitation records obtained from the selected meteorological stations between 1964 and 2023 were analyzed in order to assess the drought and compare the performance of precipitation-based drought indices. The investigation also focused on drought-wet period percentages, the percentages of occurrence of drought classes, and the negative and positive peak index values. According to all three drought indices, significant dry years were identified, including 1964, 1974–1976, 1982, 1984, 1986, 1990, 1999, 2013, 2017, and 2020. The assessment revealed that SPI, CZI, and MCZI performance was similar in identifying drought in transition climate zones. It was also determined that CZI and MCZI are a viable alternative to SPI for drought monitoring.

Key-words: drought assessment; drought indices; comparative analysis; standardized precipitation index (SPI); China-Z index (CZI); modified China-Z index (MCZI)

1. Introduction

Drought is a recurring global phenomenon characterized by multiple climatological and hydrological parameters, causing significant damage to both the natural environment and human life (*Mishra and Desai, 2005; Adisa et al., 2020; Adib et al., 2024*). Dependent variables that affect drought include temperature, precipitation, and soil properties (*Jenkins and Warren, 2015*). Drought is distinct from other natural disasters in that it does not occur abruptly. The phenomenon of drought is characterized by a decrease in precipitation, leading to a decline in water availability. This initial meteorological drought is followed by a subsequent hydrological drought, which in turn results in an agricultural drought (*Mishra and Desai, 2005*).

Drought indices (DIs) have been developed as means to monitor and measure the aforementioned negative effects, with DIs being mathematical tools used to determine the severity, duration, and effects of drought events. The application of DIs has been instrumental in the monitoring of drought conditions and the formulation of strategic decisions across a range of domains, including agricultural production and water resources management. The development of DIs has enabled the establishment of drought management and early warning systems, with DIs being used to determine the severity, duration, and effects of drought events. Furthermore, DIs have been identified as a pivotal instrument in the effort to combat climate change, as they offer insights into long-term shifts in climate and drought occurrences, thereby paving the way for the formulation of adaptation strategies (*UNEP, 2021*). The role of DIs in the establishment of drought management and early warning systems, the efficient use of water resources, the determination of agricultural policies, and the development of strategies to combat climate change is critical. The World Meteorological Organization (WMO) has recommended the utilization of the SPI by all national meteorological and hydrological services globally for the characterization of meteorological droughts (*Hayes et al., 2011; WMO, 2012*). Additionally, the SPI is proposed for use as a reference index, as it has been demonstrated to facilitate the earlier identification of droughts, to be reliable, to necessitate only precipitation data, and to yield more accurate results (*Morid et al., 2006; Dogan et al., 2012; Mishra and Singh, 2011; Yacoub and Tayfur, 2017; Zeybekoglu et al., 2023*). *Tanoglu (1943)* prepared a drought map using temperature and precipitation values throughout Türkiye. *Erinc (1949)* performed a drought analysis by Thorntwaite method by precipitation, temperature, and evaporation records. *Wu et al. (2001)* sought to compare the results of three DIs – the standard precipitation index (SPI), the China-Z index (CZI), and the Z-score index (ZSI) – for China. Their findings revealed that both the CZI and the ZSI yielded results that were analogous to those of the SPI across all temporal ranges. Moreover, the calculations required to determine the CZI and the ZSI were comparatively less onerous than those of the SPI. *Morid et al. (2006)* evaluated seven distinct DIs

(SPI, percent of normal (PN), deciles index (DI), ZSI, CZI, modified China-Z index (MCZI), and effective drought index (EDI)). The study concluded that DIs exhibited a rapid response to precipitation events in specific years but demonstrated temporal and field inconsistencies. Conversely, SPI and EDI were effective in detecting the onset of drought, exhibiting temporal and field consistency, though EDI yielded more sensitive results than SPI. *Bacanli et al.* (2011) conducted an analysis of precipitation and temperature data from 13 selected meteorological stations in the Central Anatolia Region of Türkiye, collected over the period 1965–2006. The evaluation was conducted for all stations. The results of the comparative analysis indicated that the PDSI index indicated more humid conditions than the Erinc and De Martonne indices. *Dogan et al.* (2012) conducted a comparative analysis of six drought indices in the Konya Closed Basin, Türkiye. The drought indices employed included PN, RDDI, ZSI, CZI, SPI, and EDI. In their study, *Shahabfar and Eitzinger* (2013) sought to compare and evaluate six meteorological drought indices –PN, SPI, CZI, MCZI, ZSI, and the De Martonne aridity index (I) – with a view to assessing the spatio-temporal dynamics of droughts in six climatic regions in Iran. *Jain et al.* (2015) undertook a comparative analysis of SPI, EDI, ZSI, CZI, rainfall departure (RD), and rainfall decile based drought index (RDDI), with the objective of ascertaining the suitability of indices in districts susceptible to drought in the Ken River Basin in central India. The findings of this study indicated a strong correlation between DIs at equivalent time scales. *Tadic et al.* (2015) undertook an analysis of five drought identification methods (SPI, DI, percent of normal precipitation (PNPI), rainfall anomaly index (RAI), and threshold level method) for continental Croatia. This analysis was conducted on 15 weather stations in the period from 1981 to 2011. In a separate study, *Payab and Turker* (2019) compared and evaluated the performance of the SPI, RDI, ZSI, CZI, supply and demand drought index (SDDI), and combined China-Z and supply and demand drought index (CZSDDI) in Northern Cyprus. Multiple DIs, including the PN, SPI, ZSI, and EDI, were employed to evaluate the drought conditions in the Wuyuer River Basin, Northeast China, by *Li et al.* (2019). *Katipoglu et al.* (2020) conducted a comparative analysis of five meteorological DIs: SPI, ZSI, RAI, SPEI, and RDI. This analysis was conducted across seasonal and annual time scales to monitor drought. *Boustani and Ulke* (2020) compared the drought analysis of the Yeşilirmak River basin between 1970 and 2014 with different indices (PN, DI, RAI, ZSI, CZI, MCZI, and SPI) and drought analysis between different time scales. They determined that the best index and time for the basin was SPI and 12-month scale. *Salvacion* (2021) identified drought characteristics by SPI and SPEI for the Philippines. In a related study, *Dalkilic et al.* (2021) utilized statistical analysis to calculate and evaluate four DIs (Aridity Index; PNI; SPEI; SPI) to assess the drought status of the Konya Closed Basin. *Sridhara et al.* (2021) utilized precipitation data to evaluate five DIs: the deciles index (DI), PN, CZI, ZSI, and SPI. The researchers employed monthly total precipitation data to

ascertain drought occurrences in the period 1967–2017 across diverse talukas in the Chitradurga district of Karnataka, India. The assessment revealed that the performances of SPI, CZI, and ZSI were similar in identifying drought. *Sa'adi et al.* (2022) evaluated the performance of several rain-based meteorological DIs for the Johor River Basin in Malaysia from 1970 to 2015. The indices evaluated included the RAI, SPI, CZI, PN, DI, and ZSI. *Singh et al.* (2022) compared the performance of seven DIs (SPI, CZI, MCZI, PNI, DI, RAI, and ZSI) in identifying meteorological droughts in the Betwa River basin, India. *Zeybekoglu et al.* (2023) sought to determine the drought conditions that prevailed at stations selected from the Yesilirmak Basin in Türkiye between 1970 and 2014. To this end, they employed a range of indices, including the ZSI, the CZI, the MCZI, and the SPI. The findings indicated that the indices exhibited congruent results and that SPI identified drought conditions earlier than the other indices. *Gumus* (2023) conducted a comparative analysis of drought characteristics across diverse climates and geographical regions in Türkiye. This analysis employed the SPI, utilizing the precipitation parameter, and the SPEI, which is derived by adding the Potential Evaporation (PET) values to precipitation from 1970 and 2021. In a related study, *Sener and Davraz* (2024) compared the performance of six DIs (SPI, PNI, DI, CZI, RAI, and ZSI) in the Egirdir Lake Basin in Türkiye. In their study, *Simsek et al.* (2024) sought to evaluate the meteorological drought of the Black Sea region in the north of Türkiye. To this end, they employed the SPI and RDI methods, undertaking a comparative analysis across diverse temporal scales. The meteorological parameters recorded from 28 stations between 1965 and 2019 were subjected to analysis, resulting in a high correlation coefficient of 97.8%, 97.6%, and 97.3% for the 3-, 6-, and 12-month time scales, respectively, between the SPI and RDI in the evaluation of meteorological drought in the Black Sea region.

Türkiye is located between the temperate and subtropical zones. The country's geographical characteristics, including its proximity to the sea, the presence of mountains, and the diversity of its landforms, have resulted in the diversification of its climates. The coastal regions experience a more temperate climate, influenced by the sea, while the interior is characterized by a continental climate, due to the influence of the North Anatolian and Taurus mountains (*Atalay, 1997; Sensoy et al., 2007*). The transition climate between the Black Sea region and the continental climate is characterized by the following features: (a) The summers are less arid than in the continental climate and less rainy than in the Black Sea climate. (b) The winters are less mild than in the Black Sea climate and less harsh than in the continental climate.

The present study investigates the occurrence of drought conditions in Amasya, a region situated in the transition zone between the Black Sea and continental climates in Türkiye, using three precipitation-based DIs: SPI, CZI, and MCZI. To this end, precipitation records from Amasya and Merzifon rainfall stations spanning the period 1964–2023 were investigated in order to make a comparative analysis of these indices. The objective of this research is to quantify

drought on an annual basis, thereby facilitating a more profound comprehension of the drought patterns that characterize it. The present study has therefore been designed with the following objectives in mind: (1) to examine the spatial variation of meteorological drought characteristics, (2) to determine the important dry and wet years, (3) to determine the magnitude, duration and frequency for dry/wet years, (4) to examine the performance of DIs comparatively, and (5) to identify an appropriate drought index. The present paper is composed of four sections. Section 1 and 2 provide a detailed exposition of the study area, the sources of data, and the analysis method utilized in the study. Section 3 is concerned with the evaluation of the findings obtained as a result of the analyses. The final section of the paper presents the conclusion of the study.

2. Material and methodologies

2.1. Study area

Amasya's geographical location in the inner part of the Central Black Sea region of Türkiye results in a transitional climate that exhibits characteristics of both the Black Sea climate and the continental climate. This transitional climate is characterized by the influence of the post-Black Sea climate, with summers that are less arid than in the continental climate and less rainy than in the Black Sea climate. Conversely, winters are not as mild as in the Black Sea climate and are not as harsh as in the continental climate. This results in a transitional climate that is situated between the continental climate and the Black Sea climate. Precipitation data were recorded at Amasya and Merzifon for the 1964–2023 period by the Turkish State Meteorological Service (TSMS) in the Black Sea Region of Türkiye. The list of stations is given in *Table 1*, together with their geographical and meteorological details. The localization of stations used in the study are shown in *Fig 1*. Furthermore, *Fig. 2* illustrates the precipitation time series of the stations.

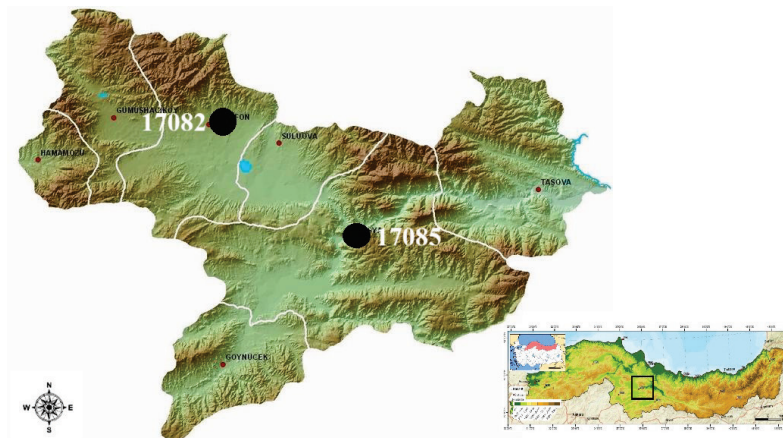


Fig. 1. The geographical and topographical situation of the study area.

Table 1. Basic characteristics of the stations: ID, geographical coordinates, and precipitation records

ID	Name	Latitude(oN)	Longitude(oE)	P _{mean} (mm/year)	P _{min} (mm/year)	P _{max} (mm/year)
17085	Amasya	40.88	35.46	461.53	293.40	681.20
17082	Merzifon	40.67	35.84	432.10	225.10	703.30

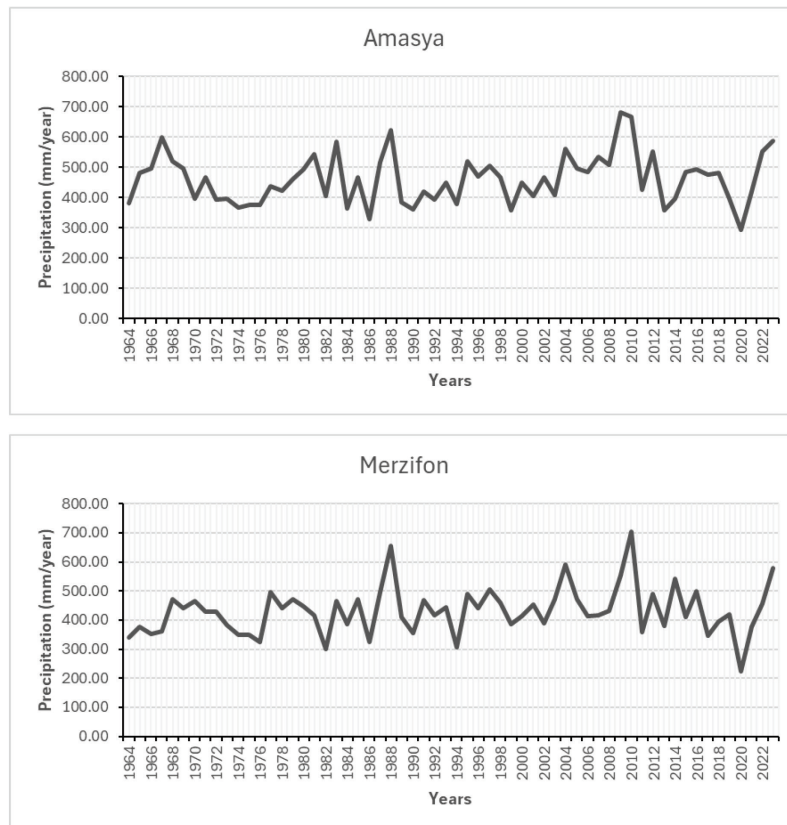


Fig. 2. Precipitation time series for stations utilised in this study.

2.2. Standardized precipitation index (SPI)

The SPI is predicated exclusively on precipitation data developed by *McKee et al.* (1993), which is extensively utilized on a global scale. It serves as a valuable instrument for the identification of drought occurrences across diverse geographical regions. The calculation of the SPI is initiated by the determination of the probability distribution function. According to a study conducted by *McKee et al.* (1995), gamma family functions are the optimal probability distribution functions for the fitting of precipitation data, as it is outlined below.

$$g(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-\frac{x}{\beta}}, \quad (1)$$

where $\Gamma(\alpha)$ denotes the gamma function, x is the precipitation amount, $\alpha > 0$ is the shape parameter, and $\beta > 0$ is the scale parameter. The parameters of the gamma probability density function are determined using the maximum likelihood method, with this being performed separately for each station and time scale:

$$\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} dy, \quad (2)$$

$$\alpha = \frac{1}{4A} \left(1 + \sqrt{1 + \frac{4A}{3}} \right); \beta = \frac{\bar{x}}{\alpha}; A = \ln(\bar{x}) - \sum \frac{\ln(x)}{n}, \quad (3)$$

where n denotes the number of precipitation observations. A mathematical cumulative probability function can accurately describe the distribution of precipitation at stations, as it is follows:

$$G(x) = \int_0^x g(x) dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-\frac{x}{\beta}} dx. \quad (4)$$

In the event that the gamma function is undefined for $x = 0$, and the precipitation distribution is zero, the cumulative probability is obtained as:

$$H(x) = q + (1 - q)G(x), \quad (5)$$

where q denotes the probability of a zero. Subsequently, the cumulative probability $H(x)$ is converted to the standard normal distribution, thereby yielding the SPI. According to *Wu et al.* (2007), the calculation of the SPI is presented based on the following equations:

$$0 < H(x) < 0.5; \text{SPI} = - \left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right); t = \sqrt{\ln \left(\frac{1}{(H(x))^2} \right)}, \quad (6)$$

$$0.5 < H(x) < 1.0; \text{SPI} = + \left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right), \quad (7)$$

where $c_0, c_1, c_2, d_1, d_2,$ and d_3 are coefficients whose values are: $c_0 = 2.515517$, $c_1 = 0.802853$, $c_2 = 0.010328$, $d_1 = 1.432788$, $d_2 = 0.189269$, and $d_3 = 0.001308$. The drought classification according to SPI is given in *Table 2*.

2.3. China-Z index (CZI) and modified China-Z index (MCZI)

In the early 1990s, the China-Z index (CZI) and modified China-Z index (MCZI) were introduced to the National Meteorological Centre of China as a drought calculation index (Ju et al., 1997; Hong et al., 2001; Kassaye et al., 2021). The CZI and MCZI are associated with the Wilson-Hilferty cube root transformation (Wilson and Hilferty, 1931; Kendall and Stuart, 1977; Wu et al., 2001). The calculation of the MCZI is analogous to that of the CZI; however, the median value (v) of the series is taken into account rather than the mean value ($\bar{\theta}$) of the series (Morid et al., 2006). In the event that precipitation is assumed to follow the Pearson type III distribution, the following equation computes the CZI/MCZI (Wu et al., 2001; Morid et al., 2006; Dogan et al., 2012; Jain et al., 2015; Singh et al., 2022):

$$CZI = \frac{6}{C_s} \left(\frac{C_s}{2} \varphi_j + 1 \right)^{1/3} - \frac{6}{C_s} + \frac{C_s}{6}, C_s = \frac{\sum_{j=1}^n (x_j - \bar{\theta})^3}{n \cdot \sigma^3}, \varphi_j = \frac{x_j - \bar{\theta}}{\sigma}, \quad (8)$$

where C_s denotes the coefficient of skewness, n signifies the total number of months within the specified record, φ is a standardized variable (also termed the Z-score), x_j represents the precipitation during a specified period, and $\bar{\theta}$ indicates the mean value. Table 2 shows the drought classification based on MCZI.

Table 2. Classification and value ranges of DIs

Symbol	Category	SPI/CZI/MCZI
EW	Extremely wet	≥ 2.00
VW	Very wet	1.50 to 1.99
MW	Moderately wet	1.00 to 1.49
N	Normal	-0.99 to 0.99
MD	Moderately dry	-1.49 to -1.00
SD	Severely dry	-1.99 to -1.50
ED	Extremely dry	≤ -2.00

3. Results and discussion

The present study focuses on investigating the meteorological drought of Amasya, which is located in the transition zone between the Black Sea and continental climates in the Black Sea region of Türkiye, through precipitation-based DIs. The precipitation records from 1964 to 2023 at Amasya and Merzifon stations within the region were analyzed employing the SPI, CZI, and MCZI indices. Moreover, a comparative evaluation of the performance of DIs was conducted. The SPI, CZI, and MCZI were calculated at annual scales for Amasya and Merzifon, as illustrated in *Fig. 3*. The dry and wet years, as determined by the DIs and their frequency distribution, are presented in *Table 3*. As indicated in *Table 4*, the correlation coefficient (R) for the SPI-CZI, SPI-MCZI, and CZI-MCZI for Amasya and Merzifon are also presented. Furthermore, scatter diagrams were prepared for the stations in order to examine the agreement between the indices (*Fig. 4*).



Fig. 3. Temporal variation of all DIs utilized in this study.

As demonstrated in *Fig. 3* and *Table 3*, the SPI, CZI, and MCZI results of Amasya and Merzifon reveal significant findings. The CZI results for Amasya demonstrate that the number of dry and wet years is equal, with 10 years classified as dry and 10 years classified as wet. Conversely, the SPI and MCZI results indicate that the number of dry years exceeds the number of wet years, with 11 and 10 years, respectively, classified as dry. In wet years, the SPI classified 10 years and the MCZI classified 9 years as wet. In Merzifon, the number of dry years exceeds the number of wet years, according to all DIs. While the CZI and SPI each define 10 years as dry, the MCZI defines 7 years as dry. In wet years, all DIs define 6 years as wet.

The all DIs showed dry conditions in 1974-1976, 1984, 1986, 1990, 1994, 1999, 2013, and 2020 for Amasya. The driest year for the SPI was -2.35 for 2020, while the CZI and MCZI for the same year in Cankiri were -2.52 and -2.63, respectively. According to the DIs results in Amasya, the MD conditions happened in 1974-1976, 1984, 1990, 1999, and 2013. On the other hand 1964 was distinguished as SD by MCZI and SPI. Also just CZI distinguished the year 1981 as MD. The year 2020 was identified as ED condition by all DIs. 1967, 1983, 1988, 2004, 2009-2010, 2012, and 2022-2023 were determined as wet years by all DIs. The EW condition happened in 2009 and 2010. The MW years include 1983, 2004, 2012, and 2022-2023. Also just SPI and CZI distinguished the year 1981 as MW. The years 1967 and 1988 showed VW conditions. In 2009, the peak value of the SPI was 2.44, whereas the corresponding CZI and MCZI were 2.29 and 2.13, respectively.

The SPI, CZI, and MCZI indicated that years 1964, 1976, 1982, 1986, 1994, 2017, and 2020 have droughts in Merzifon. The driest year for the SPI was -3.04 for 2020, while the CZI and MCZI for the same year were -4.04 and -3.93, respectively. All DIs indicate that the MD conditions occurred in 1964, 1976, 1986, and 2017. Unlike the MCZI and SPI, CZI identified the years 1966 and 1974-1975 as MD at Merzifon. All DIs indicated that 1982 and 1994 were SD years, while 2020 was ED year. According to the all DIs, wet conditions occurred in 1988, 2004, 2009-2010, 2014 and 2023. MW conditions happened in 2009 and 2014. The years 2004 and 2023 were identified as VW conditions. Unlike the other indices, SPI identified the year 2016 as MW at Merzifon. The EW condition occurred in 1988 and 2010. In 2010 the peak value of the SPI was 2.86, whereas the corresponding CZI and MCZI were 2.60 and 2.62, respectively.

The findings of the arid classes presented in *Table 3* for the meteorological stations in Amasya and Merzifon determined MD frequencies of 15% and 11.67% for SPI, 11.67% for CZI, and 16.67% and 6.67% for MCZI, respectively. In Merzifon, the MD frequencies of the SPI and CZI methods are identical, and the years belonging to this drought class are also congruent. The SD frequencies for Amasya and Merzifon were found to be 1.67% and 3.33% for SPI and MCZI, respectively, and 3.33% for CZI. In Amasya, the SD frequencies of the SPI and MCZI methods are found to be identical, and the years (e.g., 1986) belonging to this drought class are also congruent. Similarly, in Merzifon, the SD frequencies of all DIs are found to be identical, and the years (1982 and 1994) belonging to

this drought class are also congruent. In the Amasya and Merzifon, it has been determined that the ED frequencies of the SPI, CZI, and MCZI methods are identical to 1.37%. Furthermore, the year 2020, which has been designated as belonging to this drought class, corresponds with all DIs.

Table 3. Characteristics of years as detected by DIs

		SPI		CZI		MCZI		
		Years	Frequency	Years	Frequency	Years	Frequency	
Amasya	WET	EW	2009	3.33%	2009	3.33%	2009	3.33%
			2010		2010		2010	
	VW	1967	3.33%	1967	3.33%	1967	3.33%	
		1988		1988		1988		
	MW	1981	10%	1981	10%	1983	8.33%	
		1983		1983		2004		
		2004		2004		2012		
		2012		2012		2022		
		2022		2022		2023		
	DRY	MD	1964	15%	1974	11.67%	1964	16.67%
1974			1974		1974			
1975			1975		1975			
1976			1976		1976			
1984			1984		1984			
1990			1990		1989			
1994			1999		1990			
1999			2013		1994			
2013	1999	2013						
DRY	SD	1986	1.67%	1986	3.33%	1986	1.67%	
		1994		1994				
		2020		2020		2020		
WET	EW	1988	3.33%	1988	3.33%	1988	3.33%	
		2010		2010		2010		
	VW	2004	3.33%	2004	3.33%	2004	3.33%	
		2023		2023		2023		
	MW	2009	3.33%	2009	3.33%	2009	3.33%	
		2014		2014		2014		
Merzifon	DRY	MD	1964	11.67%	1964	11.67%	1964	6.67%
			1966		1966		1976	
			1974		1974		1986	
			1975		1975		2017	
			1976		1976			
			1986		1986			
	2017	2017						
	SD	1982	3.33%	1982	3.33%	1982	3.33%	
		1994		1994		1994		
	ED	2020	1.67%	2020	1.67%	2020	1.67%	

As it is demonstrated in *Table 3*, the results of the wetland classes indicate that Amasya and Merzifon exhibited the following MW frequency for the SPI: 10% and 11.67%, for the CZI: 10.00% and 3.33%, and for the MCZI: 8.33% and 3.33%, respectively. In Amasya, the MW frequencies of the SPI and CZI methods are found to be identical, and the years belonging to this drought class are also congruent. Similarly, in Merzifon, the MW frequencies of all DIs are found to be identical, and the years (2009 and 2014) belonging to this drought class are also congruent. The VW frequencies for Amasya and Merzifon were found to be 1.67% for all DIs. Moreover, the years 1988 and 2020; 2004 and 2023, which have been designated as belonging to this drought class, correspond with SPI, CZI, and MCZI for Amasya and Merzifon, respectively. While the proportional results of the EW are consistent with those of the VW, with 3.33%, it is important to note that the years 2009 and 2010, classified as EW drought class, coincide with the all DIs for Amasya and the years 1988 and 2010 coincide with the all DIs for Merzifon

Table 4. The correlations between all DIs

Years	SPI-CZI	SPI-MCZI	CZI-MCZI
Amasya	0.9991	0.9990	1.0000
Merzifon	0.9911	0.9917	1.0000
Average	0.9951	0.9954	1.0000

As it is illustrated in *Table 4*, the correlation values between all DIs on annual timescales are demonstrated. Amasya and Merzifon exhibit a higher correlation between SPI and CZI with 0.9991 and 0.9911, respectively. They exhibit a stronger correlation between SPI and MCZI with 0.9990 and 0.9917, respectively. The calculation of the CZI and MCZI correlation values (1.0000) indicates a state of complete agreement between the results obtained. Furthermore, as evidenced by the scatter diagrams in *Fig. 3*, the drought indices exhibited a high degree of concordance.

The mean of R values for all combinations were found to be 0.9951 for SPI-CZI, 0.9954 for SPI-MCZI, and 10000 for CZI-MCZI. Following the analysis, it was determined that CZI-MCZI exhibited the maximum R value of 1.0000, while SPI-CZI demonstrated the minimum. A comparison of the correlation values calculated between SPI, which is recommended as the reference index, and CZI and MCZI, was undertaken. The results of this comparison indicated that SPI-CZI has higher correlation values than SPI-MCZI in Amasya. Conversely, in Merzifon, the correlation value of SPI-MCZI was observed to be higher than SPI-CZI. In the context of drought research, the CZI and MCZI methods have been

identified as viable alternatives to the SPI reference index at the Amasya and Merzifon stations, respectively. A thorough examination of the average correlation values reveals that the MCZI method emerges as a better option in comparison to the CZI method across the entire study area.

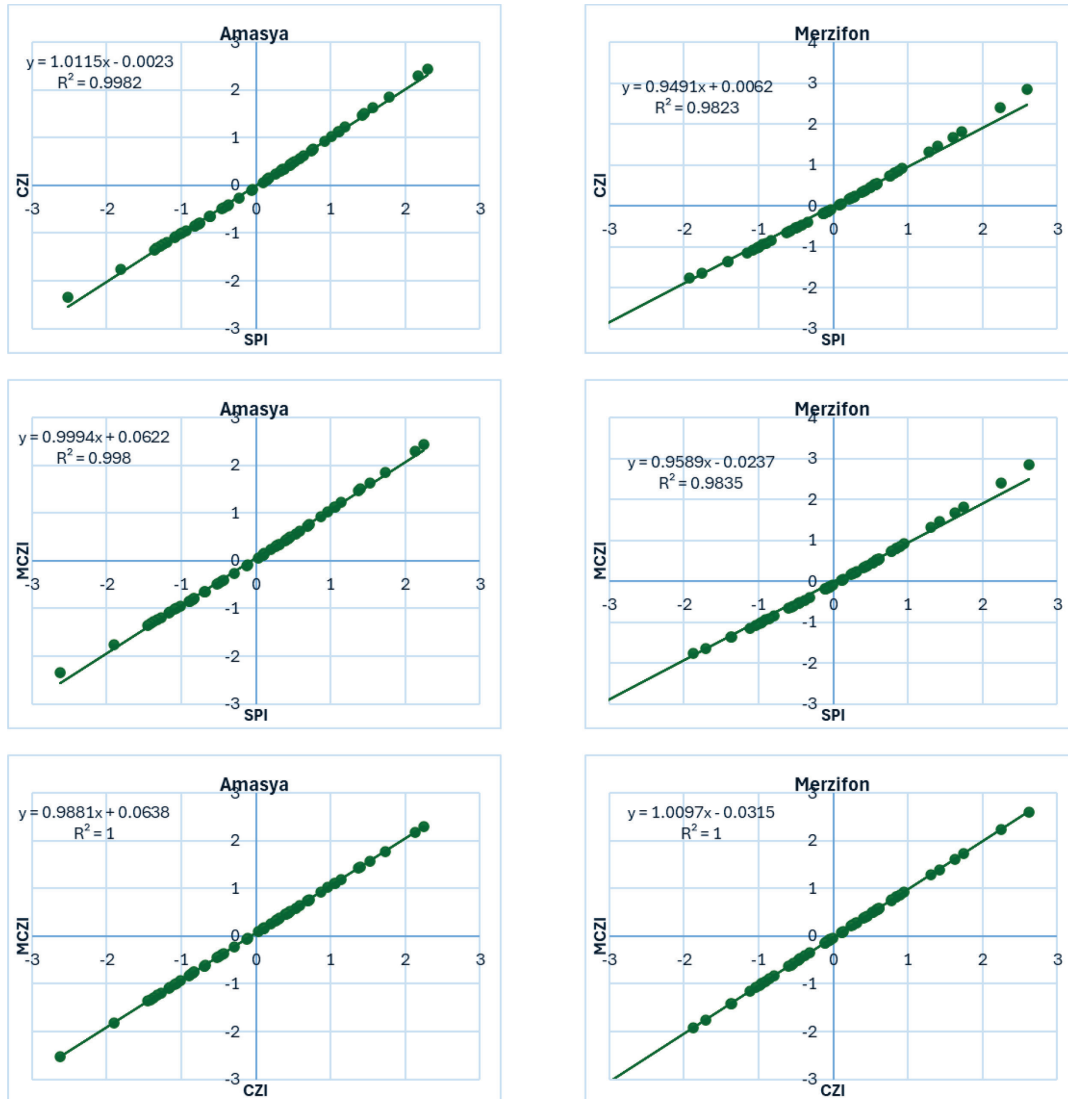


Fig. 4. The scatter diagrams between all DIs in the Amasya and Merzifon.

Drought researches will continue to represent a central focus within the broader field of climate research, both in the present moment and in the future. A substantial body of researches has been conducted employing diverse DIs across various geographical scales, ranging from regional to national, in Türkiye. The results of SPI, CZI, and MCZI demonstrate that Amasya and Merzifon, which are characterized by a transitional climate in the Black Sea region of Türkiye,

experienced drought in 1964, 1974- 1976, 1982, 1984, 1986, 1990, 1999, 2013, 2017, and 2020. *Sirdas and Sen* (2003a, b) reported that water resources in certain arid regions of Türkiye would decrease by 10–30% by the middle of the 21st century. Furthermore, they anticipated an increase in the severity, duration and effects of drought in the southern parts of the country, and an increase in the frequency of floods in the northern parts. *Ceylan et al.* (2009) have reported that significant water deficits were recorded in 1927–1928, 1956–1957, 1959, 1970, 1972–1973, 1977, 1982, 1984, 1989–1990, 1994, 2000–2001, and 2006–2007 in Türkiye. *Türkeş et al.* (2009a, b) and *Türkeş* (2014) reported that the most severe and widespread drought events in Türkiye were in 1971–1974, 1983–1984, 1989–1990, 2007–2008, and 2013–2014. *Komuscu* (1999, 2001) asserted that the Black Sea region of Türkiye experienced significant drought conditions between 1990 and 2000. *Sonmez et al.* (2005) reported that significant drought conditions were observed during the late 1980s, with this trend continuing into the late 1990s in the Central Anatolia region of Türkiye. *Bacanli et al.* (2011) provide compelling evidence that the region is still in danger of severe drought in the Central Anatolia Region of Türkiye. *Yetmen* (2014) reported that the central Black Sea in northern Türkiye experienced notable drought conditions during the years 1976–1977, 1982–1983, 1985–1986, 1994, 2001, 2003, and 2007–2008, as indicated by the SPI. *Gumus and Algin* (2017) conducted a study of the Seyhan-Ceyhan River basins, located in the south of Türkiye, utilising the SPI to identify the most protracted meteorological droughts. These were observed to be 1971–1973, 1988–1990 and 2003–2005. *Bacanli and Aksan* (2019) observed that the Mediterranean region of Türkiye experienced a period of drought in the early 1970s and early 1990s. *Altin et al.* (2020) determined that a considerable part of the drought conditions experienced in the Seyhan and Ceyhan River Basins were mild to moderate. Furthermore, *Kumanlioglu and Fistikoglu* (2019) identified a protracted drought period between 1984 and 1996 using the SPI for the upper Gediz basin. Furthermore, 1961, 1987, 2006, 2008, 2011, and 2014 were designated as severe drought years. In addition, *Dikici* (2020) analyzed the Asi basin, located in the southern part of Türkiye. This basin was the focus of studies conducted using DI, SPI, SPEI, and SRI. These studies revealed the effects of drought in the years 1973–1974, 1989–1991, 1993–1994, 2000–2001, 2004–2005, 2014, and 2016. Concurrently, *Katipoglu and Acar* (2021) and *Katipoglu et al.* (2021) reported that the most severe meteorological droughts were observed in the years 1989 and 2012–2017 in the Euphrates basin, which encompasses a substantial expanse in the east and southeast of Türkiye. *Simsek et al.* (2024) reported that the coastal strip of the Black Sea region has been impacted by prolonged droughts, particularly following the year 2010. The findings obtained from this study are consistent with those reported in the extant literature.

4. Conclusion

The present study investigates the performance of three precipitation-based drought indices (SPI, CZI, and MCZI) in order to determine the suitable indices for the study area. This investigation is based on precipitation records from the Amasya and Merzifon meteorological stations between 1964 and 2023, which represent a transitional climate zone within the Black Sea region of Türkiye. The following years have been identified as being significant in terms of drought: 1964, 1974–1976, 1982, 1984, 1986, 1990, 1999, 2013, 2017, and 2020. Correlation values were obtained between SPI-CZI, SPI-MCZI, and CZI-MCZI, with graphs that were found to be compatible with each other. The relation of the DIs with SPI, which was selected as the reference index, was investigated and evaluated. In this particular instance, the most compatible index with SPI is MCZI, which serves as a commendable alternative to SPI in drought assessment in the Amasya and Merzifon regions. The study's findings underscore the importance of utilizing CZI and MCZI in place of SPI for the purpose of enhancing drought forecasting and evaluating prevailing climatic conditions in transitional climate zones. The two DIs (CZI and MCZI), which were successfully implemented to identify droughts in the transitional climate zone, are recommended for use in detailed drought analyses to be conducted in the basin as an alternative to SPI. In future studies, it is recommended that the region has to be evaluated with DIs that take into account different parameters such as temperature, evaporation, and satellite data, together with precipitation-based DIs for drought monitoring and assessment purposes. Furthermore, the temporal trends of climate parameters, including precipitation, temperature, evaporation, and potential drought conditions, can be analyzed using climate projection data. This studies can provide policy makers and decision makers with the necessary information to implement suitable plans and strategies for the region, both in the present and in the future.

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Data availability: Rainfall data provided by the Turkish State Meteorological Service (TSMS) can be purchased from “<https://mevbis.mgm.gov.tr/mevbis/ui/index.html#/Workspace>”, (Purchase numbers: 20240527308A and 202405276447).

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