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Trend Analysis of Some Crop Yields and Agro-Meteorologic Drought in the Trakya Region

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Abstract
Drought is one of the most dangerous-meteorologic events affecting agriculture. Drought can be determined by indexes. In this study, the relationship between the Standard Precipitation Index (SPI) results and trend analysis results was examined. Thus, the consistency of the drought in Trakya with the results of the trend analysis was investigated. For this purpose, using the precipitation data of Tekirdag, Kirklareli, and Edirne Meteorological Observation Stations (MOS), drought analysis was done with SPI, trend analysis was done with the help of Mann-Kendall, Sen and Linear Regression methods. In addition, the deviation value of crop yield value from the mean were produced and compared with the drought index result. As a result, the crop most incompatible with the drought results in Trakya is the wheat. In addition, agriculture is not expected to be affected by droughts in Trakya where meteorological drought is not dominant. Edirne is prone to drought while Kirklareli is expected to be prone to humidity, relatively. Nevertheless, there is no significant trend in Trakya in general.

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1. Introduction

Drought is a natural disaster that starts with a decrease in precipitation and negatively affects the hydrological balance and water budget. Mainly drought types are meteorological, hydrological and agricultural drought (Okkan and Altun, 2019). Classification of the drought severity overlaps with the philosophy of methods such as trend analysis and fuzzy logic. In drought studies in the literature, the duration, severity, trend, temporal and spatial effects of drought have been investigated (Dabanli, 2019). The main tool used to determine drought severity is drought indices. For meteorological drought, Palmer Drought Severity Index, Reconnaissance Drought Index and Standard Precipitation Index (SPI) can be used (Gumus, 2017). In addition, remote sensing and GIS are important tool for drought studies (Ozsoy, 2021).

Climate series such as precipitation and runoff fit the Gamma distribution compared to the normal distribution. The first step of the SPI is to fit the data to the Gamma probability density function. 1-3-month periods of SPI indicate meteorological drought, 6-9-month periods indicate agricultural drought, and 12-24-month periods indicate hydrological drought (Oguz et al., 2021).

Climate change and drought are expected to have different effects on many different regions and crops. According to climate models and scenarios, it is expected that the temperature in Trakya might increase by 5 ºC by 2100 (40 % of water resources might be lost) and 30 % of water resources might be lost by 2050. The main plants that might be affected by drought in Trakya was estimated. It is predicted that these are wheat, rice and sunflower. According to future climate conditions in Trakya, wheat yield is expected to increase by 60 % and sunflower yield is expected to decrease by 20 % (Alkan, 2021; Alkan and Konukcu, 2022).

Various studies have been carried out related to drought in the world. Gocic and Trajkovic (2013) analyzed the trend of SPI by using Mann–Kendall tests at the 5 % significance level in Serbia. They said that year 2000 was extremely dry for all stations and there were increasing trends in winter and fall precipitation in the seasonal series.

Vido et al. (2019) determined decreasing trend of drought during the winter months and determined increasing trend during the summer months with the help of Standardized Precipitation Evapotranspiration Index (SPEI) and Mann-Kendall (M-K) test in Slovakia. As a result, the trend analyses revealed no significant increase in drought impacts on agriculture in the studied period. Ouatiki et al. (2019) determined the annual rainfall deficit with the help of SPI and then analyzed trends with the help of Mann–Kendall test for 1970–2010 period. As a result, the researchers found that the OER River basin in Morocco tends to have drier conditions.

Naz et al. (2020) determined drought trend at the 3-month in Balochistan-Pakistan with the help of Mann-Kendall test. They found the decreasing precipitation trend in four stations. Alsafadi et al. (2020) used SPI, SPEI and M-K methods. The M-K method showed a significant negative trend (SPI-12) in 11.5 % over the western Hungary.

Various studies have been carried out related to drought in Turkey. Bacanli (2017) analyzed the trends (with Mann-Kendall) of monthly SPI results for Aegean drought between 1960-2013. It is understood that Mann-Kendall and Spearman rho methods give similar results. After all, It was found a negative trend in Aydın, Denizli, Kutahya, Manisa and Mugla stations.

Oguz et al. (2021) examined the trend and drought in Mugla for the period 1960-2018. Mann-Kendall and SPI were applied to precipitation data. After all, in Mugla, the extreme dry period has been experienced more than the extreme wet period. According to SPI, the most severe droughts were between December 2006 and September 2007, and the longest droughts were between June 2000 and May 2001.

Kankal and Akcay (2019) determined the trend analysis of Trabzon precipitation using

Mann-Kendall and Şen methods. In both stations, increasing trends dominate in fall and spring. While no trend was observed in Trabzon in summer, a decreasing trend was observed in Akçaabat.

Nouri and Homaee (2019) applied gamma and log-logistic distribution in their study for SPI and SPEI, respectively. They also used the Mann-Kendall trend test for results of SPI and SPEI. After all, they determined that SPI do not correlate well with SPEI in arid regions.

Vaheddoost (2020) determined the trend using monthly precipitation between 2005-2018 in Counties of Bursa, with the help of linear trend, Mann-Kendall, Spearman, Sen and SPI methods.

Dabanli (2019) calculated the Drought Disaster Indicator and Drought Sensitivity Indicator. The main goal of his work was to produce drought risk maps with precipitation data and fuzzy logic from 250 stations (1971-2010) in Turkey. After all, he determined that 5 out of 81 Provinces in Turkey have low drought risk, 61 provinces are at medium drought risk and 14 provinces have high drought risk.

Demir et al. (2017) investigated the effects of precipitation trends on regional agriculture in Bingol. As a result, they determined that annual and seasonal precipitation (except in April, not statistically significant) decreased in Bingöl. It has been determined that this decrease will not affect the agriculture of Bingol in the short term.

In a study similar to our study, Eroglu (2021) analyzed the seasonal trend of precipitation in the Meriç River Basin using the Mann-Kendall and Sen method. For this purpose, the positive-negative trends of 50-year precipitation data of 10 stations in Bulgaria and Turkey were periodically examined. As a result, a significant negative trend was determined in the annual precipitation in the 1965-1990 period in Ipsala and a significant positive trend in Kirklareli in the 1991-2015 period. Besides, in the 1965-2015 period, no statistically significant trend could be detected at any station.

Also, there is a significant decrease trend in annual precipitation in Luleburgaz considering the rainfall data of the Marmara between 1930 and 1993. Except for Luleburgaz, no significant trend could be determined at the level of 95 % at any of the stations (Eroglu 2021).

Considering the scarcity of studies on meteorological drought in Trakya, which is one of the arid regions in Turkey, this study, which aims to investigate the effect of drought on agriculture in Trakya, is really important. Using meteorological data (precipitation) with the study, comments will be made on all types of drought. For this purpose, Since the 6-9-month SPI values represent agricultural drought (Oguz et al., 2021), results related to agricultural drought will be produced.

In this study, the success of drought in Trakya in representing the trend was investigated by examining the relationship between the results of the drought index and the results of the trend analysis. For this purpose, using the precipitation data of Tekirdag, Kirklareli and Edirne Meteorological Observation Stations (MOS), drought analysis was done with SPI, trend analysis was done with the help of Mann-Kendall, Sen and Linear Regression methods. Besides, the deviation value of crop yield value from the mean were obtained and compared with the SPI result. Thus, the drought effect on crop yield was determined.

2. Materials and Methods

2.1. Materials

2.1.1. Study area: the Trakya region (Tekirdag, Kirklareli, Edirne)

In Turkey, 1600 m^3 water falls per person while 500 m^3 water falls in Trakya (Bagdatli and Belliturk, 2016; Alkan, 2021). Considering that the agricultural sector in the region consumes excessive water, the future water shortage will become more evident. In terms of agricultural drought in Turkey, Trakya is one of the driest regions (Alkan, 2021; Balkan et al., 2023). Especially the Trakya side of the Marmara Region is more prone to drought (60 % of Trakya is agricultural land). For example, in 1971, while the north of Trakya was humid, drought was seen in Biga. In 2008, droughts were observed in Trakya in winter and in Kirklareli in fall (Alkan, 2021).

Main agriculture provinces in Trakya are Tekirdag, Edirne and Kirklareli (Figure 1). The years joint to all 3 stations (MOS no: 17056 Tekirdag, 17052 Kirklareli, 17050 Edirne) were chosen as the observation period (Between 1941 and 2020 years).

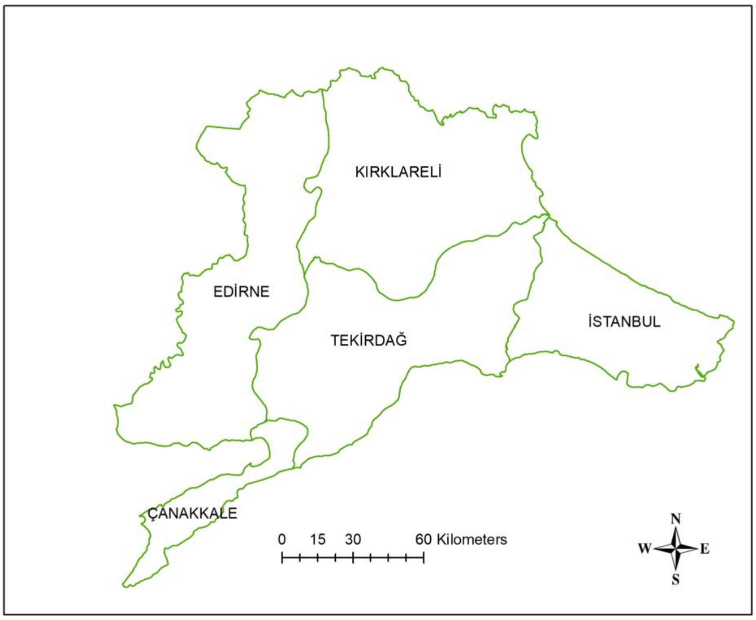

Figure 1. Trakya map

2.1.2. Agricultural production data in the Trakya region

The cities where wheat yields are from high to low are Tekirdag, Edirne and Kirlareli, respectively. The cities where sunflower yields are from high to low are Edirne, Kirlareli and Tekirdag, respectively. The cities where Barley yields are from high to low are Tekirdag, Kirlareli and Edirne, respectively (Table 1).

Table 1. Some crops yields in Trakya (kg da^{-1}) (TSI, 2023)

	Wheat			Sunflower			Barley		
Year	**Edirne**	**Kirklareli**	**Tekirdag**	**Edirne**	**Kirklareli**	**Tekirdag**	**Edirne**	**Kirklareli**	**Tekirdag**
2004	321	326	428	171	165	184	374	425	477
2005	352	333	405	179	164	193	377	444	435
2006	325	306	340	202	184	215	347	367	411
2007	420	383	436	164	181	121	462	482	542
2008	422	390	465	167	174	188	502	466	541
2009	343	308	372	181	179	183	339	361	398
2010	399	283	322	289	180	190	347	318	347
2011	303	324	355	215	178	196	298	351	387
2012	455	402	489	197	228	176	409	471	478
2013	365	378	378	227	247	229	406	424	441
2014	424	407	430	290	258	230	495	443	477
2015	356	346	407	230	258	208	431	394	441
2016	362	381	429	225	218	200	418	355	444
2017	362	437	459	243	248	235	476	477	548
2018	346	390	340	248	258	235	417	392	339
2019	381	393	451	263	285	251	412	393	487
2020	358	390	392	264	291	248	347	361	400
2021	474	460	534	266	248	240	468	430	563

2.2. Methods

Precipitation data and analysis scale were determined, then drought severity was calculated and compared with trend analysis (Figure 2).

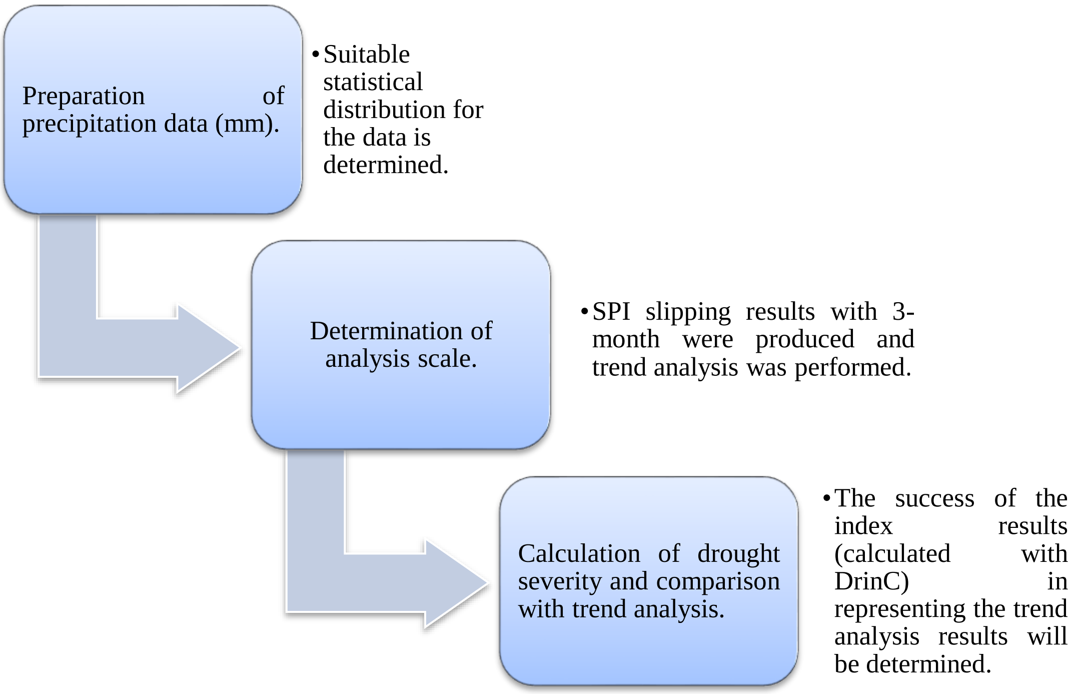

Figure 2. Flow chart of the study

2.2.1. Standard Precipitation Index

SPI, which was developed by McKee et al. in 1993, is an index that determines the meteorological drought. SPI drought classes are derived from standard normal distributed of precipitation sequences. However, the probability distribution function of precipitation sequences does not generally fit the normal distribution. Precipitation sequences generally conform to the gamma distribution. For this reason, standard precipitation sequences must be obtained in order to use precipitation data in SPI. The simplicity of the application of the method causes it to be preferred (Akbas, 2013).

Equation of Standard Precipitation Index: For the standard precipitation index, monthly precipitation data are needed. In equation 1, X_i is the amount of precipitation (mm), while X_i^{ort} is the mean amount of precipitation (mm) and σ is the standard deviation. A distrubiton function is fitted to the rainfall data. The gamma distribution is the most suitable for rainfall data. Cumulative probabilities are calculated by fitted distribution. Then, cumulative probabilities are converted to SPI values, which has a standard deviation of 1 and a mean of 0. The SPI results are available in some classes in Table 2 (McKee et al., 1993).

$$SPI = \frac{X_i - X_i^{ort}}{\sigma} \qquad (1)$$

Table 2. Drought classes of standard precipitation ındex (McKee et al., 1993)

SPI Result	Drought Class
≥ 2	Extreme wet
1.50 ~ 1.99	Very wet
1.00 ~ 1.49	Mid wet
0.99 ~ 0	Slight wet
0 ~ -0.99	Slight drought
-1.00 ~ -1.49	Mid drought
-1.50 ~ -1.99	Very drought
≤ - 2	Extreme drought

2.2.2. Trend analysis methods (mann-kendall, sen, linear regression)

Mann-Kendall Method: It is a non-parametric method that is not affected by missing data in a data series. In this method, the rank (yi) of the data in the series is used instead of the actual data. Each yi is defined by a number such as ni, counting the larger ones (Oguz et al., 2021).

$$t=\sum_{i=1}^{n} n_i \quad (2)$$

The mean of the t test value is E(t) and its variance is var(t).

$$E(t)=\mu=\frac{n\,(n-1)}{4} \quad (3)$$

$$var(t)=\mu=\frac{n\,(n-1)(2n+5)}{72} \quad (4)$$

The Mann-Kendall test value is u(t).

$$u(t)= (t - E(t))/\sqrt{var(t)} \quad (5)$$

The fact that u(t) is close to zero indicates that there is no change in time, while large values of u(t) indicate that there is a change. The first point where u(t) and u'(t) intersect is where the change begins. If u(t) and u'(t) are parallel to each other, it is understood that there is no trend (Oguz et al., 2021).

Sen's slope Method: A slope estimator is regarded as median for all data sets for different variation to identify the trend existing in data sets of a time series. The positive value of m indicates an upward trend while negative value of m indicates a downward trend. The slope is determined using the following equation (Agarwal et al., 2021).

$$m_i= \frac{T_J-t_i}{J-1} \quad (6)$$

Where, T_J *and* t_i are the time values at time J and i.

The Sen's estimator slope is the median of these N counts. The Sen's slope is determined using the following equation (Agarwal et al., 2021).

$$m=m\,(\frac{N+1}{2}) \quad (7)$$

$$m= ½\,(\frac{N}{2}+\frac{N+1}{2}) \quad (8)$$

As a result, m is calculated using two tailed test at 100 (1- α) % confidence level, then right slope is given by the nonparametric test.

Linear Regression Method: Linear regression is determined using,

$$x_t = a.t+b \quad (9)$$

Where coefficient a and b are determined based on the relationship between two variables, t and x_t. Later, the significance of coefficient a is tested using a t value at a significance (generally at 0.05 significance). In this case, the assumption of normal distribution is essential, while the results are sensitive to the outliers (Vaheddoost, 2020).

3. Results and Discussion

The results of the M-K trend and the SPI results are in parallel. If it is accepted that drought might decrease the sunflower yield, a parallelism is determined between the SPI results and the crop yield trend. Even in the prone to drought climate in Tekirdag, wheat and barley yields were very high. In this case, it was concluded that wheat and barley yields were not adversely affected by drought in Tekirdag conditions. Moreover, the crop most coherent with the drought results in Trakya is the sunflower. The trend analysis method that best represents the result of the SPI is M-K (Kendall's tau). Nouri and Homaee (2019) determined that the SPI do not correlate well with the SPEI in arid regions. Namely, the correlation of SPI results with other method results is quite variable. For this reason, the drought indices to be used should be carefully selected according to the region and the type of drought. The graphs (Figure 3-5) of wheat and barley yields in the grain group were very similar to each other in terms of both shape and count (Table 3).

Similar to Kendall's tau results, according to Sen's slope results, a relative increase was detected in Edirne and Kırklareli and a relative decrease in Tekirdag although there is no significant trend (Table 3).

Table 3. Drought-trend and (crop yield) comparison in Trakya (Between 2004 and 2021)

Province	Drought (SPI), 2004-2021	Crop yield (kg da^{-1}), 2004-2021			Trend of the drought (SPI) (Mann-Kendall and Sen, 2004-2021)		
		Wheat	Sunflower	Barley	Kendall's tau	p-value	Sen's slope
Edirne	0.39 (normal)	376	223	407	0,072 No trend (Increasing)	0.705	0.006
Kirklareli	0.47 (normal)	369	219	409	0,098 No trend (Increasing)	0.596	0.029
Tekirdag	-0.03 (normal)	413	207	453	-0,150 No trend (Decreasing)	0.405	-0.049

Naz et al. (2020) determined drought trend in Pakistan. They found the decreasing precipitation trend in half of the stations. Alsafadi et al. (2020) found a significant negative trend in 11.5% over the western Hungary. Ouatiki et al. (2019) determined the meteorological drought for 1970–2010 period. As a result, it was found that Morocco tends to have drier conditions. These results show that drought tendency is increasing in the World, especially in the Mediterranean watershed. Dabanli (2019) produced drought risk maps at 250 stations in Turkey fort he period 1971–2010. After all, the researcher determined that 5 out of 81 provinces in Turkey have low drought risk, 61 provinces are at moderate drought risk, and 14 provinces have high drought risk. Bacanli (2017) detected a negative trend in half of the Aegean Region between 1960 and 2013. Oguz et al. (2021) investigated the drought trend in Mugla for the period 1960-2018. After all, the extreme dry period was experienced more often than the extremely humid period. Moreover, the most severe droughts occurred in 2007, and the longest in 2001. Kankal and Akcay (2019) determined the trend of precipitation in Trabzon. Increasing trends dominate the city in autumn and spring. While no trend was observed in Trabzon in summer, a decreasing trend was observed in Akçaabat. These results showed that the cities of Turkey, which has a semi-arid climate, especially close to the Aegean and Mediterranean Seas, were more affected by drought. It was understood that humidity was observed in places where the Black Sea climate was dominant. Therefore, Edirne, close to the Aegean, is prone to drought and Kirklareli, close to the Black Sea, is expected to be prone to humidity. In this study, compared to Kirklareli, Edirne is more prone to drought. In Trakya, while no trend was observed in the SPI values between 2004 and 2021 years, only in Tekirdag, there was a significant increase trend in SPI 6, 9 and 12 values. This situation shows that Tekirdag Province is relatively more humid than Edirne and Kirklareli (Table 4).

Table 4. Trend analysis of the SPI in Trakya

		P values (α=0.05)	Kendall's tau	Sen's slope
Edirne	SPI 1	0.940	-0.002 (↓)	0
	SPI 3	0.459	0.017 (↑)	0
	SPI 6	0.447	0.018 (↑)	0
	SPI 9	0.532	0.015 (↑)	0
	SPI 12	0.453	0.018 (↑)	0
Kirklareli	SPI 1	0.822	0.006 (↑)	0
	SPI 3	0.173	0.034 (↑)	0
	SPI 6	0.330	0.024 (↑)	0
	SPI 9	0.436	0.019 (↑)	0
	SPI 12	0.245	0.029 (↑)	0
Tekirdag	SPI 1	0.322	0.021 (↑)	0
	SPI 3	0.066	0.040 (↑)	0
	SPI 6	**0.039 (Significant)**	**0.045 (↑)**	0
	SPI 9	**0.034 (Significant)**	**0.046 (↑)**	0
	SPI 12	**0.022 (Significant)**	**0.050 (↑)**	0

Demir et al. (2017) investigated the effects of precipitation trends on agriculture in Bingöl. As a result, it is determined that the decrease in precipitation will not affect the agriculture of Bingol in the short term. Even if there is a decrease in precipitation, agriculture will not be affected in the short term. Therefore, agriculture is not expected to be affected by droughts because meteorological humidity is dominant in Trakya. The presence of various climate types and maritime effect in Trakya can be expressed as a factor that reduces meteorological factor. Eroglu (2021) analyzed the precipitation data of 10 stations for 50 years in Bulgaria and Turkey in order to determine the trend of precipitation in the Meric (Maritza) River Basin. As a result, a significant negative trend was determined in İpsala during the 1965-1990 period and a significant positive trend in Kirklareli during the 1991-2015 period. The researcher, in the 1965-2015 period, no statistically significant trend could be detected at any station. Moreover, there is a significant decrease trend in annual precipitation in Luleburgaz between 1930 and 1993, when the Marmara region is examined. Except for Luleburgaz, no significant trend could be detected at any of the stations. This result in the literature shows parallelism with the results of this study. It is also supported by the literature that Edirne is prone to drought, Kirklareli to humidity, and that there is no significant trend in Trakya in general. The data period between 2004 and 2021 was used to compare with crop yields and drought index results. The strongest crop yield-drought relationship was in the sunflower yield in Edirne (R^2: 0.122 in Figure 4) and the weakest of the relationship was in the sunflower yield in Kirklareli (R^2: 0.0002 in Figure 4). Generally, in Tekirdag conditions, there were stronger relationships between the effects of drought and crop yields (R^2: 0.042-0.11 in Figure 3-5). The precipitation data between January and December (not the October-September water year) were used to calculate the SPI index (Figure 3, 4, 5 and 6). In Edirne, Kirklareli and Tekirdag, regression graph between drought and wheat yield deviation were produced for 18 years (2004-2021). The cities, which has correlation from strong to weak between drought and wheat yield deviation are Tekirdag, Kirklareli and Edirne, respectively (Figure 3).

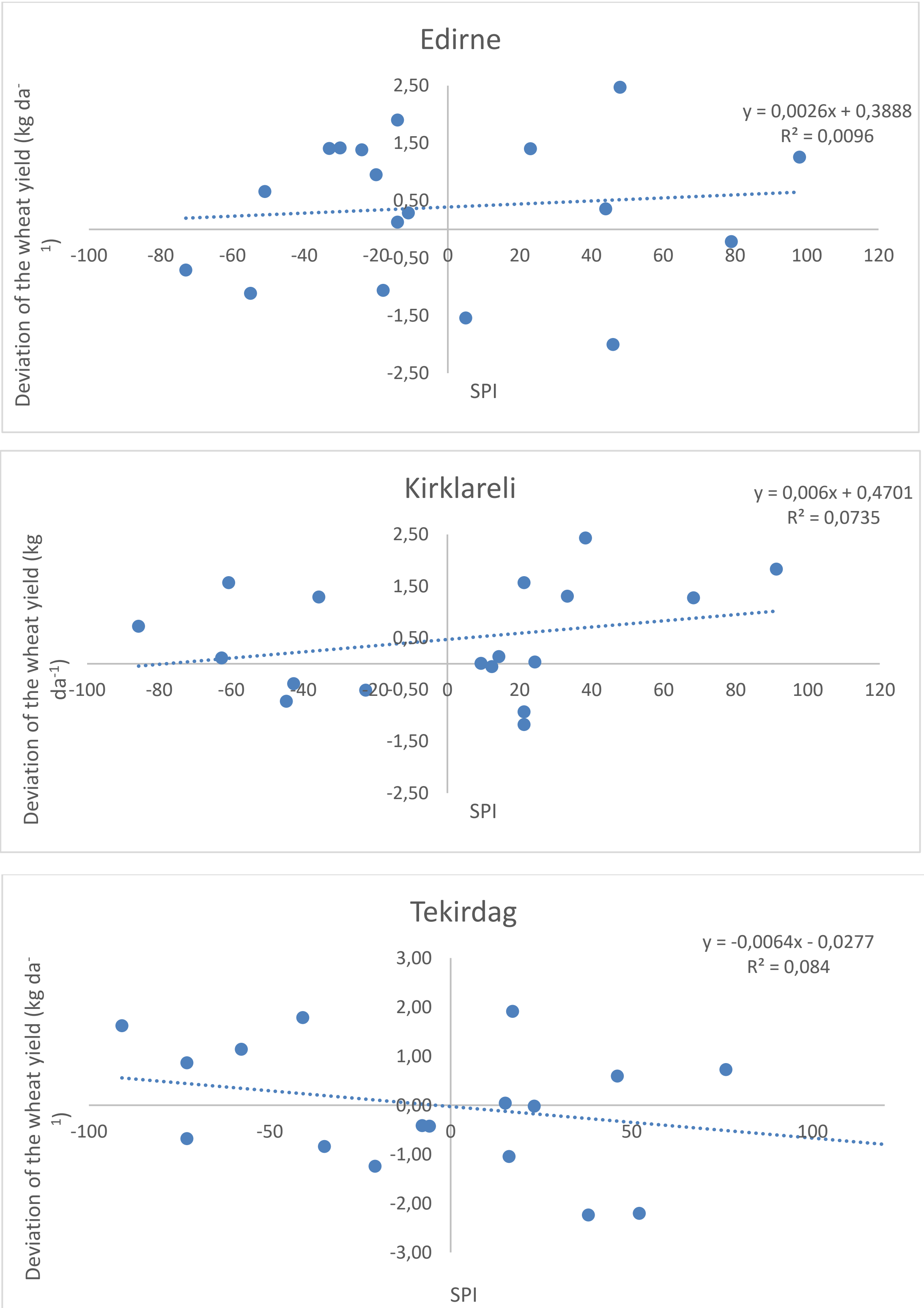

Figure 3. Regression graph of Trakya wheat yields and drought results

R² is 0.0096 in the regression graph for wheat in Edirne. It was understood that non-climatic factors were more effective on wheat yield for Edirne. This situation is thought to have occurred due to non-climatic condition for wheat in Edirne. In Edirne, Kirklareli and Tekirdag, regression graph between drought and sunflower yield deviation were produced for 18 years (2004-2021). The cities, which has correlation from strong to weak between drought and sunflower yield deviation are Edirne, Tekirdag and Kirklareli, respectively (Figure 4).

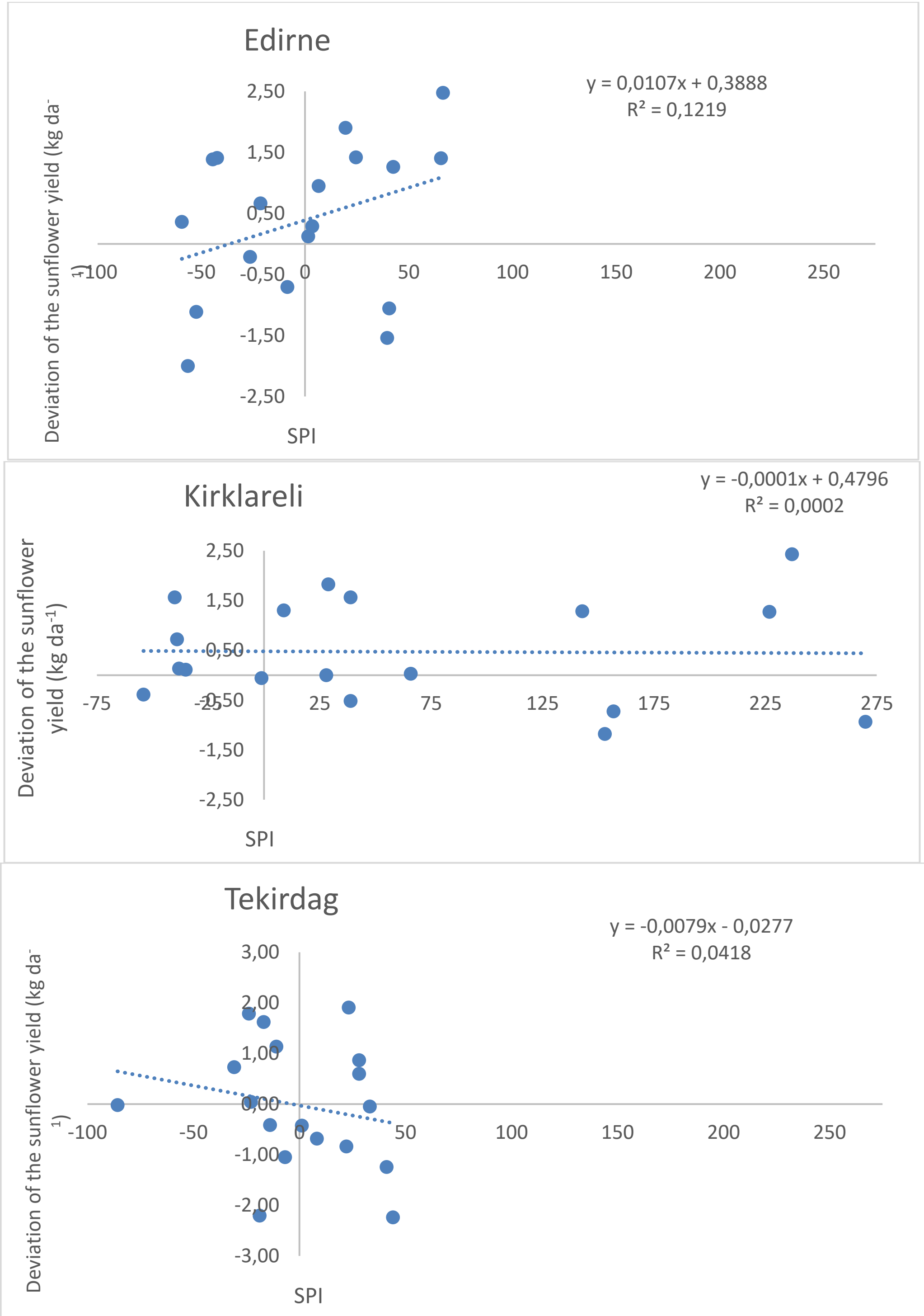

Figure 4. Regression graph of Trakya sunflower yields and drought results

R² is 0.0002 in the regression graph for sunflower in Kirklareli. It was understood that non-climatic factors were more effective on sunflower yield for Kirklareli. This situation is thought to have occurred due to non-climatic condition for sunflower in Kirklareli. In Edirne, Kirklareli and Tekirdag, regression graph between drought and barley yield deviation were produced for 18 years (2004-2021). The cities, which has correlation from strong to weak between drought and barley yield deviation are Tekirdag, Kirklareli and Edirne, respectively (Figure 5).

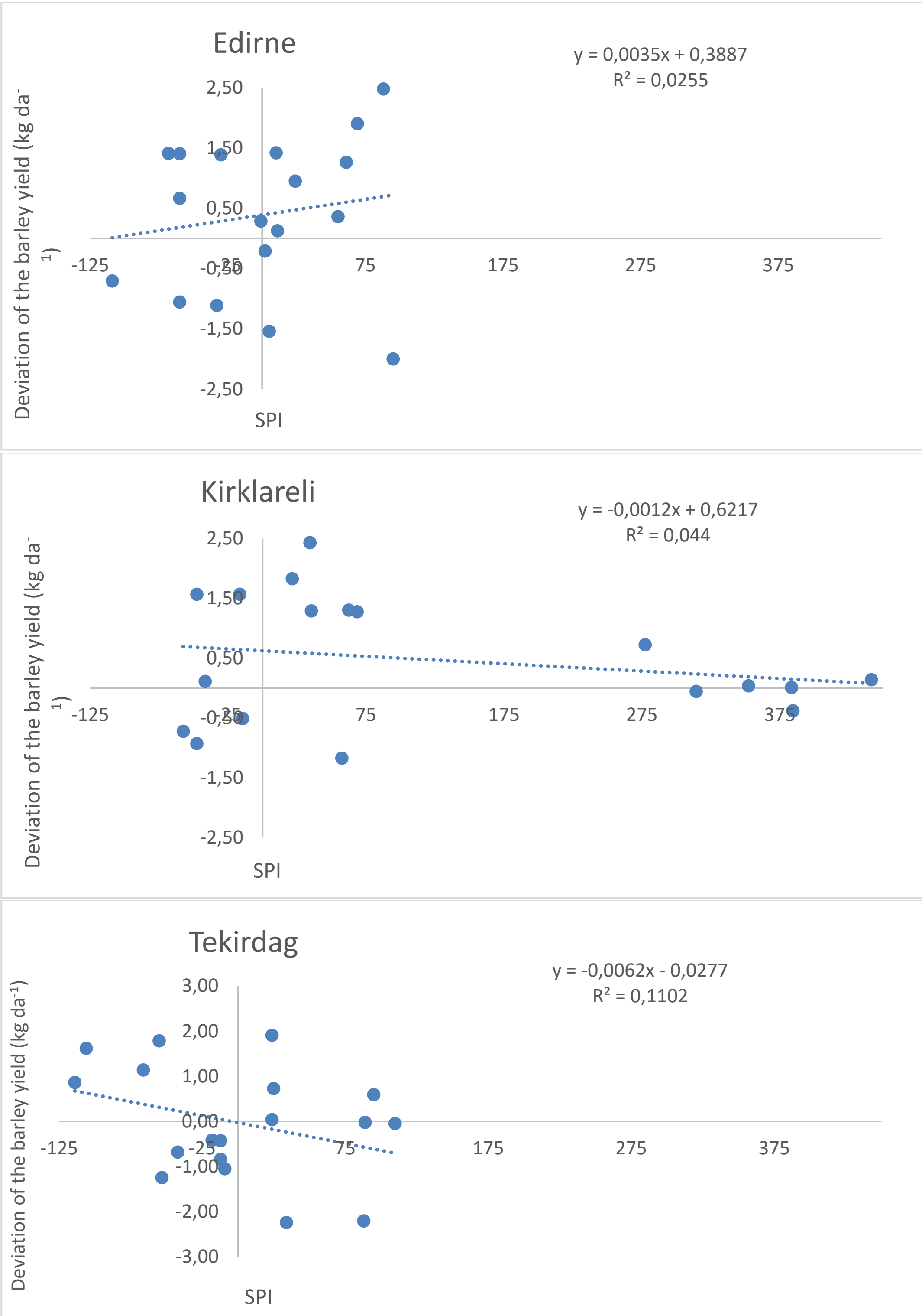

Figure 5. Regression graph of Trakya barley yields and drought results

R^2 is 0.0255 in the regression graph for barley in Edirne. It was understood that non-climatic factors were more effective on barley yield in Edirne. This situation is thought to have occurred due to non-climatic condition for barley in Edirne.

4. Conclusion

Drought tendency is increasing in the World, especially in the Mediterranean watershed. Therefore, the cities of Turkey, which has a semi-arid climate, especially close to the Aegean and Mediterranean Seas, were more affected by drought. It was understood that humidity was observed in places where the Black Sea climate was dominant. Therefore, Edirne, close to the Aegean, is prone to drought and Kirklareli, close to the Black Sea, is expected to be prone to humidity. In this study, compared to Kirklareli, Edirne is more prone to drought. An agriculturally wet situation prevails in only Tekirdag. Wheat and barley yields were not adversely affected by drought in Tekirdag conditions. Moreover, the crop most incompatible with the drought results for Trakya region was the wheat crop, when compared R^2 to each other in figure 3-5. Even if there is a relative decrease in precipitation, agriculture will not be affected in the short term. Inasmuch as meteorological drought is not dominant in Trakya, agriculture is not expected to be affected by droughts. The presence of various climate types and maritime effect in Trakya can be expressed as a factor that softens the climate of the Trakya. As a result, Edirne is prone to drought, Kirklareli to humidity, relatively. Besides, there is no significant trend in Trakya in general.

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