The Effects of Atmospheric Oscillations on Crop Yield in the Mediterranean Region, Turkey

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Abstract

In the last century climate change is a major threat to biodiversity, ecosystem services, and human well-being. Atmospheric oscillations that occur at the regional oceanic flow pattern may affect significantly the climate of the Earth. In this study, we investigate effects of ENSO (El Nino Southern Oscillation) and NAO (North Atlantic Oscillation) on the Mediterranean crop yield using the Nino 3, Nino3.4, Nino 4, ONI and NAO indices. Olive, which is a bioindicator type in the Mediterranean, and cotton and grapes with high yield and economic value crops were examined. As a method, firstly, Mann Kendall rank correlation test was applied to the yield values of the crops. After the 2000s, it has been determined that the trend of yield has changed and was obtained an increasing trend. Secondly, the correlation between the yields and the indices were determined with the Spearman correlation coefficient. Accordingly, a high correlation of 50% and 80% was found at the $p \leq 0.05$ and $p \leq 0.00$ significance level in the phenological periods of the crops. The highest correlations were determined especially during flowering period with El Nino indices. The frequency of the correlation detected with the NAO indece is weak. The effect on the efficiency of the phases when El Nino indices are strong was examined graphically. Accordingly, in the 1997 and 2015-2016 periods, when the El Nino phenomen was very stong, there were sharply decreases in the crop yields. It is seriously affects the countries whose economic activity is based on agriculture in the Mediterranean Basin, and it is likely to affect food industry in the future.

Keywords: Climate, Atmospheric Oscillations, Mediterranean, Crop Yield

1. Introduction

Climate is one of the important physical geography factors affecting the distribution and development of plants on the Earth. Many problems arising from changing climatic conditions and affecting agricultural activities are solved using today's technology, irrigation, etc. However, the climate change causes insoluble problems such as decrease crop yield, cultivation areas of the crops, etc. (Ustaoğlu and Ikiel 2007; Ustaoğlu and Karaca 2014; Doğanay et al., 2019). It is thought that the increase in the frequency of extreme weather events that have occurred frequently in recent years is related to the changes in large-scale pressure and wind circulation and atmospheric oscillations (Karabörk and Kahya, 2003; Türkeş and Erlat, 2003; Hatzaki et al., 2009; Andrade et al. 2011; Baltacı et al.2018). It is predicted that the increasing average temperatures in 2015 and the following years may increase the frequency of extreme climatic events and the tendency of the climate to deviate from the long-term average in Turkey and its surroundings (Ustaoğlu, 2018).

El Nino Southern Oscillation is one of the causes of climate variability on a global scale. The Southern Oscillation is defined as the instabilities of atmospheric pressure at sea level between the pacific subtropical high pressure and the low-pressure center along the Indian Ocean (Rasmusson and Wallace, 1983). As El Nino Southern Oscillation has an impact on climatic conditions in various parts of the world (Nazemosadat and Cordery 2000; Hasanean 2004; Vázquez et al. 2005; Vicente - Serrano 2005; Brönniman et al., 2007; Zuhairi et al. 2013; King et al. 2020; Valdez- Cepeda et al., 2020) affects the weather patterns of countries in the Mediterranean Basin (Price et al., 1998, Nazemosadat and Cordery 2000, Salameh et al., 2019) and also Turkey (Türkeş 1998; Karaca et al.2000; Türkeş, 2000; Karabörk and Kahya 2003; Karabörk et al.2005; Martı 2007; Martı and Kahya 2007; Martı 2014; Tosunoğlu et al.2018, Efe et al., 2019). El Niño-Southern Oscillation (ENSO) is a strong climate driver in the interannual timescales, its climate impact is wide-ranging in the Asia-Pacific region. However, its impact further afield such as over the North Atlantic–Europe (NAE) sector is more challenging to establish, remains debated and is a topic of ongoing research. These ENSO climate impacts in Europe overall have a north–south contrast. Furthermore, they are also consistent with the teleconnection of ENSO in the NAE through the North Atlantic Oscillation (NAO), such that negative (positive) NAO is connected to El Niño (La Niña) (King et al 2020). According to previous studies which argue for robust climate impact over Europe analysed times series for the past 500 years show that El Niño is connected to cold anomaly in northern Europe, and to warm anomaly in southern Europe and Turkey during winter (January–March).

While rainy conditions were formed in Western and Southern Europe during the strong El Nino years, drier conditions were observed in Northern Europe. In the very strong El Nino years, it can be said that dry conditions prevailed in Western Europe, rather than these observed anomalies became much stronger (King et al 2020). It was stated that winter precipitation in Turkey showed a significant increase in the previous years after El Nino and La Nina events, a weak trend in the following years after El Nino events, and a significant decrease in the following years after La Nina events (Türkeş, 2000). It has been mentioned that the decrease of rainfall in Turkey during the winter months can significantly affect the drought, and generally there is an increase in the northwestern where the rainfall decreases in the southwest of Turkey during the El Nino years (Kadıoğlu et al., 1999).

The North Atlantic Oscillation (NAO) consists of opposing variations of barometric pressure in the subpolar and subtropical regions of the North Atlantic. Generally, there is a high-pressure system in the subtropical zone near the Azores and a low pressure condition near Iceland's subpolar zone. The strength of the pressure gradient between two pressure centers changes over time in the strong and weak phases. The measure of this variation is the NAO indice (Bachmann, 2007). While the average annual precipitation in winter, spring, autumn, and partly summer in Turkey is mainly defined by longer-term rainy conditions in the negative phase of the NAO, the atmospheric circulation affecting the North Atlantic and Europe in the positive phase of the NAO are drier than the long-term average in Turkey conditions have occurred (Türkeş and Erlat, 2003). Many studies are examining the effect of NAO on climate conditions in Turkey (Baltacı et al., 2018). This effect of atmospheric oscillations on climate is also observed directly on crops (Gimeno et al., 2002; Zubair 2002; Fraisse et al. 2008; Soler et al. 2010; Bannayan et al., 2011; Rao et al., 2011; Abdolrahimi, 2012; Capa. -Morocho et al, 2014; Iizumi 2014; Gutierrez, 2017; Rojas et al, 2019; Uzun & Ustaoğlu, 2019; Qian et al, 2020; Abahous et al, 2021).

The Mediterranean Region is one of the important agricultural production areas for Turkey. The yield changes occurring in the region affect food industry. Determining the effect of periodically repeated oscillations on variability in efficiency will provide the prevent economic loss. Therefore, in this study, olives, cotton, and grapes, which have high economic value in the Mediterranean Region and can be easily affected by the variations in climatic conditions, have been examined. The relationship between the yield of these crops and atmospheric oscillations has been determined. Olive (*Olea europaea L.)* is a member of the maquis community included in the vegetation of the Mediterranean Climate. Olive is considered a bioindicator that characterizes this zone because of its perfect adaptation to the Mediterranean climate zone (Efe et al., 2009). 90% of the olives in the world are produced in the Mediterranean Basin and 10% in Latin American countries (Ministry of Customs and Trade, General Directorate of Cooperatives, 2018a). Between 1991 and 2020, Spain ranks first in olive production globally, Italy is in the second, Morocco is in third place, and Turkey is in fourth place (FAO, 2021) (Table 1). Cotton is of great importance for society, the employment it provides, the economic value it creates, and the producers with its ordinary and necessary areas of use. Due to growing conditions, 80% of world cotton production is made by a small number of countries, including Turkey (Ministry of Customs and Trade, General Directorate of Cooperatives, 2018b). Between 1991 and 2020, China ranked first in cotton production, India ranked second, and the USA ranked third in world cotton production. Turkey ranks 7th (FAO, 2021) (Table 1). Grape is one of the fruit types with a wide production area in the world. Grape is a perennial garden plant resistant to high and low temperatures, although it is a hot-temperate climate plant (Kaymaz, 2005). Between the years 1991-2020, China ranks first in grape production, Italy ranks second, and the USA ranks third. Turkey ranks 6th in production (FAO, 2021) (Table 1). Turkey is the largest exporter of seedless raisins globally, with 40-45% (Ministry of Customs and Trade, General Directorate of Cooperatives, 2018c) (Table 1).

Table 1 Cotton, Grape, Olive production worldwide (1991-2019) (FAO,2020)

2. The Features of Study Area

The Mediterranean climate is effective in the study area on the southern coastline of Turkey, but the climate does not show the same characteristics everywhere due to the influence of topography (Fig. 1). In parts up to 1000 m, there is the Mediterranean climate, where the summers are hot, and dry winters are warm and rainy, and the parts above 1000 m are the Mediterranean Mountain climate, where the summers are cool and less rainy, and the winters are cold and snowy (Atalay and Mortan, 2011). According to the Köppen-Geiger climate classification, Csa, a very hot and dry Mediterranean climate with warm summer in the region, is effective. In the northern parts, BSk, a semi-arid steppe climate in places, and Dsb, which has severe winter, dry summer, and cool, are effective (Baylan and Ustaoğlu, 2020).

Fig. 1 Location Map of Study Area

3. Data and Method

3.1 Data

Several indices (such as Nino 3, Nino 3.4, Nino 4) are used to define the tropical Pacific, each based on average SST anomalies in a particular region. Usually, anomalies are calculated against a 30-year baseline period. The Niño 3.4 indice and the Oceanic Niño indice (ONI) are the most used indices to describe El Niño and La Niña events. ONI uses the same region as the Niño 3.4 indiceand includes the quarterly average (Climate Data Guide, 2018). For the study, the ONI indice was used to determine Nino3, Nino 3.4, Nino 4, and El Nino years taken from NOAA (NOAA, 2021). Values of +0.5 and above, which are repeated for at least five consecutive periods in the indice, define the year of El Nino, and values of -0.5 and below define the year of La Nina. In addition, years with values between 0.5 and 0.9 are classified as weak, years with values between 1 and 1.4 as a medium, years with values between 1.5 and 1.9 as strong, and years with ≥2 values are classified as very strong (Subash, Gangwar, 2014; Golden Gate Weather Services, 2018). In the study, El Nino and La Nina years were taken from (Subash and Gangwar, 2011), and the other years were determined by examining the ONI indice according to the criteria mentioned above (Table 2).

Table 2 Oceanic Nino Indice (ONI) (NOAA,2021)

In the study, the areas with the highest yields were used for each crop. Yield data analyzed to Hatay city for olives, Adana city for cotton, and Mersin city for grapes. Yield, production, area information of crops were obtained from Turkish Statistical Institute (TUIK, 2017, 2021); phenology information from were obtained from the Phenology Atlas of Turkey and literature (Phenology Atlas of Turkey, 2001, 2014; Temuçin, 1993; Efe et al., 2009); monthly minimum, average, maximum temperature, and total precipitation climate data were obtained from meteorology stations (MGM, 2021).

3.2 Method

First of all, the trend analysis of the yield values of the crops was examined. According to the findings obtained from IPCC reports, after the 2000s, the effects of climate change, especially in the Mediterranean Basin, affected many physical and human environments, primarily agriculture (Ustaoğlu et al., 2021). In order to see this effect in the trend in crop yields, Mann Kendall Trend analysis was applied to yield values. It has been tried to determine the year in which the variability in yield occurred. Secondly; according to the findings obtained, the relationship between indicevalues and yield values according to phenological periods before and after the change was analyzed by applying the Spearman Correlation Coefficient at the significance level of $p \leq 0.05$ and $p \leq 0.00$. According to WMO, this period was accepted as the most effective and powerful El Nino since 1950, with drought and floods caused by various parts of the world according to WMO (World Meteorological Organization,2015). Strong El Nino years and yield values were plotted on the same graph, and the changes in yield were tried to be explained according to the phenology of the crops.

Firstly we used Mann Kendall Rank correlation test. The rank-based nonparametric Mann–Kendall statistical test has been commonly used to assess the significance of trends in climatic time series such as temperature and precipitation. The main reason for using non-parametric statistical tests is that compared with parametric statistical tests, the non-parametric tests are thought to be more suitable for non-normally distributed data, which are encountered in climatic time series (Yue et al., 2002, Ustaoğlu, 2012).

Mann Kendall Rank correlation method are as follows: "In the Mann-Kendall test, for each element xi (i= 1 , . . . , n) of a series yi of length n, ni is the number of elements j which precede i (i >j) such as xi > xj. The trend statistic t of the test is computed as follows:

$$t = \sum_{n}^{i} ni$$

The distribution of t, under the null hypothesis, is practically a normal distribution with the average and the variance given by the following expressions:

$$E(t) = \frac{n(n-1)}{4} \qquad \text{and} \qquad var(t) = \frac{n(n-1).(2n+5)}{72}$$

The reduced statistics of t he test, given by |u(t)|, is thus compared to a normal distribution law.

$$u(t) = \frac{(t - E(t))}{\sqrt{var(t)}}$$

The null hypothesis can, therefore, be rejected for high values of |u(t)|, this being the probability α1 of rejecting the null hypothesis when it is derived from a standard normal distribution table:

$$a1 = P(|u| > |u(t)|)$$

The Mann-Kendall test consists in calculating two series of statistical values, one from the beginning of the series, the second from the end. These series are shown in the form of two curves respectively called the direct curve (ui) and the backward curve (u´i). A trend is significant when the curve ui exceeds the 5% threshold, i.e. when $|ui| > 1.96$. Significance of trends were evaluated at the 0.05 levels. Sneyers (1990) demonstrated the usefulness of this test, using its direct progressive and backward forms, for identifying the intervals in which trends are most pronounced, and trend turning points and/or climate shifts. The point which marks the beginning of the change corresponds to the intersection between the direct curve and the backward curve, (u´i) . Graphically, the backward and direct curves are often confused when there is no significant trend in the series. When values of u (t) are significant, one concludes to a rising or decreasing trend, for $u(t) > 0$ or $u(t) < 0$, respectively (Samba and Nganga, 2012)".

For the Spearman Correlation coefficient analysis of the crops, the phenological periods suitable for the Mediterranean Region were determined. According to this, the phenological periods of olive are flowering between 1 April - 30 June, the first initiation fruit between 1 May - 15 August, ripening and harvesting between 1 September and 15 December. The phenological stages of cotton are sowing, flowering, and harvesting. Sowing in the Mediterranean region is between 1 April - 15 May, flowering between 16 June - 15 August, harvest between 16 August - 30 November. The phenological stages of grape are shooting, flowering and ripening (Phenology Atlas of Turkey, 2014). Grape shooting 16 March - 30 May, flowering 10 April - 24 July, and fruit ripening between 10 April - 17 September (Phenology Atlas of Turkey, 2001). The statistical relationship between indices and yieldswas determined by Spearman correlation coefficient analysis, and the significance of the results was measured with the value $p \leq 0.05$ and $p \leq 0.00$.

4.Results

4.1 Mann Kendall Rank Correlation Trend Test Results

Mann Kendall trend analysis was applied to the yield values of the crops in the period 1991-2020. Olive yield trend has changed in 2001. Because u (ti) and u´ (ti) values intersected in 2001 (Fig. 2), accordingly, there is an increasing trend in olive yield, and it's u (ti) value is 4,34 (Table 3).

Fig. 2 Mann Kendall Rank Correlation Trend Test results of olive yield

Cotton yield trend has changed in 2002. Because u (ti) and u´ (ti) values intersected in 2002 (Fig. 3), accordingly, there is an increasing trend in cotton yield, and it's u (ti) value is 5.91.

Fig. 3 Mann Kendall Rank Correlation Trend Test results of cotton yield

Grape yield trend has changed in 2005. Because u (ti) and u´ (ti) values intersected in 2005 (Fig. 3), accordingly, there is an increasing trend in grape yield, and it's u (ti) value is 6,48.

Fig. 4 Mann Kendall Rank Correlation Trend Test results of grape yield

Table 3 Mann Kendall Rank Correlation Trend Test Statistic Results of Crops

4.3 Results of Correlation between Atmospheric Indices and Crop yields in the Phenological Periods

Olive was examined by divided it into three periods as 1991-2001, 2002-2020, and 1991-2020 according to Mann Kendall Rank Correlation Trend Test results. The statistical relationship between Nino 3, Nino 3.4, Nino 4, and NAO indices at $p \leq 0.05$ and $p \leq 0.00$ significance level according to the phenological period of olive yield was analyzed. Accordingly, the most significant relationship was found in 1991-2001 with Nino 3.4 and Nino 4 during the flowering period and the first initiation fruit. Significant correlations were found with Nino 3.4 at $R = 0.70$ $p \leq 0.02$ during flowering and at $R = 0.70$ $p \leq 0.02$ during first initiation fruit. Nino 4 with $R = 0.65$ $p \leq 0.03$ and $R = 0.81$ $p \leq 0.00$ during flowering and $R = 0.65$ $p \leq 0.03$ during the first initiation fruit. A significant relationship was found between $R = 0.81$ $p \leq 0.00$. There was no significant relationship between indice values and yield in the period 2002-2020. In the period 1991-2020, a significant relationship was obtained between Nino 4 and $R = 0.40$ $p \leq 0.03$ and $R = 0.36$ $p \leq 0.05$ (Table 4).

Table 4 Result of Spearman Correlation Coefficient Analysis between Atmospheric Indices and Olive Yield Values

Cotton was analyzed by divided it into three periods as 1991-2002, 2003-2020, and 1991-2020 according to the Mann Kendall Rank Correlation Trend Test results. The statistical relationship between Nino 3, Nino 3.4, Nino 4, and NAO indices at $p \leq 0.05$ and $p \leq 0.00$ significance level according to the phenological period of cotton yield was investigated. Accordingly, the most significant relationship was found in 1991-2002, with Nino 3.4 in the sowing period. A significant relationship was found with Nino 3.4 at the level of $R = 0.64$ $p \leq 0.03$ in the sowing period. There was no significant relationship between indicevalues and yield in the 2003-2020 period. In the period 1991-2020, a significant relationship was obtained with NAO at the level of $R = 0.37$ $p \leq 0.05$ (Table 5).

Table 5 Result of Spearman Correlation Coefficient Analysis between Atmospheric Indices and Cotton Yield Values

Grape was divided into three periods as 1991-2005, 2006-2020, and 1991-2020 according to the Mann Kendall Rank Correlation Trend Test results. The statistical relationship between Nino 3, Nino 3.4, Nino 4, and NAO indices at $p \leq 0.05$ and $p \leq 0.00$ significance level according to the phenological period of grape yield was investigated. Accordingly, there was no significant relationship between indices and yield in the period 1991-2005. From 2006 to 2020, a significant relationship was found with Nino 3, Nino 4, and NAO in the phenological period. There was no significant relationship between indicevalues and yield in the 1991-2005 and 1991-2020 period. In the period 2006-2020, significant correlations were found with Nino 3 at $R = 0.58$ $p \leq 0.02$, with Nino 4 at the level of $R = 0.53$ $p \leq 0.04$, $R = 0.57$ $p \leq 0.03$, $R = 0.64$ $p \leq 0.01$, $R = 0.60$ $p \leq 0.02$ and with NAO at the level of $R = 0.54$ $p \leq 0.05$ (Table 6).

Table 6 Result of Spearman Correlation Coefficient Analysis between Atmospheric Indices and Grape Yield Values

According to the results, the most significant relationship between indices and yields was found in general El Nino indices and especially in Nino 3.4. The most statistically significant relationship was determined in the period 1991-2001, before the trend for olives began to change. For cotton, it was determined throughout the period examined 1991-2002 and 1991-2020. A statistically significant relationship was found for grapes in 2006-2020.

Correlation coefficients obtained with El Nino indices in phenological periods were more effective than the NAO indice. In this case, we can say that El Nino is more effective in terms of time and spatial yield efficiency in the south of Turkey than NAO.

4.4 Effects of Extreme El Nino Phases on Crop Yields

Particulary in the last 20-25 years, it has been stated that statistically significant relationships have been determined between atmospheric oscillations and climatic conditions (Price et al., 1998). The effect of El Nino years on precipitation variability in Turkey has been investigated (Türkeş, 1998, Karabörk and Kahya, 2003, Karabörk et al., 2005, Martı, 2007, 2014). For countries in the Mediterranean Basin, such as Spain and Iran, there are studies on El Niño on precipitation variability (Nazemosadat and Cordery 2000, Hasanean, 2004, Vaquez et al., 2005). In these studies, it was stated that there were drought signals during the El Nino years (Vincente-Serrano, 2005, Tosunoğlu, 2018, Dabanlı et al., 2017). It has been analyzed that extreme temperatures in Turkey are also affected by El Nino conditions (Martı and Kahya, 2007).

The first study investigating the effect of atmospheric oscillations on crop yield in Turkey is the relationship between hazelnut yield and the NAO indice (Ustaoğlu, 2010). It has been determined that the effect of ENSO is more effective in the south, where NAO is generally more effective in the northern regions of Turkey (Diker et al., 2018). In the study that determined the relationship between olive yield and El Nino and NAO in Turkey, no significant relationship was found with NAO, but significant relationship and low yield was found in strong El Nino years (Uzun & Ustaoğlu, 2019). Another study that found statistically significant relationships between olive yield and Nino 3.4 indicewas applied in Northwest Africa (Abahous et al., 2021). It has been determined that there are significant statistical relationships between olive yield and Nino 3.4 in Iran (Bannayan et al., 2011). El Nino event has a negative effect on wheat yield in Morocco and Egypt, especially (Qian et al., 2020). Orange and tangerine yield in Spain are highly affected by ENSO (Gimeno et al., 2002). Relationships between soybean yields and El Nino Southern Oscillation (ENSO) phases in Eastern Paraguay and were investigated. According to El Nino years, a decrease in precipitation was observed between planting and flowering periods, and it was determined that the average amount of rainfall during the maturation period of the crops was lower than in El Nino years (Fraisse et al. 2008).

Olive is sensitive to high temperatures. It needs chilling for a certain period for flower bud formation from January to April. Although olives grow in tropical regions, the fruit cannot be formed because of the absence of the cooling period that olives need in the tropical climate (Temuçin, 1993). The frequency and severity of extreme events such as high temperatures, drought, and floods, which are thought to be caused by human-induced climate change after the 2000s in the Mediterranean region, negatively affect olive cultivation. 2020 has been the year with the most extreme events in Turkey, with 984 extreme events. There is a significant increase in extreme event trends, especially after 2000 (TC Ministry of Agriculture and Forestry, General Directorate of Meteorology, 2021). Extreme weather events have greatly affected olive yield. In addition to olive yield, it also caused changes in the quality of olive oil and the grain size of the olive. The increase in temperatures experienced during the flowering period seriously affected the production due to the burning and drying of the flowers. The 2020-2021 season has also been recorded in statistics when olive production in Turkey was the lowest for the last ten years (UZZK, 2020).

The chilling period of olive is in April (Temuçin, 1993; Efe et al., 2009). Considering the average, maximum, and minimum temperatures of April in the study area, it is observed that there is an increasing trend (Fig. 5a, 5b, 5c). These values have also been determined at absolute temperatures. Considering the total monthly amount of precipitation in October, when olive need rainfall in their phenological period, a decreasing trend has been determined (Fig. 5d). In Hatay, where olive cultivation is most common, a decrease in yield has been observed by 15% compared to the average in the last ten years (2009-2020) and by 50% compared to the average in the last 20 years (2000-2020) (Fig. 6). There was no severe yield loss in cotton and grape, which were not affected much by high temperatures and low rainfall during their phenological period (Fig. 7-8). However, in 1997, there was a decrease in temperatures throughout Turkey, and this decrease was further strengthened by the El Nino event (Table 2). In 1997, there was a decrease in the crop yield in the phenological period of olive flowering and fruit formation in the grape and the sowing phenological period of cotton (Fig. 6-7-8).

The last 5 years, from 2015 to the present, have been recorded as the hottest years since the Industrial Revolution. Increasing temperatures and El Nino events etc., have affected the occurrence and frequency of extreme events such as intense rainfalls. During the harvest in September 2015, Cotton was affected by heavy rain, and its yield decreased. In 2015, grape ripening phenological time was affected by heavy rainfall (Fig. 5e, 7, 8). The El Nino incident in 2015 became more severe and effective in 2016 (Table 2), and this time caused a loss of yield in the olive during the phenological period (Fig. 6). 2016 was a year of both extreme temperatures and low precipitation. In September, the total rainfall was the lowest in the study period (21.4 mm) (Fig. 5d). Rainfall is one of the important climatic factors affecting olive yield. The low amount of precipitation causes the fruits to remain thin and decrease yield (Doğanay and Coşkun, 2012).

This study determined that there were significant decreases in yield values, especially in 1997 and 2015-2016, which are the strong El Nino years according to the ONI indice (Table 2, Fig. 5-6-7).

Fig. 5 a) Monthly Maximum Temperature in April, b) Monthly Mean Temperature in April, c) Monthly Minimum Temperature in April, d) Monthly Precipitation in October, e) Monthly Precipitation in September

Fig. 6 Phenological year of Olive Yield in Hatay

Fig. 7 Phenological year of Cotton Yield in Adana

Fig. 8 Phenological year of Grape Yield in Mersin

5. Conclusions

It has been researched that the variability of climatic conditions and the increase in the frequency of extreme weather events (extreme rainfall, floods, extreme temperatures, heat waves, hail, etc.) that have occurred frequently in recent years are related to the large-scale pressure and changes in wind circulation and atmospheric oscillations (with direct and indirect effects, e.g., North Atlantic Oscillation, Arctic Oscillation, and El Nino Southern Oscillation, etc.). In studies about the climate of Turkey, it has been determined that since the 1990s, there is a trend in some extreme values, significantly the increase of daily lowest and highest temperatures, decrease in snowy and frost days, and increase in the number of hot days and nights.

Model studies on climate change also predict that the global climate will likely be more variable in many regions of the world in the future. According to the statement made by the World Meteorological Organization (WMO), the highest temperatures have been in the last five years from the date the recorded data began (1880-2020). As a result, it increases the likelihood of a climate in Turkey and its surroundings that is in a trend of deviating more frequently than the average of the long years and in which extreme climatic events will be experienced more frequently (heavy rainfall, flood, storm, tornado event, heatwave, drought, etc.). According to the results obtained from this study, while crops that adapt to tropical conditions such as cotton and grapes have a high tolerance to extreme temperatures, they are affected by intense precipitation. Olive, the bioindicator type of the Mediterranean Basin, is affected by the constantly ongoing average high temperatures and cannot complete its development as it feels the need for chilling. In addition, low precipitation during fruit formation causes low-quality fruit formation. Hence, extreme weather conditions affect the yield of these crops with high economic value in the Mediterranean Basin.

In the research period, extreme climatic conditions occurred, especially in the strong El Nino years, and directly affected the yield in the phenological stages of the crops. It seriously affects the countries whose economic activity is based on agriculture in the Mediterranean Basin, and it is likely to affect in the future. Extreme climatic conditions directly affect agricultural yield in years when the oscillations are strong. In order to prevent the occurrence of a food crisis and prevent fluctuations in food prices, possible NAO and ENSO oscillations, which are determinants of weather and climate conditions, and the effects of these oscillations on physical and human geography should be taken into account.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest

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Figures

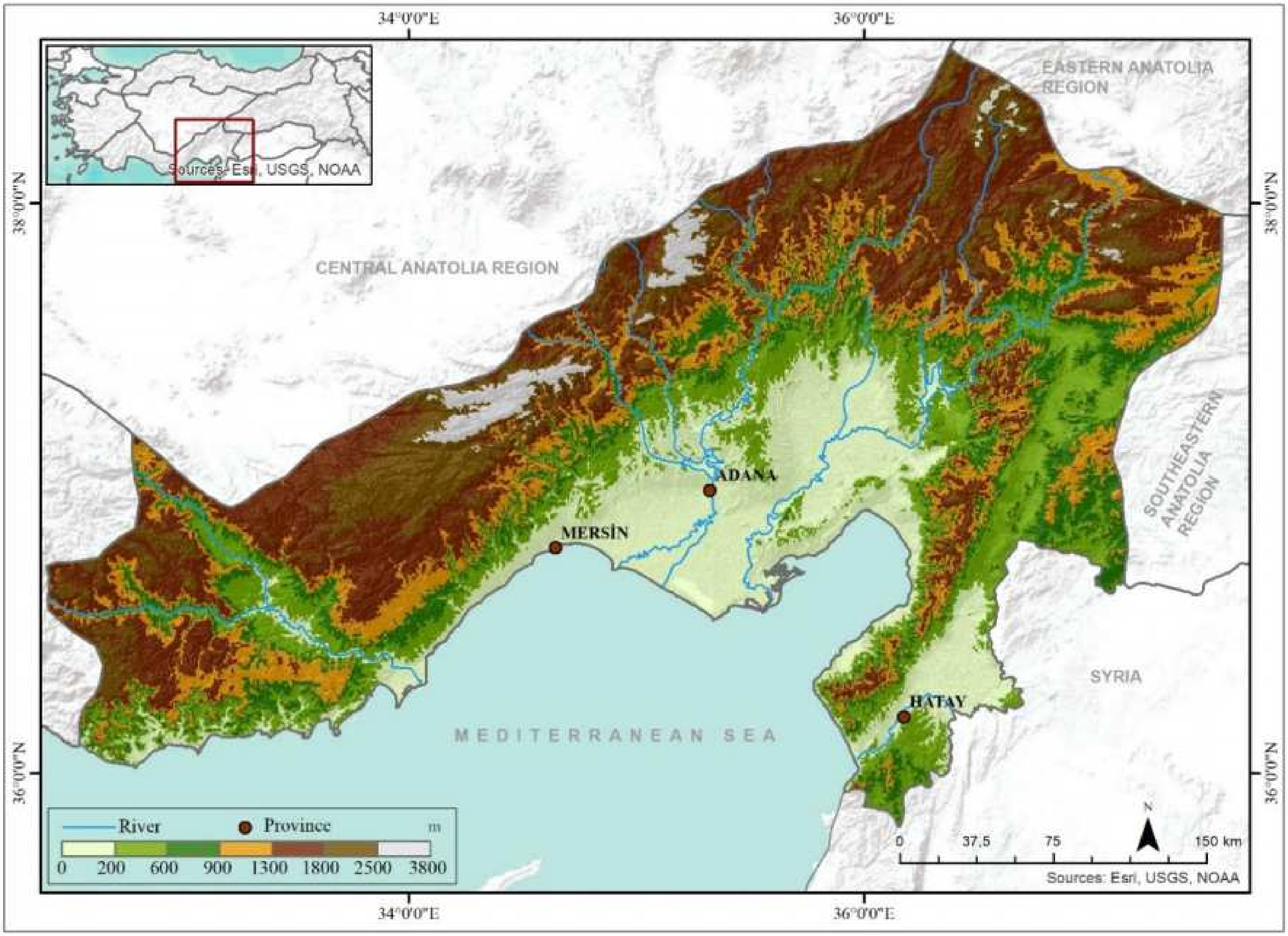

Figure 1

Location Map of Study Area

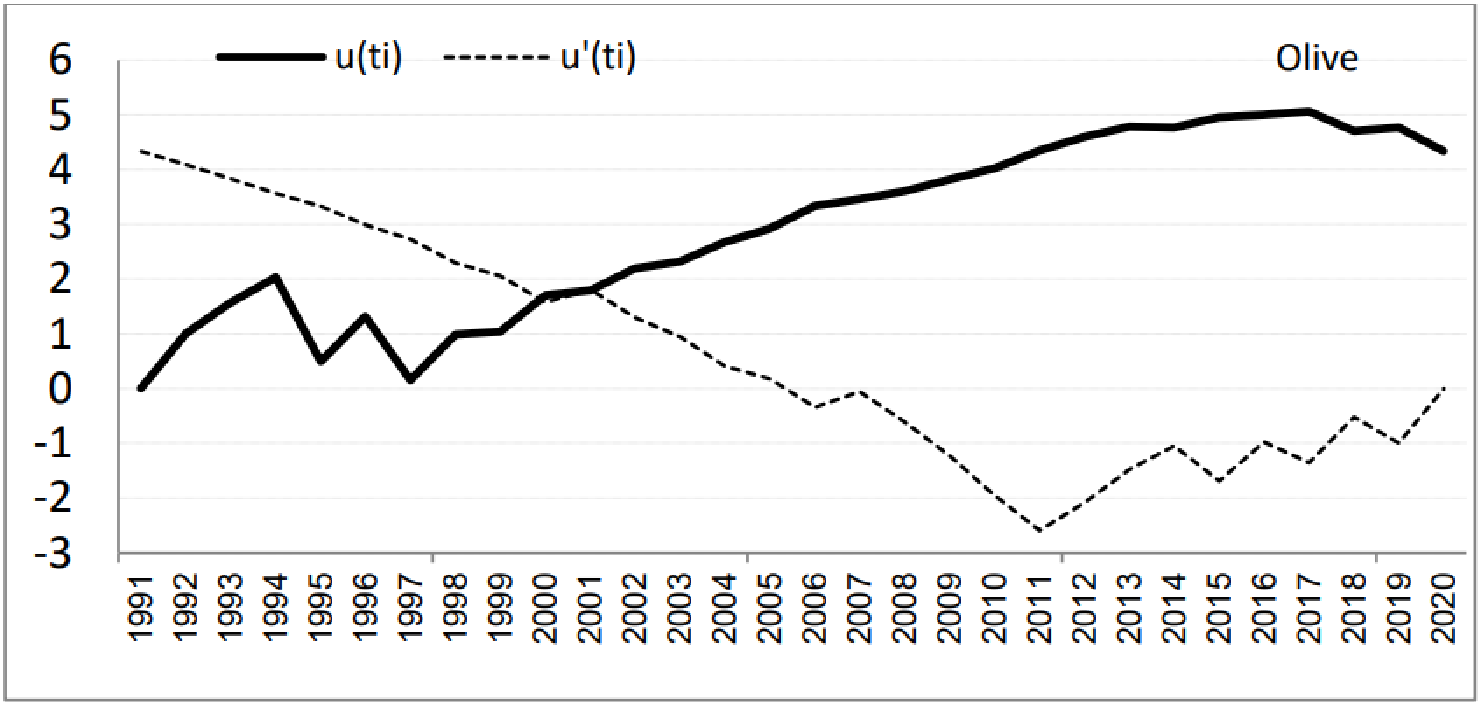

Figure 2

Mann Kendall Rank Correlation Trend Test results of olive yield

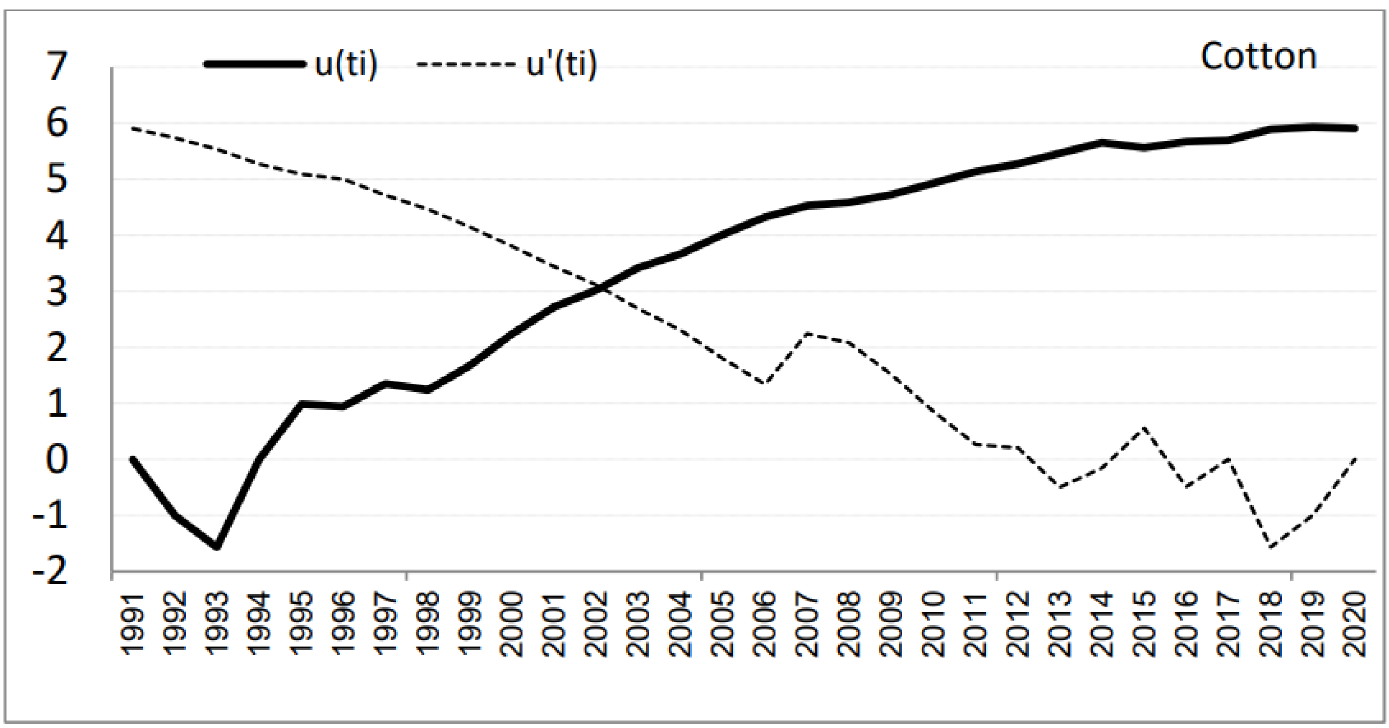

Figure 3

Mann Kendall Rank Correlation Trend Test results of cotton yield

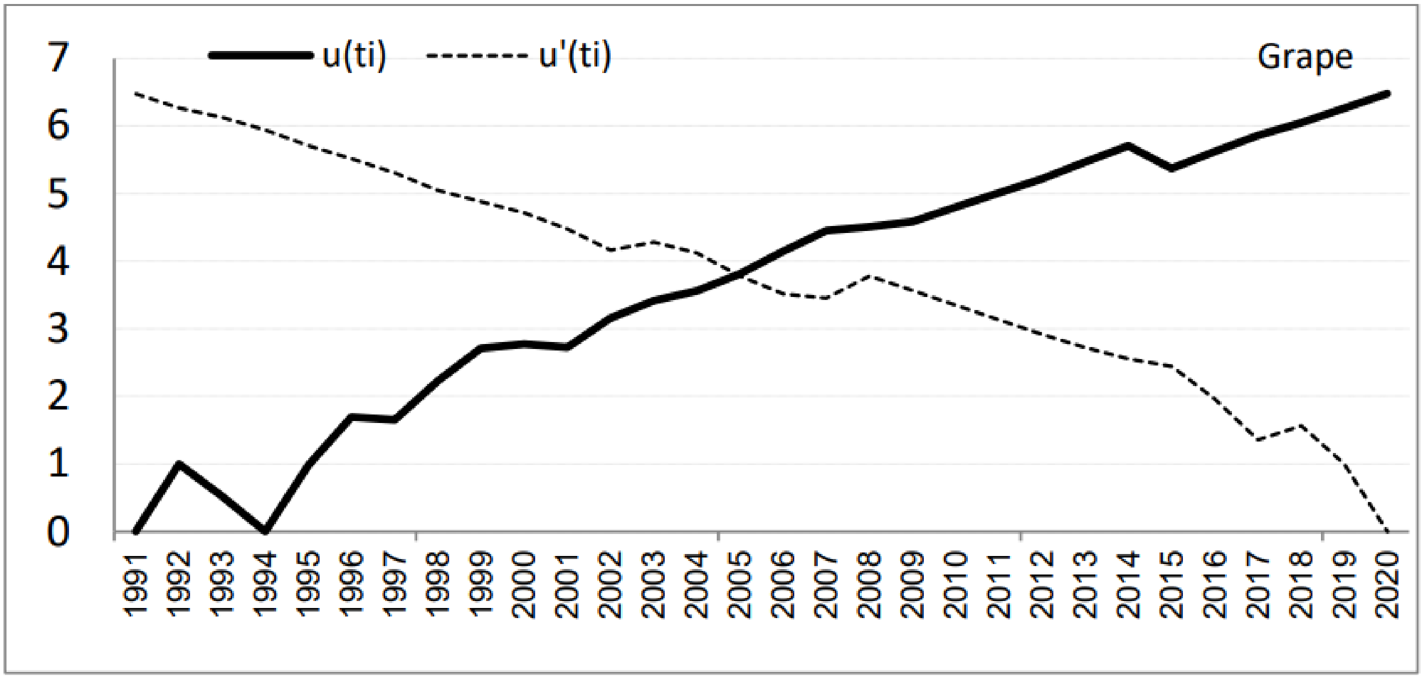

Figure 4

Mann Kendall Rank Correlation Trend Test results of grape yield

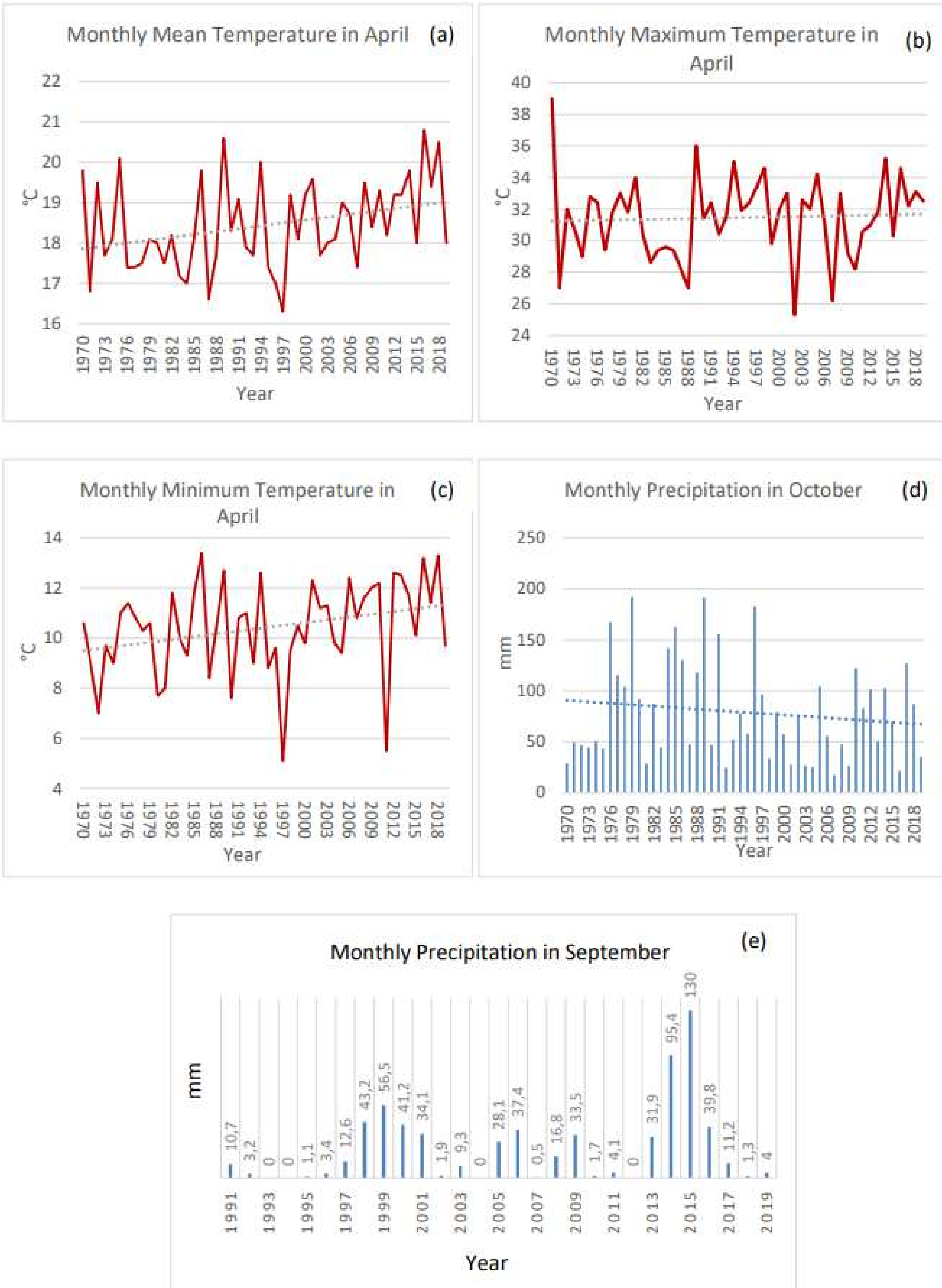

Figure 5

a) Monthly Maximum Temperature in April, b) Monthly Mean Temperature in April, c) Monthly Minimum Temperature in April, d) Monthly Precipitation in October, e) Monthly Precipitation in September

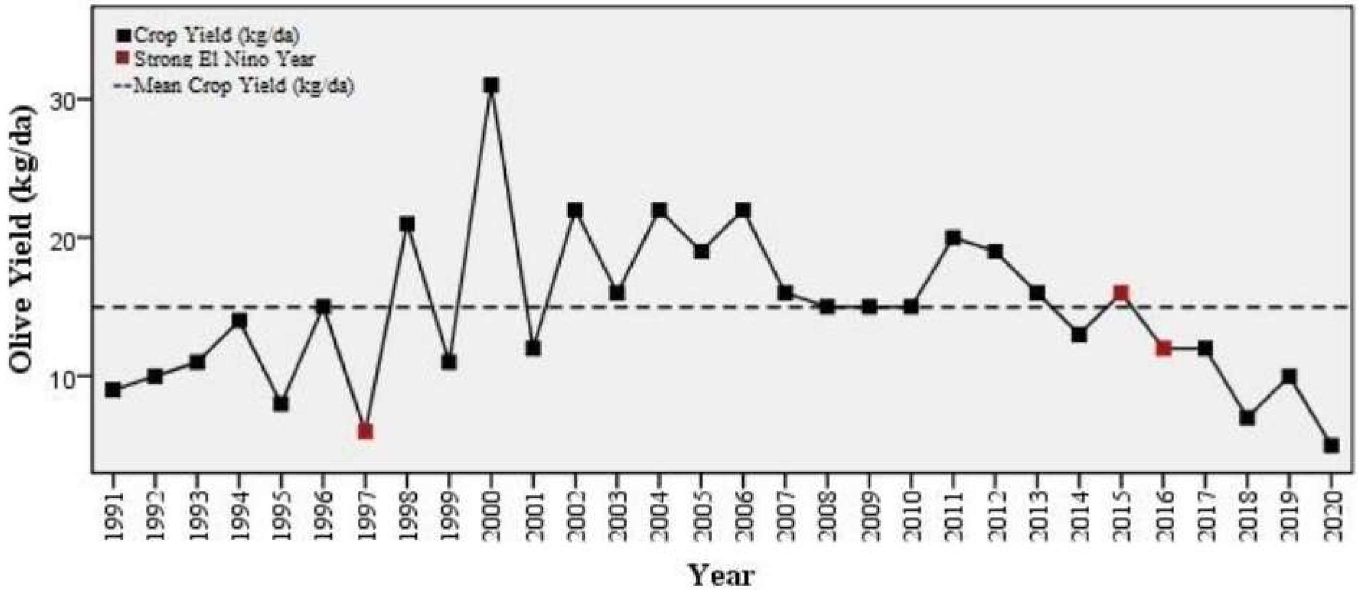

Figure 6

Phenological year of Olive Yield in Hatay

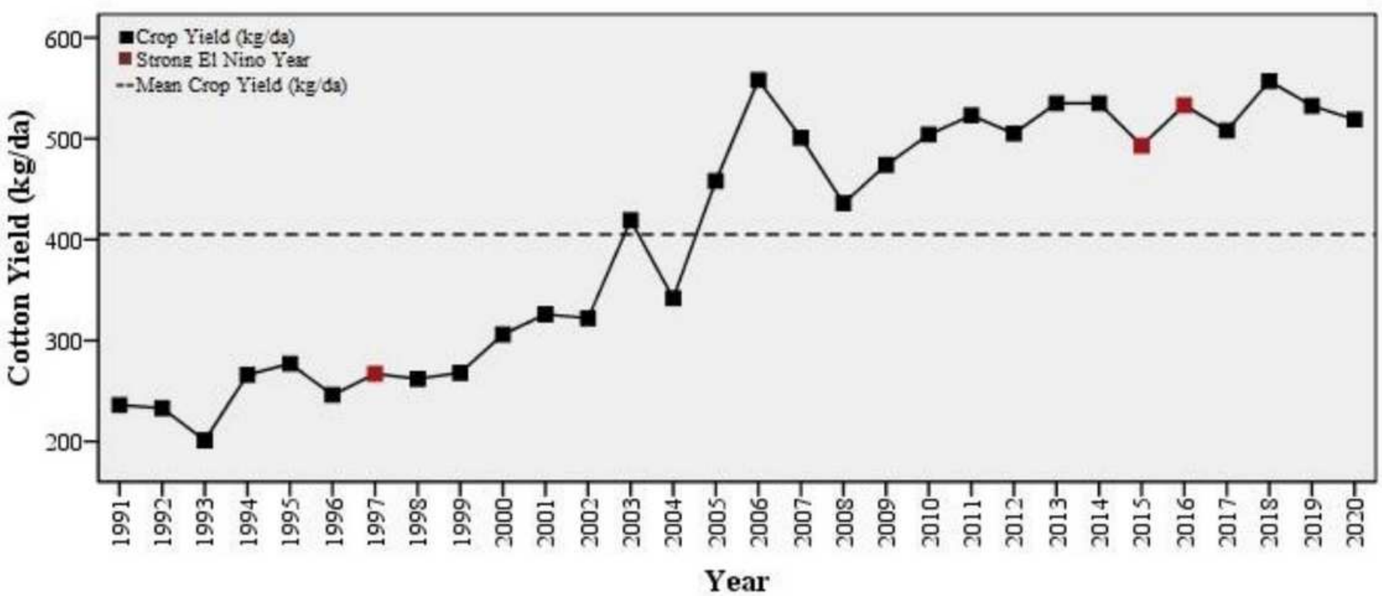

Figure 7

Phenological year of Cotton Yield in Adana

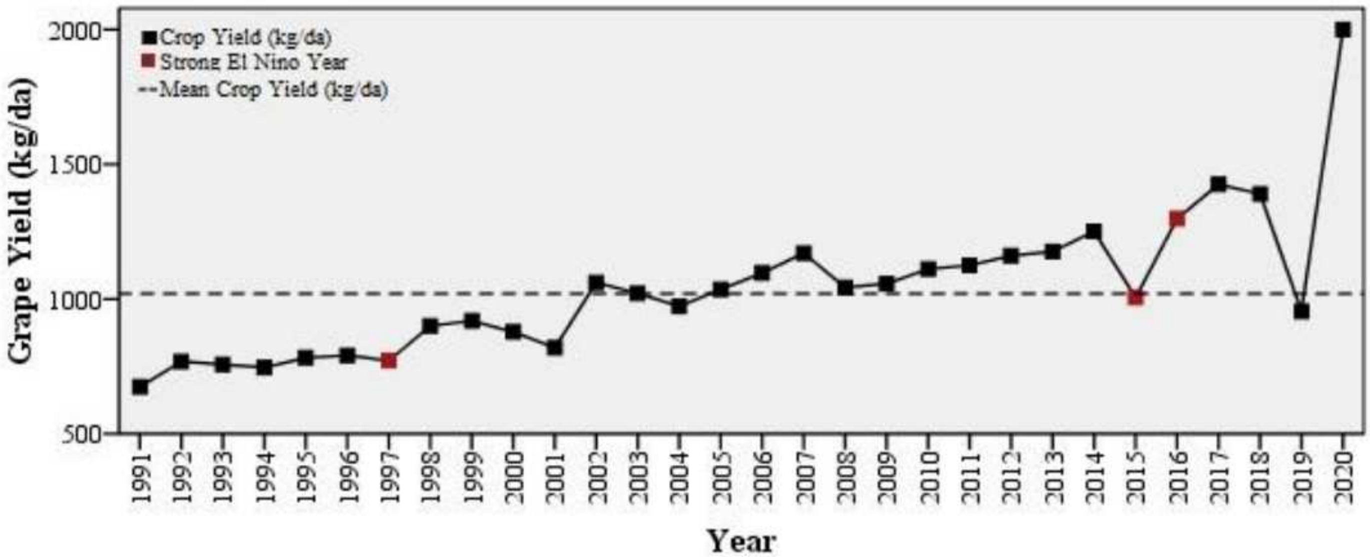

Figure 8

Phenological year of Grape Yield in Mersin

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