



Influence of climatic factor of changes in forest fire danger and fire season length in Turkey

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Abstract In contrast to the expectations of an increase in annual fire activity and the severity of fire season due to climate change and large fires, which have been occurring in recent years, a downtrend has been identified in fire activity in many studies conducted for the whole of Europe in recent years. Similarly, in Turkey, according to the General Directorate of Forestry statistics, while there is an increase in the number of annual fires, the burnt area has a downtrend pattern. In this study, fire activity and climate data statistics for Turkey were examined along with the fire season length and severity. The results obtained conform with the studies conducted in places from Spain at the westernmost part of Mediterranean Europe to Israel at the easternmost part of the Mediterranean. Considering the changes in temperatures, temperature rise of 2 to 3 °C was detected at all stations in the study area. No decrease was observed in the average temperatures at any of the stations within the study period between 1940 and 2018. On the

other hand, the precipitation trend varied according to the stations. Although there have been increases in precipitation in Fethiye, Isparta, and Marmaris since 1960, the decrease in precipitation by 132 mm in Afyon since 1970 and the decrease in precipitation by 137 mm in Bodrum since 1940 are attention-grabbing. These stations are followed by Izmir station with 66 mm and Cesme station with 37 mm of decrease, despite being smaller decreases. In the study, the long-term (1940–2018) data of the meteorological stations discussed within the study, the Canadian Fire Weather Index (FWI) and the Fine Fuel Moisture Code (FFMC) values were calculated. According to the FWI results used in determining the severity and length of fire season on the coastline of Turkey from the northern Aegean to Antalya, the likelihood of large fires decreased by about 52% in 2018 compared to 1970. This decrease in FWI value indicates that the fire severity is reduced. The specified decrease in fire severity also explains the reason of the decrease in the burnt area that occurred over the years in Turkey. No significant change was observed in the FFMC values indicating the possibility of human-induced fires between 1970 and 2018.

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Introduction

After 1980, increases in air temperature as well as significant changes in the frequency and severity of heat

waves were observed in Turkey. These increases are especially remarkable for average temperatures of summer season. While precipitation increases in the northern and eastern regions, it tends to decrease in the central regions as well as the western and southern regions with dry summer season subtropical Mediterranean climate, in general (Cetin 2015a, b, 2016a, b; Cetin and Sevik 2016; Kaya et al. 2019; Cetin 2019; Cetin 2020; Cetin et al. 2018; Adiguzel et al. 2020; Zeren Cetin and Sevik 2020; Zeren Cetin et al. 2020; Gungor et al. 2020; Cetin et al. 2019; Kilicoglu et al. 2020a, b). In his study, Turkes et al. (2002) mentioned the increases, which had occurred in heavy rainfall events in Turkey during the period from 1900 to 2005, and the fact that the temperature rises had reached to 0.33 °C according to the average rise in temperature (Turkes 2002; Turkes et al. 2002; Turkes and Sumer 2004; Turkes 2013; Erlat and Turkes 2012, 2013; Kuglitsch et al. 2010). In terms of precipitation after the 1980s compared to the recent years, a decrease by about 4.2 mm was observed in the Aegean region, and 2.8 mm in the Mediterranean region. In spite of this, increases were observed in autumn rainfall in a considerable part of the country. The most severe and widespread drought events in Turkey occurred between the period of 1971–1974, 1983–1984, 1989–1990, 1996–2001, and 2007–2008. Following the 2007–2008 droughts, in which record-low rainfall was registered, a rainy period over the long-term average or normal precipitation prevailed during the 2009–2011 period (Turkes et al. 2016; Demir et al. 2008; Turkes 2018). In the study, which sheds light on the arid and rainy periods of the last 350 years of Anatolia, conducted by Akkemik et al. (2005), it was found that the dry years lasted for one, rarely 2 years, and once in the Mediterranean Region exceptionally for 3 years (1745–1747). This study was one of the very few retrospective studies conducted in Turkey (Akkemik et al. 2005).

Turkey is located in a highly vulnerable area in terms of climate change. According to future projections, it is estimated that there will be critical climate changes in Turkey such as overall reduction in rain and snowfall, increase in the duration and frequency of air temperatures, evaporation, heat waves and drought events, and that Turkey will be adversely affected by climate change as many other countries in the Mediterranean basin (Sen 2013; Sen et al. 2013; Tatli and Turkes 2011; Ozturk et al. 2013, 2015; Turkes et al. 2011; Turkes 2014; Cetin 2015a, b, 2016a, b, 2019, 2020; Cetin and Sevik 2016; Cetin et al. 2018, 2019; Adiguzel et al. 2020; Zeren

Cetin and Sevik 2020; Zeren Cetin et al. 2020; Gungor et al. 2020). Among those changes, it is also estimated that there will be country-wide temperature rises for up to 5° as well as decreases in precipitation by 30% in the southern and western parts of Turkey. On the other hand, some models predict precipitation increases by up to 20%, especially in the Eastern Black Sea Region. Due to increasing temperatures, the summer season will expand in these regions. As a consequence, it will be inevitable for Turkey to be exposed to larger and more frequent forest fires (Giorgi and Lionello 2008; IPCC 2013). In the studies conducted by De Rigo et al. and Turkes, it was emphasized that the deep fine fuel moisture would be reduced in Turkey and Iberian Peninsula, even at 2 °C of temperature rise. It is clear that this reduction will increase the fire hazard (De Rigo et al. 2017; Turkes 2012). These changes in climate already have effects on forest fires. Jolly et al. (2015) reported that in general, the fire seasons around the world had increased by 18.7% from 1979 to 2013, and that they had prominently prolonged in the last 35 years. While the season prolonged in 25.3% of the global vegetation area, a decrease was detected in 10.7% of it. As a result of the same study, a significant relationship was determined between the prolongation of the season and the number of days without precipitation. Whereas in the Mediterranean Europe, increases of approximately 12 to 19 days and up to maximum of 29 days were determined (Jolly et al. 2015). However, in relation to precipitation, Turco et al. (2018) and Venäläinen et al. (2014) stated that the fires occurring in a year were related to the precipitation of that season.

Factors affecting fire are very diverse. Humans, ignition factor, land use history, fuel, and climate are among the primary ones (Johnson and Miyanishi 2001; Swetnam 1993; Westerling et al. 2006, Flannigan and Wotton 2001; Flannigan et al. 2005; Flannigan et al. 2013). In the Mediterranean countries such as Turkey, majority of forest fires are caused by humans. However, climate change factors are significantly effective in the expansion of the fires (Balshi et al. 2009; Parisien et al. 2011; Flannigan et al. 2013). Fire activity is particularly affected by temperature, precipitation, wind, and atmospheric humidity. It is stated that the amount of burnt area can be best explained by climate and meteorological factors (Cary et al. 2006; Flannigan et al. 2013). Prasad et al. (2008) reported that the fires in South India are related to the average annual temperature and average precipitation (Prasad et al. 2008).

Different results are obtained for various parts of the world in the studies conducted on determining the fire season. In the USA, the fire frequency and temperatures have been increasing since the 1980s, and this trend is still rising. In the western part of the USA, the average spring and summer temperatures between 1987 and 2003 are higher by 0.87 °C than those between 1970 and 1986. Fire activity has increased in the region as a result of the hotter summers and the longer fire season extending due to early spring season (Westerling et al. 2006). In the studies conducted for this region, it is stated that the fire risk in forests is strongly associated with drought during the fire season (Balling Jr et al. 1992; Westerling et al. 2003; Westerling et al. 2006). In addition, the increase, which occurred in fire activity in the 1980s, was reported to be parallel to the rise in temperature and early snow melt events. On the other hand, there are opposing views in the studies conducted for the USA. For example, while Dillon et al. (2011) stated that there was no significant increase in the burnt area, Miller and Safford (2012) mentioned an increase in fire severity, whereas Hanson and Odion (2014) reported that there was no general increase. Jolly et al. (2015) stated that the fire season had been extended for the last 35 years, and noted that the fire frequency increased as the season extended. According to the results of the study, the average season length in Western USA increased by 74 days (64%), when compared between 1970–1986 and 1987–2003 (Jolly et al. 2015). In compliance with this, Westerling also stated that there had been an increase in large fire activity since the mid-1980s in the western part of the USA. Drier soil and vegetation lead to larger fires (Westerling et al. 2006). Similarly, positive trends have been identified for Canada as well, with the exception of a small area in British Columbia (Jain et al. 2018). In a study conducted in Australia, it was determined that there were fire hazards and an increase in season length between the years of 1973 and 2010 at many locations (Clarke et al. 2013). As an example to positive trends obtained, Fréjaville and Curt (2015, 2017) also identified an increase in fire weather severity for most of the south-eastern France between the years of 1973 and 2009. Apart from this, increases have been detected in the burnt areas in both Southeast Asia and the Middle East (Doerr and Santín 2016).

There are also some research results that are contradictory with all these studies and their results. Doerr and Santín (2016) have identified decreases in burnt areas

within the past decades in Europe, Australia, and New Zealand. As for Mediterranean Europe, it was found that the increase, which had occurred in the number of fires between 1980 and 2010, at the beginning of the 90s until the mid-2000s, had been in a downtrend since 2005, and that the burnt area had been in a continuous downtrend for the last 30 years (San-Miguel-Ayán et al. 2013; Doerr and Santín 2016; De Rigo et al. 2017). Doerr and Santín (2016) mention an increase in the number of fires on a global scale from the 1980s to the end of the 1990s, and a decrease since the mid-2000s. As for the burnt area, they mention a decrease that has been going on for the last 30 years. They attribute these results to human activity, firefighting management, and abandonment of rural areas. However, it is stated that despite having an extension in fire season and an expansion in the burnt area in North America and in some parts of the world, this trend is not on a global scale (Doerr and Santín 2016). As a matter of fact, there exist other studies recently conducted and mentioning a decrease in the burnt area (Giglio et al. 2013; Van Ieper et al. 2015).

Material and method

The aim of the study is to determine whether a change occurred in the length and severity of forest fire seasons in Turkey compared to the past. In recent years, various studies have been conducted on this subject in different parts of the world, and the results show different trends. Especially in recent years, an increase has been detected in summer temperatures in the western and southern regions of Turkey, and a decrease in precipitation. The effects of this situation on fire activity and fire season were explored.

Although the fire season in Turkey generally varies across regions, it is deemed to be 5 months including May and September. The preparations made for firefighting activities in Turkey are also planned according to this period. In addition to the factors such as temperature and precipitation, which are quite critical for forest fires due to global climate change, the fire season itself has also changed. This change occurs in the length, severity, and other various characteristics of the season. The subject of this study is to explore whether fire season, which varied in different parts of the world, undergone some changes in Turkey as well.

The fire risk increases mainly with 3 components:

1. Number of days at risk of fire
2. Increasing length of fire season
3. Increasing number of extreme events (7 consecutive days with FWI > 45 days and FWI > 45).

One of the major issues of determining the fire season is the identification of the start and end time of the year in order to plan and manage the measures to be taken during the season (Wotton and Flannigan 1993). For Turkey, it is known that there is a rise in temperature (Figs. 1 and 2). Therefore, it is possible that there will be changes in the fire season as well. Fire season is generally considered as the summer months of a region in the world. However, various methods are used to determine the actual fire season according to a region.

Many researchers report that the increases, which have occurred in burnt area within the last 40 years, are due to human-caused increases in temperature (Gillett et al. 2004; Parisien et al. 2011; Cary et al. 2006; Flannigan et al. 2013). For this reason, many researchers have used the season temperature in determining the fire season. In some of the studies, a certain temperature for 3 consecutive days was preferred for determining the fire season (Turner and Lawson 1978; Simard et al. 1989). In a study conducted by Wotton and Flannigan (1993), the beginning of the season was defined as the 3 consecutive days exceeding 12 °C, which was also considered as the beginning of the season by Canadian Forest Fire Weather Index System (CFFWI), whereas they defined the end of the season as the 3 consecutive days below 5 °C, which was considered as the end of the season by Simard et al. (1989), since CFFWI did not specify a limit for the end of the season. However, the beginning and the end of the season have not been determined for the National Fire Danger Rating System (NFDRS) of the USA (Wotton and Flannigan 1993).

The calculation of fire season according to temperature involves some defects, such as ignoring the very important impacts of precipitation on the fine fuel. Moreover, the impact on fine fuel and soil is not instantaneous, but in the form of cumulative increases and decreases as in many drought indices (Standard Precipitation Index (SPI), Keetch-Byram Drought Index (KBDI)). In a study carried out by Holden et al. (2007), it was reported that the duration of dry spell within the fire season in the south-western regions of the

USA affected the length and severity of fires. Just like rain, wind is another meteorological factor that has a significant impact on fire behavior. As a matter of fact, since the Canadian FWI uses temperature, precipitation, humidity, and wind in its calculations, it is now considered to be the most successful model in the determination of daily fire hazards in many different parts of the world.

With the help of FWI in the studies conducted, it is found that there is a significant relationship between forest fires and large fires, and that it is extremely successful in predicting fires and prognosticating the potential fire situations (Carvalho et al. 2008; Fréjaville and Curt 2015; Dimitrakopoulos et al. 2011; De Rigo et al. 2017; Ertugrul and Varol 2016). In determining the fire season, FWI is only used in order to prevent errors that may occur due to the use of temperature, which is called as “minimizing some false alarms” by Moriondo et al. (2006). Hanson and Palutikof (2005) found a non-linear relationship between fire frequency and FWI in Greece and Italy, and that the frequency of fire was low, especially on days with FWI < 15. In addition, a high risk of fire was determined on days with FWI > 45 (Moriondo et al. 2006). Van Wagner (1987) and Flannigan et al. (2013) stated that FWI was an indicator of fire hazard and its severity. It was also stated that the increase of Daily Severity Rating (DSR), which was the simple power function of FWI, meant that the burnt area increased as well as the fire suppression difficulty (Williams 1959; Van Wagner 1987; Flannigan et al. 2013). Flannigan et al. (2013) used the DSR to calculate predicted fire severity. In determining the fire season in the Mediterranean Region, Moriondo et al. (2006) used the FWI values of 15 and greater. In our study, the season calculations were made using two different methods by adopting both 30 °C and that FWI value as criteria. Albeit Moriondo et al. (2006) stated that there was an extreme fire hazard for situations with FWI > 45. Lehtonen et al. (2014) and Tanskanen and Venäläinen (2008) also defined FWI > 32 as extreme risk. For cold climatic zones, FWI > 20 was accepted as the fire hazard value determining the season (Venäläinen et al. 2014).

Apart from these two most commonly used methods for determining the fire season, in a study conducted by Westerling et al. (2006) for the western parts of the USA, the fire activity was deemed as the determinant of the fire season, and the fire season was determined according to the date of the first and the last fire. Apart

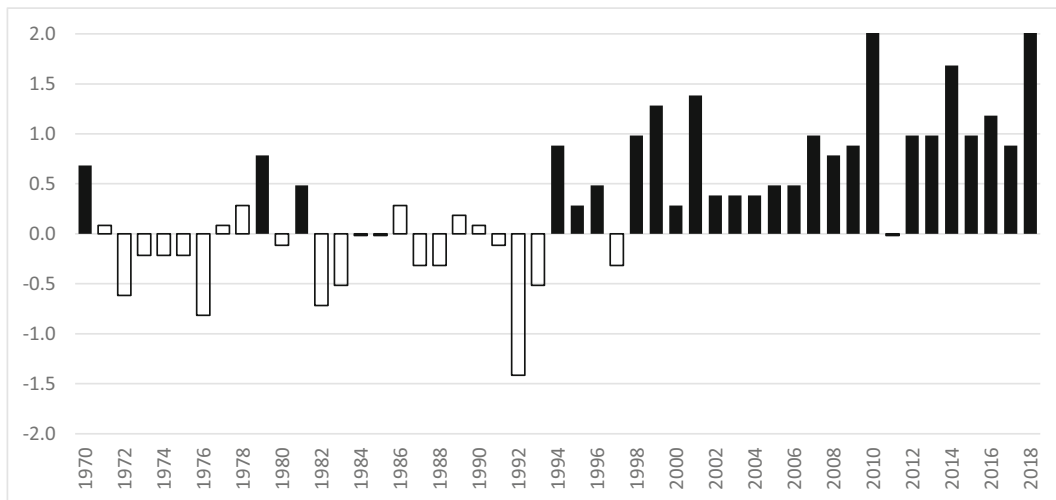


Fig. 1 Temperature anomaly of Turkey between 1970 and 2018

from that, Jolly et al. (2015) identified the fire season by means of daily meteorological data and FWI values, whereas Liu et al. (2010) by means of Keetch–Byram Drought Index (KBDI).

Results

The first remarkable result of the study is the fact that it is not possible to mention a world-wide increase or decrease as a block for both fire season and fire severity. It was found that different results could be obtained even in regions that were very close to each other in terms of their geographical locations. In Kusadasi, which was one of the places examined, no upward trend was

observed regarding the season. In terms of meteorological data and FWI values, the most severe fire season values were observed in 2000 in Kusadasi. In terms of temperature, the heat value in the average temperature (T_{ort}) during 1970–2018 season was 1.79 °C, which meant that an upward trend could be noted for temperature. For the same period, there was a heat value of 1.95 °C in Marmaris. However, according to FWI calculations, there was no prolongation in the season or an increase in the risk of fire for these two locations. In terms of drawing attention to the differences, the most severe fire season values for Fethiye were from 1960 season, and it was followed by the 2000 and 1990 seasons. The most severe fire season values for Canakkale were from 1950 season (Fig. 3).

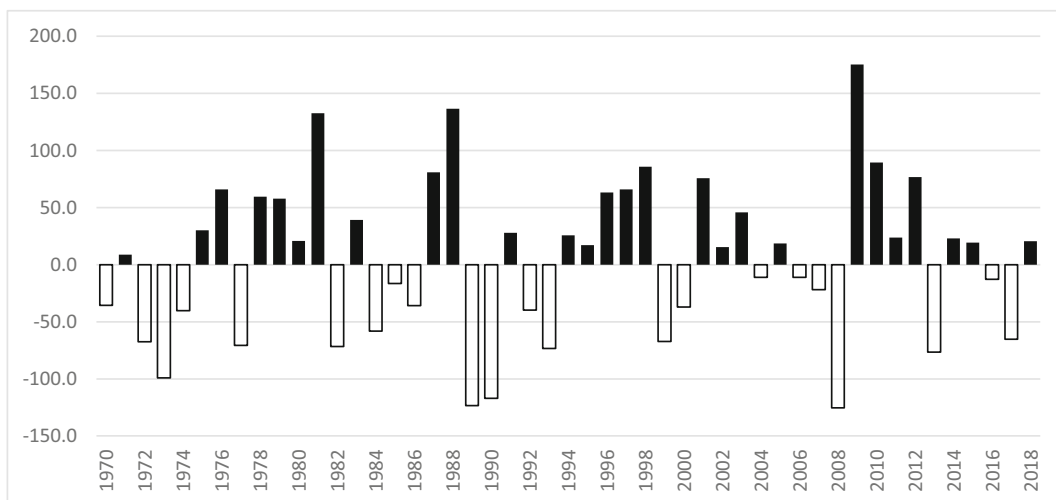


Fig. 2 Precipitation anomaly of Turkey between 1970 and 2018

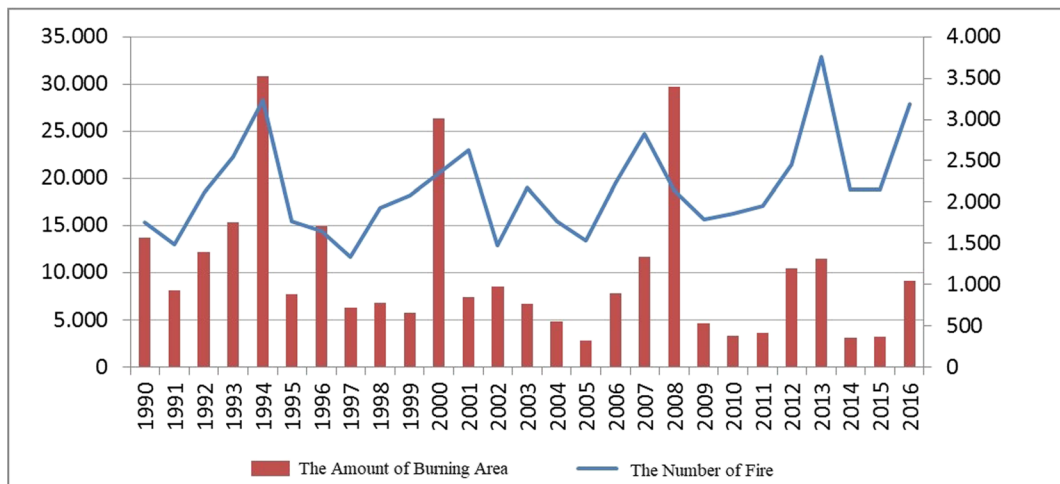


Fig. 3 Forest fire activity between the years of 1990 and 2016 in Turkey (GDF, 2018)

However, in some places, significant increases were detected in the fire season values, albeit in a small number. For example, in Bodrum, the fire season was observed to be starting around 2 months earlier. On the other hand, the end of season was observed to be delaying for up to 15 days to 1 month. Here, one of the most important decreasing variables was precipitation. Since the 1970s, precipitation (except 2000) has been reduced by almost 25%. Even though T_{or} has a wavelike graph, the 2018 season has the highest value. There was a temperature difference of 3.28 °C between 1940 and 2018. As above-mentioned places, 1950 was a season with extreme values also for Bodrum. However, if the temperature is taken as basis, the 2018 season is noted as the worst fire season. The worst period for fire risk and precipitation status determined by the extremity of FFMC and FWI values was 1990. Even though the 2018 season was not as bad as the fire risk in 1990, the downward trend in precipitation was quite clear in that year.

It was seen that the fire season for Ayvalik started 23 to 30 days earlier in 2018 compared to 1970. Although the dry season was shortened, the number of days above 35 °C increased significantly after 2000. The maximum temperature has not changed, but the number of days with the maximum temperature has. While the number of days with maximum annual temperature was between 3 and 8 in the early 1970s, this number reached up to 20 and above between 2000 and 2018. In addition to this, an increase of 2.8 °C occurred in the average temperature of the season between 1970 and 2018. However, there was a slight increase (0.7) in the fire hazard identified by using the index values (Season FWI avg.).

A decrease has been observed in FWI values indicating the fire hazard from 1970 to date at all stations except Ayvalik, Bodrum, and Akhisar. Since the related conditions occurred in parallel to the increase in precipitation, they occurred in some places despite the decrease in precipitation. Not only the total precipitation but also the distribution of precipitation during the season is important in the calculations. There is no standard end-of-season delay or early start in different locations for the seasons. Among the studied stations, an early start of 5 to 15 days was observed only for the 2018 season in Bodrum and Ayvalik. In terms of fire season lengths examined according to the FWI calculations, almost a steady trend was observed in Ayvalik after 1990, whereas the fire season in Bodrum showed a continuous zigzag trend in the form of an increase up to a certain year, then a decrease, and then an increase again; and a prolongation was determined in Izmir between 1970 and 1990 after a shortening, which had occurred following the prolongation between 1940 and 1960. Despite the shortening occurred between 1990 and 2000, a 10-day shortening is observed today, following an average of 10-day shortening between 2000 and 2010. A decrease was observed in the length of the fire season in Canakkale and Fethiye, and a prolongation in Kusadasi and Marmaris until 2000, which then was followed by a decrease. In general, no prolongation trend was observed in the fire seasons of above-mentioned places, and shortening trends were detected especially since the early 2000s (Fig. 4).

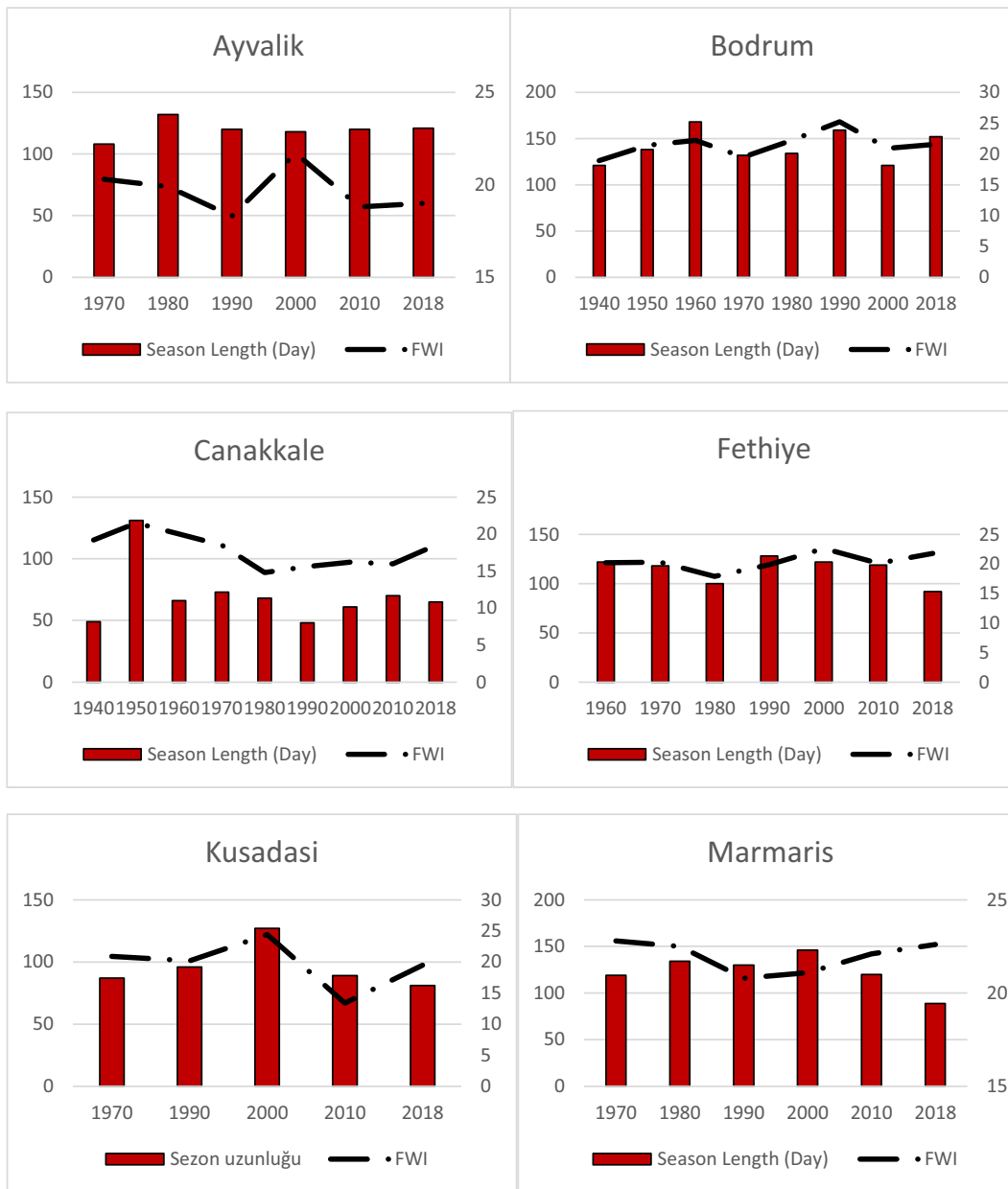


Fig. 4 Graph of season lengths and season FWI average values

Discussions

As a result of the study, there was neither a prolongation in the length of fire seasons nor an increase in the severity of fires in the Aegean Region of Turkey. In this kind of studies, determining the fire season is the first problem. Apart from these results obtained in relation to the fire season, in case of a fire activity in Turkey, it is noteworthy that there is a downward trend in burnt area,

while the number of fires increases (Fig. 3). Unlike previous studies, in this study, the length and severity of the season were determined by taking the temperature and FWI values into consideration. Considering the season between fixed dates and determining it according to temperature or FWI values will naturally make a difference in the calculated average values. For this reason, the beginning and end dates determined according to the temperature and FWI values are also critical

indicators as much as the values obtained and the values indicating the season severity.

Consequently, one of the most important deductions obtained is the fact that the impacts and levels of climate change have different outcomes in different parts of the world. Such that, even in places, which are geographically very close to each other, significant differences are found in length and severity of fire seasons. In the projections made, even though the future precipitation status varies across regions, it is estimated that heat will rise in all areas. Therefore, although the temperature rises according to the calculations made by using the index, no prolongation may be observed in the season. Other values, which form the index, such as wind and humidity are also important in the calculations. However, in determining the season based on temperature, the situation is a bit simpler. On the other hand, the calculations made based on the fire activity, which is another method for determining the season, may not provide healthy results in places where human-caused fires are intense.

In similar studies, different results are obtained in different parts of the world. For example, an increase was determined in total fire and large fire activities as well as burnt area by Gillet et al. (2004) for Canada and by Westerling et al. (2006) for the western regions of the USA, whereas Jolly et al. (2015) detected increases in the season lengths at the global level outside of Australia. For the future, Flannigan et al. (2013) and Wotton and Flannigan (1993) predicted an increase. In consideration of the results of numerous studies, the expectation that the forest fire season will be longer and more severe as a result of the changing climate in the future predominates.

These studies, in which the season length is determined by different methods, include Liu et al. (2010), who determine the fire potential by using Keetch-Byram Drought Index (KBDI); Wotton and Flannigan (1993), who consider the fire season with certain temperature limits; De Groot et al. (2013), who calculate the fire severity and season length by using the Daily Severity Rating (DSR), which is a part of Canadian Fire Weather Index (2013); Flannigan et al. (2013), who calculate fire severity and fire season by DSR; and Pitman et al. (2007), who determine the fire risk by Mc Arthur Fire Index (FDI). In addition, it is stated that early snow melting may cause the fire season to start earlier in the spring months (Räisänen 2008; Räisänen and Eklund 2012; Lehtonen et al. 2014; Westerling et al. 2006;

Flannigan et al. 2013; Wotton and Flannigan 1993). However, there are some studies showing that there will be both regional increases and decreases in the future projections, albeit small in number. For example, in the study conducted by Krawchuk et al. (2009), it is mentioned that there will be both regional decreases and increases in fire activity in the future. However, in the study, which is also critical for Turkey, conducted by De Rigo et al. (2017), it is stated that Spain, Portugal, and Turkey are among those places to have the highest risk of fire in the Mediterranean Europe, despite the fire activity that has been decreasing recently.

Contrary to popular belief, in almost all of the recent studies, it is stated that the fire activity has reduced for the Mediterranean Region, as in most parts of the world. It is stated that there is a decrease in the activity and area in all European countries except Portugal on the Mediterranean coast and Spain, which has shown a slight upward trend in the last 5 years, as well as Israel, Scandinavia, Siberia, and temperate North America (Viedma et al. 2018; Evin et al. 2018; Fréjaville and Curt 2017; San-Miguel-Ayanz et al. 2013; Turco et al. 2016; Turco et al. 2017; Wallenius et al. 2011; Campo et al. 2017; Andela et al. 2017; Silva et al. 2019; Chelsea 2017).

In this study, although no increase was observed in season and fire hazard except for a few places, it was found that interesting extreme values increased in some places over the years. For instance, even though there was generally a downward trend for Ayvalik, the number of days, when FFMC was greater than 90 and considered as extreme, was observed to be increasingly continuing until 2018. Another extreme situation was observed in Bodrum. In Bodrum, it was found that the total seasonal precipitation had a significant downward trend since 1940, the summer precipitation had decreased gradually, and at the end of 30 years since the 1980s, it had decreased by $\frac{1}{4}$ compared to 1940. This is a vast decrease. Another example of extreme values was the decrease in total seasonal precipitation, and a significant decrease occurred in summer precipitation as of 2018, although it showed a zigzag and unclear trend for Izmir.

As for the indices, the most commonly used FWI and FFMC indices were analyzed. The FFMC is a part of the CFFWI and tries to estimate moisture content of the top layer on the ground (L-layer) from measurements of temperature, relative humidity, wind velocity, and precipitation registered in the last 24 h (Van Wagner 1987;

Aguado et al. 2007). It represents moisture content of litter and cured fine fuels in forests, since forest fires are strongly linked to litter moisture as indicated by the FFMC (Cunningham and Martell 1973; Wotton et al. 2010; Flannigan et al. 2016; Stocks et al. 1991; Anderson and Englefield 2001; Varol et al. 2017). The Fire Weather Index (FWI) is the numeric rating of fire severity. It combines the Initial Spread Index and the Build-up Index. It is suitable as a general index of fire hazard throughout the forested areas of Canada (NRC 2019). Looking at the maps in Fig. 5 and considering the statements above, it is noteworthy that there is a decrease in FWI and FFMC in the 2018 fire season compared to the 1970 season. Despite having data for some stations from the 1940s, 50s, and 60s, the first date with the most station data is the 1970 season. For this reason, the 1970 season, which is the oldest year with the most data, was used for the maps to generate more accurate results. The situation obtained in Fig. 5 is in compliance with the graphs presented with the calculated data.

The decline, especially in FWI from 1970 to 2018, is noteworthy. Referring to FWI as an indicator of fire severity according to the above-mentioned statements, it is thought that the decrease in the burnt area after a long-term in Turkey can be explained logically with the map obtained according to the GDF data (Fig. 5). It is accepted that the improvement in the quality and quantity of the firefighting organization contributed to this decrease in the area. However, despite the most advanced technologies, it is seen in the fires occurred in both Europe and USA that it is not possible to prevent forest fires under extreme conditions.

While there is not that much of a change in the FFMC map, there is moderation contrary to the general belief. This was due to the fact that there was no decrease in the predicted summer rainfall, but on the contrary, there were significant increases at more than half of the stations compared to 1970. However, it is noteworthy that FFMC values have reached the extreme class in all other coastline except Marmaris-Fethiye. In fact, summer rainfall increased in Izmir, Cesme, Kusadasi, Bodrum, Kas, and Antalya despite the general decrease. This increase is attributed to the increasing population in the study area as well as the climatic conditions and the increasing human-caused fires for various reasons. According to the GDF statistics, the number of fires has been increasing to the present day (Fig. 3). The area with higher increase in FFMC is the coastal areas where there is more intensive migration and the land value is much

higher than other places. Unlike the results in precipitation, the temperature values received in the study area increased at approximately 95% of the stations. The average increase occurred between 1970 and 2018 fire seasons at these stations was 2 °C.

While the temperatures increased, summer rainfall also increased contrary to expectations, causing a decrease in FWI and FFMC values. This was explained by some researchers before. Turkes explained these changes as the change in temperature and precipitation regimes of Turkey and stated that there was a shift towards tropical climates from subtropical at places where Mediterranean climate prevails (Turkes 2019a, b). Erlat and Turkes (2017) and Sensoy et al. (2008) reported that the annual number of tropical days in Turkey had a tendency to increase by showing strong positive anomalies after 1985, and that they reached the highest numbers in 2010, 2012 and 2016. They stated that the observed tendency to increase was especially evident in coastal stations (Erlat and Turkes 2017; Sensoy et al. 2008).

Various researchers have also put forward different ideas on the decrease in fire activity. In the researches, the changes occurring in fire activity were tried to be explained with temperature and precipitation data of summer season, and sometimes with socio-economic and fine fuel conditions. We also acknowledge that, in addition to climate data, especially the socio-economic conditions and firefighting organization structure of the study area are of great importance in fire activity. However, the subject of the study is not fire activity trend, but the length and severity of the fire season. San-Miguel-Ayanz et al. (2012) stated that there was an increase in the number of fires in contrast to the decrease in burnt area in the south of Europe, similarly to Turkey (San-Miguel-Ayanz et al. 2012). For the explanation of fire activity and, in some places, the decrease in the fire season, Wallenius et al. (2011) stated that climatic indicators in Northwest Canada did not give an idea in explaining the long-term decrease in the fire trend (Wallenius et al. 2011). Regarding the fire activity trend decreasing between 1987 and 2011 in Israel, Turco et al. (2017) stated that the summer fires were mainly related to the fine fuel load in the environment in connection with local conditions. Also in Israel, despite the increased risk due to climate factors, the fire activity trend has decreased. Turco et al. (2017, 2018) mentioned the similar adverse climate-fire activity relationship for Mediterranean Europe as well. Viedma et al. (2018) found a significant downward trend for large fires in

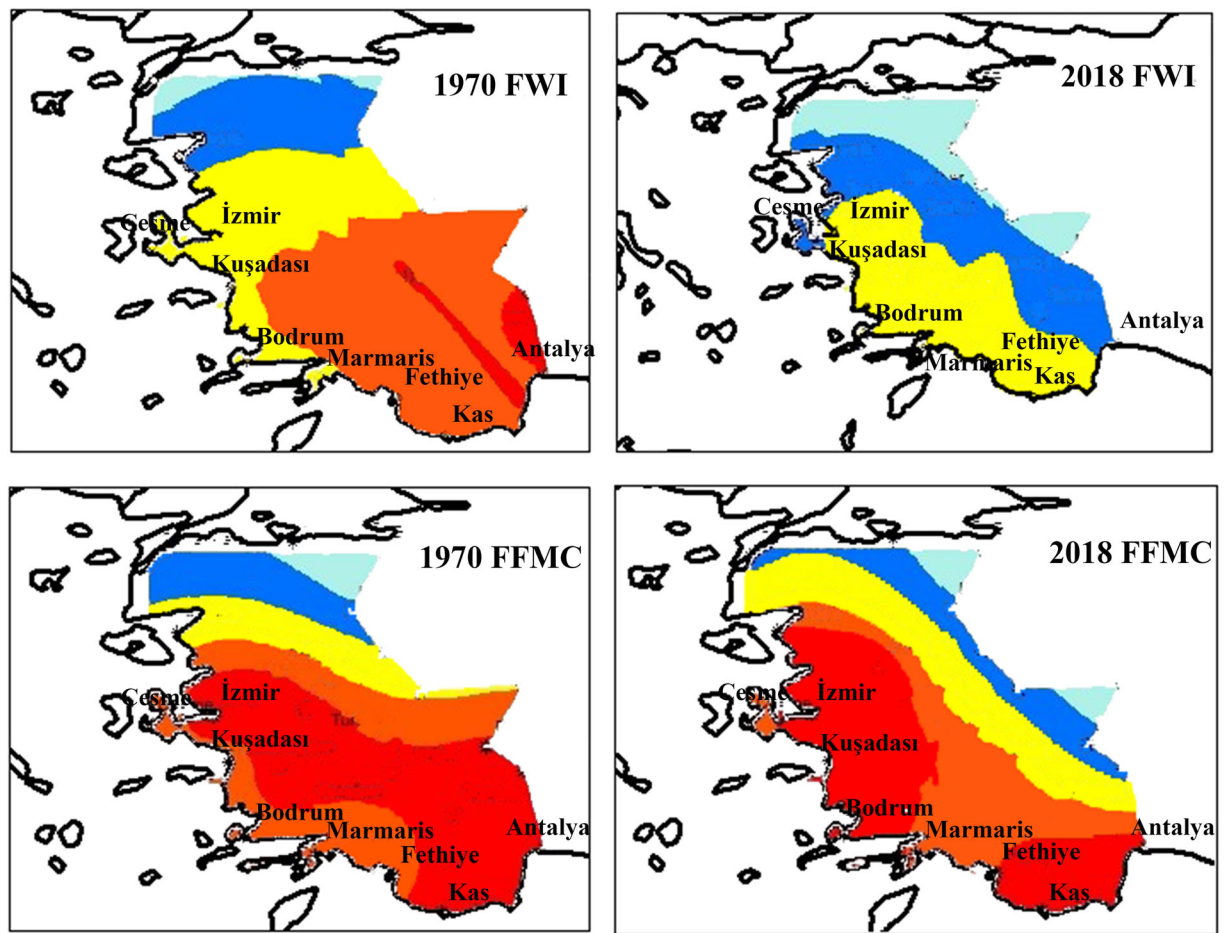


Fig. 5 The map of the average FPMC and FWI values from the 1970 and 2018 fire seasons at the study area

contrary to a temporary upward trend in small fires. In the same study, no trend was determined for medium-sized fire activity. In Turkey, it is possible to say that the upward trend in burnt area, despite the increase in the number of fires, resembles these results. As it is known, a significant amount of burnt area is due to a small number of large fires all over the world, and the vast majority of the fires are small fires. Therefore, it can be said that the fire activities of the fire of Central and Western Spain and Turkey are similar. In France, it is stated that the decrease in burnt area is due to the solid and rapid fire intervention, which has been implemented since 1994. However, in the mentioned study, it was also stated that the effect of that fire suppression policy on large fires could not be determined. Evin et al. (2018) state that fires can be coped with adequate extinguishing organization, but when fires exceed the capacity of firefighting teams, they evolve into large fires. This

result is also related to the increase in the frequency of large fires. For France, it was also reported that large fires had been reduced since the 90s (Ganteaume and Barbero 2019). Robinne et al. (2018) also state that the extreme fires and catastrophic results increase regardless of decreasing fire activity. It is also stated that this increase in large fires will continue its upward trend in the future (Robinne et al. 2018). Scientific studies on forest fires continue to be in the limelight all over the world. Similar studies with extraordinary results obtained in our study are expressed as surprise results in the media. It is stated that the burnt areas around the world have decreased by 25% within the last 20 years. It was stated that the enormous decrease detected as a result of the examination of the data obtained from satellite images between 1998 and 2015 took place, especially in grassland and savannas all over the world. The researchers found that the long-term effect of precipitation

on the burnt area was low, while the human activity was high. The obtained decreases were attributed to socio-economic developments (Chelsea 2017).

On the other hand, Turco et al. (2016) tried to explain this negative trend with the increase in fire management and prevention efforts after the large fires in the 1980s, and stated that the tendency to increase detected at some places could be related to heating observed with the latest socio-economic transformations that led to more dangerous landscape arrangements. Notwithstanding with the views of some researchers on explaining the widespread downward trend in fire activity around the world, Keeley and Syphard (2015) stated that they could not provide an explanation for this subject, and that the reason was not fully understood. However, they stated that fire activity during the twentieth century was related to human population and activity.

Conclusions

Our views formed as a result of our study are consistent with the views of some of the above-mentioned researchers. Although extreme fires have been observed in the Mediterranean Europe in recent years, there is generally a decrease in fire activity. In Turkey, while there is an increase in fire activity, burnt area is continuing to decrease. Of course, these results are significantly related to the socio-economic conditions of the countries as well as the climatic conditions. Like the comments made in the studies conducted for the Mediterranean Region of Europe, the results obtained in Turkey are also related to the fact that the firefighting organization is sufficient for suppressing most of the fires, regardless of climatic conditions. A similar result was also found by Turco et al. (2018). However, Turco et al. (2018) and Evin et al. (2018) also mention that the fire extinguishing efforts, which are sufficient for today, will not be sufficient in the future (Evin et al. 2018; Turco et al. 2018).

Like France's fire suppression policy mentioned by Evin et al. (2018), also in Turkey, where firefighting system is based on the rapid intervention, almost all of the fires are extinguished before they become large fires, despite the increasing number of fires. Only under conditions, where firefighting organization cannot cope with, fires become extreme fires. The occurrence of many fires at the same time, the quality and quantity problems to occur in vehicles and equipment of the

firefighting organization, and the formation of a perfect environment for an extreme fire exceeding the organizational capacity due to climate, topography, and human-caused conditions are among these conditions. Recently, it is observed that in many countries under above-mentioned conditions, the firefighting organization is inadequate and fires cause large amount of life and forest losses. Among the mentioned conditions, the occurrence of many fires at the same time is one of the events, which is very likely to take place in Turkey. Apart from the socio-economic structure, one of the most important reasons for this is the fact that a vast majority of forest fires are human-caused fires. On the other hand, qualitative and quantitative deficiencies in firefighting vehicles and equipment will increase the vulnerability of large fires. Surely, this situation is directly related to the budget and economic status allocated to the organization. Finally, the formation of the worst scenario due to climate, topography, and human-caused conditions is a factor that should be taken into consideration today. Ever-increasing summer temperatures and decreasing summer rainfall, increasing population especially in fire-sensitive areas, irregular urbanization and other human-induced reasons can easily cause extreme fires in forests that are ready to explode due to topography and vegetation. Fire statistics may vary for each country for a variety of reasons. As in the whole Mediterranean region, human-caused fires constitute the biggest cause of fire. However, for other socio-economic reasons, the relationship between forest fires and human factor has always been very important. Thus, public education is still very important in raising awareness about these fires. In addition to the fighting methods used during the fire, the measures to be taken before the fire will gain more importance in the future. These methods, which are to be applied before the fire season, will have benefits beyond being considered as measures only taken during the fire. Today, most of the firefighting costs are the budget allocated to air and other ground vehicles such as planes and helicopters. The biggest issue in here is the fact that this system can be operated as long as there is a budget allocated for firefighting organization. However, there should be a system which will not stop, in case of a budgetary cut. For this reason, concentrating on other measures, which may support vehicles and equipment, to be taken before and during fire would be the right thing to do. With increasing fire statistics, the USA is a country that uses fires in suppressing the fires, more actively compared to

other parts of the world. In spite of that, the fatal fires, which have recently broken out also in the USA, like in Europe, could not be prevented either. However, the controlled burning practices used all over the world for the regulation of fire are necessary to be used in Turkey as well. In order to prevent the fires to occur under climatic conditions, which the researchers warn about, from turning into undesired disasters, it is absolutely required to make the necessary preparations in the firefighting organization for the future. As it is known, for Turkey, Flannigan et al. (2013) identified significant increases in all scenarios on the map showing the fire season length anomaly for the years of 2050 and 2100, whereas Ertugrul (2019) identified fire risk at extreme levels for most of Turkey, in the results obtained with different projections for 2050 and 2100 (Ertugrul 2019). Therefore, it is of prime importance to take the necessary measures as soon as possible and to make a plan suitable for the fire season conditions, which are predicted to worsen.

Authors' contributions All authors contribute equally.

Compliance with ethical standards

Competing interest The authors declare that they have no conflict of interest.

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