Dendrochronologia 69 (2021) 125874

Contents lists available at ScienceDirect

Dendrochronologia

journal homepage: www.elsevier.com/locate/dendro

Original Article

Fire history of *Pinus nigra* in Western Anatolia: A first dendrochronological study

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ARTICLE INFO

Keywords:
Black pine
Mediterranean forests
Tree ring
Documentary data
Fire frequency
Drought

ABSTRACT

Forests in the Mediterranean basin frequently experience fires due to both anthropogenic and natural causes. There are concerns that the fire season will prolong in the Mediterranean basin, the fire frequency will increase with ongoing climate change, moreover, the fire regimes will shift from surface fires to local crown fires. Here, we aim to improve our understanding of the fire regime components of black pine forests in Turkey by 1) reconstructing a high-resolution fire chronology based on tree rings, 2) revealing the seasonality of fires, 3) investigating the relationship between fire and climate, and 4) comparing our reconstruction results with documentary data from forest management units. We collected 62 fire-scarred trees from three sites in Kütahya and developed a 368 year-long (1652–2019) composite fire chronology using dendrochronological methods. We found that at two sites major fire years coincided with dry years. Two major fire years (1853 and 1879) were common to all sites and two additional fire years (1822 and 1894) were found at two sites. Our results show a sharp decline in fire frequency after the beginning of the 20th century at all sites that can be attributed to increased fire suppression efforts and forest management activities in the 20th century. Our results suggest that the spread of fires has been actively suppressed since the first forest protection law in Turkey. Yet, tree-ring based and documentary data corroboration shows that seasonality did not change over the past +350 years.

1. Introduction

Wildfire is a key factor in shaping ecological landscapes by affecting ecosystem processes, forest dynamics and structure, ecological functioning, and biodiversity (Bowman et al., 2009; Touchan et al., 2012; Piha et al., 2013; Pausas and Bond, 2020; Szymczak et al., 2020). Forest ecosystems in the Mediterranean Basin have been experiencing frequent fires of both anthropogenic and natural origins over the late Quaternary period (Carrión et al., 2003; Pausas et al., 2008). The severity and extent of fires in the Mediterranean basin vary on spatial and temporal scales (Pausas, 2004). Although the number of anthropogenic fires has increased significantly in recent decades (Turco et al., 2017), climatic factors are still the major determinants of the fire occurrence in the Mediterranean basin (Dube, 2009; Türkeş and Altan, 2012; Pausas and Ribeiro, 2013; Tatlı and Türkeş, 2014; Bekar and Tavşanoğlu, 2017). Due to climate change, an increase in temperatures, a decrease in precipitation, and an increased drought risk are expected in the Mediterranean basin in the near future (FAO, 2018; IPCC, 2019). These future climatic conditions will affect the flammability of vegetation and an increase in the severity of fires is therefore also expected in Mediterranean forests (Turco et al., 2017; IPCC, 2019). At the global scale, the occurrence of severe forest fires will create feedback effects on climate change with the release of greenhouse gases (e.g., CO_2, CH_4, N_2O) and by increasing the surface albedo (IPCC, 2019). Increased fire risk also threatens the present occurrence and the future distribution of some non-fire-prone species by changing regional fire regimes (FAO, 2018).

In the Mediterranean basin, many woody plants have developed various strategies to survive or regenerate after fire. In some pine species (e.g., *Pinus halepensis* Mill., *Pinus brutia* Ten.), the presence of serotinous cones is an adaptation that allows the seeds in the cones to survive crown fires (Pausas et al., 2008; Hernández-Serrano et al., 2013). Other fire adaptations include the formation of thick and insulating bark,

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https://doi.org/10.1016/j.dendro.2021.125874
Received 6 April 2021; Received in revised form 11 June 2021; Accepted 4 August 2021
Available online 8 August 2021
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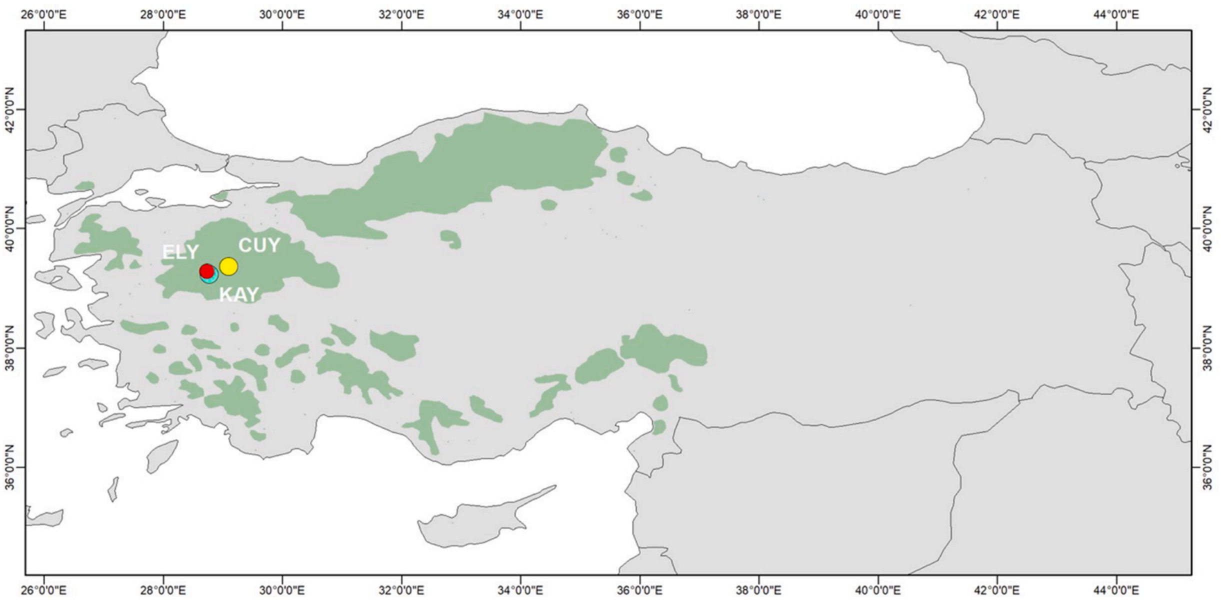

Fig. 1. Distribution of *P. nigra* in Turkey (EUFORGEN, 2004) and the three study sites.

post-fire seedling recruitment, and resprouting from basal or epicormic buds (Pausas et al., 2008; Paula et al., 2009; Keeley et al., 2012; Çatav et al., 2018; Tavşanoğlu and Pausas, 2018). Unlike species adapted to crown fires, the post-fire recovery of *Pinus nigra* JF Arnold (black pine) relies solely on surviving individuals within the burned site and seed dispersal from surrounding unburned forest patches (Richardson, 2000; Tavşanoğlu, 2008; Christopoulou et al., 2014; Prichard et al., 2017; Szymczak et al., 2020). In this species, the thick bark protects vital tissues from the impact of fire and enhances the probability of survival of the trees during surface fires, while self-pruning of dead branches at the lower part of the bole creates a gap between the understorey and tree crown that inhibits the transition of a surface fire into a crown fire (Pausas et al., 2008; Keeley, 2012; Keeley et al., 2012; Touchan et al., 2012).

There are concerns, however, over the change of severity and fire regimes from low-intensity surface fires to local crown fires in the mountainous forest ecosystems of the Mediterranean basin (Fyllas and Troumbis, 2009; Keeley, 2012; Christopoulou et al., 2013). Indeed, such crown fires have occurred more frequently in recent years in these ecosystems and may result in local and regional extinctions (Christopoulou et al., 2013) or vegetation changes (Fyllas and Troumbis, 2009; Christopoulou et al., 2019). Moreover, recent evidence suggests that warming and increasing drought negatively affect seedling establishment and tree growth in montane conifer species (Janssen et al., 2018; Rodman et al., 2020). Understanding the response of dominant tree species in the mountainous Mediterranean forests to past climatic variability and fire regimes is therefore important for the development of better management strategies to conserve these forests under climate change.

To put recent fire trends in a long-term context and to understand the contribution of anthropogenic climate change to these trends, we need records of past fires at a high spatial and temporal resolution that extend back over decades or centuries. Written records of annual and seasonal fire variability can be used for this purpose (Swetnam, 1993; Keeley et al., 2012). In Turkey, the first written forest fire records start during the Ottoman Era in 1918 (Kılıç, 2020), but for many areas of Anatolia, such documentary data have only short-term coverage.

Another method to study regional fire history at annual resolution is through tree-ring based fire reconstruction. Dendrochronological methods are widely used to determine past regional fire regime characteristics (Piha et al., 2013), including fire interval statistics (Bowman et al., 2009; Drobyshev et al., 2012; Pausas and Fernández-Muñoz, 2012; Prichard et al., 2017; Slimani et al., 2014), and fire-climate relationship (e.g., Lafon et al., 2005; Taylor et al., 2008; Skinner et al., 2009; Drobyshev et al., 2012; Margolis et al., 2017; Taylor et al., 2016). Such dendropyrochronological studies have focused primarily on North America (e.g., Swetnam and Baisan, 1996; Falk et al., 2011), and to a lesser extent have also included studies in Northern Europe (Lageard et al., 2000; Kitenberga et al., 2019), Asia (Ivanova et al., 2010; Mazarzhanova et al., 2017; Yao et al., 2017), and the Mediterranean basin (Fulé et al., 2008; Touchan et al., 2012; Christopoulou et al., 2013; Fournier et al., 2013; Slimani et al., 2014; Molina-Terrén et al., 2016; Szymczak et al., 2020). However, no high-resolution, tree-ring based fire history records are available for Turkey, despite various dendroclimate and ecology applications in regional black pine forests (Akkemik, 2000; Akkemik and Aras, 2005; Akkemik et al., 2008; Akkemik and Aras, 2005; Köse et al., 2005, 2012, 2013, 2017; Güner et al., 2016; Janssen et al., 2018; Doğan and Köse, 2019).

In this study, we explore the fire history of *P. nigra* forests in western Anatolia (Turkey), using dendrochronological methods. Our objectives are: 1) to develop a high-resolution reconstruction of the fire history of black pine forests in Turkey, 2) to determine the seasonality of historical fires, 3) to understand the association between climate variability and fire occurrence, and 4) to compare relatively recent fire records from dendrochronological data with those compiled by local forest management units.

2. Materials and methods

2.1. Study area and sampling

To develop the longest fire history, we sampled the trees from old-growth black pine forests in Kütahya, in western Anatolia (Fig. 1). The climate is of a warm-summer Mediterranean type according to the Köppen classification (Peel et al., 2007). The distribution of black pine forests continues under transitional climate conditions between Central Anatolia and Marmara (Fig. 1) (Ocak and Konuk, 2018). The long-term (1950–2020); data from Turkish State Meteorological Service) records of the closest meteorological station (Kütahya, 969 m a.s.l.) indicate a mean annual total precipitation of 560.7 mm (monthly peak in December, 77.7 mm and minimum in August, 18.3 mm) and a mean annual temperature of 10.8 °C, with January as the coldest (mean

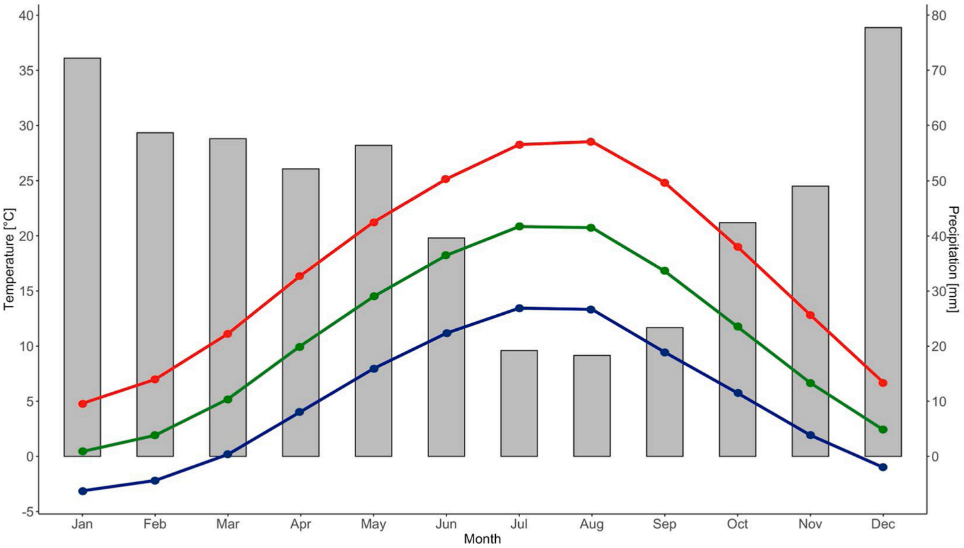

Fig. 2. The climograph for Kütahya meteorological station (1950-2020). Bars indicate precipitation (mm), and red, green, and blue lines represent the maximum, mean, and minimum temperature (°C), respectively.

Table 1
Site characteristics.

Site	Çukurçayır	Elmaalanı	Karagöl
Code	CUY	ELY	KAY
Latitude	39°22’8"N	39°16’55"N	39°14’26" N
Longitude	29 ° 5’55"E	28°44’58"E	28°46’10"E
Elevation Range (m)	1508 - 1558	1427 - 1484	1404 - 1456
Average Slope (%)	37	31	20
Aspect	S-SW	W-NW	E-SE
Samples collected/used	21/20	20/20	21/19

temperature is 0.4 °C) and July as the warmest (mean temperature is 20.8 °C) month (Fig. 2).

We sampled three black pine sites: Çukurçayır (CUY), Elmaalanı (ELY), and Karagöl (KAY) in June 2019 (Fig. 1). Akdere creek valley, a branch of the Simav stream, spatially separates CUY from ELY and KAY (Fig. 1). Consequently, the distance between the CUY site and ELY and KAY sites is approximately 33 km. Sites differed significantly in terms of geographic features. CUY, which is the site with the youngest trees, is located in the Alaçam mountains and was partly logged in 2017. The elevation of the site ranges from 1508 to 1558 m a.s.l. and it occupies a southern to southwestern aspect, with a steep slope (24–46 %) (Table 1). ELY and KAY are located on Mount Eğrigöz. The elevation of ELY ranges from 1427 to 1484 m a.s.l. and the site occupies a western to northwestern aspect with a medium to steep slope (9–45 %). Trees struck by lightning were observed at this site (Fig. 3D). The elevation of KAY ranges from 1404 to 1456 m a.s.l. The site occupies a southeastern to eastern aspect with a medium to steep slope (12–26 %).

Observation of fire scars on stumps and the presence of catface formation on trees, logs, and snags lead us to select suitable samples. At least 20 samples were collected from each site as wedges from living trees and as discs from dead trees (logs, snags, and stumps) using a chainsaw. We selected the oldest black pines with the highest numbers of repeated, well-preserved fire scars for sampling (Fig. 3). In total, we collected 62 partial cross-sections from dead trees and 23 of the samples were from living trees.

2.2. *Laboratory methods*

The samples were dried for several weeks before sanding, as the resin leakage continued even immediately after sampling. Each cross-section was sanded progressively with a belt sander (60-grit, 280-grit). To allow for the determination of fire scar seasonality, fire scars were then polished by hand with finer sandpaper (800-grit, 1200-grit) to make the scars better visible. First, we’ve crossdated samples visually based on the characteristic years of previously developed reference chronologies from Kütahya (Mutlu et al., 2011; Köse et al., 2012). Then, cross-sections were scanned at 600 dpi resolution to measure the ring widths in WinDENDRO software (Regent Instrument Inc., 2002). Tree-ring widths were measured with an accuracy of 0.01 mm on a path far from the scars to avoid ring anomalies associated with injury. The accuracy of cross-dating was verified with the statistical software COFECHA (Holmes, 1986). Rotten and/or undated samples were not used for further analysis.

Fire can affect tree-ring patterns in various ways, and we identified scars on the cross-sections of dated samples based primarily on callus tissues and cambial injury (Schweingruber, 1988; Guyette and Spetich, 2003). All fire scars and scarlets with callus tissue formations were marked. The seasonality of scars was determined based on the intra-ring position of the scars within the calendar year (Baisan and Swetnam, 1990). The intra-ring position of each scar was described as EE (early earlywood), ME (middle earlywood), LE (late earlywood), L (latewood), D (dormant), or U (undetermined) (Fig. 4). The dormant season was used to represent fires that occur after cambial cell division has ceased and here were interpreted as occurring in the calendar year corresponding to the adjacent latewood cells (Caprio and Swetnam, 1995).

2.3. *Recent fire records from local forest management units*

Seventy-one years (1950–2020) of fire records were obtained from the local forest management unit (Fig. 1). All details of data in fire record books were digitized and prepared for analysis. Since data coverage showed variability among forest management sub-units (between 21 and 71 years of coverage), all analyses were performed using the pooled data of the forest management unit. Specific large fire years in the annual fire data were examined for the forest management unit and also for each sub-unit individually. We defined the fire season of the forest management unit as the time of year when >80 % of all fires recorded in the area occur. For each year, the percentage of total burned area was also calculated by dividing the total burned area by the total land area of the forest management sub-units considered for the corresponding year. In this way, the burned area (%) data was standardized to avoid any bias due to different coverage lengths of fire data in different forest management sub-units. We used these estimates in further statistical

Fig. 3. Sampling from A) a living tree with a catface formation. B) A collected sample, C) sampling from a remnant stump, and D) a tree with a lightning scar from the ELY site.

analyses to detect possible trends in the total burned area (%) over time (1950–2020) and compared this trend to our tree-ring based fire chronology. For this purpose, we performed a linear regression analysis. The total burned area (%) data were log-transformed before analysis to approximate normal distribution of residuals.

2.4. Data analysis

We calculated fire interval statistics for each site with years in which either at least two or at least 25 % of the recording trees were scarred. We selected the filter of two scarred trees for the occurrence of a fire in a given year to minimize the possible detection of false negatives and the 25 % filter to represent 'major fires' (e.g., Fulé et al., 2009). We used both recording and non-recording periods of time for each sample during calculations (Rother et al., 2020). Using the recording and non-recording periods is significant for the analysis of possible gaps in the samples (such as partial wood deterioration and missing pieces of the samples). For this purpose, dated cross-sections were recorded from the most recent year to the first fire year, while gap periods among wood pieces were entered as non-recording periods. We developed three site-specific fire chronologies, as well as a regional fire chronology (hereafter RFC) from a combination of all fire scars (unfiltered) from all three sites. We then applied the same two filters to the regional fire chronology.

To understand the spatial and temporal fire patterns, we calculated fire regime parameters (Fulé et al., 2009). We used the burnr package

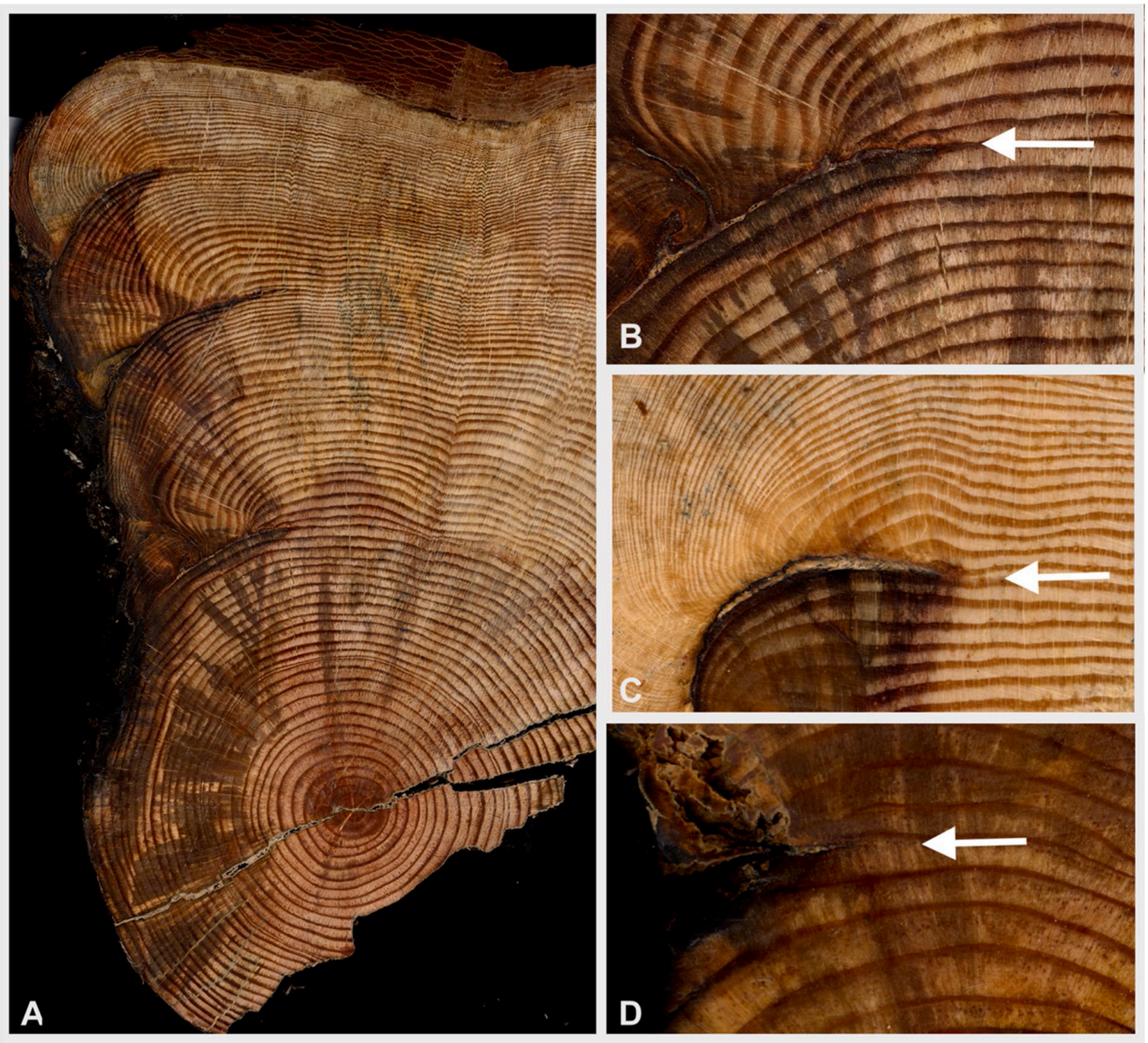

Fig. 4. A) Scanned cross-section of a sample (CUY21) and B) latewood (CUY21), C) dormant (KAY06), and D) late earlywood (CUY20) intra-ring positions of scars.

Table 2
Descriptive statistics of the fire interval data of the study area.

	CUY		ELY		KAY	
Parameters	Min 2-scars	25 % scarred	Min 2-scars	25 % scarred	Min 2-scars	25 % scarred
Period	1840–1973	1840–1954	1751–1934	1751–1916	1822 - 1920	1822- 1920
Mean Fire Interval (MFI)	12.1	16.3	8.7	11.8	8.2	9.8
Minimum Fire Interval	2	8	1	4	2	6
Maximum Fire Interval	23	36	17	17	15	18
Fire Frequency	0.08	0.06	0.12	0.08	0.12	0.10
Weibull Median Probability Interval (WMPI) ± Standard Deviation	11.6 ± 6.1	15.5 ± 9.3	7.7 ± 5.5	11.8 ± 4.4	7.8 ± 4.2	9.7 ± 4.0
Lower Exceedance Interval	5.4	6.9	2.8	7.0	3.7	5.3
Upper Exceedance Interval	19.0	26.5	15.2	16.6	13.0	14.4

(version 0.5.0) (Malevich et al., 2018) in the R environment (R Core Team, 2020) to record the fire years as. fhx files and for fire interval statistical analysis. For each site and for the regional chronology, we computed minimum, maximum, and mean fire interval (MFI), fire frequency, standard deviation, and lower/upper exceedance intervals based on two-samples, as well as 25 % filtered fire chronologies (Table 2). The MFI provides information about site fire frequency. Lower/upper exceedance intervals indicate if a fire interval is significantly longer or shorter than the mean (per time period) (Sutherland et al., 2015). We also calculated the Weibull median probability interval (WMPI) for each fire chronology, which is a better estimator than MFI because fire intervals are often not normally distributed (Margolis and Balmat, 2009; Fulé et al., 2009; Tarancon et al., 2018). WMPI represents a measure of central tendency.

We applied Superposed Epoch Analysis (SEA) to test the relationship between past fires and past drought (Haurwitz and Brier, 1981; Rao et al., 2019). We used the burnr package in the R environment (Malevich et al., 2018) for the SEA. We used the two-sample, as well as 25 % filtered site-specific and regional fire chronologies as event years in the SEA analysis, and a regional self-calibrated Palmer Drought Severity Index (scPDSI) reconstruction (Cook et al. (2015); 0.5*0.5 degree) as the continuous climate time series. We used the scPDSI data for the

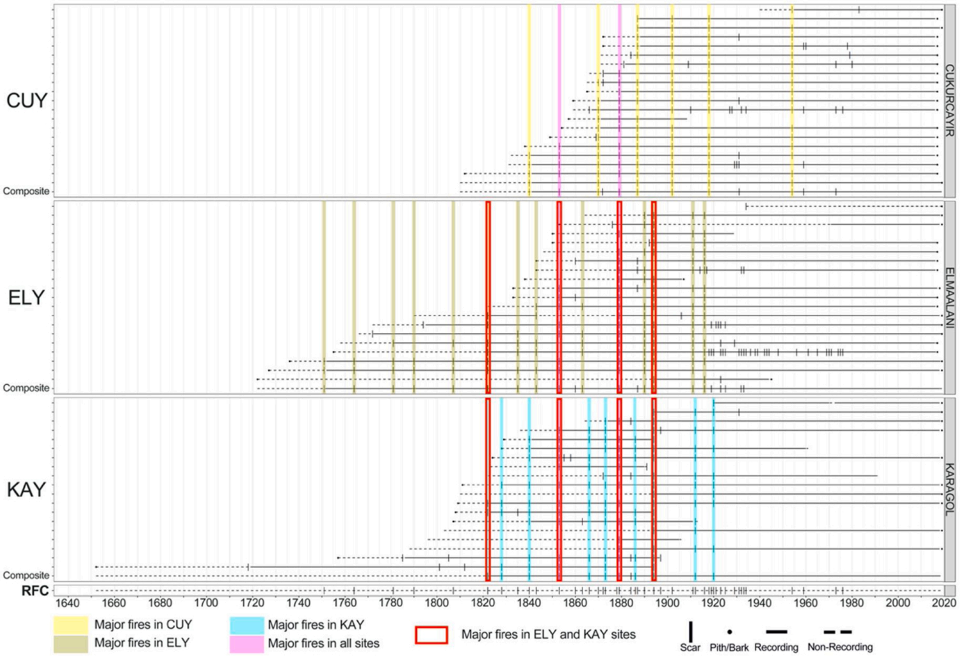

Fig. 5. Fire chart of three sites with composite local chronologies and regional fire chronology (with minimum 2 scarred trees). Highlighted colours represent the major and common major fire years.

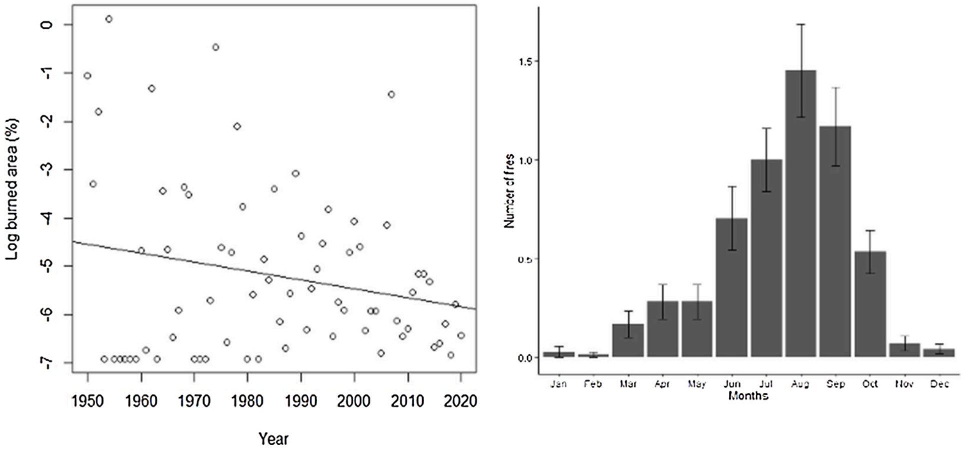

Fig. 6. Trend (1950–2020) in the total burned area (%) (left) and the seasonality of fires (mean number of fires in months) (right) in the forest management unit. Burned area (%) data are presented in the log scale and the line is the regression line fitted to data (left). Error bars represent the standard error of the mean (right).

Table 3
Seasonal distribution of fires and statistics of each site according to fire scar data.

	CUY		ELY		KAY	
Parameters	No	%	No	%	No	%
Total Number of fires	126	–	160	–	116	–
Number of events with season recorded	99	79	103	64	83	72
Number of 'D' fires	5	5	18	17.5	14	17
Number of 'EE' fires	1	1	0	0	0	0
Number of 'ME' fires	0	0	0	0	0	0
Number of 'LE' fires	9	9	0	0	0	0
Number of 'L' fires	84	85	85	82.5	69	83

gridpoints between 39–40 ° N, 28–30 °E and from 1600 to 2012.

3. Results

3.1. Western Anatolia fire history

3.1.1. Tree-ring based fire history

We recorded 88 fire years across the three sites (30 in CUY, 55 in ELY, and 26 in KAY) (Fig. 5). Three samples (1 from CUY and 2 from KAY) were excluded from the analysis due to failure of cross-dating caused by wood deterioration. At all sites, fires were frequent from the start of the record in the 18th or 19th century until the early twentieth century (Fig. 5). A sharp decline in fire frequency occurs after 1954 in CUY, 1916 in ELY, and 1920 in KAY (Fig. 5).

The CUY fire chronology shows thirty fire years (at least two trees scarred) for the period 1810–2019, including eight major fire years (at least 25 % of the trees scarred; 1840, 1853, 1870, 1879, 1887, 1902, 1918, and 1954). The ELY composite fire chronology (1722–2019)

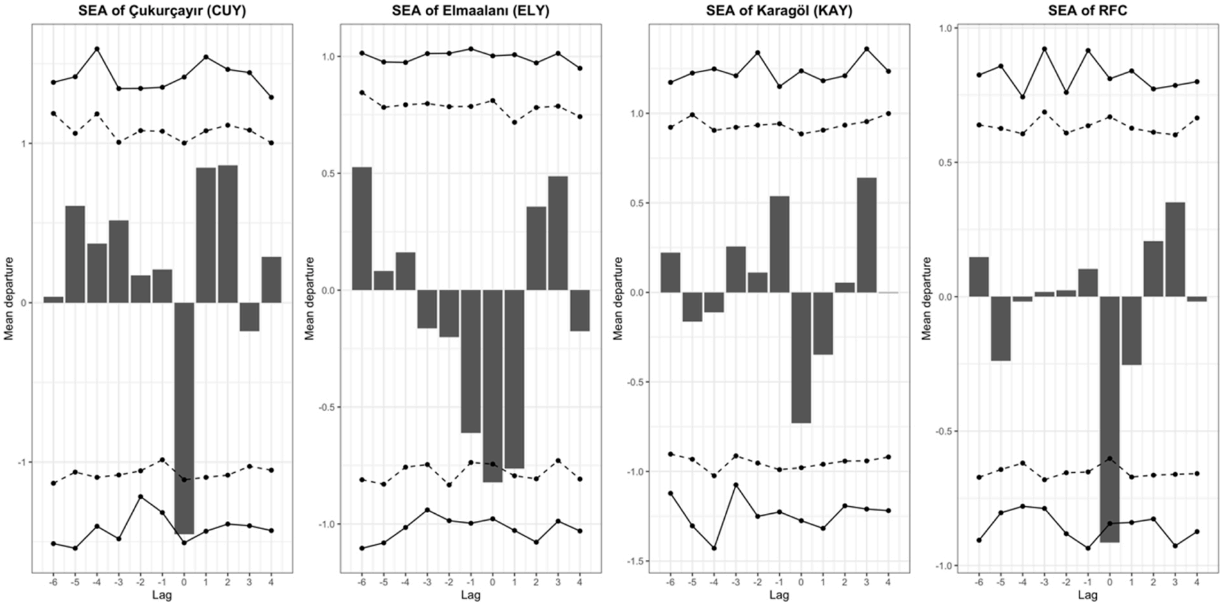

Fig. 7. SEA results of major fire years based on site-specific and regional fire chronologies with the scPDSI reconstruction (Cook et al., 2015). Solid lines represent the 99 % confidence limits and dashed lines represent the 95 % confidence limits.

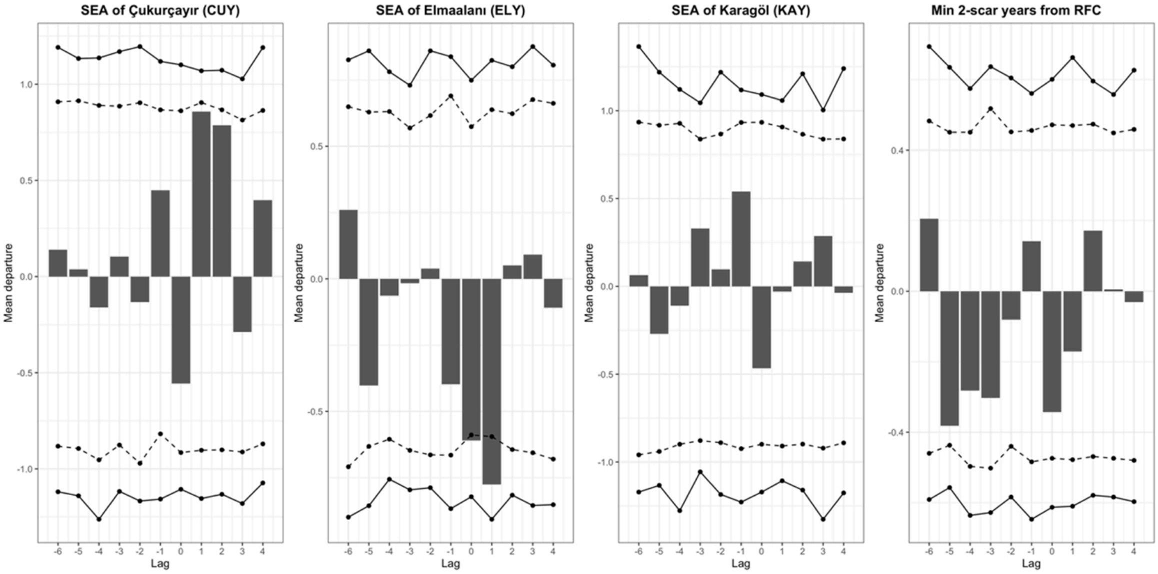

Fig. A1. Superposed Epoch Analysis results of fire years (minimum 2 scarred trees) based on site-specific and regional fire chronologies with the scPDSI reconstruction (Cook et al., 2015).

consists of 55 fire years, with 15 major fires (1751, 1764, 1781, 1790, 1807, 1822, 1835, 1843, 1853, 1863, 1879, 1890, 1894, 1911, and 1916). The KAY composite fire chronology (1652–2019) shows 26 fire years, including eleven major fire years (1822, 1828, 1840, 1853, 1866, 1873, 1879, 1886, 1894, 1912, and 1920).

Only two major fire years, 1853 and 1879, were common to all three sites. ELY and KAY share two additional common major fire years (1822 and 1894), while CUY and KAY have one additional common major fire year (1840) (Fig. 5). The highest number of common major fire years occurred in ELY and KAY. Among the regular fire years, only 1887 was found common between CUY and ELY.

3.1.2. Fire history from documentary data

According to the data from the local forest management unit, a total of 405 fires that burned 2857 ha of forest area occurred between 1950 and 2020 in the Kütahya area. Most fires were surface fires and occurred in black pine stands. Of the 150 fires whose causes are known or recorded, ca. 25 % were caused by lightning and the remaining were of human origin. The percentage of lightning-caused fires is possibly underestimated due to the lack of accuracy in detecting lightning fires in the past. 1954 (also recorded as a major fire year in CUY) was a significant fire year in the records of the two forest management sub-units with the longest coverage (1950–2020 and 1954–2020), with three of four fires larger than 100 ha occurring in this year. Moreover, eight of the twelve fires larger than 25 ha occurred in or before 1954 and the burned area per year is lower in later years. Indeed, the linear regression analysis indicates a critically decreasing trend in the burned area (%) between 1950 and 2020 ($R^2 = 0.05$, $p = 0.068$; Fig. 6).

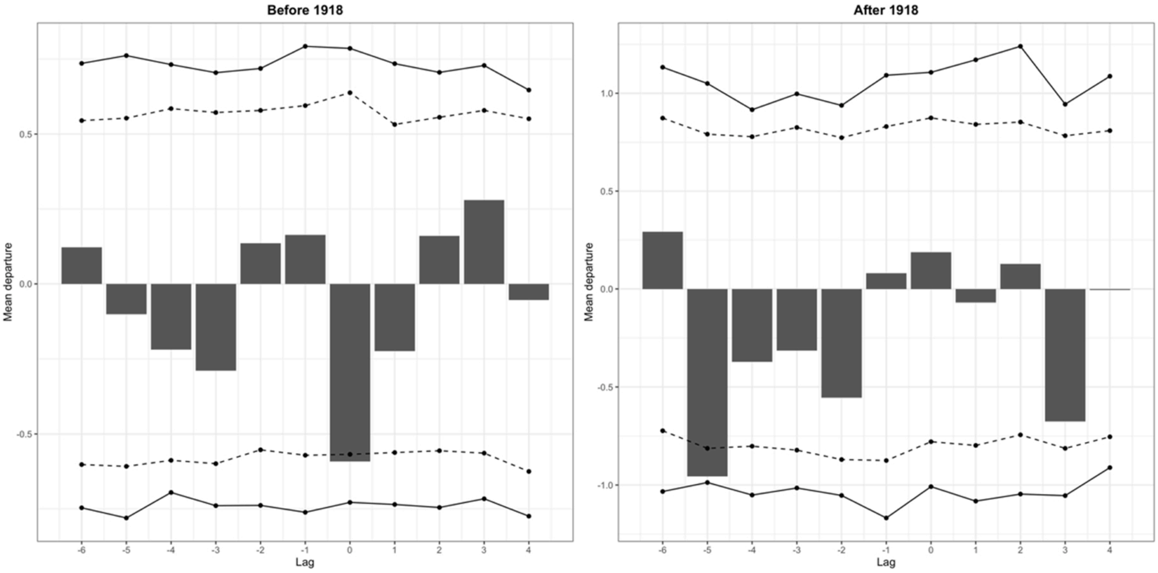

Fig. B1. Superposed Epoch Analysis of regional fire years (minimum 2 scarred trees) with the scPDSI reconstruction (Cook et al., 2015). SEA is calculated for two periods with high fire frequency (before 1918) (left) and low fire frequency (after 1918) (right).

3.2. *Seasonality of fires*

We were able to determine the seasonality of between 64 % (ELY) and 79 % (CUY) of the fire scars. Most fires occurred in the latewood (Table 3). This seasonality was confirmed by the documentary fire records, which showed that the majority of fires (87 %; 1950–2020) occurred between June and October, with more than half of the fires (231 fires or 51 %; Fig. 6) occurring from August-October, the season of latewood formation.

3.3. *Fire-climate association*

Major fire years in CUY, ELY, and RFC occurred during anomalously dry years ($p < 0.05$) (Fig. 7). We found no significant relationship between drought years and major fire years in KAY (Fig. 7) or regular fire years at all sites and RFC (Fig. A1).

4. Discussion

We present the first tree-ring based fire history reconstruction for Turkey. We developed a 368-year long fire history from three sites in the black pine forests of Kütahya (Fig. 5). The three sites have two common major fire years (1853 and 1879), with ELY and KAY sharing the most common major fire years. The spatial proximity of these two sites (5 km) suggests that these major fires were likely common not only temporally but also spatially. Fire return intervals were also similar for these two sites. The last important fire in the region recorded in the tree-ring record occurred in 1954 and is corroborated by fire management unit data.

Fire frequency at all sites peaked in the first quarter of the 20th century, after which a dramatic decline in fire frequency occurred (Fig. 5). In the last hundred years, we found four (one major fire year) in CUY, five in ELY (no major fire) and only one fire year, which is also a major fire, in KAY. This decreasing trend in fire and fire frequency is maintained in the second half of the 20th century, as shown by documentary total burned area data (Fig. 6). Decreasing fire frequency in the 20th century has been witnessed in many parts of the world and is primarily attributed to fire suppression efforts (Marlon et al., 2008; Taylor et al., 2016; Camarero et al., 2018; Chavardès et al., 2018; Li et al., 2018). Indeed, fire exclusion policies result in longer fire return intervals in surface fire ecosystems (Pausas and Keeley, 2021) such as black pine forests. Our results on the lack of fire scars in our samples since the 1920s at two sites and the 1950s at one site and a decreasing trend in the total burned area of the region since the 1950s are thus in accordance with these observations in other regions.

The sharp decline in fire frequency after the beginning and mid-20th century coincides with the promulgation of the first laws governing land and forest use in Turkey (Table 3; Fig. 5). During the Ottoman Era (ca. 1299–1922), various regulations were applied to protect forests, such as the 1870 Forest Regulation ("Orman Nizamnamesi"). The 1870 Forest Regulation came into force to protect forests and to organize fire suppression efforts. Early suppression activities, however, were only of limited success when faced with large fires due to a lack of planning, experience, and organization (Küçükosmanoğlu, 1987; Koç, 2005; Kılıç, 2020). The first forest law (Forest Law No. 3116) was enacted during the early Republican period of Turkey (ca. 1923–1945) in 1937 and the task of protecting forests was handed to the state (Official Gazette, 1937).

In addition to the effects of this regulation change on our fire frequency results, the SEA showed that major fires in two of the three sites occurred in anomalously dry years, revealing a significant effect of climate conditions on fire occurrence. Moreover, documented catastrophic drought and famine events during the Ottoman Era coincided with some major fire years, such as 1870 (Tekemen Altındaş, 2018) for CUY, 1873 (Kuniholm, 1990) for KAY, 1886 (Tekemen Altındaş, 2018) for KAY and 1887 (Gül, 2009; Tekemen Altındaş, 2018) for CUY, 1894 (Tekemen Altındaş, 2018) for ELY and KAY. High pre-twentieth century fire frequency could therefore be related to droughts, whereas low post-twentieth century fire frequency can be caused by fire suppression. In order to see the effects of climate on the frequent fires in the 19th century, we calculated the SEA between fire years in our RFC and drought separately for the periods before and after 1918 (Fig. B1). We found that fire years correspond to drought years prior to 1918, but not after. This result suggests that the drought-fire relationship in the study region has disappeared after that period due to fire suppression activities. Our results thus confirm the impact of the increase in fire suppression efforts and forest management activities since the first forest law in modern Turkey and resulting active prevention of the spread of fires. In conclusion, fire suppression and forest management, not climate, are responsible for the decrease in the fire activity of our study area during the 20th century. Fire exclusion results in the accumulation of surface fuels over years in black pine forests (Camarero et al., 2018), which in turn may lead to more intense fires (i.e., crown fires) under ongoing warming. Such a fire regime shift is a major concern for the persistence of black pine forests (Christopoulou et al., 2013), especially because black pine trees have no adaptation to survive under crown fire regimes (Tapias et al., 2004; Pausas et al., 2008). The revival of historic surface fire regimes by using prescribed fires may help to protect the Mediterranean black pine populations from local extinctions due to intense crown fires in future.

Most (~84 %) Kütahya fire scars occurred in the latewood and very few (~4%) scars occurred in the earlywood (Table 3). Our results correspond to fire seasonality in other black pine forests in the Mediterranean basin (Christopoulou et al., 2013; Fulé et al., 2008). This fire seasonality was further confirmed by our analysis of recent documentary fire records, which revealed that the majority of fires occurred between June and October, which corresponds to the period of mature latewood tracheid cell formation (August-October) in Mediterranean black pine forests (Guada et al., 2016). The similarity of fire seasonality between the recent (post-1950) and historical (from 1751 onwards) periods suggests that fire seasonality has remained unchanged over the past 350+ years, despite fire-suppression related disruptions of the fire regime.

We present the first results of a broader research program that is mainly focused on historical fires in the entire range of black pine in Western Anatolia, Turkey. Providing evidence about the components of past fire regimes is valuable for future forest management strategies under a changing climate and human influences in high fire risk regions such as the Mediterranean basin. Furthermore, long-term monitoring and research following major fire events are necessary to understand changes in stand dynamics and species composition. This combined knowledge could serve as important guidance to managers and foresters for future forest protection strategies and plans and as a reference for future restoration studies.

Declaration of Competing Interest

Nesibe Kose reports financial support was provided by Scientific and Technological Research Council of Turkey. Evrim A. Sahan reports financial support was provided by Scientific and Technological Research Council of Turkey. Anil Bahar reports financial support was provided by Scientific and Technological Research Council of Turkey. Anil Bahar reports a relationship with Council of Higher Education of the Republic of Turkey that includes: funding grants. Evrim A. Sahan reports a relationship with Council of Higher Education of Turkey that includes: funding grants.

Acknowledgements

We would like to thank Osman Aksoy, the manager of the forestry operation directorate, Simav. We also would like to thank the employees of the Regional Directorate of Forestry, Kütahya, and Forestry Operation Directorate, Simav, Kütahya for helping us during the fieldwork. E. A. Şahan expresses her gratitude to Hakan Çelik for his help in the laboratory. A. Bahar and E. A. Şahan acknowledges the financial support of the 100/2000 priority areas scholarship by the Council of Higher Education of Turkey (CoHE). This project is funded by the Scientific and Technological Research Council of Turkey (TÜBİTAK) [Project number: 118O306].

Appendix A

Appendix B

References

Akkemik, Ü, 2000. Dendrochronological investigations in two monumental *Pinus nigra* Arn. stands near Antalya (Turkey). In: Proceedings of the International Scientific Conference—75 Years University Forestry Education in Bulgaria. Sofia, Bulgaria, 15–16 June 2000, pp. 179–187.

Akkemik, Ü, Aras, A., 2005. Reconstruction (1689-1994 AD) of April-August precipitation in the southern part of central Turkey. Int. J. Climatol. 25 (4), 537–548. https://doi.org/10.1002/joc.1145.

Akkemik, Ü., D'Arrigo, R., Cherubini, P., Köse, N., Jacoby, G.C., 2008. Tree-ring reconstructions of precipitation and streamflow for north-western Turkey. Int. J. Climatol. 28 (2), 173–183. https://doi.org/10.1002/joc.1522.

Baisan, C., Swetnam, T., 1990. Fire history on a desert mountain range: Rincon Mountain Wilderness, Arizona, U.S.A. Can. J. For. Res. 20 (10), 1559–1569. https://doi.org/10.1139/x90-208.

Bekar, İ., Tavşanoğlu, Ç., 2017. Modelling the drivers of natural fire activity: the bias created by cropland fires. Int. J. Wildland Fire 26 (10), 845. https://doi.org/10.1071/wf16183.

Bowman, D.M.J.S., Balch, J.K., Artaxo, P., Bond, W.J., Carlson, J.M., Cochrane, M.A., et al., 2009. Fire in the earth system. Science 324 (5926), 481–484. https://doi.org/10.1126/science.1163886.

Camarero, J.J., Sangüesa-Barreda, G., Montiel-Molina, C., Seijo, F., López-Sáez, J.A., 2018. Past growth suppressions as proxies of fire incidence in relict Mediterranean black pine forests. For. Ecol. Manage. 413, 9–20. https://doi.org/10.1016/j.foreco.2018.01.046.

Caprio, A.C., Swetnam, T.W., 1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada. In: Brown, J.K., Mutch, R.W., Spoon, C.W., Wakimoto, R.H. (Eds.), Proceedings of the Symposium of Fire in the Wilderness and Park Management. General Technical Report INT-GTR-320 USFS Intermountain Forest and Range Experimental Station, Ogden, UT, pp. 173–179.

Carrión, J.S., Sánchez-Gómez, P., Mota, J.F., Yll, R., Chaín, C., 2003. Holocene vegetation dynamics, fire and grazing in the Sierra de Gádor, southern Spain. Holocene 13 (6), 839–849. https://doi.org/10.1191/0959683603hl662rp.

Çatav, Ş.S., Küçükakyüz, K., Tavşanoğlu, Ç., Pausas, J.G., 2018. Effect of fire-derived chemicals on germination and seedling growth in Mediterranean plant species. Basic Appl. Ecol. 30, 65–75.

Chavardès, R.D., Daniels, L.D., Gedalof, Z.E., Andison, D.W., 2018. Human influences superseded climate to disrupt the 20th century fire regime in Jasper National Park, Canada. Dendrochronologia 48, 10–19.

Christopoulou, A., Fulé, P., Andriopoulos, P., Sarris, D., Arianoutsou, M., 2013. Dendrochronology-based fire history of *Pinus nigra* forests in Mount Taygetos, Southern Greece. For. Ecol. Manage. 293, 132–139.

Christopoulou, A., Fyllas, N., Andriopoulos, P., Koutsias, N., Dimitrakopoulos, P., Arianoutsou, M., 2014. Post-fire regeneration patterns of *Pinus nigra* in a recently burned area in Mount Taygetos, Southern Greece: the role of unburned forest patches. For. Ecol. Manage. 327, 148–156. https://doi.org/10.1016/j.foreco.2014.05.006.

Christopoulou, A., Mallinis, G., Vassilakis, E., Farangitakis, G.P., Fyllas, N.M., Kokkoris, G., Arianoutsou, M., 2019. Assessing the impact of different landscape features on post-fire forest recovery with multi-temporal remote sensing data: the case of Mount Taygetos (southern Greece). Int. J. Wildland Fire 28, 521–532. https://doi.org/10.1071/WF18153.

Cook, E., Seager, R., Kushnir, Y., Briffa, K., Büntgen, U., Frank, D., et al., 2015. Old World megadroughts and pluvials during the Common Era. Sci. Adv. 1 (10), e1500561.

Doğan, M., Köse, N., 2019. Influence of climate on radial growth of black pine on the mountain regions of Southwestern Turkey. Plants 8, 276. https://doi.org/10.3390/plants8080276.

Drobyshev, I., Goebel, P.C., Bergeron, Y., Corace, R.G., 2012. Detecting changes in climate forcing on the fire regime of a North American mixed-pine forest: a case study of Seney National Wildlife Refuge, Upper Michigan. Dendrochronologia 30 (2), 137–145. https://doi.org/10.1016/j.dendro.2011.07.002.

Dube, O., 2009. Linking fire and climate: interactions with land use, vegetation, and soil. Curr. Opin. Environ. Sustain. 1 (2), 161–169. https://doi.org/10.1016/j.cosust.2009.10.008.

EUFORGEN, 2004. Technical Guidelines for Genetic Conservation and Use for European Black Pine (*Pinus Nigra*). International Plant Genetic Resources Institute, Rome, Italy.

Falk, D., Heyerdahl, E., Brown, P., Farris, C., Fulé, P., McKenzie, D., et al., 2011. Multi-scale controls of historical forest-fire regimes: new insights from fire-scar networks. Front. Ecol. Environ. 9 (8), 446–454. https://doi.org/10.1890/100052.

FAO, 2018. State of Mediterranean Forests 2018. Food and Agriculture Organization of the United Nations, Rome and Plan Bleu, Marseille.

Fournier, T., Battipaglia, G., Brossier, B., Carcaillet, C., 2013. Fire-scars and polymodal age-structure provide evidence of fire-events in an Aleppo pine population in southern France. Dendrochronologia 31 (3), 159–164. https://doi.org/10.1016/j.dendro.2013.05.001.

Fulé, P., Ribas, M., Gutiérrez, E., Vallejo, R., Kaye, M., 2008. Forest structure and fire history in an old *Pinus nigra* forest, eastern Spain. For. Ecol. Manage. 255 (3-4), 1234–1242.

Fulé, P., Korb, J., Wu, R., 2009. Changes in forest structure of a mixed conifer forest, southwestern Colorado, USA. For. Ecol. Manage. 258 (7), 1200–1210. https://doi.org/10.1016/j.foreco.2009.06.015.

Fyllas, N., Troumbis, A., 2009. Simulating vegetation shifts in north-eastern Mediterranean mountain forests under climatic change scenarios. Glob. Ecol. Biogeogr. 18 (1), 64–77. https://doi.org/10.1111/j.1466-8238.2008.00419.x.

Guada, G., Camarero, J.J., Sánchez-Salguero, R., Navarro Cerrillo, R.M., 2016. Limited growth recovery after drought-induced forest dieback in very defoliated trees of two pine species. Front. Plant Sci. 7, 418. https://doi.org/10.3389/fpls.2016.00418.

Gül, A., 2009. Drought and famine in Ottoman Empire (Case of Erzurum Province: 1892–1893 and 1906–1908). J. Int. Soc. Res. 2 (9), 144–158.

Güner, H., Köse, N., Harley, G., 2016. A 200-year reconstruction of Kocasu River (Sakarya River Basin, Turkey) streamflow derived from a tree-ring network. Int. J. Biometeorol. 61 (3), 427–437. https://doi.org/10.1007/s00484-016-1223-y.

Guyette, R., Spetich, M., 2003. Fire history of oak–pine forests in the Lower Boston Mountains, Arkansas, USA. For. Ecol. Manage. 180 (1-3), 463–474. https://doi.org/10.1016/s0378-1127(02)00613-8.

Haurwitz, M.W., Brier, G.W., 1981. A critique of the superposed epoch analysis method: its application to solar-weather relations. Mon. Weath. Rev 109, 2074.

Hernández-Serrano, A., Verdú, M., González-Martínez, S., Pausas, J., 2013. Fire structures pine serotiny at different scales. Am. J. Bot. 100 (12), 2349–2356. https://doi.org/10.3732/ajb.1300182.

Holmes, R.L., 1986. Quality control of cross-dating and measuring. A users manual for computer program COFECHA. In: Holmes, R.L., Adams, R.K., Fritts, H.C. (Eds.), Tree-Rings Chronologies of Western North America: California, Eastern Oregon and Northern Great Basin. Chronology Ser. 6. Univ. of Arizona, Tucson, 41249.

IPCC, 2019. In: Shukla, P.R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Pörtner, H.-O., Roberts, D.C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., Malley, J. (Eds.), Climate Change and Land: an IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. IPCC.

Ivanova, G., Ivanov, V., Kukavskaya, E., Soja, A., 2010. The frequency of forest fires in Scots pine stands of Tuva, Russia. Environ. Res. Lett. 5 (1), 015002. https://doi.org/10.1088/1748-9326/5/1/015002.

Janssen, E., Kint, V., Bontemps, J.D., Özkan, K., Mert, A., Köse, N., et al., 2018. Recent growth trends of black pine (*Pinus nigra* JF Arnold) in the eastern mediterranean. For. Ecol. Manage. 412, 21–28.

Keeley, J., 2012. Ecology and evolution of pine life histories. Ann. For. Sci. 69 (4), 445–453. https://doi.org/10.1007/s13595-012-0201-8.

Keeley, J., Bradstock, R., Bond, W., Pausas, J., Rundel, P., 2012. Fire in Mediterranean Ecosystems. Cambridge University Press, Cambridge, UK.

Kılıç, E., 2020. Osmanlı ormancılığında orman yangınlarıyla mücadele yöntemleri. Ağaç ve Orman 1 (1), 12–20.

Kitenberga, M., Drobyshev, I., Elferts, D., Matisons, R., Adamovics, A., Katrevics, J., et al., 2019. A mixture of human and climatic effects shapes the 250-year long fire history of a semi-natural pine dominated landscape of Northern Latvia. For. Ecol. Manage. 441, 192–201. https://doi.org/10.1016/j.foreco.2019.03.020.

Koç, B., 2005. 1870 orman nizamnamesi'nin osmanlı ormancılığına katkısı üzerine bazı notlar ——Some notes on 1870 forest nizamname's (Regulation) contribution to the ottoman forestry. Tarih Araştırmaları Dergisi. 24 (37), 231–257.

Köse, N., Akkemik, Ü., Dalfes, H.N., 2005. Anadolu'nun Iklim Tarihinin Son 500 Yılı: Dendroklimatolojik Ilk Sonuçlar. In: Proceedings of the Türkiye Kuvaterner Sempozyumu-TURQUA-V. Istanbul, Turkey, 2–3 June 2005, pp. 136–142.

Köse, N., Akkemik, Ü., Dalfes, H., Özeren, M., Tolunay, D., 2012. Tree-ring growth of *Pinus nigra* Arn. subsp. *pallasiana* under different climate conditions throughout western Anatolia. Dendrochronologia 30 (4), 295–301. https://doi.org/10.1016/j.dendro.2012.04.003.

Köse, N., Akkemik, Ü., Güner, H.T., et al., 2013. An improved reconstruction of May–June precipitation using tree-ring data from western Turkey and its links to volcanic eruptions. Int. J. Biometeorol. 57, 691–701. https://doi.org/10.1007/s00484-012-0595-x.

Köse, N., Güner, H.T., Harley, G.L., Guiot, J., 2017. Spring temperature variability over Turkey since 1800 CE reconstructed from a broad network of tree-ring data. Clim. Past Discuss. 13, 1–15. https://doi.org/10.5194/cp-13-1-2017, 2017.

Küçükosmanoğlu, A., 1987. Türkiye ormanlarında çıkan yangınların sınıflandırılması ile büyük yangınların çıkma ve gelişme nedenleri. OGM Yayınları, Ankara.

Kuniholm, P.I., 1990. Archaeological evidence and non-evidence for climatic change. Phil. Trans. R. Soc. Lond., A. 330, 645–655.

Lafon, C., Hoss, J., Grissino-Mayer, H., 2005. The contemporary fire regime of the Central Appalachian Mountains and its relation to climate. Phys. Geogr. 26 (2), 126–146. https://doi.org/10.2747/0272-3646.26.2.126.

Lageard, J., Thomas, P., Chambers, F., 2000. Using fire scars and growth release in subfossil Scots pine to reconstruct prehistoric fires. Palaeogeogr. Palaeoclimatol. Palaeoecol. 164 (1-4), 87–99. https://doi.org/10.1016/s0031-0182(00)00177-2.

Li, F., Lawrence, D.M., Bond-Lamberty, B., 2018. Human impacts on 20th century fire dynamics and implications for global carbon and water trajectories. Glob. Planet. Change 162, 18–27. https://doi.org/10.1016/j.gloplacha.2018.01.002.

Malevich, S.B., Guiterman, C.H., Margolis, E.Q., 2018. Burnr: fire history analysis and graphics in R. Dendrochronologia 49, 9–15. https://doi.org/10.1016/j.dendro.2018.02.005.

Margolis, E., Balmat, J., 2009. Fire history and fire–climate relationships along a fire regime gradient in the Santa Fe Municipal Watershed, NM, USA. For. Ecol. Manage. 258 (11), 2416–2430. https://doi.org/10.1016/j.foreco.2009.08.019.

Margolis, E., Woodhouse, C., Swetnam, T., 2017. Drought, multi-seasonal climate, and wildfire in northern New Mexico. Clim. Change 142 (3-4), 433–446. https://doi.org/10.1007/s10584-017-1958-4.

Marlon, J.R., Bartlein, P.J., Carcaillet, C., Gavin, D.G., Harrison, S.P., Higuera, P.E., Joos, F., Power, M.J., Prentice, I.C., 2008. Climate and human influences on global biomass burning over the past two millennia. Nat. Geosci. 1 (10), 697–702.

Mazarzhanova, K., Kopabayeva, A., Köse, N., Akkemik, Ü., 2017. The first forest fire history of the Burabai Region (Kazakhstan) from tree rings of *Pinus sylvestris*. Turk. J. Agric. For. 41, 165–174. https://doi.org/10.3906/tar-1610-72.

Molina-Terrén, D., Fry, D., Grillo, F., Cardil, A., Stephens, S., 2016. Fire history and management of *Pinus canariensis* forests on the western Canary Islands Archipelago, Spain. For. Ecol. Manage. 382, 184–192. https://doi.org/10.1016/j.foreco.2016.10.007.

Mutlu, H., Köse, N., Akkemik, Ü., Aral, D., Kaya, A., Manning, S., et al., 2011. Environmental and climatic signals from stable isotopes in Anatolian tree rings, Turkey. Region. Environ. Change 12 (3), 559–570. https://doi.org/10.1007/s10113-011-0273-2.

Ocak, İ., Konuk, M., 2018. Diversity and ecology of Myxomycetes from Kütahya and Konya (Turkey) with four new records. Mycobiology 46 (3), 215–3223. https://doi.org/10.1080/12298093.2018.1497793.

Official Gazette, 1937. Forest Law. Official Gazette of the Republic of Turkey. No: 3537 (in Turkish).

Paula, S., Arianoutsou, M., Kazanis, D., Tavsanoglu, Ç., Lloret, F., Buhk, C., Ojeda, F., Luna, B., Moreno, J.M., Rodrigo, A., Espelta, J.M., Palacio, S., Fernández-Santos, B., Fernandes, P.M., Pausas, J.G., 2009. Fire-related traits for plant species of the Mediterranean Basin. Ecology 90, 1420. https://doi.org/10.1890/08-1309.1.

Pausas, J., 2004. Changes in fire and climate in the Eastern Iberian Peninsula (Mediterranean Basin). Clim. Change 63 (3), 337–350. https://doi.org/10.1023/b:clim.0000018508.94901.9c.

Pausas, J.G., Bond, W.J., 2020. On the three major recycling pathways in terrestrial ecosystems. Trends Ecol. Evol. 35 (9), 767–775.

Pausas, J.G., Fernández-Muñoz, S., 2012. Fire regime changes in the Western Mediterranean Basin: from fuel-limited to drought-driven fire regime. Clim. Change 110, 215–226.

Pausas, J.G., Keeley, J.E., 2021. Wildfires and global change. Front. Ecol. Environ. (in press).

Pausas, J., Ribeiro, E., 2013. The global fire-productivity relationship. Glob. Ecol. Biogeogr. 22 (6), 728–736. https://doi.org/10.1111/geb.12043.

Pausas, J., Llovet, J., Rodrigo, A., Vallejo, R., 2008. Are wildfires a disaster in the Mediterranean basin? - A review. Int. J. Wildland Fire 17 (6), 713. https://doi.org/10.1071/wf07151.

Peel, M.C., Finlaysonm, B.L., McMahon, T.A., 2007. Updated world map of the Köppen-Geiger climate classification. Hydrol Earth Syst Sci Discuss. 4 (2), 439–473.

Piha, A., Kuuluvainen, T., Lindberg, H., Vanha-Majamaa, I., 2013. Can scar-based fire history reconstructions be biased? An experimental study in boreal Scots pine. Can. J. For. Res. 43 (7), 669–675. https://doi.org/10.1139/cjfr-2012-0471.

Prichard, S.J., Stevens-Rumann, C.S., Hessburg, P.F., 2017. Tamm Review: shifting global fire regimes: lessons from reburns and research needs. For. Ecol. Manage. 396, 217–233. https://doi.org/10.1016/j.foreco.2017.03.035.

R Core Team, 2020. R: a Language and Environment for Statistical Computing. URL. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/.

Rao, M., Cook, E., Cook, B., Anchukaitis, K., D'Arrigo, R., Krusic, P., LeGrande, A., 2019. A double bootstrap approach to Superposed Epoch Analysis to evaluate response uncertainty. Dendrochronologia 55, 119–124. https://doi.org/10.1016/j.dendro.2019.05.001.

Regent Instrument Inc, 2002. Windendro TM v.2002a. Regent Instrument Inc., Québec, Qc.

Richardson, D.M., 2000. Ecology and Biogeography of Pinus. Cambridge University Press, Cambridge, UK.

Rodman, K.C., Veblen, T.T., Battaglia, M.A., Chambers, M.E., Fornwalt, P.J., Holden, Z. A., et al., 2020. A changing climate is snuffing out post-fire recovery in montane forests. Glob. Ecol. Biogeogr. 29 (11), 2039–2051.

Rother, M., Huffman, J., Guiterman, C., Robertson, K., Jones, N., 2020. A history of recurrent, low-severity fire without fire exclusion in southeastern pine savannas, USA. For. Ecol. Manage. 475, 118406 https://doi.org/10.1016/j.foreco.2020.118406.

Schweingruber, F., 1988. Tree Rings. Kluwer, Dordrecht.

Skinner, C.N., Abbott, C.S., Fry, D.L., Stephens, S.L., Taylor, A.H., Trouet, V., 2009. Human and climatic influences on fire occurrence in California's North Coast Range, USA. Fire Ecol. 5 (3), 73–96. https://doi.org/10.4996/fireecology.0503076.

Slimani, S., Touchan, R., Derridj, A., Kherchouche, D., Gutiérrez, E., 2014. Fire history of Atlas cedar (*Cedrus atlantica* Manetti) in Mount Chélia, northern Algeria. J. Arid Environ. 104, 116–123. https://doi.org/10.1016/j.jaridenv.2014.02.008.

Sutherland, E.K., Brewer, P.W., Falk, D.A., Velasquez, M.E., 2015. Fire History Analysis and Exploration System (FHAES) User Manual. [compiled on 21/12/2017]. http://www.fhaes.org.

Swetnam, T.W., 1993. Fire history and climate change in giant sequoia groves. Science 262, 885–889.

Swetnam, T.W., Baisan, C., 1996. Historical Fire Regime Patterns in the Southwestern United States Since AD 1700. January 1996 USDA Forest Service - General Technical Report RMRS-GTR GTR 286, pp. 11–32.

Szymczak, S., Bräuning, A., Häusser, M., Garel, E., Huneau, F., Santoni, S., 2020. A dendroecological fire history for central Corsica/France. Tree. Res. 76 (1), 40. https://doi.org/10.3959/trr2019-2.

Tapias, R., Climent, J., Pardos, J.A., Gil, L., 2004. Life histories of Mediterranean pines. Plant Ecol. 171 (1), 53–68.

Tarancon, A., Fule, P.Z., Sanchez Meador, A.J., Kim, Y.-S., Padilla, T., 2018. Spatiotemporal variability of fire regimes in adjacent Native American and public forests, New Mexico, USA. Ecosphere 9 (11), e02492. https://doi.org/10.1002/ecs2.2492.

Tatlı, H., Türkeş, M., 2014. Climatological evaluation of Haines forest fire weather index over the Mediterranean Basin. Meteorol. Appl. 21 (3), 545–552. https://doi.org/10.1002/met.1367.

Tavşanoğlu, Ç., 2008. The effect of aspect on post-fire recovery of a mixed Lebanon Cedar-Anatolian Black Pine forest: after the first 5 years. Asian J. Plant Sci. 7, 696–699.

Tavşanoğlu, Ç., Pausas, J.G., 2018. A functional trait database for Mediterranean Basin plants. Sci. Data 5, 180135.

Taylor, A.H., Trouet, V., Skinner, C.N., 2008. Climatic influences on fire regimes in mountain forests of the southern Cascades, California, USA. Int. J. Wildland Fire 17, 60–71.

Taylor, A., Trouet, V., Skinner, C., Stephens, S., 2016. Socioecological transitions trigger fire regime shifts and modulate fire–climate interactions in the Sierra Nevada, USA, 1600–2015 CE. Proc. Natl. Acad. Sci. 113 (48), 13684–13689. https://doi.org/10.1073/pnas.1609775113.

Tekemen Altındaş, E., 2018. 19. yüzyılda Osmanlı Devleti'nde Yaşanan Kuraklığın Ankara'ya Yansıması. Çanakkale Araştırmaları Türk Yıllığı 16 (24), 1–12.

Touchan, R., Baisan, C., Mitsopoulos, I.D., Dimitrakopoulos, A.P., 2012. Fire History in European Black Pine (*Pinus nigra* Arn.) Forests of the Valia Kalda, Pindus Mountains, Greece. Tree-Ring Res. 68 (1), 45–50. https://doi.org/10.3959/2011-12.1.

Turco, M., von Hardenberg, J., AghaKouchak, A., Llasat, M., Provenzale, A., Trigo, R., 2017. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Sci. Rep. 7 (1), 81. https://doi.org/10.1038/s41598-017-00116-9.

Türkeş, M., Altan, G., 2012. Çanakkale'nin 2008 yılı büyük orman yangınlarının meteorolojik ve hidroklimatolojik analizi. Coğrafi Bilimler Dergisi 10 (2), 195–218.

Yao, Q., Brown, P.M., Liu, S., Rocca, M.E., Trouet, V., Zheng, B., Chen, H., Li, Y., Wang, X., 2017. Pacific-Atlantic Ocean influence on wildfires in northeast China (1774 to 2010). Geophys. Res. Lett. 44, 1025–1033. https://doi.org/10.1002/2016GL071821.