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Research Article

Relationships Between Temperature and Precipitation Conditions and Tree- Ring Growth in Küre Mountains National Park in the Context of Climate Change

Selinay ATAY*[1], Cemil İRDEM[2]

[1]Karabük University, The Institute of Graduate Programs, Karabük, TÜRKİYE
[2]Karabük University, Faculty of Letters, Geography Department, Karabük, TÜRKİYE
*Corresponding Author: selinayatay12@gmail.com

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Abstract

Aim of study: The aim of this study was to determine the effect of temperature and precipitation on annual ring growth at the upper and lower growth limits of Scots pine, fir and black pine in the Küre Mountains National Park.

Area of study: Küre Mountains National Park located in the Western Black Sea part of the Black Sea Region, is located between the borders of Pınarbaşı, Azdavay, Cide and Şenpazar districts of Kastamonu province and the central and Ulus, districts of Bartın province. This park is one of the 9 Hotspots in Türkiye.

Material and method: For dendrochronological analyses, samples were taken from the lower and upper growth limits of Scots pine, fir and black pine using increment borers. Measurements of the samples taken were made using the LINTAB-TSAP measurement system with a sensitivity of 0.01 mm. In the analysis of climate-tree ring relations, climate data with a resolution of 0.5° x 0.5° grid, taken from the website of the World Meteorological Organization Regional Climate Center, were used. Response Functions were calculated to reveal the statistical relationships between climate data and tree ring growth.

Main results: According to our results, tree ring growth on trees in the research area is positively affected by the increases in monthly total precipitation in June and July for all site all chronologies and negatively affected by November of the previous year and January, February, September and October of the current year.

Research highlights: In this study, a positive relationship was found between precipitation and tree-ring growth in March-August. Temperature tree-ring relationships were positive in spring in all sites.

Keywords: Tree Ring, Küre Mountains National Park, Climate Change, Dendroclimatology

İklim Değişikliği Bağlamında Küre Dağları Milli Parkı’nda Sıcaklık ve Yağış ile Yıllık Halka Gelişimi Arasındaki İlişkiler

Öz

Çalışmanın amacı: Bu çalışmanın amacı, Küre Dağları Milli Parkı'ndaki sarıçam, göknar ve karaçamın üst ve alt yetişme sınırlarında sıcaklık ve yağışın yıllık halka büyümesi üzerindeki etkisini belirlemektir.

Çalışma alanı: Karadeniz bölgesinin Batı Karadeniz bölümünde bulunan Küre Dağları Milli Parkı Kastamonu ili Pınarbaşı, Azdavay, Cide ve Şenpazar ilçeleri ile Bartın ili merkez ve Ulus ilçeleri sınırlarında arasında bulunmaktadır. Bu park, Türkiye’deki 9 sıcak noktadan birisidir.

Materyal ve yöntem: Dendrokronolojik analizler için sarıçam, göknar ve karaçam alt ve üst yetişme sınırlarından artım bulguları kullanılarak örnekler alınmıştır. Alınan örneklerin ölçümleri LINTAB-TSAP ölçüm sistemi kullanılarak 0.01 mm duyarlılıkta yapılmıştır. İklim-halka ilişkilerinin analizinde Dünya Meteoroloji Örgütü Bölgesel İklim Merkezi’nin web sitesinden alınan 0.5° x 0.5° grid çözünürlüklü iklim verileri kullanılmıştır. İklim verileri ile yıllık halka gelişimi arasındaki istatistik ilişkileri ortaya koymak için Tepki Fonksiyonları hesaplanmıştır.

Temel sonuçlar: Elde edilen sonuçlara göre, çalışma sahasındaki ağaçlarda yıllık halka gelişimi tüm lokasyonlar için Haziran ve Temmuz aylarındaki aylık toplam yağış artışlarından tüm kronolojilerde olumlu yönde, bir önceki yılın Kasım ayı ile Ocak, Şubat, Eylül ve Ekim aylarında ise olumsuz yönde etkilenmiştir.

Araştırma vurguları: Bu çalışmada yağış ve yıllık halka gelişimi arasında mart- ağustos aylarında pozitif ilişki bulunmuştur. Sıcaklık- yıllık halka ilişkileri ilkbahar aylarında tüm yörelerde pozitif yönlüdür.

Anahtar kelimeler: Yıllık Halka, Küre Dağları Milli Parkı, İklim Değişikliği, Dendroklimatoloji

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Introduction

Tree rings are a critical data source in determining dry and rainy years in the past. Knowing the reactions of trees to climate conditions in the past can provide insight into the effects of future climate changes on growth. In particular, some species may be more sensitive to changes in climate. Scots pine, fir and black pine trees are frequently preferred for dendrochronological studies in Türkiye and the world. Black pine is an important forest tree that grows in the transition zone between continental and marine climates and, therefore, starts from the Black Sea coast in Türkiye and extends to the Central Anatolian steppes. In the second volume of the Illustrated Flora of Turkey (Güner et al., 2018) Distribution from Kazdağları to Kızılırmak Delta all firs showing Kazdağı fir (Abies nordmanniana subsp. equi-trojani) together as subspecies distinctions were eliminated by collecting them (Usta and Tavşanoğlu, 2023). Firs, seen in parts of the Küre Mountains higher than 500 meters, reach the upper limit of the forest in Uludağ (Bursa) (Atalay, 2015). Growing in cold, humid and semi-humid regions Scots pines are seen at altitudes close to sea level along the Black Sea coastal zone, especially in the west (Akçaabat) and east (Çamburnu) of Trabzon and Kurucaşile (Bartın), while in Sarıkamış (Kars) in Northeastern Anatolia, it rises to 2800 meters (Atalay and Efe, 2015). The effect of altitude on forest trees occurs along with other factors. Its limiting effects occur with low precipitation and high temperatures in the lower habitats where the altitude is low and with high precipitation and low temperatures in the upper limits. Accordingly, annual rings are more sensitive in lower and upper-growing environments. For this reason, in dendrochronological studies, taking samples from the lower and upper limits of the growing environment rather than from optimum conditions provides more reliable results (Akkemik, 2004). In the field of dendrochronology in Turkey, there are an increasing number of studies on Scots pine, fir and black pine. (About Scots pine, Yaman and Sarıbaş 2004, Martin Benito et al. 2016, Martin-Benito et al. 2018, İrdem 2019, Martin-Benito et al. 2019, Bozkurt et al. 2021, Özel et al. 2021, İrdem & Coşkun 2023; about fir, Özkan 1990, Akkemik 2000, Dağdeviren 2002, Martin-Benito et al. 2016, Martin-Benito et al. 2018, Martin-Benito et al. 2019), and about black pines, Akkemik 1997, Akkemik 2000, Dağdeviren 2002, Güner 2010, Köse et al. 2011, Doğan 2014, Yurtseven 2021).

As stated in RCP4.5 and RCP8.5 scenarios, prepared by Akçakaya et al. (2015), temperatures are predicted to increase in all of Türkiye. The precipitation will decrease for Türkiye in the period of 2016-2099 (İrdem, 2022). According to the literature review, studies comparing three different species (Martin Benito et al. 2018, Alkan & İrdem 2023) are few and none of these studies include a comparative analysis of tree-ring growth and climate relationships of Scots pine, black pine and fir trees. Although our research has similar aspects to the methodology used in the studies mentioned above, no analysis was made on the possible effects of climate change on diameter increment in these studies.

The purpose of this study; (1) To create climate-sensitive chronologies with the help of samples taken from the lower and upper growing limits of Scots pine, black pine and fir trees in the Küre Mountains National Park, (2) To analyze the statistical relationships between climatic conditions and annual ring growth, (3) To make forward-looking inferences regarding the effect of climate change on the diameter increment of trees.

Material and Methods

Research Area

The scope of the study is limited to the area of Küre Mountains National Park. Küre Mountains National Park (KDMP), located in the Western Black Sea part of the Black Sea Region, is located between the borders of Pınarbaşı, Azdavay, Cide and Şenpazar districts of Kastamonu province and the central and Ulus, districts of Bartın province (Figure 1). It was declared a national park on 07.07.2000, and 18.121 ha of the national park, which has an area surface of 37,753 hectares, is located within the provincial borders of Kastamonu (Çoban and Göktuğ, 2019; Şen and Buğday, 2015). In 1999, the World Wildlife Fund identified 100 forest areas in Europe that are valuable in biodiversity and need urgent protection. Nine of these areas, called 'Hot Spots of European Forests', are in Türkiye. Küre Mountains National Park is an important place, one of these nine hot spots. In addition, it became the first national park to join the protected areas network in Türkiye by receiving the PAN Parks certificate in 2012 (Belkayalı and Aydın, 2016).

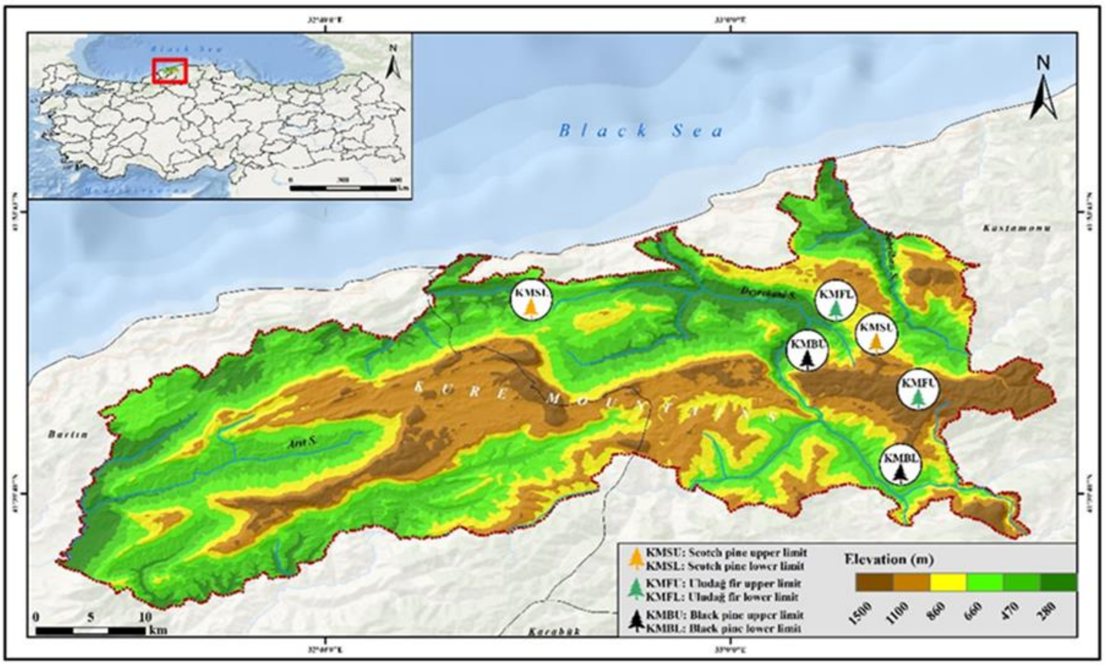

Figure 1. Location Map of the Study Area

Method

Within the scope of the study, samples were taken from the lower and upper growth limits using increment borers for dendrochronological analysis from locations determined within the borders of Küre Mountains National Park. For this propose, six distinct site chronologies have been established: the Scots pine upper growth limit (KMSU), which comprises 31 samples obtained from 17 trees; Scots pine lower growth limit (KMSL), consisting of 22 samples collected from 18 trees; Kazdağı Fir Upper growth limit (KMFU) which includes 28 samples taken from 16 trees; Kazdağı Fir Lower growth limit (KMFL) which comprises 26 samples obtained from 15 trees; Black Pine Upper growth Limit (KMBU) consisting of 26 samples collected from 15 trees and Black Pine Lower growth limit (KMBL) which includes 27 samples taken from 16 trees (Table 1).

Measurements of the samples taken for dendrochronological analyses were made using the LINTAB-TSAP measurement system (Rinntech, Germany) with a sensitivity of 0.01 mm. The COFECHA program (Holmes, 1983; Grisino Mayer, 2001) was used to verify the reliability of the dating. COFECHA, like other programs in the Dendrochronology Program Library (DPL), is a program that can read data in several ASCII formats, helping to locate missing and false rings in annual ring series. COFECHA matches based on correlation coefficients. Each transformed series is then tested against the average chronology by correlation analysis using the selected segment length and overlap (Köse,2007).

There is an important relationship between the growth and development of trees and their environment. Therefore, during annual ring formation, long-term trends are observed in annual ring widths depending on the age of the tree, the soil conditions of its environment, its aspect, slope and closure status. These trends need to be eliminated and chronologies need to be standardized(Fritts, 1976; Schweingruber, 1988; Akkemik, 2004; Güner, 2010). ARSTAN program was used to create and standardize site chronologies. The standardization process was performed with the ARTSAN program by fitting a 67% cubic smoothing spline with a 50% cutoff frequency (Cook, 1985). Many years of data are needed to analyze climate-annual ring-width relations. The research area and its immediate surroundings have no long-term MGM station data. Therefore, as it has longer-term data, gridded data from the World Meteorological Organization Regional Climate Center website was used for areal precipitation totals and temperature averages.

The most used and effective method in dendroclimatological analysis is the response function method. Problems arising from correlation between variables can be eliminated by transforming the independent variables into a new orthogonal and uncorrelated set of data, expressed as eigenvectors or principal components. Determining the relationship between climate variables and annual ring widths using the response function method is carried out in two stages. First of all, the main components of the climate variables are determined, and then the response function coefficients are calculated using these main components (Friits, 1976; Dağdeviren et al., 2004). Response Functions were calculated with the help of DENDROCLIM2002 (Biondi and Waikul, 2004) to reveal the statistical relationships between these climate data and tree-ring growth. To assess the stability of limiting climatic factors, a moving window correlation analysis was conducted over a 30-year period with 5-year intervals. This approach enabled an investigation into the temporal variability of climate-related relationships.

This study analyzed possible changes in diameter increment based on the globally most preferred RCP8.5 scenarios developed by the IPCC. RCP8.5 is the highest possible radiative forcing and concentration route. RCP8.5 represents higher greenhouse gas emissions than other scenarios, indicating the upper limit of RCPs (Fisher et al., 2007; IPCC, 2008; Riahi et al., 2011; Gürkan et al., 2016). This scenario have two advantages over other scenarios. The first is that an excellent signal can be obtained due to the difference between it and the higher route, and the second is that there are many published studies on this route in the literatüre (IPCC 2013; Gürkan et al. 2016).

Results

Dendrochronological Results

A total of 6 siteal chronologies were created from the lower and upper growth limits of the Küre Mountains National Park, which is the research area (Table 1). The preferred tree species for site chronologies are Scots pine (Pinus sylvestris), Kazdağı Fir (Abies nordmanniana subsp. equi-trojani) and Black Pine (Pinus nigra). The site chronology lengths obtained indicate that the upper limit of Scots pine is 147 years. (1875-2022), Scots pine lower limit is 96 years (1926-2022), Fir upper limit is 207 years (1815-2022), fir lower limit is 84 years (1938-2022), black pine upper limit is 133 years (1889-2022) and the lower limit of black pine appears to be 143 years (1875-2023).

Statistical information on the upper and lower growth border is presented in Table 2 and Table 3. When the statistical results in Table 2 are examined, residual chronologies were preferred in the analysis because the results obtained from the residual chronology were found to be stronger in all sites.

Since the annual sensitivity coefficient determines how much change the ring formed in year i shows compared to the ring of the previous year, it is also used as a method (Fritts, 1976, Schweingruber, 1988; Akkemik, 2004). If the average sensitivity coefficient is between 0.10-0.19, it is less sensitive, if it is between 0.20-0.29, it is moderately sensitive, and if it is greater than 0.30, it is sensitive (Grissino-Mayer 2001; İrdem 2019). When Table 2 is examined, it is seen that it is moderately sensitive.

The width of the ring in a year t is affected by the rings formed in years t-1, t-2, t-3 , t-k. In other words, there is an autocorrelation between the current year t and the rings in previous years. To eliminate this autocorrelation and to see only the effects of year t on the annual ring series, autoregressive models are used. AR (Autoregreesive Models) model applies AR(1), AR(2),...AR(k) depends on the autocorrelation status of the annual rings that form the chronology. In this model, if AR(1) is applied, the chronology decreases by 1 ring from the end, when AR(2) is applied, it decreases by 2 rings, and when AR(3) is applied, it decreases by 3 rings. In dendrochronological studies, the ARSTAN program developed for this purpose constitutes the most appropriate model (Güner, 2010).

In Table 3, the correlations of individual chronologies within themselves and with all trees are given, and the obtained values are significant at the confidence level of 0.95 in the lower limit of Scots pine and 0.99 in other sites. On the other hand, the variance in the first eigenvector values, which show the power of climate data to explain the changes in annual ring width from year to year, are over 40% and are strong. Eigenvectors represent the original climate data and contain the same information as the original dataset. The most significant eigenvectors are expressed as principal components and account for most of the data variance. Insignificant eigenvectors explain low variances in the original data (Fritts, 1976; Köse, 2007).

Table 1. Information on the sample locations

Site Locations	Site Code	Tree/core number	Altitude	Slope ~	Aspect
Scots pine upper growth limit	KMSU	17/31	1004-1079	40%	S - SE
Scots pine lower growth limit	KMSL	18/22	173-241	30%	SW
Kazdağı Fir Upper growth limit	KMFU	16/28	1118-1166	40%	N - NE
Kazdağı Fir Lower growth limit	KMFL	15/26	529-540	40%	N
Black Pine Upper growth Limit	KMBU	15/26	969-1031	40%	SE
Black Pine Lower growth limit	KMBL	16/27	702-810	40%	SW

Table 2. Statistics of residual site chronologies

Sites	KMSU	KMFU	KMBU	KMSL	KMFL	KMBL
Residual	AR1	AR3	AR1	AR1	AR2	AR1
Mean	0.9779	0.9778	0.9997	0.9786	0.9873	0.9809
Median	0.9779	0.9626	1.0040	0.9996	0.9954	0.9732
Mean sensitivity	0.2179	0.2357	0.2312	0.1893	0.2121	0.2829
Standard deviation	0.1944	0.2033	0.1917	0.1711	0.1783	0.2387
Skewness	0.1329	0.2654	-0.0648	-1.1977	0.1049	0.4314
Kurtosis	0.0582	4.0394	0.0637	3.1005	0.0457	0.3371
Autocorrelations						
t=1	0.0641	-0.1215	-0.547	-0.1576	-0.0455	-0.0705
t=2	-0.0115	0.0123	0.0265	-0.2269	0.0678	-0.1185
t=3	-0.0095	-0.0005	-0.0036	0.1623	0.0586	0.0197

Table 3. Site chronology common time interval statistics

	KMSU	KMFU	KMBU	KMSL	KMFL	KMBL
			Mean correlations			
Between all radii	0.389	0.369	0.413	0.228	0.454	0.463
Between trees	0.389	0.389	0.409	0.207	0.455	0.447
Within trees	0.392	0.337	0.416	0.250	0.454	0.479
Radii vs mean	0.638	0.618	0.658	0.509	0.687	0.693
Agreement with population	0.718	0.761	0.580	0.343	0.625	0.617
Variance in the first eigenvector	42.01%	46.63%	44.47%	28.69%	48.23%	0.4938%

Dendroclimatological Results

In this section, the level of statistical significance $p<0.05$ is taken as the level of statistical significance in the interpretation of positive or negative relationships between climate data and tree ring width.

In the KMSU site chronology in Küre Mountains National Park, monthly average temperatures negatively affect ring growth in October of the previous year and May-October in the year of ring growth, and the increase in temperatures positively affects November and December of the last year and January- April in the year of ring growth.

No statistically significant relationship was found between temperature and tree-ring growth in any month. For KMSL site chronology, monthly average temperatures indicate that while October of the previous year and June, August and October of the current year negatively affected ring growth, temperature increases in November and December of the last year, January- April period of the current year and July and September were positive appears to affect it. The effect of temperature on tree-ring growth is insignificant in any month. In the KMFU site chronology, the increase in temperatures between October of the previous year and January-March of the current year affects ring growth positively and negatively affects November and December of the previous year and April - September of the current year. In May, the year of ring growth, the effect of temperature on ring growth is negatively significant. In the KMFL site, monthly average temperatures in October and November of the previous year and February, March, May and September of the current year negatively affected the ring growth, and the temperatures in December of the previous year and January, April, June, July, August and October of the current year increased. It positively affected the ring growth. In May, the effect of temperature on ring growth is negatively significant. In the KMBU site, annual rings are negatively affected by the temperatures in October of the previous year and in the May-October period of the current year; it is positively affected in November and December of the previous year and in January and April of the current year. However, the effect of temperature on tree-ring growth is insignificant in any month. In the KMBL site, the increase in temperatures between October and December of the previous year and January-April of the current year affected the ring growth positively, while it negatively affected the ring growth between November of the previous year and May-October of the current year. In April, the effect of temperature on ring growth was found to be positively significant (Figure 2).

In high elevations, where low spring temperatures generally parallel high precipitation levels, tree growth responses are shaped by low temperatures rather than drought, indicating that temperature is the primary determinant. On the other hand, precipitation plays a more selective role during the summer period.

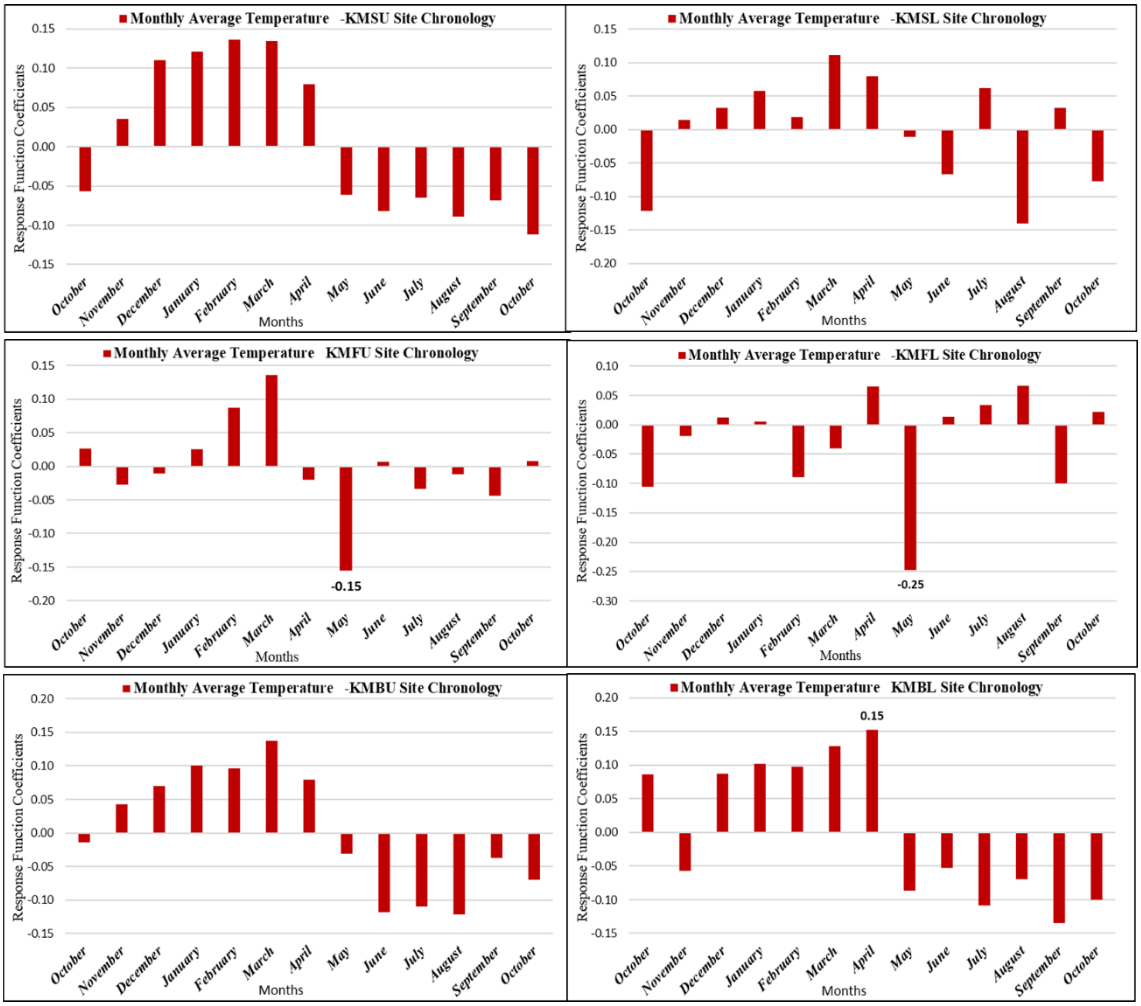

Figure 2. The response function results in the calculated temperature for the site chronologies

Total monthly precipitation for the KMSU site in the Küre Mountains National Park negatively affects the ring growth in October and November of the previous year and in January, February, September and October in the current year, while the precipitation between December of the previous year and March-August of the current year negatively affects the ring growth. The increase positively affected the ring growth. In the KMSL site, the increase in precipitation is negative for ring growth in October and November of the previous year and in January, February, May and October of the current year. It positively impacted December of the previous year and March, April, June, July and August of the current year. In the KMFU site, while the increase in precipitation in October and December of the previous year and in the March-August period of the current year affected the ring growth positively, it negatively affected the ring growth in November of the previous year and January, February, September and October of the current year. The relationship between June and July of the current year is positively significant. In the KMFL site, while the increase in precipitation in October and December of the previous year and in the March - July period of the current year affects the ring growth positively, it is observed that November of the previous year and January, February, September and October of the current year negatively affect it. The effect of total precipitation on ring growth is positively significant for June and July. For the KMBU site, the increase in precipitation in October and December of the previous year and in the March-August period of the current year has a positive effect on ring growth and a negative impact on ring growth in November of the previous year and in January, February, September and October of the current year. In the KMBL site chronology, the increase in precipitation in the October-December period of the previous year, the January - April period of the current year and the September-October months affected the ring growth negatively and positively in the May-August period. The effect of total precipitation on ring growth was positively significant for May, June and July (Figure 3).

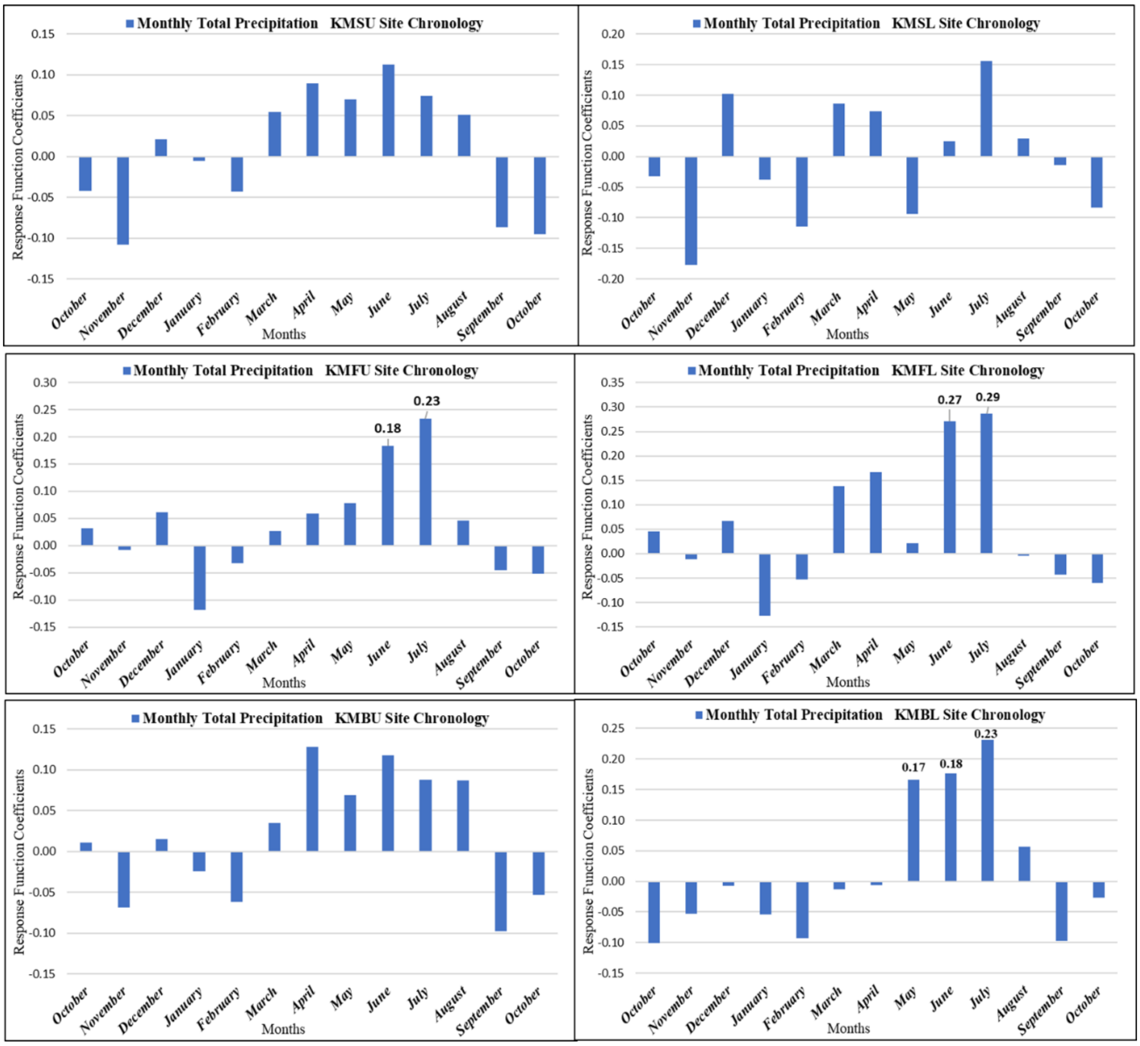

Figure 3. The response function results of precipitation calculated for the site chronologies

Possible Changes in Diameter Increment According to Climate Change Scenarios

"Climate change scenarios" generally refer to projected future climate changes under a particular climate model. Climate modeling tools are often used to more comprehensively evaluate the impacts of climate change scenarios on a particular region or species. These climate modeling tools can predict how diameter increments will respond under changing conditions based on specific climate scenarios. But generally, it is difficult to state a particular scenario's impact. Because many factors are effective. Variables such as temperature, precipitation amount and distribution, and tree species are considered among the effective factors to determine the effects of climate changes on the tree-ring growth. According to the RCP8.5 scenario, it is predicted that the warming in Türkiye will be around 3°C in the 2016-2040 period, especially in the spring and summer seasons (Akçakaya et al., 2015). It is noteworthy that there will be decreases in autumn precipitation throughout the country, decreases in the area where the study area is located in the west of the Mersin-Ordu line in the spring, and increases of up to 40% in summer precipitation in all coastal regions except the Western Mediterranean (Demircan et al. 2014). Trees at the upper growth limit in the study area are generally less tolerant of low temperatures. Projected 3 °C warming may provide more favorable conditions for these tree species. Since warming is predicted to occur primarily in the spring, this may start the vegetation period of trees earlier, positively affecting the diameter increment. Trees at the lower growth limit generally need more water. Projected decreases in autumn precipitation may create water shortages for these trees and may negatively affect their diameter increment. With decreases in spring precipitation, trees may experience water shortage at the beginning of the vegetation period. In this case, the diameter increment will be negatively affected. As a result of the increases in the summer months, trees will have more access to water, which will positively impact the diameter increment.

It is predicted that there will be an increase of 2-3°C in winter temperatures, 3-4°C in spring and autumn temperatures, and 5 °C in summer temperatures in the 2041-2070 period (Akçakaya et al. 2015). According to precipitation projections, while an increase is seen only in the Black Sea Region during the winter season, it is predicted that there will be decreases of up to 50% in the rest of the country, especially in the Mediterranean and Southeastern Anatolia regions (Gürkan et. 2016). There will be a decrease of around 20% in spring precipitation throughout the country except for the coastal Aegean and north-eastern Anatolia (Akçakaya et al. 2015). The increase in spring and autumn temperatures at the lower growth limit may cause a further extension of the vegetation period and a more extended diameter increment period. On the other hand, high summer temperatures will negatively affect the diameter increment for trees at the lower and upper growth limits.

In 2071- 2099, temperature increases exceeding 6 °C are expected in the last quarter of the century, especially in summer temperatures. However, it is predicted that temperature increases will reach 6 °C in the spring and autumn months, especially in Southeastern Anatolia, and that there will be an increase of 3-4°C in the west of the Trabzon-Mersin line and 4-5°C in the east of this line in the winter months (Akçakaya et al. 2015). According to precipitation projections, serious decreases are predicted throughout the period across the country (Gürkan et al. 2016). Trees at the lower growth limit generally prefer milder conditions. Increasing temperatures will increase evaporation for trees; water resources will be consumed faster, increasing the risk of drought and negatively affecting diameter increment. According to the scenario, the expected increase in summer precipitation in the Western Black Sea Region may increase soil moisture and provide suitable conditions for trees. It will positively affect the diameter increment.

To test the temporal stability of climate-growth relationships, a moving correlation analysis was conducted for climate variables that showed a statistically significant relationship with annual ring growth at a 0.95 confidence level. These variables included the March-April mean temperatures, the May-August mean temperatures, and the total precipitation for the May-August period.

Correlations indicating the relationship between March-April temperatures and growth have weakened over time across all sites. For the May-August temperature-growth correlations, an initial increase was observed during the 1933-2022 period, followed by a sharp decline. After a slight increase from 1983 to 2012, these correlations continued to decline. The relationship between May-August precipitation and annual ring growth exhibited a variable yet positive trend from 1933 to 2007. Although a decline was observed in the following period, statistically significant positive correlations between precipitation and growth remain, except for the KMSL site (Figure 4).

The results of the moving correlation analysis indicate a gradual decline in the influence of spring and summer temperatures on annual ring growth. This finding suggests that the projected positive impact on diameter growth under the RCP8.5 scenario may be constrained. In terms of precipitation, the analysis results reveal that although the positive effect of the anticipated increase in summer rainfall on growth in the Western Black Sea Region may diminish, it will likely remain significant (Figure 4).

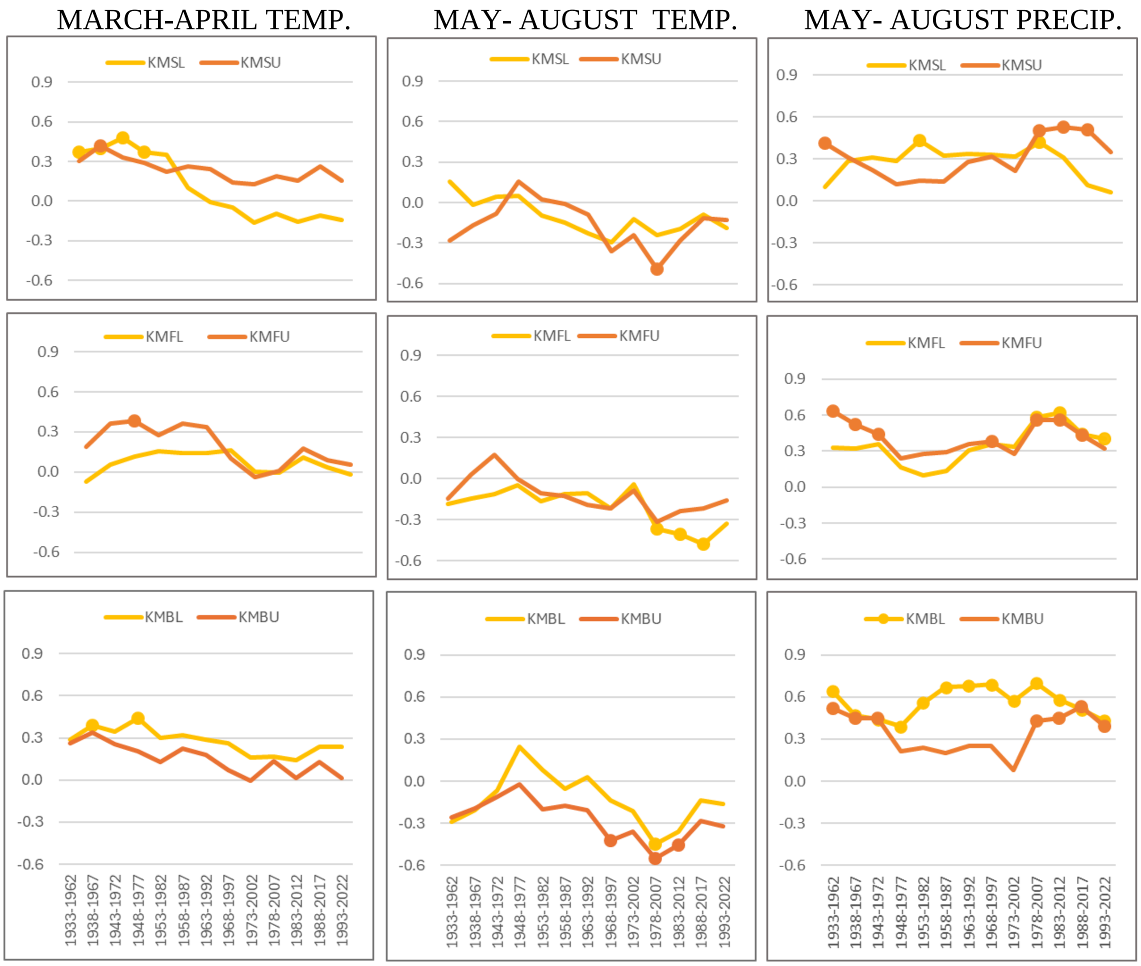

Figure 4. Results of moving window correlation analyses. Dots represent significant relations at $p \leq 0.05$

Discussion

Tree-ring growth on trees in the research area is positively affected by the increases in monthly total precipitation in June and July for all site all chronologies and negatively affected by November of the previous year and January, February, September and October of the current year. A negative relationship was determined between the previous year's October precipitation and the tree-ring growth in Scots pine's lower and upper growing limits. In their research on Bartın-Kumluca Scots pine trees, Yaman and Sarıbaş (2004) found a significant positive relationship between the July precipitation index and tree-ring growth. Köse et al. (2017) found that May-August rains positively affected ring growth in Scots pine trees around Bolu-Yedigöller. In their research on the southern border of Scots pine trees growing in Türkiye, Bozkurt et al. (2021) revealed that the precipitation in November of the previous year and in May and June of the current year had a positive effect on ring growth, and negatively affected it in January, April and September. For the lower and upper fir growing limits, only the effect of June and July precipitation on diameter increment is statistically significant. Dağdeviren (2002), in his study on Kazdağı fir growing in Kazdağı, found that there is a positive relationship between precipitation in May and August and the tree-ring width. Alkan & İrdem (2023) stated that precipitation in May and June positively affected the tree-ring growth of fir trees in all site chronologies, while precipitation in April and October negatively affected the tree-ring growth in all site chronologies. sWhen the relationships between precipitation and ring growth for black pines are examined, only May, June, and July are statistically significant for the lower limits of black pine. Akkemik (2000) stated that precipitation in spring and summer positively affects tree-ring growth. Doğan (2014) found that May-June precipitation positively affected tree-ring growth for black pines.

A positive relationship was found between the temperatures of November and December of the previous year and January - April of the current year in Scots pine. The increase in temperatures in June and August negatively affected ring growth. Similarly, Yaman and Sarıbaş (2004), as a result of their research on Bartın-Kumluca Scots pine trees, found a negative relationship in the June-August period and a positive relationship in the January-May period. In his study, İrdem (2019) revealed a positive relationship between January-April temperatures and tree-ring width in Scots pine trees on Elmacık Mountain. For the lower and upper growing limits of fir in the study area, the temperatures of November of the previous year and October of the current year negatively affected ring growth; the increase in temperatures in June and October positively affected ring growth. Dağdeviren (2002) found similar findings in his study on Kazdağı Fir. Accordingly, the temperature increase in February and March positively affects the tree ring width, while the temperature increase in July, August and September negatively affects the tree ring width. Alkan & İrdem (2023) found a negative relationship between the average temperatures of October of the previous year and the average temperatures between May and June of the current year and ring growth, and a positive relationship between the average temperatures of February, March and July and ring growth. For black pine, temperature affected the ring growth in the lower and upper growth limits negatively in the period from June to October and positively in the period between February and April. Similarly, Akkemik (2000) stated that the temperature in January and February negatively affects the tree ring growth, and Doğan (2014) said that high temperatures in February and May have a positive effect on the tree growth of black pine trees, and high temperatures in June and August have a negative impact.

According to the climate change scenarios relied on this study, increases are predicted for all seasons and annual average temperatures until 2100. Contractions in annual ring widths are expected due to the increase in plant water consumption, mainly due to the increase in summer temperatures. Kale (2020) emphasizes that the temperature increase in the Western Black Sea will reach 3.2 °C according to the reference values according to the RCP8.5 synthesis in the 2071-2100 period. Except for the 2015-2040 period, annual total precipitation is expected to increase between 52% and 67.4%. Particularly, the increase in precipitation can be expected to increase the annual ring development in the study area after 2040.

Conclusion

In this study, the relationships between tree-ring growth and temperature-precipitation conditions in Küre Mountains National Park were analyzed with the help of samples taken from the lower and upper growing limits of Scots pine, black pine and fir trees.

The study area has a positive relationship between precipitation and ring development in March-August. The positive effect of June and July precipitation is especially more pronounced. Precipitation-ring development correlations in the lower growing limit of Scots pine is very similar to each other. There are more irregular relationships in the lower increasing limit for Scots pine. Temperature-tree ring relationships are positive in all sites in spring. Increasing summer temperatures negatively affect annual ring development in the upper and lower growth limits of black pine and lower growth limits of Scots pine. According to RCP8.5 scenarios, the expected increase in summer temperatures and decrease in spring and summer precipitation until 2040 will seriously negatively affect the diameter increment in the study area.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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