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The effect of climate on tree-ring of Fir, Spruce, and Scotch pine in Karçal Mountains

Karçal Dağlarında iklimin Göknar, Ladin ve Sarıçam ağaç halkalarına etkisi

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Abstract

This study aims to analyze the effects of temperature and precipitation on tree-ring growth in the lower and upper growing borders of Scots pine (*Pinus sylvestris* L. subsp. *hamata*), Caucasian Fir (*Abies nordmanniana* (Stev.) Spach. subsp. *nordmanniana*) and Oriental Spruce (*Picea orientalis* L.carr.) in the Karçal Mountains (Artvin). This area hosts the first and pioneering biosphere reserve area of Türkiye in terms of biodiversity. This area is also one of the rare areas in Türkiye where Scots pine Fir and Spruce trees coexist. For dendrochronological analysis, 2 core samples were taken from each of the 15 trees using an increment borer from the lower and upper growth limits of Fir, scotch pine and Spruce. Tree-ring series are standardized. To reveal the statistical relationships between tree-ring growth and temperature and precipitation, Response functions were calculated separately for each site chronology. The rainy month of September has a positive effect on the tree-ring growth of Spruce. In the study area, a generally positive relationship was determined between July precipitation and the tree-ring growth for the lower and upper growing limits of Scots pine. In the study area, the precipitations of April and October affect the tree ring negatively for all regional chronologies, and May and June precipitation positively. The average temperatures between October of the previous year and May-June of the current year were negative; The positive relationship between the average temperatures of February, March and July and the growth of the ring predominates.

Özet

Bu çalışma, Karçal Dağları'nda (Artvin) Sarıçam (*Pinus sylvestris* L. subsp. *hamata*), Göknar (*Abies nordmanniana* (Stev.) Spach. subsp. *nordmanniana*) and Ladin (*Picea orientalis* L.carr.)'nin alt ve üst yetişme sınırlarında sıcaklık ve yağışın yıllık halka gelişimine etkisini incelemeyi amaçlamaktadır. Bu saha biyoçeşitlilik açısından Türkiye'nin ilk ve öncü biyosfer rezerv alanına ev sahipliği yapar. Burası aynı zamanda Türkiye'de Sarıçam, Göknar ve Ladin ağaçlarının bir arada bulunduğu ender yerlerden biridir. Dendrokronolojik analizler için Göknar, Sarıçam ve Ladin ağaçlarının alt ve üst yetişme sınırlarından artım burgusu kullanılarak 15'er ağaçtan 2'şer kalem örnek alınmıştır. Yıllık halka serileri standardize edilmiştir. Yıllık halka gelişimi ile sıcaklık ve yağış arasındaki istatistiksel ilişkileri ortaya çıkarmak için, Tepki Fonksiyonları her bölge kronolojisi için ayrı ayrı hesaplanmıştır. Eylül ayının yağışlı geçmesi Ladin yıllık halka gelişimine pozitif etki yapmaktadır. İnceleme alanında Sarıçamın alt ve üst yetişme sınırları için temmuz ayı yağışları ile yıllık halka gelişimi arasında genel olarak pozitif bir ilişki saptanmıştır. Çalışma alanında tüm yöre kronolojileri için Nisan ve Ekim yağışları yıllık halkayı olumsuz, Mayıs ve Haziran yağışları ise olumlu etkilemektedir. Sıcaklık yıllık halka ilişkileri analizi sonuçlarına göre önceki yılın ekim ayı ile halka oluşum yılının Mayıs Haziran ayının ortalama sıcaklıkları arasında negatif; Şubat, Mart ve Temmuz aylarının ortalama sıcaklıklar ile halka gelişimi arasında pozitif yönlü ilişki ağır basmaktadır.

INTRODUCTION

The science of geography thoroughly examines the relationships between human and natural environments. In doing so, it uses different research methods, which include dendrochronological methods. In dating of past historical and natural events, the climatically induced sequences of wide and narrow rings are used only to identify the year in which each ring was formed (Fritts 1976).

The scope of this study consists of dendroclimatological analyses on Fir, Scotch pine and Spruce samples taken from the Karçal Mountains. The deep and wide valleys that cut through the mountain ranges let the humid air of the Black Sea into the interior parts, allowing the growth of Scotch pines, especially in semi-arid areas (Atalay and

Efe 2015). The Scotch pines in the study area are partly mixed with Firs on the slopes of the valley where Ortaköy Stream is located. The Ardanuç and Şavşat basins on the north-facing foggy slopes of the Yalnızçam Mountains, as well as the upper parts of the Eastern Black Sea coastal range, are areas where Fir is joint. Pure communities occasionally form forests with mostly Spruce and rarely Scots pine (Atalay and Efe 2015). Oriental Spruce, generally expanding in Türkiye and the Caucasus builds forests in the Eastern Black Sea Mountains. It is primarily a dominant tree, forming pure or mixed stands with *Pinus sylvestris*, *Abies nordmanniana*, and *Fagus orientalis* on north-facing humid slopes at altitudes of 1000–2000 m (Eminağaoğlu 2018).

Temperature and precipitation are the most important reasons for the changes in the annual ring width from one year to the next (Dağdeviren 2004, Köse 2007). In order to examine the indirect or direct effect of precipitation on tree-ring growth, sampling from the lower borders of the forest gives more reliable results; on the other hand, it has a limiting effect as high precipitation causes fewer sunny and hot days, in other words, low temperatures. In general, the rings are wide in years when precipitation is high, and narrow in years when precipitation is low. Temperature is an important factor with precipitation, which is another important climatic variable, but in the opposite direction. The effect of temperature varies according to the conditions of the environment where the trees are located. High temperatures cause drought and narrow rings in the lower zones of a species (negative effect), while it has a positive effect in the upper zones of the same species (Akkemik 2004).

There are increasing numbers of studies on Scotch pines in the field of dendrochronology in Türkiye (Yaman and Sarıbaş 2004, Martin-Benito et al. 2016, Martin-Benito et al. 2018, İrdem 2019, Martin-Benito et al. 2020, Bozkurt et al. 2021, Özel et al. 2021). There are also studies on Fir and Spruce (Özkan 1990, Akkemik 2000, Dağdeviren 2002). According to the literature review, it has been thought that the fact that there is only one study (Martin-Benito et al. 2018) to compare these three different species in the same research would make this study meaningful in terms of its contribution to the field.

The aims of this study are (Figure 1) to establish tree-ring chronologies from the lower and upper growth limits of Scotch pine, Spruce, and Fir in the Karçal Mountains, (Figure 2) to comparatively analyze the relationships of temperature and precipitation with annual ring growth for the lower and upper growth borders.

RESEARCH AREA

Karçal Mountain, which forms the scope of the study and is located in the Eastern part of the Black Sea Region, remains in the colchic (Avcı 1993) part of the Euro-Siberian floral region (Figure 1). Karçal Mountain has created a particular area in terms of vegetation with its climate, soil, and relief features. There are zonal, intrazonal, and azonal soils on Karçal Mountain, a volcanic mass with rocks from the Paleozoic, Mesozoic, and Cenozoic periods are seen (Yılmaz 2016).

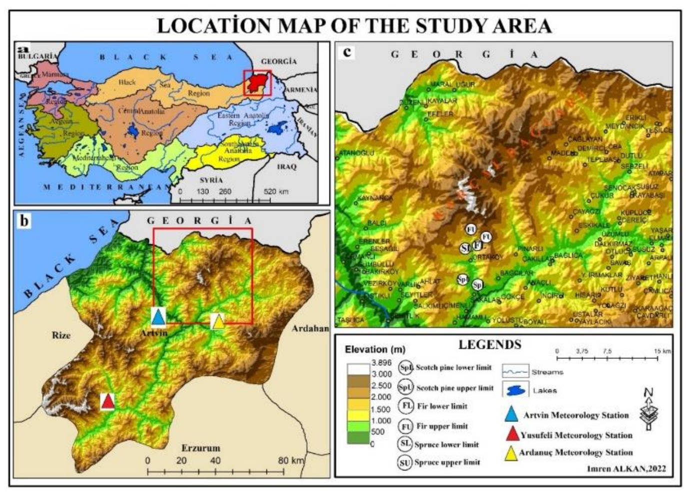

Figure 1. Location map of the study area

The annual average temperature is 13.6 °C at the Artvin station, located within the borders of the research area. The month with the lowest temperature is January (3.2 ºC), and the highest month is July (22.5 ºC). The annual average temperature at Ardanuç station is 14.1°C. The month with the lowest temperature is January (2.5 ºC), and the highest month is July (25.1ºC). The annual average temperature at Yusufeli station is 15.5 °C. The month with the lowest temperature is January (3 ºC), and the month with the highest is July (26.2 ºC). The total annual precipitation at Artvin station is 636.7 mm. The month with the lowest precipitation is October (18,4 mm) and the month with the highest is February (110.7 mm).

The total annual rainfall at Ardanuç station is 60.8 mm. The month with the lowest precipitation is October (0.1 mm), and the highest is February (11.6 mm). The annual total rainfall at Yusufeli station is 77.0 mm. The month with the lowest precipitation is June, and the highest is May (MGM 2020).

Study area hosts the Camili biosphere reserve area, which is Türkiye's first and pioneering biosphere reserve area in terms of biodiversity. It is located in the mountainous northeastern region of Türkiye. The total area of Camili Biosphere Reserve is 25.395 ha. The richness of water resources in the entire Camili basin (villages, hamlets, and plateaus) draws attention (Aydın and Türker, 2010).

MATERIAL AND METHODS

Data Collection

The monthly total precipitation and monthly average temperature data of Artvin (Center, Ardanuç, Yusufeli) meteorology stations were obtained from the Turkish State Meteorological Service and arranged. Information about the stations used in the study is presented in the Table 1.

Table 1. Information of the stations used in the study

	Station Information		
Station	**Artvin**	**Yusufeli**	**Ardanuç**
Latitude	41.1752N	40.8228N	41.1267N
Longitude	41.8187E	41.5464E	42.0653E
Altitude(m)	613	601	577
Measurement Period	1929-2021	1968-2021	1966-2021

Sample Area Selection and Taking Samples

Samples from the Karçal Mountains were taken from a total of six different sites from the lower and upper limits of the Forest. While the samples were taken, natural habitats were preferred, away from human influence, in accordance with dendrochronological studies. In this way, the effect of the climate has been revealed more accurately. Wounded or defective-bodied samples were not preferred when collecting samples.

Samples were taken from living trees from a height of 130 cm with the help of 40 and 50 cm Haglöf Increment Borers. 180 core samples were taken from 90 trees from 6 sites in the study area (Table 2, Figure 1b). Tree types, coordinates, elevation, latitude, longitude, elevation, slope and aspect characteristics of the areas were noted. Core samples were placed on wooden carriers after labeling the region code and tree number (In region coding, U represents the upper border, and A represents the lower border).

Table 2. Information of the sample locations.

Site name	Site code	Tree/ Increment core number	Latitude	Longitude	Altitude	Slope	Aspect
Scotch pine lower limit	KSA	13/22	41.48867N	45.67940E	825-860	70%	SE
Scotch pine upper limit	KSU	14/27	41.46990N	45.69612E	1732-1760	70%	SW
Caucasian Fir lower limit	KGA	7/13	41.14838N	41.56475E	1410-1470	30%	NE
Caucasian Fir upper limit	KGU	14/25	41.14708N	41.55760E	1891-1940	40%	E
Oriental Spruce lower limit	KLA	15/28	41.14818N	41.58387E	90-150	70%	N
Oriental Spruce upper limit	KLU	14/28	41.47355N	45.69689E	1700-1750	60%	NE

Tree-Ring Analyses

Before the measurement process, the core samples were sectioned 10-year by 10-year. Then, tree-ring widths were measured with a sensitivity of 0.01 in the LINTAB-TSAP measurement system and recorded as *.rwl in the TSAP-

WIN program. To test the measurements' reliability, the COFECHA (Holmes 1983, Grisino Mayer 2007) program was run, and the detected errors were revised and corrected. The site chronology did not include samples that couldn't have been corrected. Cross-dated tree-ring chronologies were standardized with ARTSAN program by fitting a 67% cubic smoothing spline with a 50% cutoff frequency (Cook 1985).

Tree Ring-Climate Relations

Four methods are commonly used to examine the similarities between the current climate records and the annual ring widths occurring in the same period. These are simple correlation coefficients, multivariate regression, stepwise multivariate regression, and response function methods (Fritts 1976, Akkemik 2004). The response function method was used in this study. Response functions were calculated separately for each site chronology using monthly total precipitation and monthly average temperature data from Artvin merkez, Yusufeli and Ardanuç stations. DENDROCLIM2002 program was used in the calculations (Biondi and Waikul 2004) and based on from October of the previous year to October of the current year, which was called the biological year (Fritts 1976).

RESULTS

Dendrochronological Findings

Within the scope of the study, a total of 6 site chronologies were created from the lower and upper borders of the southern parts of Karçal Mountains (Figure 1b). The preferred tree species for site chronologies are Scotch pine (*Pinus sylvestris*), Caucasian Fir (*Abies bornmuelleriana*), and Oriental Spruce (*Picea orientalis*).

When Figure 2 is examined, it is seen that the obtained site chronology lengths are 159 years at the Fir lower border (1863-2021), 163 years at the Fir upper border (1859-2021), 133 years at the Spruce lower border (1890-2021), 118 years at the Spruce upper border (1904-2021), 145 years at scotch pine lower border (1877-2021) and 98 years at scotch pine upper border (1914-2021) (Figure 2c).

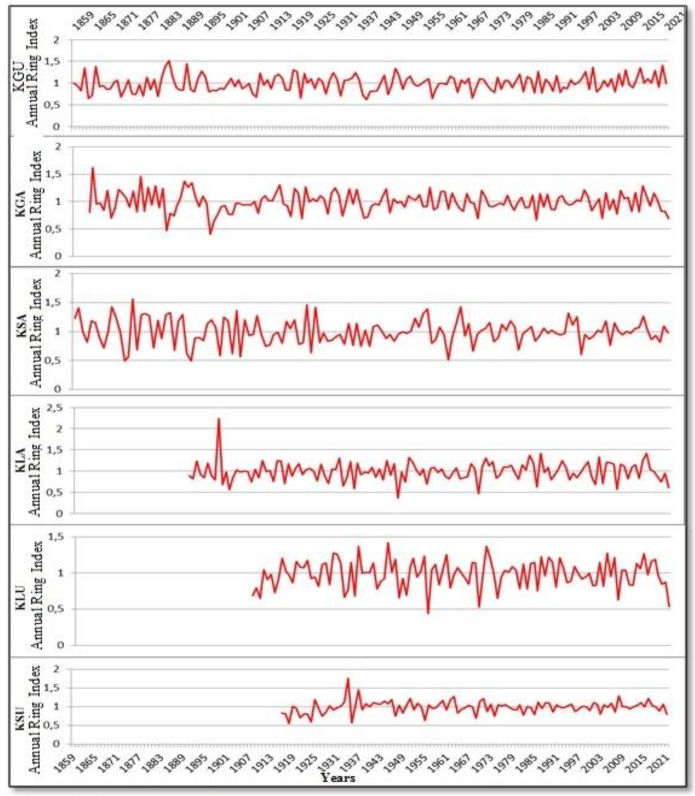

Figure 2. Site chronologies created from the samples taken from the research area

Lower Growth Border Chronologies of Scotch Pine, Fir, and Spruce Trees

30 core samples taken from 15 trees around Sakalar village in Artvin Province Merkez district for Scotch pine. 30 core samples taken from 15 trees around Ortaköy Village of Ortaköy Hamlet in Artvin Province Merkez district for Fir, and 30 core samples taken from 15 trees from Ortaköy Forests located around Dere Mahallesi within the borders of Ortaköy village for Spruce were used as a representation of the lower growth border. After the measurement errors were eliminated and the unsolved and broken samples were removed by running the COFECHA program, the KSA site chronology from 22 core samples taken from 13 trees representing Scotch pine, the KGA site chronology from 13 core samples from 7 trees representing Fir, and the KLA site chronology from 28 core samples from 15 trees representing Spruce were formed (Figure 2c). Statistical information on the lower growth border is presented in Table 3 and Table 4.

Table 3. Statistics of Scotch pine, Fir and Spruce samples for lower growth limit standard and residual site chronologies ("t" denotes the year in which the last ring was formed)

	KSA		KGA		KLA	
	Standard	**Residual (AR2)**	**Standard**	**Residual (AR2)**	**Standard**	**Residual (AR2)**
Mean	0,9908	0.9847	1.0081	1.0247	0.9674	0.9816
Median	0.9579	0.9811	0.9927	1.0039	0.9734	0.9965
Mean sensitivity	0.2023	0.1892	0.1868	0.1967	0.2269	0.2361
Standard deviation	0.2558	0.1769	0.35	0.3181	0.2391	0.2021
Skewness	0.3809	0.3764	6.2469	5.5556	-0.3113	-0.3107
Kurtosis	0.3422	0.6294	58.7108	34.8515	0.7389	0.0223
			Autocorrelations			
t-1	0.4976	0.009	0.1375	-0.1711	0.3391	0.0097
t-2	-0.0576	0.0494	0.0856	0.3451	0.1687	-0.0901
t-3	-0.0566	-0.2124	0.0267	-0.0108	-0.0073	-0.0773

Table 4. Site chronology common time interval statistics for the lower growth limit of scotch pine. Fir and Spruce samples

	KSA		KGA		KLA	
	Standard	**Residual**	**Standard**	**Residual**	**Standard**	**Residual**
		Mean correlations				
Between all radii	0.22	0.293	0.186	0.281	0.296	0.445
Between trees	0.211	0.282	0.161	0.262	0.278	0.434
Within trees	0.496	0.622	0.61	0.614	0.721	0.716
Radii vs mean	0.502	0.564	0.488	0.553	0.546	0.664
Signal-to-noise ratio	3.474	5.107	1.537	2.842	5.005	9.959
Agreement with population	0.776	0.836	0.606	0.74	0.833	0.909
Variance in first eigenvector	28.01%	34.10%	28.38%	34.97%	34.32%	47.88%
Chron common interval mean	0.998	1	0.981	0.986	1.008	1.004
Chron common interval std dev	0.221	0.172	0.158	0.139	0.231	0.203

Upper Growth Limit Chronologies of Scotch Pine, Fir, and Spruce Trees

30 samples taken from 15 trees from Sakalar Hamlet for scotch pine, 30 from 15 trees around Ortaköy Mountains for Fir, and 30 from 15 trees from Çakmaklı Forests for Spruce were used to represent the upper growing borders. After the measurement errors were eliminated and the unsolved and broken samples were removed by running the COFECHA program, the KSU site chronologies from 27 samples taken from 14 trees representing Scotch pine, the KGU site chronologies from 25 samples taken from 14 trees representing Fir, and the KLU site chronologies from 28 samples taken from 14 trees representing Spruce were created (Figure 2c). Statistical information on the upper growth border is presented in Table 3 and Table 4.

Table 5. Statistics of Scotch pine, Fir and Spruce samples for upper growth limit standard and residual site chronologies ("t" denotes the year in which the last ring was formed)

	KSU		KGU		KLU	
	Standard	**Residual (AR2)**	**Standard**	**Residual (AR2)**	**Standard**	**Residual(AR2)**
Mean	0.989	1.0002	0.9487	0.993	0.9762	9.896
Median	0.9773	1.0083	0.9546	0.9899	0.98	1.01
Mean sensitivity	0.1536	0.1405	0.1955	0.2213	0.2016	0.2179
Standard deviation	0.2093	0.1261	0.2679	0.187	0.2032	0.1919
Skewness	1.096	-0.26	0.1123	0.3042	-0.3178	-0.4071
Kurtosis	3.2119	0.8123	0.2774	-0.2294	-0.0632	-0.0127
			Autocorrelations			
t-1	0.4784	0.015	0.6671	-0.0693	0.2732	0.0296
t-2	0.1122	-0.0344	0.1061	-0.0845	0.0735	-0.1222
t-3	0.0969	0.06	0.1529	0.0056	0.0193	-0.0814

Table 6. Site chronology common time interval statistics for Scotch pine, Fir and Spruce upper growth limit samples

	KSU		KGU		KLU	
	Standard	**Residual**	**Standartd**	**Residual**	**Standard**	**Residual**
Mean correlations						
Between all radii	0.22	0.294	0.356	0.438	0.351	0.526
Between trees	0.203	0.282	0.34	0.428	0.337	0.518
Within trees	0.769	0.667	0.804	0.723	0.663	0.708
Radii vs mean	0.546	0.546	0.607	0.674	0.607	0.727
Signal-to-noise ratio	3.813	5.888	7.203	10.481	6.088	12.906
Agreement with population	0.792	0.855	0.878	0.913	0.859	0.928
Variance in first eigenvector	33.64%	34.17%	40.14%	47.14%	38.73%	54.96%
Chron common interval mean	0.988	1.001	0.974	0.996	0.999	0.991
Chron common interval std dev	0.139	0.117	0.219	0.167	0.186	0.187

Dendroclimatological Findings

Karçal (Sakalar) Scotch Pine Lower Border (KSA) For Temperature

According to the response function coefficients, no significant relation was found between the monthly average temperature and tree-ring growth at Artvin, Yusufeli, and Ardanuç stations (Figure 2b). On the other hand, in all three stations, the monthly average temperature has a negative impact in the month of October of the previous year and in June of the current year. It was determined that the increase in temperature in November and December of the previous year and in February, March and July of the current year affected the tree-ring growth positively.

Karçal (Sakalar) Scotch Pine Upper Border (KSU) For Temperature

In Artvin Station, the monthly average temperature negatively affects tree-ring growth in the months of November and December of the previous year and in May, June, September, and October of the current year of ring formation. The increasing temperatures in October of the previous year and in January, February, March, April, July, and August of the currnet year of ring formation increased tree-ring growth (Table 7).

In Yusufeli Station, the monthly average temperature has a negative effect on tree-ring width in the months of October and December of the previous year and the months of January, May, June, and October of the current year. Increased temperature in November of the previous year and in February, March, April, July, and August of the current year increased tree-ring growth. March has a significantly positive effect on tree-ring width, while May has significantly negative (Table 7).

In Ardanuç Station, the monthly average temperature negatively affects ring width in the months of October of the previous year and in January, May, June, August, and October of the current year. It was determined that the increase in temperature in November and December of the previous year and in February, March, April, July, and September of the current year increased the ring growth (Table 7).

Karçal (Ortaköy) Fir Lower Border (KGA) For Temperature

According to the response function correlation coefficients, no significant relationship could be found between the monthly average temperature and ring growth at Artvin, Yusufeli, and Ardanuç stations (Table 7). On the other hand, in all three stations, the monthly average temperature has a negative impact in the month of October of the previous year and in May of the current year. It was determined that the increase in temperature in December of the previous year and in March, April and July of the current year affected the tree-ring growth positively.

Karçal (Ortaköy) Fir Upper Border (KGU) For Temperature

In Artvin Station, the monthly average temperature negatively affects the months of May, August, September, and October of the current year. The increase in temperature in the months of October, November, and December of the previous year and in January, February, March, April, June, and July of the current year of ring formation increases the ring growth (Table 7).

In Yusufeli Station, the monthly average temperature negatively affects tree-ring width in the months of October of the previous year and in May, June, and October of the current year (Table 7).

In Ardanuç Station, the monthly average temperature negatively affects width in the month of October of the previous year and in January, May, June, August, and October of the current year. It has a positive effect in November, December, February, March, April, July, and September of the previous year (Table 7).

Karçal (Ortaköy) Spruce Lower Border (KLA) For Temperature

No significant relationship was found between the monthly average temperature and ring growth at Artvin and Yusufeli stations (Table 7).

In Ardanuç Station, it is seen that the monthly average temperature negatively affects the months of October and December of the previous year and the months of January, February, April, May, June, and August of the current year (Table 7).

Karçal (Ortaköy) Spruce Upper Border (KLU) For Temperature

There is no significant relation between the monthly average temperature and the tree-ring growth at Artvin station (Table 7).

In Yusufeli Station, the monthly average temperature has a negative effect in the months of October, November, and December of the previous year and in January, May, and July of the current year. It was determined that the increase in temperature in February, March, April, June, August, September, and October of the current year affected the tree-ring growth positively (Table 7).

In Ardanuç Station, the monthly average temperature has a negative impact in the months of October and December of the previous year and in January, August and June of the current year. It was determined that the increase in temperature in November of the previous year and in February, March, April, July, September, and October of the current year affected the tree-ring growth positively (Table 7).

Karçal (Sakalar) Scotch Pine Lower Border (KSA) For Precipitation

In Artvin Station, the monthly total precipitation has negative effects in the months of April and October of the current year. The increase in precipitation in October, November, and December of the previous year and in January, February, March, May, June, July, August, and September of the current year affected the ring growth positively (Table 7).

In Yusufeli Station, monthly total precipitation negatively affects tree-ring growth in December of the previous year and April, August, September, and October of the year of ring formation. The increase in precipitation in October and November and in January, February, March, May, June, and July of the year of ring formation affected the ring growth positively. Monthly total precipitation is negative effects in the months of December of the previous year and April, August, September, and October of the current year of ring formation (Table 7).

In Ardanuç Station, the monthly total precipitation negatively affects tree-ring growth in the months of November and December of the previous year and February, March, April, September, and October of the current year. It has a positive effect in October of the previous year and in January, May, June, July and August of the current year. (Table 7).

Karçal (Sakalar) Scotch Pine Upper Border (KSU) For Precipitation

In Artvin Station, the monthly total precipitation negatively affects tree-ring growth the months of April and October of the current year. It has a positive effect in the months of October, November and December of the previous year and in January, February, March, May, June, July, August, and September of the current year. June and July are positively significant (Table 7).

In Yusufeli Station, the monthly total precipitation negatively affects ring growth in December of the previous year and in April, September and October of the current year. On the other hand, it positively affects tree-ring growth in the months of October and November of the previous year and in January, February, March, May, June, and July of the current year (Table 7).

In Ardanuç Station, the monthly total precipitation negatively affects tree-ring growth in the months of November and December of the previous year and February, March, April, September and October of the year of ring formation. It has a positive effect in October of the previous year and the months of January, May, June, July and August of the current year. April is negative and June is positively significant (Table 7).

Karçal (Ortaköy) Fir Lower Border (KGA) For Precipitation

In Artvin Station, the monthly total precipitation negatively affects tree-ring growth in the months of November of the previous year and April and October of the current year. Increasing precipitation in October and December of the previous year and in January, February, March, May, June, July, August, and September of the ring formation year increased the ring growth (Table 7).

In Yusufeli Station, the monthly total precipitation at negatively affects tree-ring growth in December of the previous year and January, April, and October of the current year. Increasing precipitation in October, November, February, March, May, June, July, August, and September of the previous year affects it positively. May and June are positively significant (Table 7).

In Ardanuç Station, the monthly total precipitation negatively affects ring width in November and December of the previous year and in February, April, September, and October of the current year. Increasing precipitation in October of the previous year and in January, March, May, June, July, and August of the current year affects it positively. Relations in May are positively significant (Table 7).

Karçal (Ortaköy) Fir Upper Border (KGU) For Precipitation

In Artvin Station, the monthly total precipitation adversely affects the tree-ring growth in the months of October, November and December of the previous year and in February, April, August, September and October of the current year. The increase in precipitation in January, March, May, June, and July of the current year positively affects tree-ring growth. May is positively significant (Table 7).

The monthly total precipitation in Yusufeli Station negatively affects ring width in the months of October and November of the previous year and in January, February, March, April, June, August, September, and October of the current year. The increase in precipitation in October of the previous year and in May and July of the current year increased the ring growth. April is negative, and May is positively significant (Table 7).

In Ardanuç Station, the monthly total precipitation negatively affects tree-ring growth in the months of October, November, and December of the previous year and February, March, April, July, August, September, and October of the current year. Increasing precipitation in the current year's January, May, and June affects ring growth positively. February, April, and September are negatively significant (Table 7).

Karçal (Ortaköy) Spruce Lower Border (KLA) For Precipitation

In Artvin Station, the monthly total precipitation negatively affects tree-ring growth in the month of November of the previous year and in April, July, August, and October of the current year. Increasing precipitation in October and December of the previous year and in January, February, March, May, June, and September of the current year affects the ring growth positively. May and June are positively significant (Table 7).

The monthly total precipitation *in Yusufeli Station*, negatively affects ring width in December of the previous year and in December, January, March, April, July, August, and October of the current year. Increasing precipitation in October and November of the previous year and in February, May, June, and September of the current year affects the ring growth positively. May and June are positively significant (Table 7).

In Ardanuç Station, the monthly total precipitation negatively affects tree-ring growth in November of the previous year and in February, March, April, August, and October of the current year. The increase in precipitation in November of the previous year and in January, May, June, and July of the current year positively affect the ring width. May and June are positively significant (Table 7).

Karçal (Ortaköy) Spruce Forest Upper Border (KLU) For Precipitation

In Artvin Station, the monthly total precipitation negatively affects tree-ring width in November of the previous year and April, August, and in October of the current year. The increase in precipitation in October and December of the previous year and in January, February, March, May, June, July, and September of the current year has positively affected ring growth. May and June are positively significant (Table 7).

The monthly total precipitation in *Yusufeli Station* negatively affects ring width in the months of January, April, August, and October of the current year. The increase in precipitation in October, November, and December of the previous year and in February, March, May, June, July, and September of the current year affects ring growth positively. April is negative, and May is positively significant (Table 7).

Ardanuç Station, the monthly total precipitation negatively affects tree-ring growth in November of the previous year and March, April, August, and October of the current year. The increase in precipitation in October and December of the previous year and in January, February, May, June, July, and September of the current year affects ring growth positively. May and June are positively significant (Table 7).

Table 7. Summary of the response function results calculated for the site chronologies created within the scope of the research (blue colors show the months with a significant effect in the positive direction and red colors are negative at the 95% confidence level)

Code	Station	Total Precipitation													Average Temperature												
		O	N	D	J	F	M	A	M	J	J	A	S	O	O	N	D	J	F	M	A	M	J	J	A	S	O
KSA	Artvin	+	-	-	+	-	+	-	+	+	+	-	-	-	-	+	+	+	+	+	-	-	-	+	-	-	-
	Yusufeli	+	-	-	-	+	+	-	+	+	+	-	-	-	-	+	+	-	+	+	+	+	-	+	+	+	+
	Ardanuç	+	-	-	+	-	+	-	-	+	-	+	-	-	-	+	+	-	+	+	-	-	-	+	-	+	-
KSU	Artvin	+	+	+	+	+	+	-	+	+	+	+	+	-	+	-	-	+	+	+	+	-	-	+	+	-	-
	Yusufeli	+	+	-	+	+	+	-	+	+	+	-	-	-	-	+	-	-	+	+	+	-	-	+	+	+	-
	Ardanuç	+	-	-	+	-	-	-	+	+	+	+	-	-	-	+	+	-	+	+	+	-	-	+	-	+	-
KGA	Artvin	+	-	+	+	+	+	-	+	+	+	+	+	-	-	+	+	+	+	+	+	-	-	+	+	-	+
	Yusufeli	+	+	-	-	+	+	-	+	+	+	+	+	-	-	-	+	+	-	+	+	-	+	+	+	+	+
	Ardanuç	+	-	-	+	-	+	-	+	+	+	+	-	-	-	-	+	-	+	+	+	-	-	+	-	+	+
KGU	Artvin	-	-	-	+	-	+	-	+	+	+	-	-	-	+	+	+	+	+	+	+	-	+	+	-	-	-
	Yusufeli	-	-	+	-	-	-	-	+	-	+	-	-	-	-	+	+	+	+	+	+	-	-	+	+	+	-
	Ardanuç	-	-	-	+	-	-	-	+	+	-	-	-	-	-	+	+	-	+	+	+	-	-	+	-	+	-
KLA	Artvin	+	-	+	+	+	+	-	+	+	-	-	+	-	-	+	-	-	+	+	+	-	-	+	+	+	+
	Yusufeli	+	+	-	-	+	-	-	+	+	-	-	+	-	-	-	+	-	+	+	+	-	-	+	+	+	+
	Ardanuç	+	-	+	+	-	-	-	+	+	+	-	+	-	-	+	-	-	-	+	-	-	-	+	-	+	+
KLU	Artvin	+	-	+	+	+	+	-	+	+	+	-	+	-	-	-	-	+	-	+	+	+	-	+	-	+	-
	Yusufeli	+	+	+	-	+	+	-	+	+	+	-	+	-	-	-	-	-	+	+	+	-	+	-	+	+	+
	Ardanuç	+	-	+	+	+	-	-	+	+	+	-	+	-	-	+	-	-	+	+	+	-	-	+	-	+	+

DISCUSSION AND CONCLUSION

In the study area, precipitation in April and October affects the annual ring growth negatively for all site chronologies, and precipitation in May and June affects it positively. The effect of the previous year's October precipitation on the ring growth is positive except for the fir upper border; however, it is not statistically significant. The positive effect of September precipitation on Spruces is remarkable (Table 7). İrdem (2019), in his study on Scotch pines, showed that the precipitation of the February-August period positively affected the ring growth and negatively affected the precipitation of October-November of the previous year. Bozkurt, Şahan, and Köse (2021), in their research on the growing southern border of Scotch pines in Türkiye, determined that the precipitation of May and June had a positive effect on the ring growth and the precipitation of November of the previous year and January, April and September of the ring formation year had a negative impact on it.

In the study area, a generally positive relationship was determined between the precipitation in July and the annual ring growth for the lower and upper growing border of scotch pine. When the relationships between precipitation and tree ring growth in three cite stations created for Taurus Fir were examined. Dağdeviren (2002) found that there was a positive relationship between precipitation and annual ring width in May and August in his study on Kazdağı Fir growing in Kazdağı. Yaman and Sarıbaş (2004) found a significant positive relationship between the July precipitation effectiveness index and annual ring growth due to their research on Bartın-Kumluca Scotch pines. Kose et al. (2017) reported that May-August precipitation positively affected the ring growth of Scotch pines around Bolu-Yedigöller and Firs and Spruces around Artvin-Borçka.

According to the annual temperature-ring relations analysis results, a negative relationship exists between average temperatures in October of the previous year and May-June of the ring formation year predominates. A positive relationship between the average temperatures of February, March, and July and ring growth prevails. Similarly, Dağdeviren (2002), in his research on Kazdağı Fir growing in Kazdağı, found that between October of the previous year and May and August of the year of ring formation, there was a positive effect between annual ring growth and temperature, and a negative impact in June, July, and September. Yaman and Sarıbaş (2004), as a result of their research on Bartın-Kumluca Scotch pines, found a negative relationship between June and August and a positive relationship between January and May. Köse et al. (2017) stated that there was a strong positive relationship between the average temperatures in March and the ring growth of Scotch pines around Bolu-Yedigöller and Firs and Spruces around Artvin-Borçka. In their study on Scotch pines, İrdem (2019), in his research on Scotch pines in Elmacık Mountain, determined that there was a positive relationship in the average temperatures of the January-April period when the annual ring width and temperature relations were evaluated. Bozkurt, Şahan and Köse (2021), as a result of their studies on the southern borders of scotch pines in Türkiye, determined that there was a positive relationship in March and April and a negative relationship in May. Martin-Benito et al. (2016) have developed four new treering width chronologies from the lesser Caucasus in northeastern Türkiye from a Broadleaf species (*Q. petraea*) and three Conifers (*P. pinea, A. nordmanniana, and P. orientalis*). These new sites constitute the most drought sensitive tree ring width chronologies for the area to date. All five species used (including *Pinus sylvestris*) were important in developing a precipitation reconstruction for the spring and early summer. Köse and Hüner (2012) determined in tehir sutdy for intra-annual radial growth of *Fagus orientalis* Lipsky in Artvin that the most distinctive eff ect of temperature on tree-ring growth occurred with maximum temperature. High mean and minimum temperatures in the period of March to July (especially in May) resulted in growth early in the growing season and wide earlywood, latewood, and total ring formation. Martin-Benito et al. (2018) found that growth responses to precipitation and drought among species were more similar than they were to temperature, even at humid sites, providing further evidence of drought vulnerability in mesic forestsin in the temperate forests of the Caucasus. The productivity of high-elevation conifer forests, limited by summer drought and low temperatures, will depend on the balance between temperature and precipitation. Martin-Benito et al. (2018) investigated for the first time the structure, natural disturbance, and recruitment dynamics of a mixed Colchic old-growth rainforest, dominated by *Fagus orientalis* and *Picea orientalis*. Acording to results of theit study, Spruces were the oldest (up to 427 years) and fastest growing trees in the forest, suggesting that their low presence in the forest is due to low disturbance rates that limit their recruitment. Özel et al (2021) determined that while higher rains in July and higher temperatures in the late winter early spring have caused the wider growth rings, the narrower growth rings have been formed in the years with higher maximum temperatures in August in the isolated coastal site of Scots pine in Bartın.

Özkan (1990) found that the sensitivity coefficients were low (0.11) due to his analyses of the oriental Spruce samples taken from Artvin Borçka. The sensitivity coefficients of the samples taken in our study (Spruce lower border: 0.23, upper Spruce boundary: 0.21) are pretty high compared to the study mentioned above, which increases the importance of the study.

In conclusion, the effects of temperature in the spring and precipitation in the summer are visible in the annual ring development of Scotch pine and Spruce. These results also indicate that the research area has the potential to make retrospective climate forecasts using dendrochronological methods in future studies. The study can be strengthened with site chronologies to be created by taking samples from several species and older trees in the research area and its surroundings. Since institutional climate records couldn't go very far back, dendrochronological studies can be used when making local assessments of global climate change studies.

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