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Annual Mean Total Precipitation Reconstruction of the Elmacık Mountain and Its Surroundings for 1858-2015 Using Scotch Pine Tree Rings

Sarıçam Yıllık Halkaları Kullanılarak Elmacık Dağı ve Yakın Çevresinin 1858-2015 Dönemi Yıllık Toplam Yağış Rekonstrüksiyonu

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ABSTRACT
The present study aims to use dendrochronological methods to reconstruct the precipitation history of Elmacık Mountain of Northwest Türkiye and its immediate surroundings. This research is the first dendroclimatological study in Türkiye regarding total annual precipitation reconstruction in the current literature. The study created three Scotch pine (Pinus sylvestris L. ssp. hamata) site chronologies (214-, 233-, and 248-year spans) using samples from Elmacık Mountain before combining the site chronologies into one regional chronology. The study calculated relations between this regional chronology and the total annual precipitation data of the Bolu, Düzce, and Sakarya meteorological stations using Pearson's correlation coefficient. As the results are statistically suitable for reconstructing the total annual precipitation data in Bolu and Düzce, the total rainfall reconstruction of these stations was carried out over a 158 year span from 1858-2015. Low- and high-precipitation years were also revealed for 1858-1950 when the stations were not in operation. Accordingly, the years in which the annual total precipitation was at least one standard deviation unit below the average for both stations were 1860-1861, 1875, 1878, 1887, 1893, 1904-1905, 1907, 1909, 1935, 1942, 1945, and 1949. Meanwhile, 1865, 1873, 1877, 1885, 1910, 1912-1914, 1917, 1919, 1922, 1939-1940 were the years when the total annual rainfall was at least one standard deviation unit above the average. In 1901 and 1936, total annual rainfall was two standard deviations above average.
Keywords: Dendrochronology, precipitation, Scotch pine

ÖZ
Bu çalışma, Türkiye'nin kuzeybatısında yer alan Elmacık Dağı ve yakın çevresi için dendrokronolojik yöntemlerle yağışın geriye dönük yapılandırılmasını amaçlamaktadır. Bu çalışma, yapılan literatür taramasına göre yıllık toplam yağış rekonstrüksiyonu açısından Türkiye'de ilk dendroklimatolojik çalışmadır. Çalışmada Elmacık Dağı'ndan örneklerle 3 sarıçam (*Pinus sylvestris* L. ssp. *hamata*) yöre kronolojisi (214, 233 ve 248 yıllık) oluşturulmuştur. Ardından yöre kronolojileri birleştirilerek bir bölgesel kronolojiye dönüştürülmüştür. Bu bölgesel kronoloji ile Bolu, Düzce ve Sakarya meteoroloji istasyonlarının yıllık toplam yağış verileri arasındaki ilişkiler Pearson korelasyon katsayısı yöntemi kullanılarak hesaplanmıştır. Sonuçlar Bolu ve Düzce yıllık toplam yağış verileri için istatistik açıdan rekonstrüksiyon yapmaya uygun bulunduğundan, bu istasyonların yıllık toplam yağışlarının 158 yıllık (MS 1858-1915) geriye dönük tahmini yapılmış, aletsel dönem öncesi (1858-1950) az yağışlı ve yağışlı yıllar belirlenmiştir. Buna göre 1860-1861, 1875, 1878, 1887, 1893, 1904-1905, 1907, 1909, 1935, 1942, 1945 ve 1949 yılları ortalamadan en az bir standart sapma az yağışlı; 1865, 1873, 1877, 1885, 1910, 1912-1914, 1917, 1919, 1922 ve 1939-1940 yılları ortalamadan en az bir standart sapma çok yağışlı yıllar olarak belirlenmiştir. 1901 ve 1936 yıllarında yıllık toplam yağış, ortalamanın en az 2 standart sapma üzerindedir.
Anahtar kelimeler: Dendrokronoloji, yağış, sarıçam

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1. INTRODUCTION

Recent climate change-related events have shifted the scientific community's focus toward reconstructing past climate to explore climate dynamics in detail (Kostakova et al., 2018; Tamkevičiūtė et al., 2018). The climate parameters of temperature and precipitation show distinct characteristics at the global level. A temperature rise has been observed in almost every part of the globe, while precipitation shows heterogenic behavior due to differences in relief patterns. Therefore, precipitation analysis is considered more important at the regional level (Belokopytova et al., 2018).

Rainfall cycles are critical to understanding precipitation systems and predicting the future (Yılmaz et al., 2021). Tree-ring chronologies built from living and dead trees offer valuable information for understanding different aspects of natural and human history, ranging from archeological dating to past climate conditions (Ljungqvist et al., 2020). The instrumental recording of meteorological data in Türkiye does not cover an extensive period. Even the oldest meteorological stations have no records over 100 years. According to the literature review, dendroclimatological precipitation reconstructions in Türkiye cover certain months or periods of the year (D'arrigo & Cullen, 2001; Touchan et al., 2003; Akkemik & Aras, 2005; Akkemik et al., 2005, Köse et al., 2011; Köse et al., 2013; Martin-Benito et al., 2016).

Some studies are found to have revealed the relationships between temperature and precipitation conditions through the annual ring development of Scotch pines in Türkiye (Yaman & Sarıbaş 2004, Köse at al. 2017, Bozkurt et al. 2021, Özel et al. 2021, Alkan & İrdem 2023). When considering the common results of these studies, the increase in temperatures in the March-April period and in precipitation in the May-June period are seen to have positively affected the annual ring development of Scotch pines.

The present study aims to create climate-sensitive chronologies for Elmacık Mountain and its immediate surroundings using Scotch pine trees' growth rings and to reconstruct the research area's annual total rainfall data. Bolu, Sakarya, and Düzce meteorological stations are the ones with long-term data in and around Elmacık Mountain. The resulting correlation coefficients and other statistical results were unsuitable for reconstructing the Sakarya station's data. Therefore, retrospective precipitation predictions were made for the Bolu and Düzce stations. The study's results are further compared with those of other studies. According to the authors' best knowledge, no previous studies are found regarding the reconstruction of total annual precipitation in Türkiye, which makes this research very important. The number of Scotch pine chronologies created in previous research in Türkiye has also been determined to be quite limited. Therefore, reconstructions

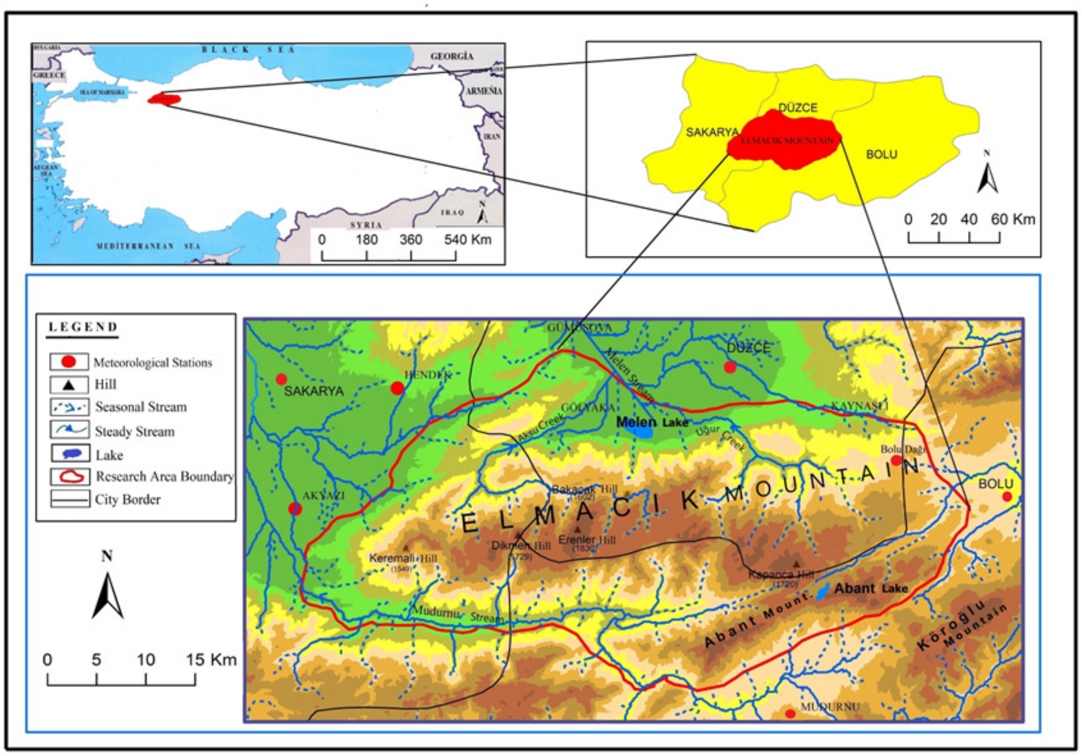

Figure 1. Location map of the research area.

Table 1: Site Information Where Samples Were Collected

Site code	Site name	Species	Core/Tree number	Slope (%)	Aspect	Elevation (m)	Latitude (N)	Longitude (E)
CIG	Çiğdem	*Pinus sylvestris*	54/27	20	SE	1430	40° 39′	30° 50
BAL	Balıklı	*Pinus sylvestris*	40/21	25	S	1366	40° 38′	31° 02
SIN	Sinekli	*Pinus sylvestris*	49/26	15	S	1358	40° 37′	31° 18

using annual ring chronologies made from old trees in the research area would be helpful for palaeoclimatological analyses.

Description of the Study Area

Elmacık Mountain is located in Northwest Türkiye, east of the Çatalca-Kocaeli section of the Marmara Region and west of the Western Black Sea section of the Black Sea Region within the borders of Sakarya, Düzce, and Bolu provinces. The mountain covers an area of 1,582 square kilometers. The approximate distance from west to east is 75 km and about 35 km from north to south (Figure 1).

The mountains span east to west in the research area, following the general span of mountains in Türkiye. This makes inhibits the humid air masses of the Black Sea from passing to the southern parts of the mountain. As a result, the northern slopes are more humid than the south, with a minor temperature difference between summer and winter. The elevation in the study area exceeds 1,800 meters, with Erenler Hill being at 1,830 meters. This situation causes temperature and precipitation conditions to change rapidly over a short distance in the area. For example, the average annual temperature of Düzce is 13.3 ºC, which decreases to 8.7 ºC at the Bolu Mountain meteorological station.

The northwestern slopes of Elmacık Mountain, which extend perpendicular to the direction of the air masses, receive more precipitation. Bolu meteorological station, located at an altitude of 740 meters on the eastern side of the mountain, has a total annual precipitation of 553.9 mm. However, the total annual precipitation of the Bolu Mountain meteorological station, which is located at an altitude of 901 meters on the northwestern slope of the mountain, is 1,057.8 mm.

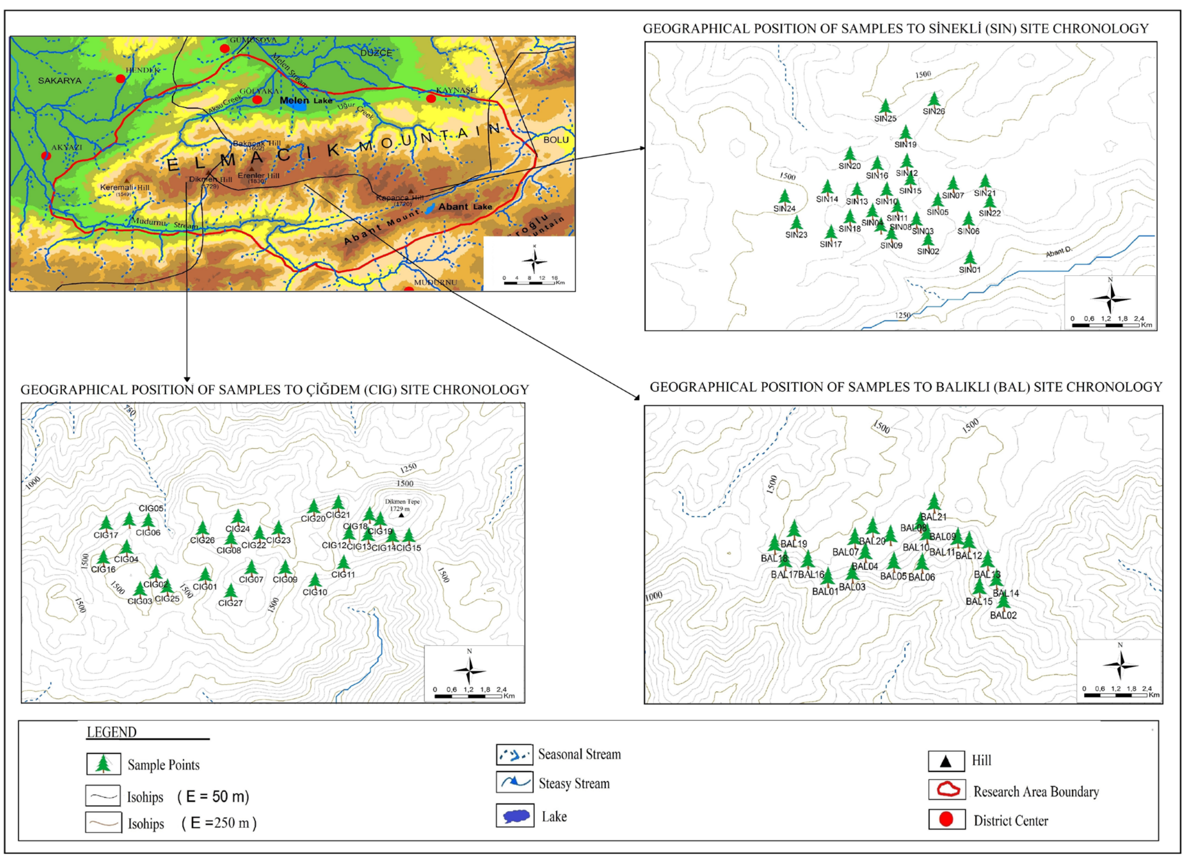

Figure 2. Map representation of sampled points.

2. METHODOLOGY

2.1. Data Collection

2.2.1. Preparing the Meteorological Data

The Sakarya, Akyazı, Düzce, Hendek, Bolu, Mudurnu, and Bolu Mountain meteorological stations have measurements on Elmacık Mountain and its immediate surroundings (Figure 1). The data from the station apart from Bolu, Düzce, and Sakarya are too short or are incomplete. The study gathered the Bolu, Sakarya, and Düzce meteorological stations' rainfall data from the Turkish State Meteorological Service. The homogeneity of the data was tested using the Kruskal-Wallis homogeneity test.

2.2.2. Annual Ring Chronologies Development

For the dendrochronological analyses, samples were taken from the appropriate places in the research area with incremental borers by identifying suitable trees. In this context, three site chronologies have been created: the Çiğdem Site Chronology (CIG), which consists of 54 cores taken from 27 trees around Çiğdem Plateau in Hendek, Sakarya, the Balıklı Site Chronology (BAL) consisting of 40 cores taken from 21 trees from the vicinity of Balıklı Plateau in Düzce, and the Sinekli Site Chronology (SIN) consisting of 49 cores taken from 26 trees from around Sinekli Plateau in Mudurnu, Bolu (Table 1, Figure 2). Afterward, these three site chronologies were combined by considering their agreement to obtain the Elmacık Regional Chronology (ELM), consisting of 143 cores taken from 74 trees. The regional chronology was created using the program CRONOL (Holmes, 1992). The biweight robust mean method was chosen for this process (Cook et al., 1990). This method is very effective and very complex to calculate, with the details explained by Cook et al. (1990; as cited in Köse, 2007).

Samples were usually taken from a height of 130 cm above the ground. Two cores were sampled from each tree. The study preferred Scotch pines (*Pinus sylvestris L*. ssp. *hamata*) due to their suitability for dendrochronological analysis and the number of aged samples in the field.

2.2.3. Method

Incremental cores were measured in the Dendrochronology Laboratory of the Istanbul University Cerrahpasa Forestry Faculty. Samples were sanded so that the ring boundary could be seen more clearly. Tree-ring widths were measured at a precision of 0.01 mm using the LINTAB™ and TSAP-Win™ measurement system, with the measurement results being recorded as files with the extension *.rwl in the TSAP-Win program (Rinntech, Germany).

The program COFECHA was used to identify missing and false rings in annual ring series and to eliminate measurement errors (Holmes, 1983; Grissino-Mayer, 2001). For cross-dating the measurement results of cores taken incrementally from the field, the data were saved in files with the *.rwl extension, converted into a single file, and then entered into COFECHA as a historically known data set, after which the program was run. Missing and false rings were resolved as a result of cross-dating, and samples whose problems could not be resolved were removed from the data set.

Four methods are used to obtain tree-ring chronologies: 1) skeleton plotting, 2) showing absolute ring widths on a graph, 3) semi-logarithmic presentation of annual ring widths, and 4) standardization of annual ring series (Trenard, 1982; Schweingruber, 1988; Akkemik, 2004). This research uses the fourth method, the standardization of annual ring series and created standard chronologies with a linear regression model using the program ARSTAN (Cook, 1985). A meaningful relationship is known to exist between the growth and development of trees and their environment. Therefore, long-term trends in annual ring widths are observed during annual ring formations according to the tree's age, soil conditions of the environment, aspect, slope, and closure. These trends need to be resolved in order to standardize chronologies. One of the simplest methods for standardizing annual ring chronologies is to construct a linear regression model. This is the preferred model when the chronology shows a linear, horizontal, decreasing, or increasing trend (Akkemik, 2004).

After obtaining individual standard graphs, two basic methods were used to determine the similarities between these graphs (Akkemik, 2004). The first is the Gleichlaufigkeit value, which determines the percentage of changes in the same direction from one year to the next (Eckstein & Bauch, 1969). The second is the correlation coefficient method. The study calculated the Gleichlaufigkeit values and correlation coefficients using TSAP-Win.

Site chronologies were created in ARSTAN by selecting the biweight robust mean method (Cook et al., 1990). Standard and residual site chronologies were then produced for each region.

To determine the changes in annual ring width from year to year, the signal-to-noise ratio (Akkemik, 2004) was calculated in

ARSTAN based on the mean sensitivities, yearly number of ring chronologies, and the mean correlation coefficients between the chronologies.

2.2.3.1. Performing precipitation reconstruction

Site chronologies were created with the samples taken from the trees in the research area. The regional chronology was made by combining the site chronologies. The study used the total annual precipitation data from the meteorological stations of Sakarya (covering the years 1956-2015), Düzce (covering the years 1956-2015), and Bolu (covering the years 1950-2015). Pearson's correlation coefficients were calculated in terms of the climate data from these stations and the regional chronology.

Pearson's correlation coefficients were obtained from the program IBM SPSS 22.0. The calculations considered the total annual precipitation data from October of the previous year to October of the ring formation year, which Fritts (1976) called the biological year, as the independent variables and the standardized regional chronologies as the dependent variables.

Pearson's correlation analysis values (r) range from -1 to +1, with a value of -1 indicating an excellent negative correlation between variables and a value of +1 indicating an excellent positive correlation between variables. A value of $r = 0$ indicates no relationship to exist between variables. If r is positive, one of the variables increases as the other increases, while a negative value for r means one variable decreases as the other increases (Sungur, 2010).

The degree of the relationship between variables is expressed by the value calculated for r, with $0.10 \leq r \leq 0.29$ indicating a small correlation, $0.30 \leq r \leq 0.49$ indicating a medium correlation, and $0.50 \leq r \leq 1.00$ indicating a high correlation (Pallant, 2017).

The results show a high correlation for annual total precipitation. Based on this, the decision was made to carry out reconstructions for the yearly total precipitation data. Firstly, the climate data set to be reconstructed was divided into two sequences, then two separate models were created. The first sequence was used for calibration and the second sequence for verification. The second sequence was then used for calibration in the second model, and the first sequence was now used for verification. Due to the similarity between the derived calibration equations and verification test results, the full calibration period was used for the reconstructions. Statistical results did not permit a reconstruction for the Sakarya station data. Thus, this research made reconstructions for the Bolu and Düzce meteorological stations.

Correlation coefficients, reduction of error ($RE > 0$), and sign tests were used to confirm the estimates. Correlations were calculated separately for the calibration, verification, and overall periods, checking their significance (Fritts, 1976; Akkemik, 2004; Köse, 2007). When determining the reconstruction period, the subsample signal strength (SSS) values were based on periods when the values exceeded 0.85 (Briffa & Jones, 1990).

2.2.3.2. **Determining low and high-precipitation years.**

Standard deviation (SD) values were used to determine the low- and high-precipitation years for the pre-instrumental period (1858-1950). Years exceeding the arithmetic mean values at one and two standard deviation levels are considered high- and very high-precipitation years, respectively; years below the one and two standard deviation levels for their average values were evaluated as low- and very low-precipitation years, respectively.

Table 2: *Statistics for Standard and Residual Site Chronologies Produced in the Research Area*

	CIG		BAL		SIN	
Chronology Type	Standart	Residual (AR1)	Standart	Residual (AR1)	Standart	Residual (AR1)
Mean	0.9810	0.9878	0.9633	0.9895	0.9687	0.9864
Median	0.9410	0.9816	0.9603	0.9805	0.9509	0.9702
Mean sensitivity	0.1432	0.1776	0.1429	0.1815	0.1540	0.1801
Standart deviation	0.2238	0.1562	0.1859	0.1498	0.2105	0.1647
Skewness coefficient	1.6173	-0.0249	0.1090	-0.0929	0.3454	0.8188
Kurtosis coefficient	6.3126	1.0973	-0.4704	-0.0929	0.3932	1.6567
Autocorrations						
t-1	0.6724	-0.0860	0.5868	-0.0762	0.5742	-0.0812
t-2	-0.0856	-0.0647	-0.0310	-0.1336	0.0323	-0.1167
t-3	-0.0617	-0.0731	0.1251	-0.0680	0.0185	0.0008

If t occurs as a superscrıpt, use: t the year the last ring was formed.

3. FINDINGS

3.1. Developing Annual Ring Chronologies

The study developed a regional chronology using three site chronologies (CIG, BAL, and SIN) created from Elmacık Mountain and its immediate surroundings. The mean sensitivity, signal-to-noise ratio, average correlations, and residual chronology with a higher variance for the first eigenvector were preferred when developing the chronologies.

The study used 45 cores from 25 trees for CIG, 40 cores from 21 trees for BAL, and 49 cores from 26 trees for SIN when developing the chronologies. Statistics for the standard and residual local chronologies are given in Table 2.

Common time interval statistics covering the years 1901–2015 (115 years) for CIG, 1917–2015 (99 years) for BAL, and 1894–2017 (124 years) for SIN are given in Table 3.

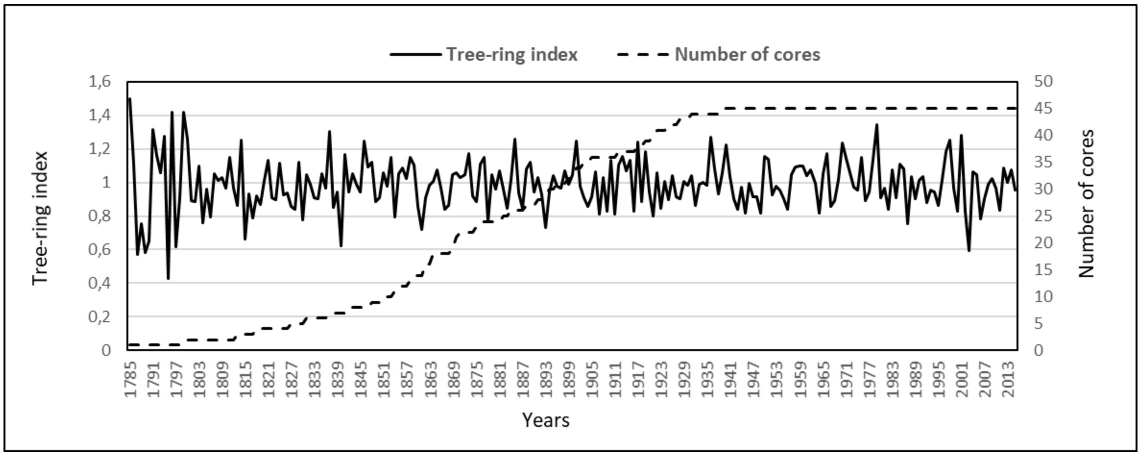

Figure 3. CIG site chronology covering 1785–2015 and the 45 cores.

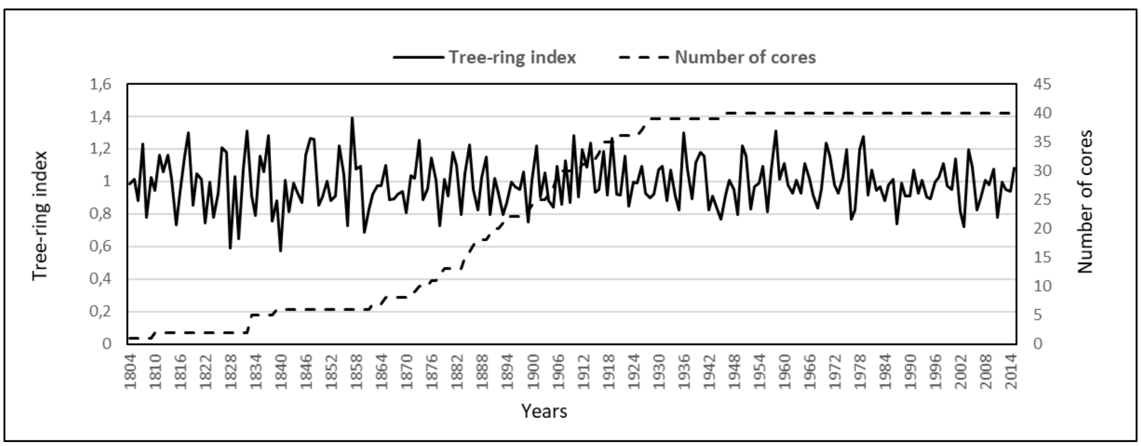

Figure 4. BAL site chronology covering 1804–2015 and the 40 cores.

Table 3: Chronology Statistics from ARSTAN for the Common Time Interval

	CIG		BAL		SIN	
	Standart	Residual	Standart	Residual	Standart	Residual
Mean correlations						
Correlations among all radii	0.237	0.294	0.182	0.283	0.309	0.365
Correlations between trees	0.230	0.287	0.174	0.276	0.302	0.360
Correlations within trees	0.522	0.534	0.484	0.538	0.646	0.586
Correlations radii vs mean	0.500	0.551	0.446	0.547	0.567	0.614
Signal-to-noise ratio	5.960	8.068	3.992	7.254	10.798	14.091
Agreement with population chronology	0.856	0.890	0.800	0.879	0.915	0.934
Variance in first eigenvector (%)	28.09	31.98	27.17	31.59	35.70	39.13
Chronology common range average	0.988	0.991	0.991	0.991	0.989	0.993
Chronology common range standard deviation	0.184	0.133	0.167	0.132	0.223	0.166

Figure 3 shows the 231-year CIG site chronology covering 1785–2015, Figure 4 shows the 212-year BAL site chronology covering 1804–2015, and Figure 5 shows the 246-year SIN site chronology covering 1770–2015. Figure 6 shows the 246-year ELM regional chronology covering 1770–2015. This was created by combining the site chronologies.

Correlation coefficients and Gleichläufigkeit values (*GL*) were calculated, and their significance levels were checked to determine the appropriateness with the generated site chronologies. The *GL* values and correlation coefficients of the curves between the site chronologies are seen to be statistically significant ($p \leq 0.001$; Table 4).

3.2. Precipitation Reconstruction

The total annual rainfall reconstruction of the Düzce meteorological station for 1858-2015 was made using the following formula:

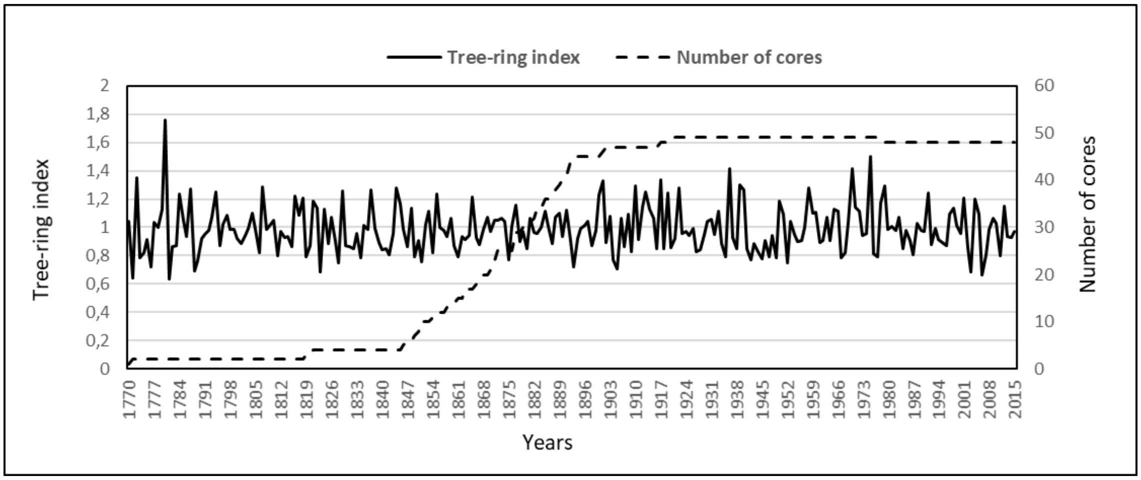

Figure 5. SIN site chronology covering 1770–2015 and the 49 cores.

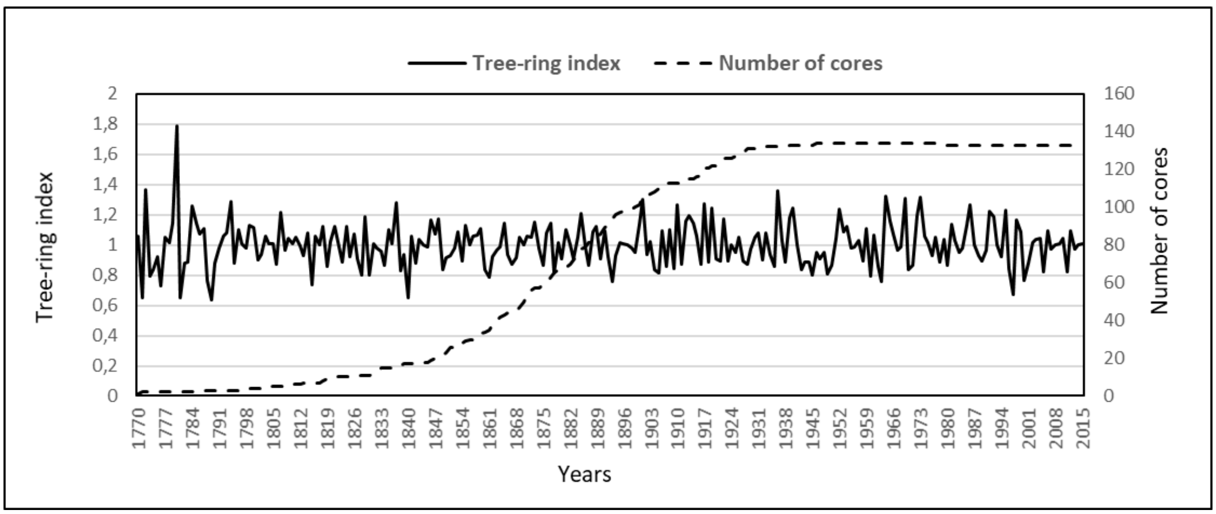

Figure 6. ELM regional chronology covering1770–2015 and the 134 cores.

Table 4: Correlation coefficients and Gleichläufigkeit values between the Site Chronologies and the Regional Chronology

		Gleichlaufigkeit values (%)		
		SIN	**CIG**	**BAL**
Correlation coefficients	SIN	100	75	76
	CIG	0.61	100	76
	BAL	0.63	0.63	100

All values are statistically significant ($p \leq 0.001$).

Total precipitation (mm) = Annual ring width of the prediction year x 0.57 + 233.95 (1)

The total annual rainfall reconstruction of the Bolu meteorological station for 1858–2015 was made using the following formula:

Total precipitation (mm) = Annual ring width of the prediction year x 0.36 + 193.84 (2)

Figures 7 and 8 provide graphs showing the agreement between the Düzce annual total precipitation data and regional chronology, while Figures 10 and 11 provide the graphs showing

Table 5: Düzce and Bolu Meteorological Station Annual Total Precipitation Reconstruction Adjustment and Verification Statistics

	Calibration period	Verification period	Constant	Coefficients	R^2	RE	Calibration Sign test	Verification Sign test
DÜZCE	1956-1985	1986–2015	235.44	0.57	0.36	0.61	22 + / 8 - P ≤ 0.05	22 + / 8 - P ≤ 0.05
	1986–2015	1956–1985	240.65	0.56	0.39	0.61	22 + / 8 - P ≤ 0.05	22 + / 8 - P ≤ 0.05
	1956-2015	-	233.95	0.57	0.38	-	44 + / 16 - P ≤ 0.01	-
BOLU	1950–1982	1983–2015	222.07	0.32	0.35	0.55	24 + / 9 - P ≤ 0.05	24 + / 9 - P ≤ 0.05
	1983–2015	1950–1982	146.75	0.41	0.35	0.54	24 + / 9 - P ≤ 0.05	24 + / 9 - P ≤ 0.05
	1950-2015	-	193.84	0.36	0.34	-	48 + / 18 - P ≤ 0.01	-

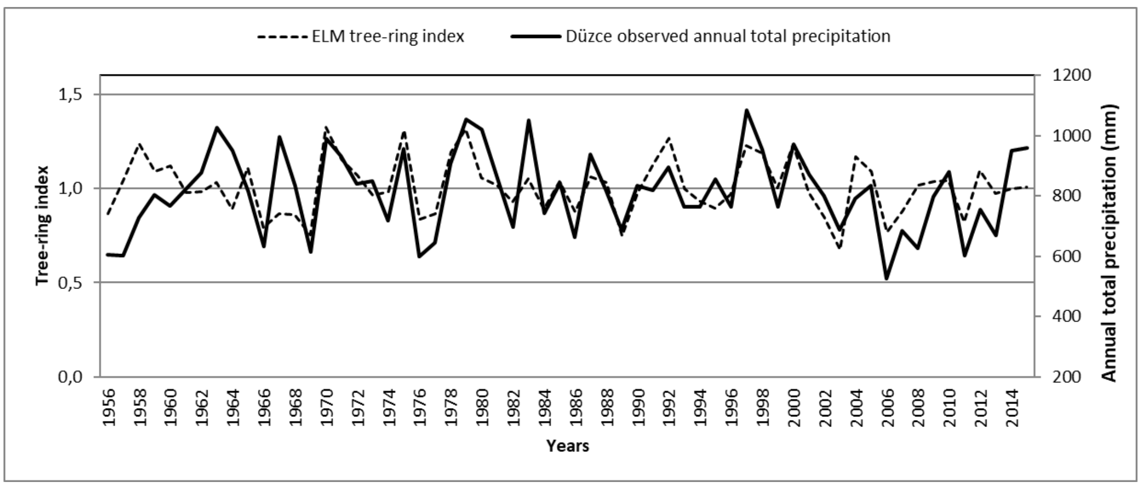

Figure 7. 1956-2015 ELM regional chronology tree-ring index and total annual precipitation at Düzce meteorological station for 1956-2015.

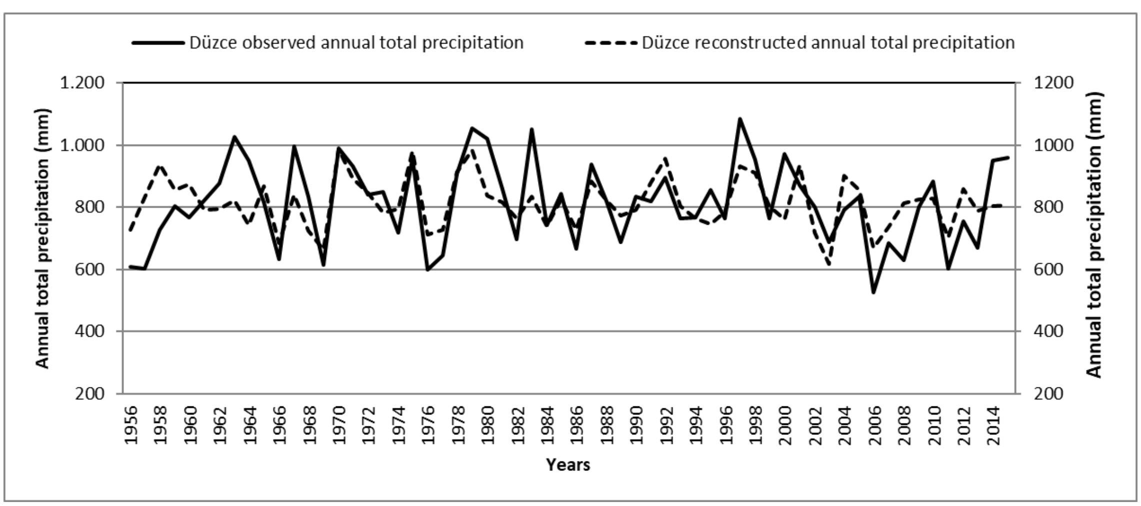

Figure 8. Total annual rainfall reconstructed and observed at the Düzce meteorological station for 1956-2015.

the agreement between the Bolu annual total precipitation data and regional chronology. Figure 9 shows the estimated annual rainfall at the Düzce meteorological station for 1858–2015. Figure 12 shows the estimated yearly rainfall at the Bolu meteorological station for 1858–2015. Table 5 provides the adjustment and validation statistics for the reconstructions.

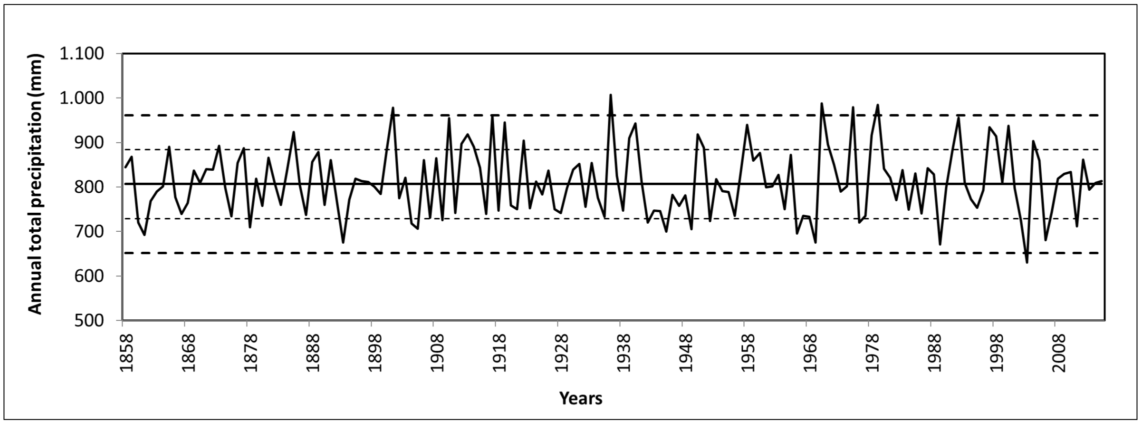

Figure 9. Reconstructed total annual rainfall at the Düzce meteorological station for 1858-2015 (Black horizontal line indicates mean, inner horizontal dashed lines indicate the limits of ±1*SD*, and outer horizontal dashed lines indicate the limits of ±2 *SD*s).

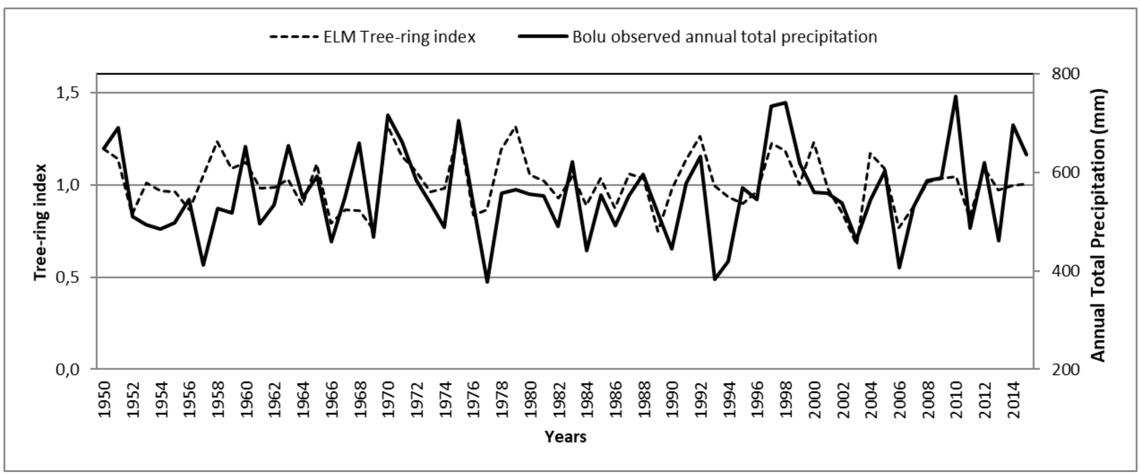

Figure 10. 1956-2015 ELM regional chronology tree-ring index and total annual precipitation at the Bolu meteorological station for 1956-2015.

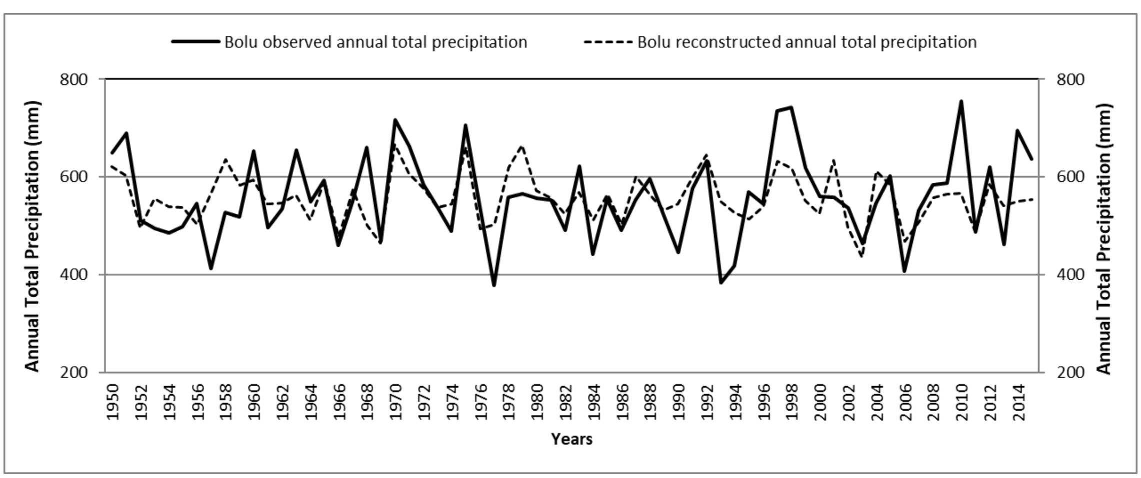

Figure 11. Total annual rainfall reconstructed and observed at the Bolu meteorological station for 1956-2015.

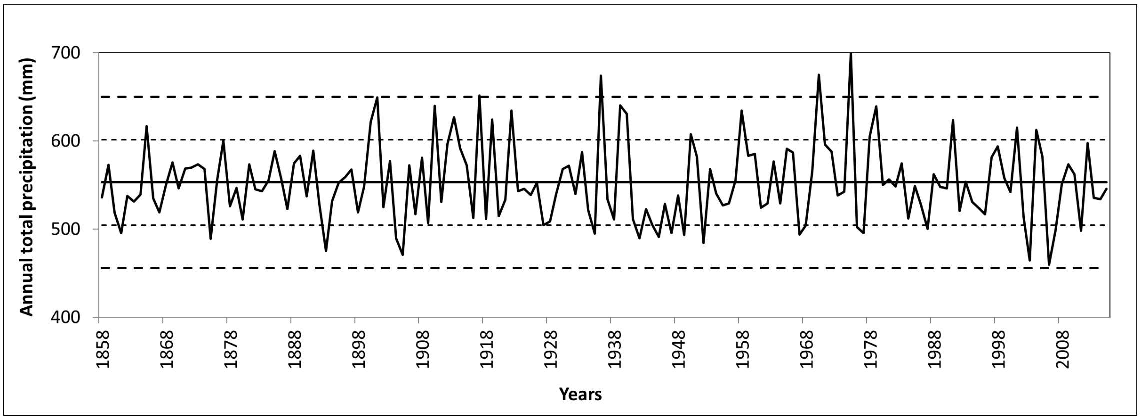

Figure 12. Reconstructed total annual rainfall at the Bolu meteorological station for 1858-2015 (Black horizontal line indicates mean, inner horizontal dashed lines indicate the limits of ±1*SD*, and outer horizontal dashed lines indicate the limits of ±2 *SD*s).

3.3. Determining Low- and High-Precipitation Years

Standard deviation (*SD*) values were used to determine low- and high-precipitation years. Years exceeding the arithmetic mean values at a level of one or 2 positive *SD*s are considered respectively as high- and very high-precipitation years, respectively. Years whose average precipitation values fall below one or two negative *SD*s are evaluated as low- or very low-precipitation years, respectively.

The results of the precipitation reconstruction at the Bolu and Düzce meteorological stations were in agreement, as expected. No very low-precipitation year could be determined in the reconstructed period. The analyses demonstrated low-precipitation events to have never lasted more than two years between 1858-1950. Of the 14 low-rainy years found in this period, 10 were lasted one year, and two lasted two years. However, 1901 and 1936 were very high precipitation years. In addition, 13 high-precipitation years were found, 8 of which lasted one year, and two of which lasted two years. Only one high precipitation period lasting 3 years occurred (1912–1914) over the reconstructed period (Table 6).

3.4 Comparing the Results with Previous Studies

Akkemik et al. (2005) defined 1887 as a very dry year for the vicinity of Kastamonu, as well as Akkemik & Aras (2005) for Konya, Hughes et al. (2001) for the Aegean basin, and Köse (2007) for Kütahya, Afyon, Eskişehir, and Isparta. Köse (2007) discusses how the Ottoman Archives mentioned Anatolia to have had a great drought and famine in 1887. According to the results of the current study, 1887 also had less precipitation than normal for the Bolu and Düzce stations, where the precipitation reconstructions were made.

Köse (2007) stated 1893-94 to have been a 2-year dry period for Western Anatolia. Akkemik & Aras (2005) found 1893 to have been extremely dry for Konya. Cook et al. (2015) determined 1893 as the dry year for the European continent in general. Tekin (2015) quoted a drought to have occurred in 1892-1893 and to have affected the Eastern Anatolia region, especially Erzurum and Bitlis. In addition, the drought affected Bayburt and its surroundings in the Black Sea region, with around 20,000 poor people from these regions having had to migrate to Trabzon. Moreover, the current paper also identified 1893 as a low-precipitation year for the research area.

Gönüllü (2010) mentioned extreme rainfall, floods, and overflows in many parts of Anatolia throughout 1901, especially in July, with these floods and overflows also causing loss of life and property. Köse (2007) reported the same year to have high precipitation for Western Anatolia. According to the May-August rainfall predictions Akkemik & Aras (2005) made for 1689-1994 at the Konya meteorological station, the three years of 1900-1902 were detected as having high precipitation.

Table 6: Reconstructed Total Annual Precipitation for Düzce and Bolu Meteorological Stations Below or Above the Long-Term Average by One or Two Standard Deviations

Very rainy years (over 2 SD)	1901, 1936
Rainy years (over 1 SD)	1865, 1873, 1877, 1885, 1910, 1912, 1913, 1914, 1917, 1919, 1922, 1939, 1940
Very low-rainy years (below -2 SD)	-
Low-rainy years (below -1 SD)	1860, 1861, 1875, 1878, 1887, 1893, 1904, 1905, 1907, 1909, 1935, 1942, 1945, 1949

Köse et al. (2013) and Cook et al. (2015) stated 1909 to have had low precipitation, as well as 1893. The Ottoman archives reported wheat exports to have been banned due to famine in these years. Likewise, this study determined 1893 and 1909 to have had low precipitation.

Hughes et al. (2001) presented 1901, 1910, 1917, 1919, and 1936 as high-precipitation years for the Aegean basin. The current research also found these years to have had high precipitation. Moreover, 1901 and 1936 were years with very high precipitation. These same two years were also expressed as having high precipitation according to the results of the May-June precipitation reconstruction by Martin-Benito et al. (2016), which included northeastern Türkiye. The years 1912-1914 were also revealed as a high precipitation period. Similarly, Martin-Benito et al. (2016) indicated 1913-1914 to have been wet years.

According to the spring precipitation reconstruction (1776-1998) Touchan et al. (2003) made for Southwest Türkiye, 1935 was the driest year, while 1936 was the wettest. This study also found 1935 to have had low precipitation and 1936 to have had very high precipitation. 1936 was also expressed as a high-precipitation year according to the results of the May-June precipitation reconstruction Griggs et al. (2007) made for the Northern Aegean.

4. CONCLUSIONS

This research has created three Scotch pine (*Pinus sylvestris* L. ssp. *hamata*) site chronologies of 214, 233, and 248 years using core samples from Elmacık Mountain in Northwest Türkiye where the Western Black Sea and the Eastern Marmara regions meet. The site chronologies were then combined into a regional chronology. With this chronology, a 158-year (1858-1915 AD) retrospective estimate was made of the total annual precipitation data from the Bolu and Düzce meteorological stations. In addition, low- and high-precipitation years were revealed for 1858-1950 before the stations started recording data.

According to the results, very low-precipitation years could not be determined between 1858-1950. Low-precipitation years were understood to have been 1860-1861, 1875, 1878, 1887, 1893, 1904-1905, 1907, 1909, 1935, 1942, 1945, and 1949. On the other hand, 1865, 1873, 1877, 1885, 1910, 1912-1914, 1917, 1919, 1922, and 1939-1940 were high-precipitation years, and 1901 and 1936 were determined as very high-precipitation years.

According to our literature review, this research is the first dendroclimatological study in Türkiye to regard a total annual precipitation reconstruction. In addition, the number of Scotch pine chronologies in Türkiye is limited. In this sense, performing longer-term studies and making comparisons by increasing the Scotch pine chronologies for different areas would be helpful in terms of precipitation data.

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