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# CLIMATE-GROWTH RELATIONSHIP OF *PINUS NIGRA* TREE-RING WIDTH CHRONOLOGY FROM THE RHODOPE MOUNTAINS, BULGARIA

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## Abstract

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Previous studies of Austrian pine (*Pinus nigra* Arnold) from different parts of Europe outlined the species as valuable for dendroclimatic analysis. It is usually suitable for high quality precipitation reconstruction for the periods before instrumental measurements. Despite this and the fact that in Bulgaria there are centuries-old *Pinus nigra* forests, local dendroclimatic studies are scarce. The aim of the study is to analyze the climate-growth relationship in tree-ring width chronology constructed from *Pinus nigra* trees from the region of Dobrostan in the Rhodope Mts., Bulgaria. The constructed chronology was composed of 32 cores from 17 trees for the period 1741-2007 using standard dendrochronological methods. The statistical analysis showed high inter-series correlation (r = 0.645) and population signal (EPS) above 0.85 after 1850. Correlation analysis of the constructed chronology was performed with the climatic data from Sadovo, which is close to the study site and offers one of the longest reliable climate series in Bulgaria with continuous measurements since 1893. Our results showed high statistically significant negative correlation with the temperatures from the summer of growth and the summer prior to growth (r > 0.4). The relationship with precipitation amounts is high and positive. Therefore, we consider that there is clear and temporally stable drought signal in the constructed chronology and it could be successfully used to reconstruct precipitation for the period without instrumental data.

*Key words:* tree rings, dendroclimatology, *Pinus nigra*, Rhodopes
*Abbreviations: DBH* – diameter at breast height; TRW – tree ring width; PDSI – Palmer drought severity index; EPS – expressed population signal

## Introduction

Tree rings provide very good proxy records of past environments prior to the existence of instrumental measurements (Leal et al., 2008). The Balkan Peninsula is one of the regions with the highest climate vulnerability in the European region, but proxies are scarce for the area and this limits better understanding of long-term climate variability (Trouet et al., 2012).

A number of dendroecological studies of Austrian pine (*Pinus nigra* Arnold) define it as sensitive to climate variation (Levanic and Toromani, 2010). The tree ring widths of *Pinus nigra* trees in the Vienna basin, Austria, showed strong and positive correlation with spring-summer precipitation (Leal et al., 2008). Studies from Turkey (Akkemik et al., 2005), Bosnia and Herzegovina (Poljansek et al., 2012) and Albania (Levanic and Toromani, 2010) came to similar results. Despite the species suitability for climate-growth analysis and the presence of centuries-old *P. nigra* forests in Bulgaria such studies are limited (Grozev and Jonov, 1995; Grozev and Nedelchev, 1996) and the results are often not published.

Our study aims at finding if tree-ring width series from *Pinus nigra* trees, growing in the Rhodopes, contain reliable

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and temporally stable climate signal. Our purpose is to estimate the characteristics of the climate-growth relationship, which is a necessary step for building models, used for proxy climate reconstructions.

## Material and Methods

The study area is an open forest with trees with DBH above 50 cm. It is located near Dobrostan village in the Rhodopes, Bulgaria at 41°54‘ N 24°55‘E on a plateau at elevation of 1200 m a.s.l.

We collected 38 samples from 19 trees with increment borer. Two cores per tree were taken at breast height (1.3 m), in perpendicular directions. The cores were air-dried and glued on wooden holders. Afterwards they were sanded with progressively finer sandpaper until the annual rings and tree ring morphology were clearly visible. Samples were scanned at 1200 dpi and tree-ring widths were measured with Cybis CooRecorder 7.3 software to the nearest 0.01 mm. The tree-ring width (TRW) series were crossdated visually and with software CDendro 7.3. The program COFECHA (Holmes, 1983) was used for between-series correlation analysis and measurement verification. The single tree-ring width series were standardized with ARSTAN (Cook, 1985), using negative exponential curves to remove the age-trend. The expressed population signal (EPS) was computed over 30-year windows, lagged by 15 years. It quantifies the degree to which the constructed chronology portrays the hypothetically perfect one. EPS value of 0.85 was used as a threshold for the reliability of our chronologies (Wigley et al. 1984).

Climate data was obtained from Sadovo meteorological station, situated 25 km to the north of the study area. Average monthly temperatures and precipitation sums for the period 1893 – 2007 were used to investigate the dependence of TRW variance on climate. Palmer Drought Severity Index was also calculated (PDSI, Palmer, 1965) using PDSI software (Wells, 2003) of the National Agricultural Decision Support System (http://greenleaf.unl.edu, accessed on April 18, 2012). This index provides standardized value showing prolonged droughts and is frequently used in climate analysis. Pearson correlation coefficients were calculated between values in the standard chronology and the climate data for the months from May of the year prior to growth to October of the current year. Correlation coefficient with August PDSI was also estimated.

## Results and Discussion

The presented tree-ring width chronology was composed of 32 cores from 17 trees. The other 6 series were excluded because they contained growth anomalies. Such anomalies could be due to other factors than climate, affecting tree growth (i.e. stem breakage from snow accumulation). The chronology has a total length of 267 years and covers the period 1741 – 2007 (Table 1).

**Table 1**

**Statistical and descriptive parameters of the chronology**

| | |
|---|---|
| Length | 267 |
| First year | 1741 |
| Last year | 2007 |
| Number of series | 32 |
| Number of trees | 17 |
| Mean ring width (mm) | 1,21 |
| Mean sensitivity | 0,295 |
| Autocorrelation (1st order) | 0,807 |
| Correlation between series | 0,645 |

The high inter-series correlation ($r = 0.645$) shows that the sampled trees reacted relatively similarly to the factors influencing tree ring width. This is also supported by high EPS values (Figure 1) and suggests that the chronology is useful for climate–growth relationship analysis.

Correlation with the average monthly temperature series was statistically significant and negative ($r < -0.273$) for months June to September of the year prior to growth and July and August of the year of growth (Figure 2a). Also statistically significant, but positive are the correlations with precipitation sums for July of the relevant and August of the preceding year (Figure 2b). These relations apply with little difference to the two periods 1893–1950 and 1951–2007, which means the signal, is temporally stable. There is an inverse dependency ratio of temperatures to precipitation and it is one possible explanation of the negative relationship between growth and summer temperatures. Correlation with August PDSI is also high ($r = 0.475$) which indicates that the trees are sensitive to available moisture. This climate-growth relationship is typical for species, growing in conditions of moisture insufficiency (i.e. drought) (Fritts, 1976). Water shortage affects cell metabolism and division. Drought during summer months influences tracheid formation in that period and thus causes reduced annual growth (Panayotov et al., 2012).

Our results correspond to those of other studies of Austrian pine from the Balkan Peninsula (Levanic & Toromani, 2010; Poljansek et al., 2012) where climatic conditions are similar. This is a further proof for the reliability of our results.

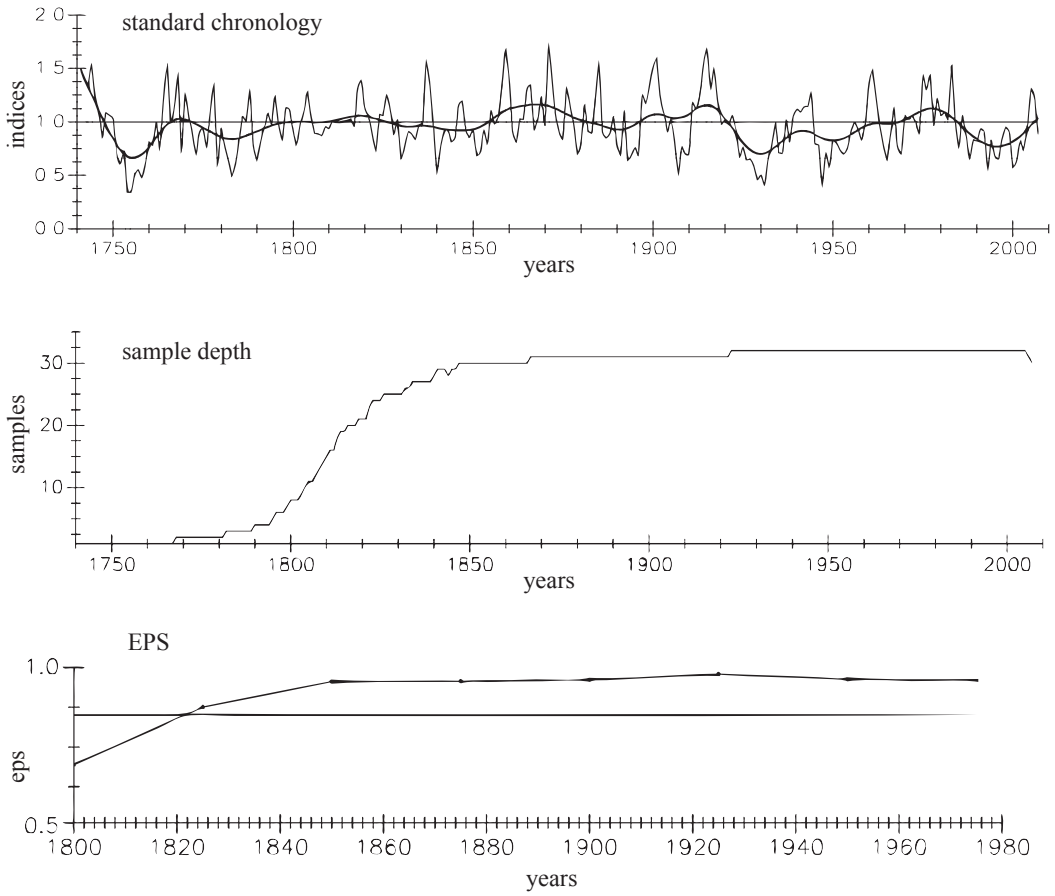


**Fig. 1. Standard tree-ring width chronology, sample depth and expressed population signal (EPS)**

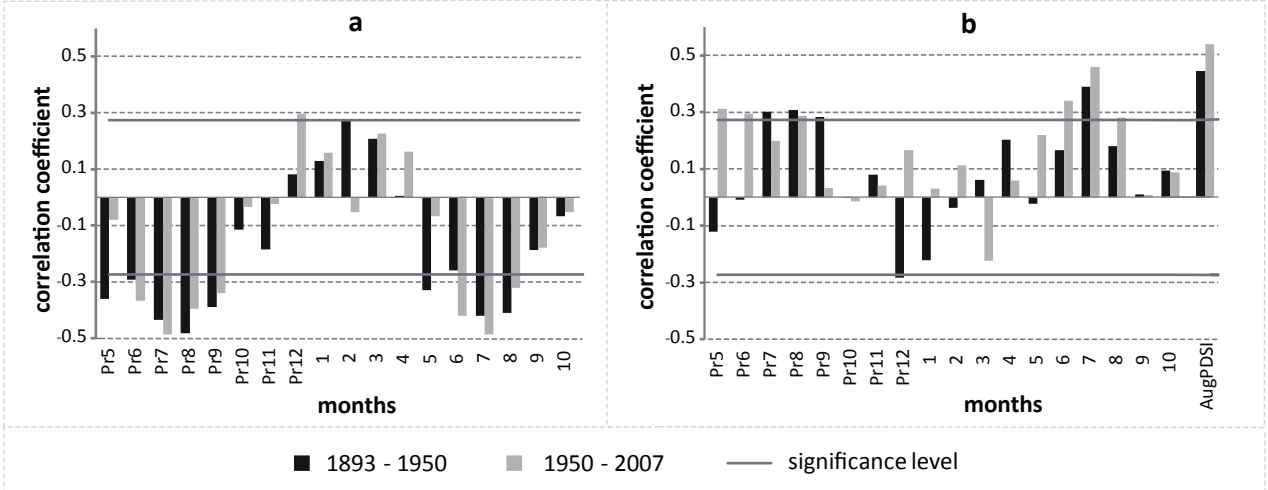


**Fig. 2. Correlation coefficients between the standard tree ring width chronology and: a) average monthly temperatures; b) monthly precipitation sums and August PDSI. Solid grey lines indicate significance levels**

## Conclusions

This study characterizes Austrian pine trees from the Rhodopes, Bulgaria as sensitive to summer drought and summer temperatures of both year of growth and the previous year. The results indicate that *Pinus nigra* tree ring width chronologies from similar sites in the region are most likely suitable for climate–growth studies and could be used as proxy climate records.

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