BOSNIAN PINE (PINUS HELDREICHII) AS GEOARCHIVE AT THE TIMBERLINE IN THE PIRIN MOUNTAINS AND ON THE BALKAN PENINSULA

J. Scheithauer¹, K. Grunewald¹, G. Helle², B. Günther³ and A. Gikov⁴
¹Landscape Research Centre Dresden, Germany
²German Centre for GeoSciences - GFZ, Potsdam, Germany
³University of Technologies Dresden, Institute of Forest Utilization and Forest Technology, Germany
⁴Bulgarian Academy of Sciences, Sofia, Bulgaria
Correspondence to: Jörg Scheithauer
E-mail: j.scheithauer@lfz-dresden.de

ABSTRACT

High mountains and their ecosystems offer an outstanding opportunity for studies on the impact of climate change. The Pirin Mountains in Southeast Europe, situated at the transition between temperate and Mediterranean climate, are considered as very sensitive to historical and current global changes. Site specific effects as well as the impact of historical disturbances have been analysed at treeline ecotone testplots. Bosnian Pine (Pinus heldreichii) and Macedonian Pine (Pinus peuce) are the most common species at the recent timberline around 2,100 m a.s.l. in the Pirin Mountains. The results on dendroclimatology provide an insight into the potential of the Bosnian Pine and its chronologies in the Northern Pirin Mountains. First conclusions can be drawn from the chronology and site comparison respectively as well as the climate-growth-analysis. On the one hand, the width growth is humidity limited. On the other hand, the tree-rings similarly reflect high summer temperatures as a negative impact factor at sunny south flanks. At the same time, mild winters have a positive effect.

Keywords: Bosnian Pine, dendroclimatology, Pinus heldreichii, Pirin Mountains, ring width chronology

Introduction

In the context of the currently enforced debate on global climate change, the reconstruction of the modern landscape development in the Bulgarian Pirin Mountains constitutes an important element for the understanding of the current climate dynamics in Southeastern Europe. Located at the transition zone from temperate to Mediterranean latitudes, the high mountain ranges of Pirin are strongly sensitive to climatic changes (1). Tree-rings of coniferous trees at extreme sites have proven to be reliable and valuable archives for climate signals, especially for regions where there are no direct measurements of temperature and precipitation available or where data records are short in time and/or fragmentary. The Bosnian Pine (Pinus heldreichii Christ. or Pinus leucodermis Ant. respectively), found at the timberline in the Northern Pirin Mountains, is a conifer growing up to 1000 years, which was subject of a mere marginal dendroecological interest up to now. Generally, this species only occurs on the Balkan Peninsula and in the southern part of Italy. So far comprehensive studies on the climate-growth relationships of Pinus leucodermis are only established in South Italy (2).

Mainly since the 1990s the study region is subject to the analyses of landscape history and climate change utilising different methods. Geoarchives like glaciers, moraines, soils and lake sediments serve proxy data archives for reconstructions of the Holocene development at the subalpine level (3). However these archives partly provide environmental information with a temporal resolution of several hundred or thousand years. Recently, the analysis of highly resolved climate data (4) and annual tree-rings of Bosnian Pines at the timberline ecotone are established within the network of proxy data to better understand the climate and landscape dynamics (3).

This paper presents first results of dendroecological study in the northern Pirin Mountains, Bulgaria. Firstly, we aimed at the development of a statistically robust ring width...
From the two climate data sets the number of days with different temperature threshold values were calculated for the study site at daily solution (days with temperature > 5 °C and > 10 °C). In addition, the standardised precipitation index (SPI) using the software SPI_SL_6 as well as the Walter Index according to the formula (P / 2,1) - T (P: precipitation in mm, 2,1: factor, T: temperature) were determined. SPI was used as a monthly parameter for evaluating the influence of changing humidity or drought on tree growth. Negative values indicate drought (SPI < -1), while positive values indicate humidity or precipitation surplus, respectively (SPI > 1).

To determine a climate-growth relationship of *Pinus heldreichii*, the standard ring width chronology was regressed against the monthly parameters temperature, precipitation (snow + rain), snow amount, number of days with snowfall, SPI and Walter index as well as thresholds (days with temperature > 5 °C and > 10 °C) using the software package DENDROCLIM2002. Pearson correlations and more complex response functions were calculated by applying principle components analysis. Bootstrapped confidence intervals were calculated to assess the significance of both. To study changes in monthly climate response between October of the previous year and September of the current growth year, moving interval correlation was established with a base length of 24 years according to the available time periods of climate parameters and stations (5).

**Results and Discussion**

A ring width chronology that goes back 722 years could be established for the Bosnian Pine at site G1 (1285-2006, Fig. 1). The raw data of the tree-ring width show a high variability and a declining age trend during the course of the first 150 years. The latter was successfully eliminated by detrending whereby the high frequent interannual climate signal was intensified. Nevertheless, a change of perennial phases with a positive or negative tendency was observed. Between 1500 AD and today, more than 20 individual measurement series always ensure the required minimum coverage. The Cofecha quality parameters as well as the Arstan parameters average correlation between all series (rbar), expressed population signal (eps), standard deviation (stdev), skewness (skew), sensitivity (sens) and 1-year autocorrelation (ac) show the chronology’s robustness (5).

In contrast to site influences, extremely cold or dry but also very mild and wet phases as well as late frost events and insects calamities become locally-regionally effective and
can persist several years and be reflected in the entire sampling group in form of pointer years and intervals (6). In this context, the regional comparison with other chronologies of the *Pinus leucodermis* from Northern Greece (Olympos Oros, Katara Pass) and Southern Italy from the Sierra da Crispo / Mt. Pollino is interesting (WSL Dendro Database, Switzerland. www.wsl.ch/dendro). Moreover, there is a chronology by Schweingruber for the Vihren National Park (1721 to 1981). The implementation in Cofecha showed no relation to Mt. Pollino and Katara Pass, whereas the Northern Pirin Mountains and in particular the Olympos series closely correlate with their own ring width series (correlation with master 0.59 and 0.64). The variability of the analysed segments is largely synchronous (no B-flags). This fact promises a high dendroclimatological potential of the established *Pinus heldreichii* standard chronology.

![Fig. 1](image1.png) **Fig. 1.** Average ring width (a), standard chronology (b) and number of samples (c) for the timberline ecotone at study site G1 (period 1285 to 2005)

![Fig. 2](image2.png) **Fig. 2.** Reconstructed growing seasons of the *Pinus heldreichii* (Pirin Mountains) (3)

Due to its exposure and partial old age, the Bosnian Pine takes an outstanding position for the long-term climate...
reconstruction for the Pirin Mountains and potentially for the Balkan Peninsula (compare the fluctuations in the chronology, fig. 1). With the second detrending the long-term tendency is indeed eliminated, but the interannual variability of the ring width reflects monthly temperature and precipitation of the previous year and the current growth year. Finally, the understanding of the current climate-growth relationship is the basis for intended long-term climate reconstruction (3).

The results on dendroclimatology and dendroecology provide a first insight into the potential of the Bosnian Pine and its high mountains chronology in the Northern Pirin Mountains. Finally, the ecological plausibility of the statistic contexts for the south-exposed study site shall be assessed. For a better understanding of the limiting and supporting factors, the reconstruction of the growing season of the Pinus heldreichii based on the model of the Yellow Cedar by Laroque and Smith (7) appears to be useful. Beginning and end of the annual growth could be converged for instance, by comparing the months which show a clear correlation change (Figure 2).

Cambial activity and cell growth commence mid May at Mt. Pollino (2). Own observations in the Northern Pirin Mountains show that the snow is completely melted on the investigated, south-exposed rock flank by the end of April/beginning of May. This corresponds with the amount of days with temperatures > 5 °C in April, which are significantly positive correlated with the growth. In contrast, days with temperatures > 10 °C in May have already a limiting effect.

Furthermore, the July-SPI is significantly positive in the current growth year, however the August-SPI is weakly correlated only. Hence, the latter does not play any role for the summerly tree-ring growth. There is instead a close relation between the SPI in last year’s August and the tree-ring width. As a result, cambial activity and cell growth should be completed by the end of July or beginning of August of each year and thereafter under wet conditions should start with the accumulation of reserves for the following year (applicable for the analysed period 1956-2005). In turn, these assumptions correspond with the results of Todaro et al. (2) in South Italy, where cambial activity is completed at the end of July and cell growth during the first half of August.

Thus, dry conditions in summer have basically a limiting effect, analogous a cold winter and a cool spring-time with few days with temperatures of > 5 °C. The currently discussed divergence problem between climate and tree-ring parameters insofar gains an interesting component as far as the Bosnian Pine is concerned, as the mean growth has increased over the last 50 years despite increasingly drier and warmer conditions in Southwestern Bulgaria. Although the Bosnian Pine forms thinner tree-rings in dry years in comparison with wet years, it tolerates relatively well the sparse conditions. It is assumed that there will not be any competition for the Bosnian Pine by tree species of the upper montane level zone during the course of hypsometric shifting of vegetation zones towards the summit, which means that the Pinus heldreichii would be a winner of climatic changes (3).

Acknowledgment
The studies were realised with support of the German Research Foundation DFG (funding number: GR 1432/11-1) as well as in cooperation with the administration of Pirin National Park.

REFERENCES