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SCOTS PINE (*PINUS SYLVESTRIS* L.) RESPONSE TO CLIMATE CHANGES AND THINNING ACTIVITIES: A TREE-RING STUDY FROM SOUTH-EAST RILA MOUNTAIN, BULGARIA

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Abstract

As a result of the study, the Scots pine (*Pinus sylvestris* L.) local chronology in 'Vasil Serafimov' Ecological Station (Southeast Rila Mountains, Bulgaria) was extended with 21 years, till 2008. A significant relationship ($\alpha < 0.01$) was ascertained between tree-growth indices (*ITR*) of the Scots pine and precipitation indices (*IP*), temperature indices (*IT*) and presence of Norway spruce (*Picea abies* (L.) Karst) understorey (SU). Initially, pine decreased its radial growth rate as a consequence of the drought started in 1993. Removal of Spruce understorey in the middle of the dry period (1995), however, positively influenced Scots pine radial growth since 1997. The cooler and wetter years from 2001 to the end of the studied period resulted in increased growth rate for the pine.

Key words: *Pinus sylvestris*, dendrochronology, climate changes, thinning

INTRODUCTION

A number of dendrochronological studies focused on Scots pine (*Pinus sylvestris* L.) have been published in the last decade of XX century in Bulgaria (Raev, Grozev, 1990; Grozev, 1992; Mirchev, Grozev, 1994; Grozev, Delkov, 1995). Geographically, these studies have been undertaken in mountains located in the south-west part of the country, especially in West Rhodopes and Rila Mountains: regions covered mainly by natural coniferous forests, including pure Scots pine or mixed Scots pine – Norway spruce (*Picea abies* (L.) Karst) stands. Important deliverables of these studies were the numerous, more than century long, master chronologies constructed. Recently, some new chronologies have been built in order to investigate relation between fungal diseases, climate change and trees response of Scots pine forest plantations (Zafirov, 2008).

The first Scots pine master chronology for Southwest Rila Mountain was elaborated by Raev et al. (1990). Its span is 170 years, covering the period from 1816 to 1986. The climatic data from 'Vasil Serafimov' Ecological Station, analyzed by Dimitrov et al. (2009), defined eight years dry period, which started in 1993 and ended in 2000, with driest years being 1993, 1994 and 2000. The extension of the master chronology is to fill the gap of 21 years – from 1987 to 2008: a period which is globally related with intensive climate change with many possible effects, presumably negative, on the forest vegetation.

The objectives of the study were to (*i*) extend the *Pinus sylvestris* L. master chronology (Raev et al., 1990) in 'Vasil Serafimov' Ecological Station, Southeast Rila and (*ii*) based on the extension to analyze combination of both 'tree-rings – climate' and 'tree-rings – competition' dependence of radial growth.

MATERIALS AND METHODS

Study area

The study stand belongs to the 'Vasil Serafimov' Ecological Station (lat. 42°06'14.13" N, long. 23°42'54.52" E) and is part of the extensive Scots pine (*Pinus sylvestris* L.) dominated forests growing from 1450 to 1650 m a. s. l. on the southern slopes of Rila Mountain. The climate is typically mountainous. The mean year temperature is 5 °C and the average annual precipitation is 821 mm, predominantly occurring from April to July (51.8%). The average annual shining period duration is 1939 h. The vegetation period starts mid-May and ends mid-September, its average year span being 118 days. The forests in 'Vasil Serafimov' Ecological Station fit in the zone of optimum for Bulgarian coniferous forests in the belt of 'Cool mountain climate' within the elevation diapason from 900-950 to 1650-1750 m (Raev, 1983). The studied stand has been declared as permanent seed production forest with main designation to supply the local forest enterprise of 'Yakoruda' with Scots pine seed material. In 1995 a thinning was performed in the stand in order to remove the spruce understorey.

Data collection and processing

Increment core samples were extracted from 18 dominant Scots pine trees (one radii per tree). Samples were visually and cross dated, according to Stokes, Smiley (1968). Tree-ring width was determined with the accuracy of 0.1 mm by increment measuring table LINTAB 5 and software TSAP (Rinn, 2005). The precision of visual and cross dating was checked by statistical package COFECHA (Holmes, 1983; Grissino-Mayer, 2001). The series standardization was performed by a detrending technique according to Fritts (1976). Tree ring indices were calculated by Eq. 1:

$$ITR = Wt / Yt \qquad (1),$$

where ITR is the year tree-ring index, Wt is the corresponding year ring width and Yt is the corresponding year ring width determined by a negative exponential curve. Calculation of the negative exponential curves for the 18 measured single series was performed by ARSTAN software (Cook, 1985). Coherency of the master series and dendrochronologycal series of extension were examined by bivariate Pearson correlation in the 40 years window started 1945 and ended 1986 (last 40 years of the master chronology).

The climatic data used in the analyses were obtained from an open gap inside the studied Scots pine dominated stand and covered the period from 1987 to 2007. The indices for the precipitation were calculated by Eq. 2:

$IP = Pi / \overline{P}$ (2),

where IP is the year precipitation index, Pi is the amount of precipitation for the corresponding year and $\overline{P}$ is the mean amount of precipitation for the whole period of observation (1987-2007). The indices for the temperature were calculated by Eq. 3:

$IT = Ti / \overline{T}$ (3),

where IT is the year temperature index, Ti is the corresponding year mean temperature and $\overline{T}$ is the mean temperature for the observation period.

Multiple OLS regression analysis was used to investigate relationship between Tree-growth indices (*ITR*) and Precipitation indices (*IP*), Temperature indices (*IT*) and Presence of spruce understorey (*SU*), Eq. 4:

$ITR = b_0+b_1IP+b_2IT+b_3SU$ (4)

All predictors except *SU* are continuous variables. The latter is a binary coded variable. The goodness of fit of the regression models was assessed through the coefficient of determination (R^2) and the standard error of the coefficient estimates. Plots of the independent variables against the residuals and the predicted values against the residuals were examined to check for data deficiencies (Draper, Smith, 1981).

RESULTS AND DISCUSSION

There is a high coherence between 'Vasil Serafimov' master chronology (Raev et al., 1990) and the chronology of extension (Fig. 1). The overlapping between two series is prominent for the negative growth periods (1945-1950 and 1966-1970) as well as for the periods with high radial growth (1955-1965 and 1970-1980). The negative pointer years (1947, 1949, 1968) and the positive ones (1956, 1959, 1975, 1983) match in both chronologies. The association between the master chronology and the chronology of extensions is statistically significant at $\alpha < 0.01$; $r\,(39) = 0.62$. Therefore, the extension of 'Vasil Serafimov' master chronology with a period of 21 years (from 1987 to 2008) is suggested. Consequently, the span of the series reach 192 years and now cover period from 1816 to 2008 (Fig. 2).

The regression model (Table 1) significantly predicts the relationship between Tree-growth indices (*ITR*) and Precipitation indices (*IP*), Temperature indices (*IT*) and presence of Norway spruce understorey (SU). The adjusted R^2 value is 0.51, which indicates that 51% of the variance of *ITR* is explained by the model (all tree predictor variables taken together). The Standardized Beta weights suggest that *IP* contribute most to predicting tree growth rates. The presence of Norway spruce understorey negatively influenced Scots pine radial increment. Climate – growth and competition – growth relationships calculated by the multiple regression model are visually depicted in Fig. 3. The yearly variation of Precipitation indices (*IP*), Temperature indices (*IT*) and Tree-growth indices (*ITR*) as outcome of standardization of the data are shown in Fig. 4.

It is the nineties, that was the driest period of XX century not only in Bulgaria (Koleva, Alexandrov, 2008), but in all northern hemisphere (IPCC, 2007). For the

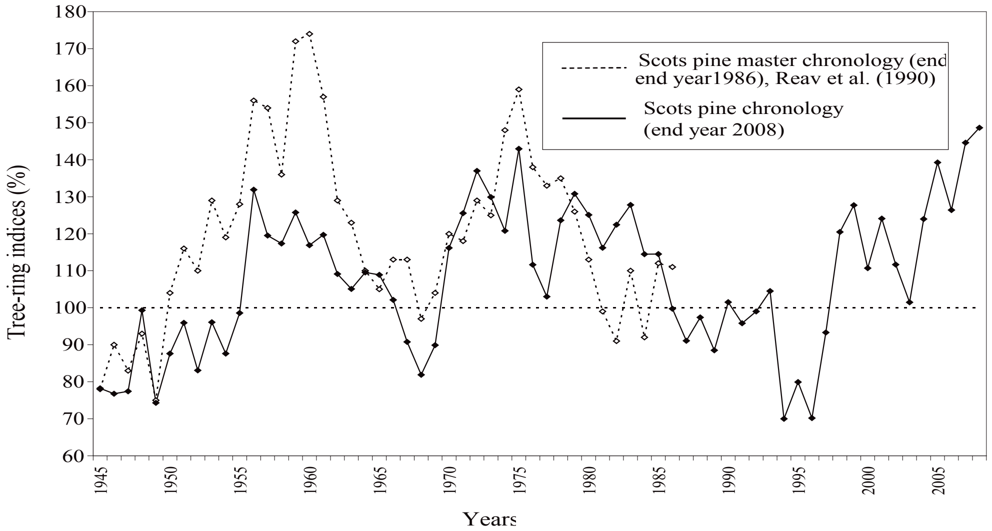

Fig. 1. Overlapping between master and extended Scots pine (*Pinus sylvestris* L.) chronology in 'Vasil Serafimov' Ecological Station, Southeast Rila, Bulgaria

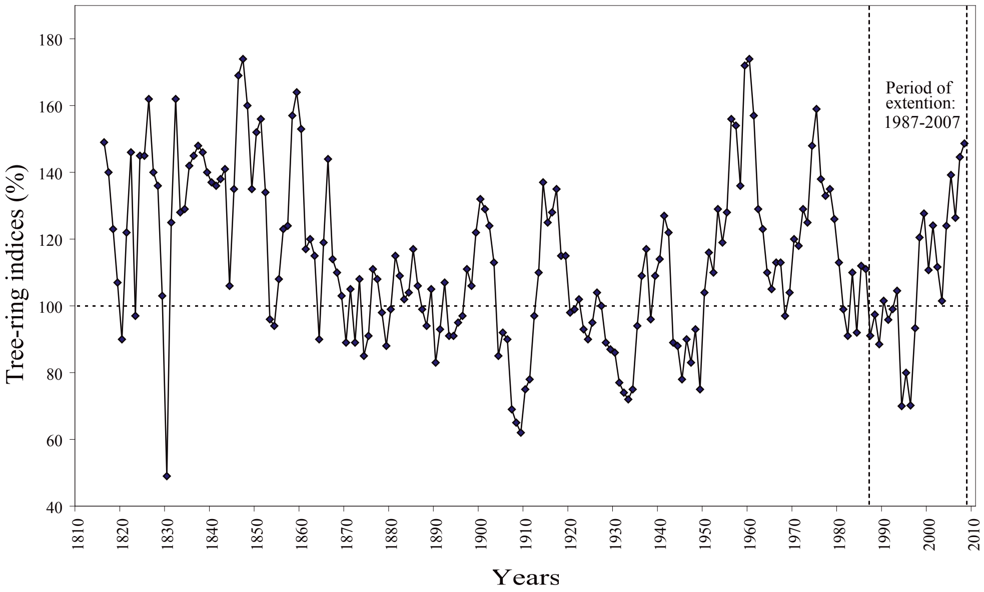

Fig. 2. Scots pine (*Pinus sylvestris* L.), extended master chronology, 'Vasil Serafimov' Ecological Station, Southeast Rila, Bulgaria

Table 1

Multiple linear regression model relating tree-ring index and precipitation index, temperature index and presence of spruce (*Picea abies* (L.) Karst) understorey in studied mature Scots pine (*Pinus sylvestris* L.) dominated stand

$R_{adj.}^2 = 0.51$; N = 21; F (3; 17) = 8.029, p = 0.002

Variables	**Beta**	**Beta Standard Error**	**Standardized Beta**
Precipitation index	0.25	0.08	0.62
Temperature index	0.26	0.16	0.30
Spruce understorey	– 0.11	0.08	– 0.28
Constant	0.60	0.24	

area of 'Vasil Serafimov' Ecological Station, Dimitrov et al. (2009) pointed out that the driest years during the last decade of XX century were 1993, 1994, 1999 and 2000. Consequently, Scots pine individuals responded with reduction in width growth during the period 1993–1996. The species' sensitivity to drought is in accordance with the results published for the Swiss Alps (Kienast et al., 1987; Tessier et al., 1994; Oberhuber, 2001; Rigling et al., 2002; Eilmann et al., 2006). For the studied area, Scots pine indices started upper trend in 1997 despite the drought intensification. Even in the year 2000, which was the peak of the unfavourable climatic conditions, the tree-ring index values were above average for the period. It is considered that removing the competition of Norway spruce (thinning in 1995) is the change point of pine radial growth behavior. According to Fritts (1976) and Schweingruber (1983) the ecological and climatic forces from both, current and previous years influence tree-ring width growth. Hence, the pine positive reaction commenced one year later, in 1997. The delayed response could be explained by anatomical and physiological specifics of Scots pine. Water conductive speed is generally faster in deciduous than in coniferous species (Maherali et al., 2004) and the Haugen-Poiseuille law states that an increment in diameter causes an increase in cell conductivity to the fourth power (Tyree, Zimmermann, 2002). Consequently, Scots pine radial growth alteration following sudden changes in the ecosystem (as thinning) is dependent on water conductivity speed capabilities. Soil water competition dynamics could explain the commence of intensive radial growth of Scots pine in the middle of the dry period started in 1993. The small amount of rainfall water first reached the surface soil layer occupied by the Norway spruce root system. The intensive water consummation of spruce trees dried up deeper soil horizons. Consequently, Scots pine root system suffered from lack of moisture and trees responded with formation of very narrow year rings (1993, 1994 and 1995). Increased penetration of the rainfall water in the deep soils followed by intensive radial growth of the pine (years 1997, 1998, 1999, and 2000) could be a logic consequence of the spruce removal in 1995. After the year of 2000, favourable climate conditions - cool years with greater amount of precipitation (Fig. 4) promoted greater Scots pine radial growth, the tree indices values having been above average till the last year of the chronology extension.

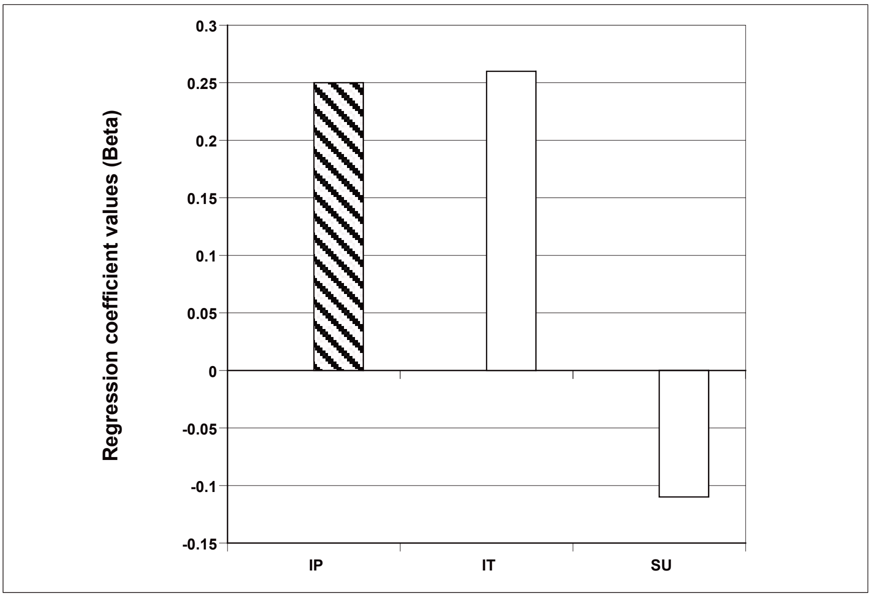

Fig. 3. Climate – growth and competition – growth relationships calculated by the multiple regression model for 'Vasil Serafimov' Ecological Station, Southeast Rila, Bulgaria. Block with slanting lines marked statistically significant ($\alpha < 0.01$) regression coefficient: *IP* – Precipitation indices; *IT* – temperature indices; and SU presence of Norway spruce understorey

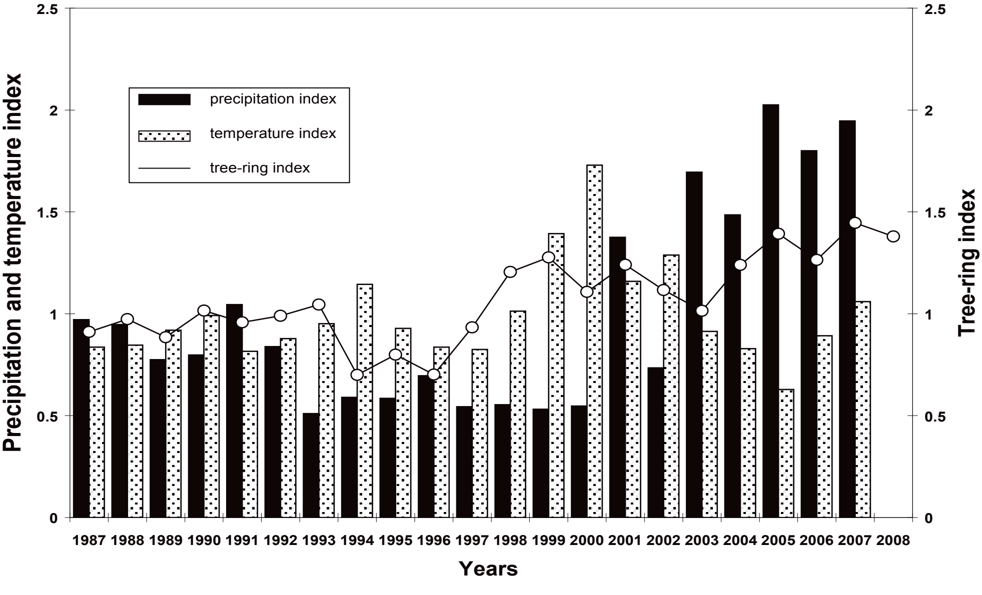

Fig. 4. Yearly based fluctuations of Scots pine (*Pinus sylvestris* L.) tree-ring indices, in comparison with precipitation and temperature indices for the period 1987-2008 for 'Vasil Serafimov' Ecological Station, Southeast Rila, Bulgaria

It could be generalized from the results of the study that the Scots pine radial growth in 'Vasil Serafimov' Ecological Station, was in significant relationship with both climate conditions and presence of spruce understorey. Scots pine responded with radial growth reduction to the dry climate period started in 1993. In spite of the negative climatic conditions (low amount of precipitation and high temperatures), removal of the Norway spruce understorey in 1995 provided a drought overcome impulse for the pine. The cooler and wetter years from 2001 to the end of the studied period resulted in increased pine radial growth rate.

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