THE CLIMATIC SIGNAL IN RADIAL GROWTH VARIATIONS OF *PINUS SYLVESTRIS* L. TREES GROWING IN RAISED BOG HABITAT

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Abstract

The relationships between annual radial growth of Scots pine from peat bog habitat and climatic factors were analyzed. Standardized chronology of tree ring indices and the chronology of residuals from autoregressive modeling were used as site chronologies. The amplitudes of principal components from individual tree growth data set were also used in the analysis. A positive correlation between tree radial growth and averaged February through September temperatures was detected. Regression models for estimating this climatic parameter based on standard tree ring width chronology and based on the amplitudes of two principal components of the individual tree growth data set were established.

Keywords: dendroclimatology, environmental factors, peat bog, autoregressive modeling, principal component analysis, Pinus sylvestris L., Lithuania

INTRODUCTION

Many of Lithuanian oligotrophic bogs contain a huge ammount of subfossil pine timbers that could be used to construct long term tree ring chronologies and, therefore, to reconstruct past climatic conditions and past environmental changes. For instance, an analysis of subfossil timbers excavated from one Lithuanian bog peat layers has been used to develope not continuous *Pinus sylvestris* tree - ring chronology that covered about 80% of almost 2200 year length period (Bitvinskas, 1978; Pukiene, 1997). In order to reconstruct some parameters of past climate from tree ring chronologies, knowledge about the climatic signal these chronologies comprise is necessary.

MATERIALS AND METHODS

Annual radial growth (tree ring width) data of Scots pine trees from a peat bog site was used in this study. The site (Uzpelkiu Tyrelis bog) is located in the North - west part of Lithuania, 47 km east of the Baltic sea, 138 m above sea level. Geographical co-ordinates: latitude 56°05' N, longitude 21°50' E. Ten model trees were sampled at the breast height in the site. Meteorological data (average monthly temperature and monthly precipitation sum) from Telsiai meteorological station (55°59' N, longitude 22°15' E, 149 m above sea level) has been used to analyze relationships between tree radial growth and climatic variables.

We have used two types of site chronologies and series of individual tree radial growth as tree growth data. Standardized chronology of tree ring indices (STD) and the chronology of residuals from autoregressive modeling (RES) were used as site chronologies. Age curve from the series was removed by fitting a spline function. For the analysis of the relationships between annual radial growth of individual trees and climatic variables the principal component method (Zhukovskaja, Muchnik, 1976; Fritts, 1976; Belonin et al., 1978; Wonnacott, Wonnacott, 1979; Stupneva, 1984a, b) was used to reexpress the variability of individual tree growth by reduced number of principal components (PC). Detrending, autoregressive modeling and chronology computation were carried out using ARSTAN40 program from ITRDB Program Library (Cook, Holmes, 1986). ARSTAN40 was also used for the principal component analysis and to compute the time series of the principal component amplitudes. Those components were considered as significant for which the cumulative product of eigenvalues exeeded 1 (unparametric value) (Belonin et al., 1978; Briffa et al., 1983; etc.).

The relationships between the growth chronologies and the climatic variables were analysed by using simple linear correlation. We used EXCEL program for calculating correlation coefficients and their statistical significance. To investigate the possibility of climatic reconstructions we have used simple regression models with the site chronology data as the predictor, and multiple regression model, where the amplitudes of the most significant PC's from the growth data of the trees were used as the predictors. The regression models and climatic estimates were computed also by using EXCEL program.

RESULTS AND DISCUSSION

Coefficients of correlation between the site chronologies (STD and RES) of tree ring width and climatic parameters are presented in figure 1. The temperature of vegetative season month has a positive influence on the growth of pine trees in Uzpelkiu Tyrelis bog site. Temperatures in previous vegetative season have also positive effect, especially in previous June. Positive correlation was also obtained between tree growth and temperatures in late winter and early spring. A prevailing influence of precipitation on the bog tree growth is negative.

The analysis has revealed that on the whole the relationships between the annual radial growth of Scots pine in oligotrophic bog and the monthly climatic parameters are not very strong. Removing of the first order autocorrelation from the annual growth series (RES chronology) has improved correlations with some meteorological factors. After the removing of the series autocorrelation significant correlations persist between the tree annual growth and meteorological parameters in previous growth season.

Temperature has a possitive effect on the growth of Uzpelkiu Tyrelis bog trees almost entirely from February till September (current year). So, correlation between averaged temperature for that aggregated period and tree ring chronologies was calculated. Coefficient of correlation between the STD chronology and average February - September temperature is +0.41. Model of linear regression to estimate that aggregated climatic parameter from STD tree ring chronology of the bog pine trees has been established:

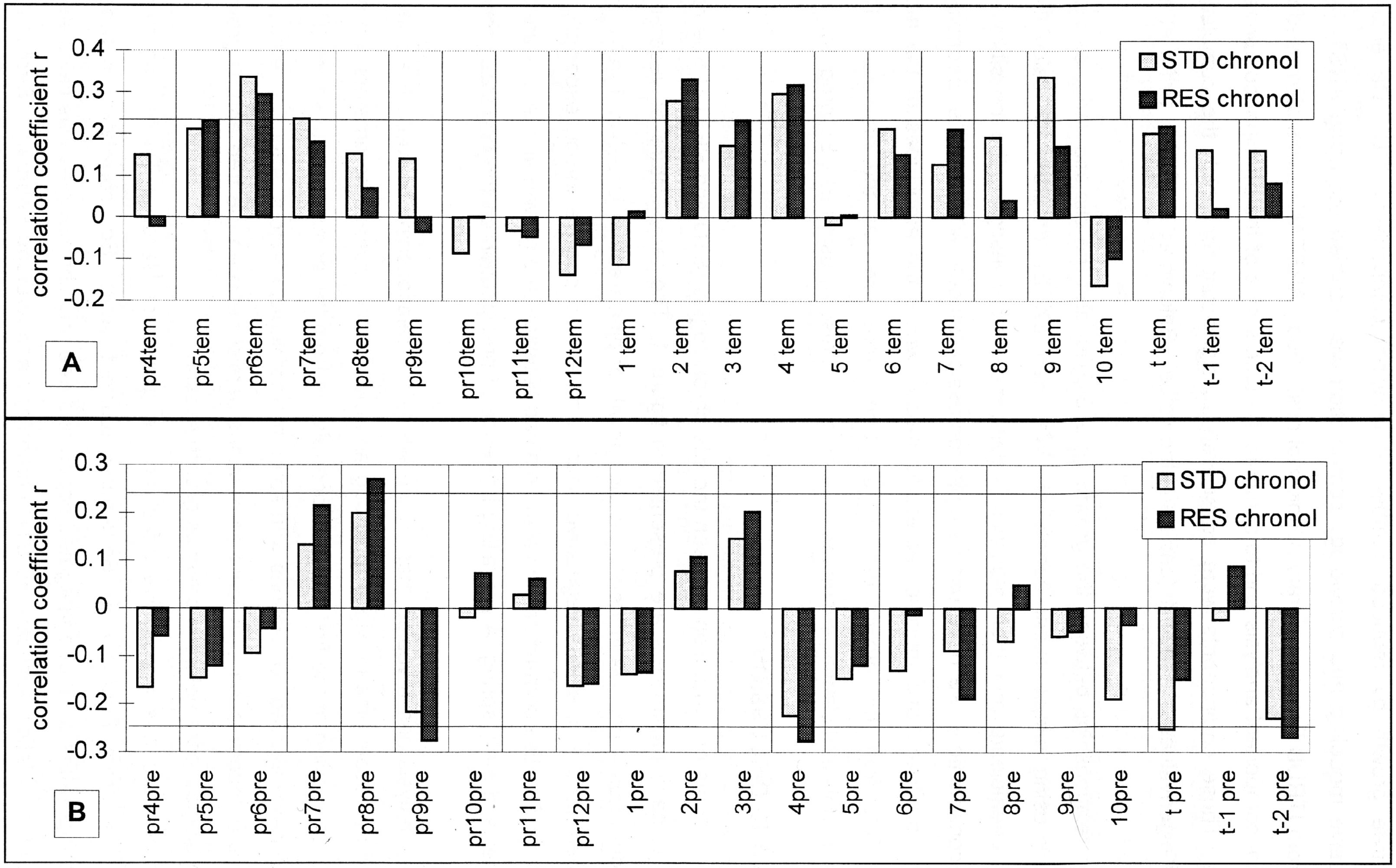

Figure 1. Correlation between two tree-ring width chronologies from Uzpelkiu Tyrelis bog and climatic parameters: A - mean monthly and yearly temperature, B - total monthly and yearly precipitation. STD chronol - standard chronology of ring width indices, RES chronol - chronology of residuals from autoregressive modeling

$$Y_i = 6.25 + 2.08 x_i$$

where Y_i means an estimated averaged temperature of February through September period for the year *i*,; x_i is a value of the standard chronology in the year *i*.

The parameters of this regression model are presented in table 1.

Table 1. Parameters of the regression model to estimate average February through September temperatures, based on standard tree ring width chronology

REGRESSION STATISTICS						
Multiple R	0.4087					
R Square	0.1671					
Adjust. R Square	0.1493					
Standard Error	1.0372					
Observations						
ANOVA						
	df	***SS***	***MS***	***F***	***Signif. F***	
Regression	1	10.1417	10.1417	9.4269	0.0036	
Residual	47	50.5636	1.0758			
Total	48	60.7053				
MODEL						
	Coefficients	***Std. Error***	***t - stat***	***P- value***	***Lover 95%***	***Upper 95%***
Intercept	6.2264	0.7002	8.8926	0.0000	4.8179	7.6350
STD value	2.1223	0.6912	3.0703	0.0035	0.7317	3.5129

The analysis of annual radial growth dynamics of individual trees by use of principal component method has revealed that the first PC explains 40.9% of the variance in ring width series, the second PC explains 18.4% and the third PC explains 12.1% of the variance (see table 2). The weight of the first PC that acounts for the major part of the variance is loaded almost equally on the growth series of all the trees (see figure 2). The weights of higher order PC's vary in the growth dynamics of separate trees, tree groups with differing weights can be detected.

Table 2. Principal component analysis of annual radial growth data set of the pine trees from Uzpelkiu Tyrelis bog site

PC	Eigen value	Variance %	Cumu lative %	Plot
1.	3.6851	40.946	40.946	**
2.	1.6523	18.359	59.305	************************************
3.	1.1153	12.392	71.697	************************
4.	0.7398	8.220	79.917	****************
5.	0.6398	7.109	87.026	**************
6.	0.3814	4.237	91.263	********
7.	0.3478	3.864	95.127	********
8.	0.2865	3.183	98.311	******
9.	0.1520	1.689	100.000	***

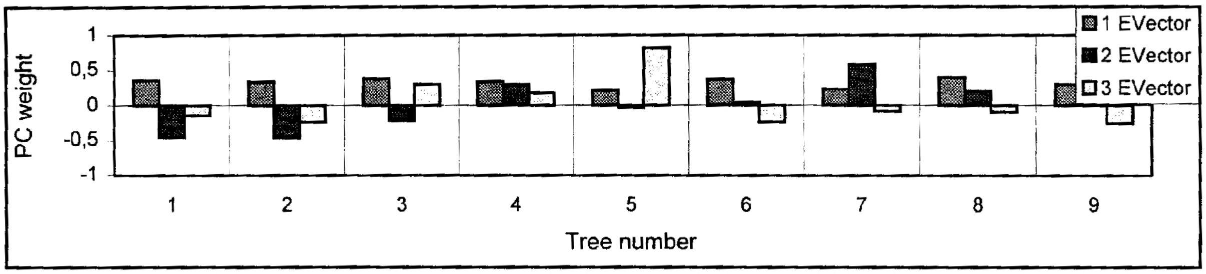

Figure 2. The weights of significant principal components (eigenvectors - EVector) in the radial growth series of Uzpelkiu Tyrelis site trees

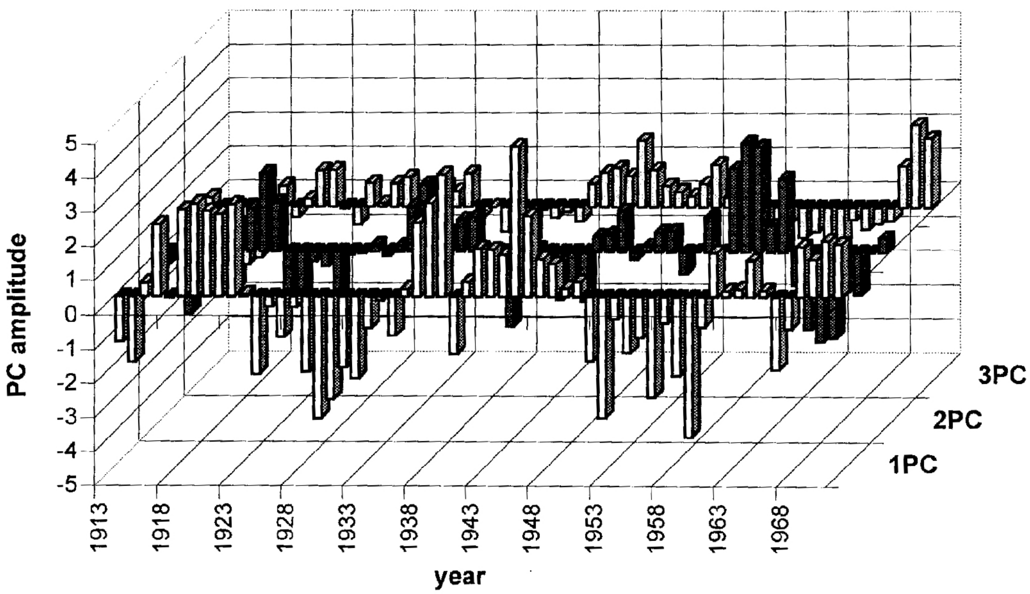

Figure 3. The chronologies of significant principal component amplitudes from the annual radial growth data set of Uzpelkiu Tyrelis bog pine trees

In figure 3 the amplitudes of the significant PC's are represented.

Correlations between the chronologies of significant PC amplitudes and climatic parameters were also analyzed. Since amplitudes of separate PC's show different correlations with climatic factors, multiple regression was used to evaluate the total relations between climatic variables and the principal components of tree growth (used as predictors). The mean standard chronology (STD) for Uzpelkiu Tyrelis bog site shows the best correlation with the fluctuations in average February - September temperature. By use of multiple regression approach, a regression model with first two principal components of the individual tree growth data set used as predictors was established to estimate that climatic parameter.

The regression equation is:

$$Y_i=8.37+0.25x_{i\,1}+0.26x_{i\,2},$$

where Y_i means an estimated averaged temperature of February through September period for the year *I;* $x_{i\,1}$ is a value of the amplitude of the first principal component in the year *I;* $x_{i\,2}$ is a value of the amplitude of the second principal component in the year *i.*

Coefficient of the multiple correlation R=0.49. The parameters of this multiple regression model are presented in table 3.

Table 3. Parameters of the multiple regression model to estimate average February through September temperatures, based on the amplitudes of two principal components of the individual tree growth data set

REGRESSION STATISTICS						
Multiple R	0.4914					
R Square	0.2415					
Adjust. R Square	0.2078					
Standard Error	0.9990					
Observations						
ANOVA						
	df	***SS***	***MS***	***F***	***Signif. F***	
Regression	2	14.3004	7.1502	7.1645	0.0020	
Residual	45	44.9104	0.9980			
Total	47	59.2108				
MODEL						
	Coefficients	***Std. Error***	***t - stat***	***P- value***	***Lover 95%***	***Upper 95%***
Intercept	6.2264	0.7002	8.8926	0.0000	4.8179	7.6350
PC1 amplitude	0.2464	0.0766	3.2171	0.0024	0.0922	0.4007
PC2 amplitude	0.2565	0.1113	2.3052	0.0258	0.0324	0.4807

In figure 4 the actual values for average February through September temperature and that reconstructed according to the established multiple regression model are compared.

CONCLUSIONS

The temperatures of vegetative season months, also of late winter and early spring, have a positive influence on the growth of pine trees in Uzpelkiu Tyrelis bog site. A prevailing influence of precipitation on the bog tree growth is negative. But, on the whole, the relationships between the tree annual radial growth and monthly climatic parameters are not very strong. The standard site chronology showed the best correlation with the fluctuations in average February through September temperature (r=+0.41).

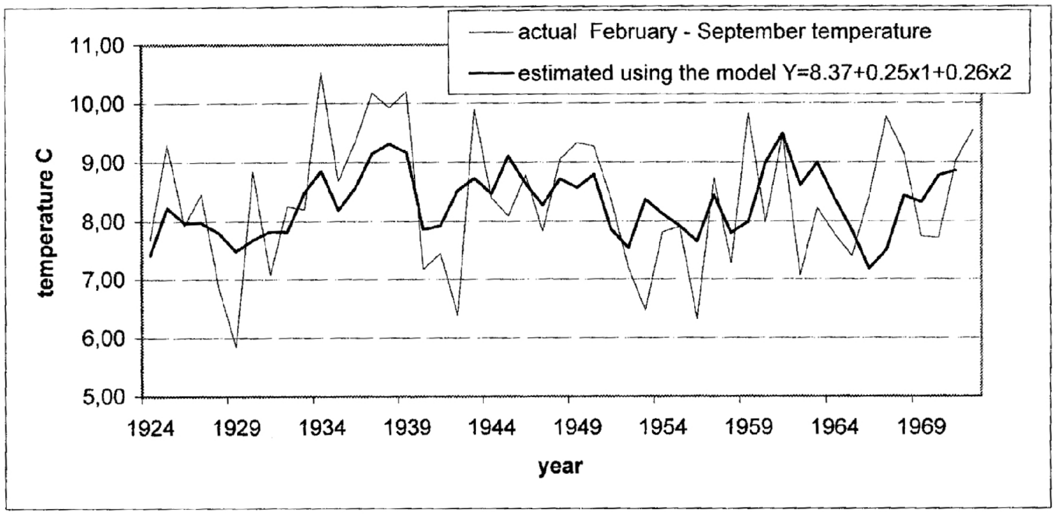

Figure 4. Actual mean temperature for the February through September period and that reconstructed according to the model based on the amplitudes of two principal components from the individual tree growth data set

Because individual pine trees differ in some extent in their reaction to environmental changes, more variance in climatic parameter was reconstructed by the regression model where predictors were the amplitudes of separate principal components, reexpressing the variability in individual tree growth, than by the model based on the site mean chronology unifying growth data of all the trees.

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