SPATIAL VARIABILITY OF DENDROCHRONOLOGICAL SERIES FROM RODNA MOUNTAINS (EASTERN CARPATHIANS – ROMANIA)

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Nine growth index chronologies from three species (*Pinus mugo, Pinus cembra* and *Picea abies*) from Rodna Mountain were statistically investigated regarding the spatial variability. Two types of variables were used in cluster analysis: one is the growth index for each chronology and second are the correlation coefficients between tree-ring width index and temperature and precipitation. In the first case the clustering is done by species and site location and in the second case the criteria are altitude gradient and species. Three type of climate response were identified: one specific to mountain pine and stone pine; second to spruce from high altitude and last to spruce from mean altitude. The temperature from June-July represents the main climate limiting factor for Rodna Mountains.

Key words: Cluster analysis; Dendrochronology; Rodna Mountains; Spatial variability.

INTRODUCTION

Environmental signal stored in tree-ring parameters (tree-ring width, maximum density and chemical composition etc.) is the result of complex interactions between environmental input and tree physiological output[1]. Radial growth and its associated parameters for a growing season integrate current and past environmental conditions, as modified by the genetic background of species[2].

Forest ecosystems located at high latitude and high altitude are particularly sensitive to climate variations due to their location at the edge of forest distribution limit[3]. Dendrochronological series integrate both regional environmental signals and local specific microclimate. Statistical analysis in dendrochronological networks allows the study of the variability of tree response to climatic factors and hence to identify homogeneous areas[4,5]. The interaction between variations in environmental factors and trees sensitivity has clear altitudinal stratification in mountain.

Using a network of dendrochronological series from the north part of Rodnei Mountains by multivariate statistical analysis (cluster analysis) we studied how those spatial segregate using as explanatory variables: a) radial growth indices, b) correlation coefficients between growth indices and climate factors.

MATERIAL AND METHODS

Study area

The dendrochronological network was compiled from 9 chronologies: (1 – mountain pine (*Pinus mugo*); 2 – stone pine (*Pinus cembra*); 6 – spruce (*Picea abies*)) located on the main valleys of north part of Rodna Mts. (Table 1). Sampled site were located in timberline forests, on altitude over 1500 m, except two spruce chronologies (PITM – 1400 m and PITJ – 1200 m).

Tree-ring chronology

In each site two cores were extracted from 20-25 dominant and undamaged trees. In the laboratory each core was prepare according with standard procedures[6] and tree-ring width were measured to 0,001 mm precision using a Lintab system. Individual growth series were crossdated by graphical comparison with the mean series and statistically verified with COFECHA software[7].

Crossdated series were standardized to remove the tree circumference increase effect by a spline function with a 50% frequency response of 67% from the total length of series. Indexes were calculated as ration between raw data and spline value. Autoregressive modeling was used to remove the significant autocorrelation retained in standard index chronologies. The residual chronologies for each site has obtained by biweight mean.

To compare site chronologies descriptive statistics were computed[8]: mean growth, mean sensitivity, standard deviation of growth index and the variability explained by the first principal component. Statistical computing was done by ARSTAN software[9].

Spatial analysis of chronologies

Cluster analysis was used as multivariate grouping technique. This method is a descriptive classification techniques that cluster the site based on the similarity degree, quantified in this case by correlation coefficient[10]. Statistical analysis was done in two ways: one using the growth index of each chronology for the common period (1927-2000) as explicative variables and second using the correlation coefficients between growth index and main climate factors: temperature and precipitation (from June precedent year to August current year).

RESULTS

Chronologies statistics

Table 1 lists the descriptive statistics and geographic parameters of each analyzed chronologies.

Tree-ring chronologies computed are statistically significant for a period of 160–200 years, except those of spruce from Pietrosul Rodnei (the 1400 m and 1200 m altitude) and mountain pine. Average radial growth is lower in stone pine (1.36–1.56 mm) compared to spruce in the upper altitudinal limit (1.46–2.03 mm) minimum values been recorded for mountain pine (0.93 mm). The influence of altitude on radial growth is evident in spruce series of Pietrosul Rodnei observing an increase of the tree-ring width with decreasing altitude.

Developed dendrochronological series are comparable according with the average standard deviation of residual index series (0.21 to 0.23). Regarding the sensitivity is not observed statistically significant differences, being slightly higher for spruce (0.25) compared with stone pine (0.22). In general, spruce has greater population signal (38-49%), quantified by the variance explained by first principal component, compared with stone pine (32–33%).

Graphic comparison of chronologies highlights the existence of a common signal generated by regional climate. Regardless of species or altitudinal position, the overall dynamics of the growth indices are similar, being related to climate variability. Tree response to major changes in the climate system is identical, which varies is the intensity of reaction.

Spatial variability of tree-ring chronologies

Growth index series integrates local and regional climate signal differently in relation to particular species. Cluster analysis with growth indices as variables allows a spatial differentiation

Table 1

Site location and descriptive statistics of studied chronologies

Parameter	Stone pine		Spruce						Mountain pine
	LALA	PTRA	LALB	BILA	PUTA	PITS	PITM	PITJ	LALC
Latitude	47°31′	47°36′	47°31′	47°32′	47°35′	47°36′	47°36′	47°36′	47°31′
Longitude	24°54′	24°38′	24°54′	24°53′	24°50′	24°37′	24°36′	24°35′	24°54′
Altitude (m)	1650	1750	1650	1550	1500	1650	1400	1200	1700
Length (>10 series) (year)	1785-2005 (221)	1796-2008 (213)	1838-2005 (168)	1818-2000 (183)	1776-2000 (225)	1810-2007 (197)	1927-2007 (81)	1887-2007 (121)	1898-2005 (108)
Mean growth (mm)	1.56	1.36	1.77	2.03	1.99	1.46	3.03	2.72	0.93
Mean sensitivity	0.22	0.24	0.23	0.24	0.25	0.25	0.18	0.25	0.23
Index standard deviation	0.21	0.22	0.21	0.22	0.23	0.23	0.21	0.23	0.22
Variability explained by first principal component (%)	33.8	32.2	49.3	38.3	36.2	41.8	43.7	36.6	-

by two criteria: species and geographic area (Fig. 1). Thus the mountain pine spruce and stone pine chronologies separate statistically between them. In spruce group can be observed a clustering according with spatial location, been identified two groups: one specific for Pietrosul Rodnei and the second series from Bistrita Valley.

Interestingly is that the chronologies from Pietrosul Rodnei form the same cluster indifferent of altitude.

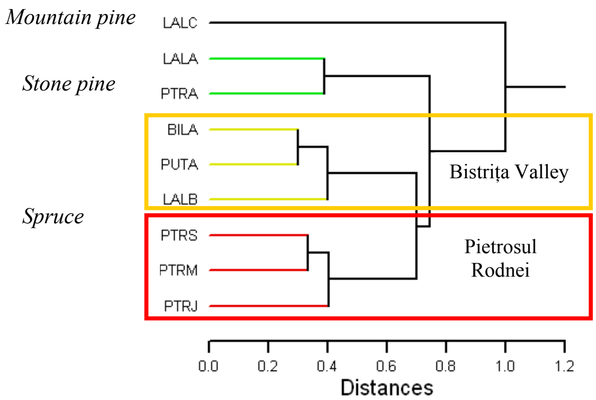

Fig. 1. Cluster analysis of Rodna Mountains chronologies using as variables the growth index.

When applied cluster analysis to correlation coefficients between growth index and climate factors as variables, the clustering of sites is done by altitude and species (Fig. 2). A first analysis enables differentiation of two main groups in relation to altitude: one specific to timberline ecosystems and the second for optimum spruce vegetation zone (1400 and 1200 m). In the first group there is a separation of spruce from mountain pine and stone pine. This classification of chronologies corresponds to three types of climate response: a) specific to stone pine and mountain pine b) a second to spruce from high altitude c) and last specific to spruce from mean elevation.

The first climate response model is characterized by a positive correlation with the thermal regime of the current year of tree-ring formation. Statistically significant is the July temperatures. It also noted a positive response and statistically significant to previous autumn temperatures (October and November). On seasonal level statistically significant are June-July and the previous October-November temperature. Regarding the precipitation that is positively correlated for April and May and negative in October precedent year, but the correlation intensity is low and statistically insignificant.

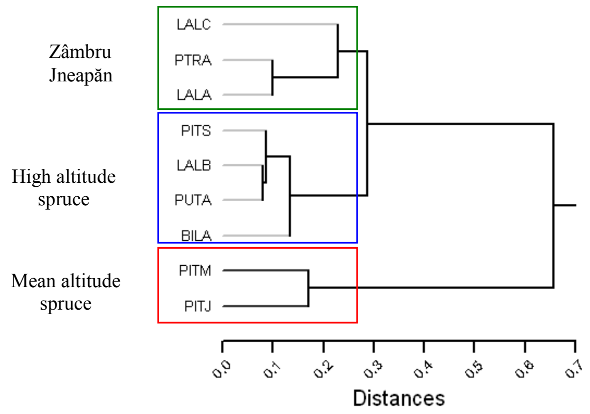

Fig. 2. Cluster analysis of Rodna Mountains chronologies using as variables the correlation coefficients between growth index and climate factors (temperature and precipitation).

The second climate response pattern specific spruce forest located at high altitude that is similar to the previous one, but determining is June temperature. We also noted a positive influence of thermal regime in May, but statistically insignificant. The positive effect of October temperature from precedent year on tree-ring formation is also evident.

The last model is specifically to spruce located at altitudes of 1400 and 1200 m of Pietrosul Rodnei massif. Dormant season temperatures are positively correlated with radial growth of next vegetation season. Statistically significant are the temperatures in February, April and June. Unlike spruce chronologies from high altitude the previous autumn temperatures are not statistically significant, correlations were low. Previous growing season temperatures are negatively correlated with current tree-ring width, but without reaching the threshold of statistical significance.

DISCUSSIONS AND CONCLUSIONS

Nine dendrochronological series for three species from north part of Rodna Mts. were computed by multivariate analysis – cluster classification. Depending on the variables used was possible to evidence different spatial patterns. When tree-ring index are used as clustering variables the spatial grouping criteria was species and geographic location. This demonstrates the capacity of high altitude species (stone pine and spruce) to retain in tree-ring growth series varying climate[11,12]. When climate response coefficients are used in the analysis three major clusters were statistically separate having as criteria the altitude gradient and the species. For the study area the major climate driver is the summer temperature with small different between cluster.

Stone pine and mountain pine, representing the first group, are sensible to July and precedent October temperature. Spruce from timberline is sensitive to end May, June and precedent October temperature. Contrary spruce tree-ring index from 1400 m and 1200 m altitude have a slight different climate response been statistically significant the temperature from February, April and June.

Similar climate response of stone pine and spruce was observed in Alps[11, 13, 14].

Extensive dendrochronological network constitute tools to detect spatial climate response variability of trees. Future studies must consider more species and a large altitudinal and aspect gradients. Extending the network also to the south part of Rodna Mts. will provide a clear understanding of mountains tree species sensibility to actual climate change.

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