CLIMATE SIGNAL DERIVED FROM OAKS TREE RING USING DAILY RESOLUTION CLIMATE DATA

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Abstract

It is known that increased temperatures and decreased precipitation level, combined with extreme summer droughts will affect growth of pedunculate oak (Quercus robur L.) at low altitudes. Sessile oak (Quercus petraea (Mat.) Liebl.) has the same reaction at the lower altitude boundary of its naturally range. In this study, we have developed three chronologies from samples taken from living trees and we have performed correlations with climate parameters. In our case, we used the values of the temperature and precipitation at daily resolution to highlight significant correlation field barrier, eliminating the monthly barrier. Thus, it was estimated with accuracy in what day of the year the radial growth became active, with reference to the action of restrictive or favouring climatic factors. The trees have grown up in adjacent environments on the same soil type, under the same climatic conditions. Clear differences were obtained in tree ring signal observed through the climate-growth relationship. The analysis suggests that Q. robur reply most intense to water stress factor, even if the stand is located at medium altitude, where amount of precipitation is significant higher, comparing with low elevation. Q. petraea it has different response to climate even that the sites geographic are located close, less than 10 km in straight line. The only noticeable difference, between these two sites is represented by altitude.

Key words: CLIMTREG, daily climate data, oak, dendroclimatology

INTRODUCTION

The tree ring width react to a variety of factors, starting with management and ending with environmental factors such as temperature and precipitations. Our study is focused to the relationship between tree ring width and climate, using two species of oak (sessile oak and pedunculate oak) (Stajić et al., 2015). We used an approach, which highlights the periods in which living trees correlate significantly with climate (Fang et al., 2010). We have tested the hypothesis that even the trees are situated in close locations may have different response related to climatic factor induced by species ecology.

In general, in the case of oaks the relation from tree rings and climate depends on species and region (Friedrichs et al., 2009). This species respond positive to precipitation factor at large scale (Andersson et al., 2011) and negative to temperature (Stajić et al., 2015). The most dendroclimatological studies are largely based on quantitative analysis of radial growth on the base of climate. The present study is based on a descriptive representation of periods of dependence between climate and growth.

The present study will answer to the following questions: there are differences between pedunculate oak and sessile oak dendrochronological series regarding the climate response? Within the same species, in a relatively small area, which is the variability of response of trees to climate?

MATERIAL AND METHOD

This study vas conducted in three sites mixed oak forests from Rona de Sus: pedunculate oak (RNS) (47°52′41″N, 24°01′22″E, 464 m), sessile oak (RNG) with the same geographic coordinates and a third site located about 1 km distance with sessile oak (ROG) (47°52′57″N, 24°04′42″E, 669 m). Climate of the region is continental with Nordic influences. July is the warmest month (multiannual mean = 16.65°C), and January is the coldest (mean = -4.52°C). In 1980 have been recorded the lowest mean temperature (1950-2015) respectively 4.98°C. The mean annual sum precipitation is 650 mm; June is the wettest month (mean = 3.57 mm/day).

One increment core per tree was collected at breast height from at least 40 trees per site. To maximize growth trend variation of pedunculate oak and sessile oak we chose to collect samples from each species in the same sit and a different site with sessile oak. All samples were prepared for tree ring measurement and statistical processing (Schweingruber, 1996). For standardization, we have chosen a cubic smoothing spline, with a 50% frequency response to 100 years.

Tree ring width index was calibrated against the climate variable (mean precipitation and temperature). The correlation was calculated using daily mean values and residual chronology resulted after standardization. The CLIMTREG software was used and correlations were calculated in time spans from 21 to 121 days of climate data.

RESULTS AND DISCUSSION

The tree ring chronologies have a length ranging from 163 years (RNG) to 244 years (ROG). The correlation between the three chronologies is high in the case of ROG and RNS (0.66), and lower between ROG and RNG (0.40). For ROG chronology, the statistics reveal the following parameters: mean correlations along all radii 0.43; correlations between radii versus mean 0.67; signal to noise ratio 17.41; variance expressed in first eigenvector is 47.07%. The RNS it shows relatively similar parameters with ROG chronology: mean correlations along all radii 0.42; correlations between radii versus mean 0.66; signal to noise ratio 12.44; variance expressed in first eigenvector is 46.30%. RNG chronology differs distinctly from the first two. The mean correlations along all radii has a lower value (0.33) and the correlation between radii versus mean is only 0.59, as well as variance in first eigenvector, 36,89%. The signal to noise ratio it can be compared with values obtained from first two discussed series.

The general correlation patterns from monthly precipitation and temperature data suggest different sensitivities of trees to the variability of climatic factors. The correlation between ROG and precipitations display a restricted correlation field. Significant values occur in short periods as follows: 39 days from 29 May to 06 July current year (*r* = *0.37*); 22 September to 24 October previous year (33 days, *r* = *-0.33*); 28 September to 18 October previous year (21 days, *r* = - *0.29*) and starting from 22 December previous year until 21 January current year (31 days, *r*= *-0.30*). For temperature correlations indicate significant periods starting from previous year in the following order: 15 June 18 August (35 days, *r* = *-0.36*); 06 October 09 November (35 days, *r*= *0.40*); 18 November until 15 March current year (118 days, *r* = *0.31*) and from 29 May to 28 June (31 days, *r* = *-0.33*) (Fig. 1).

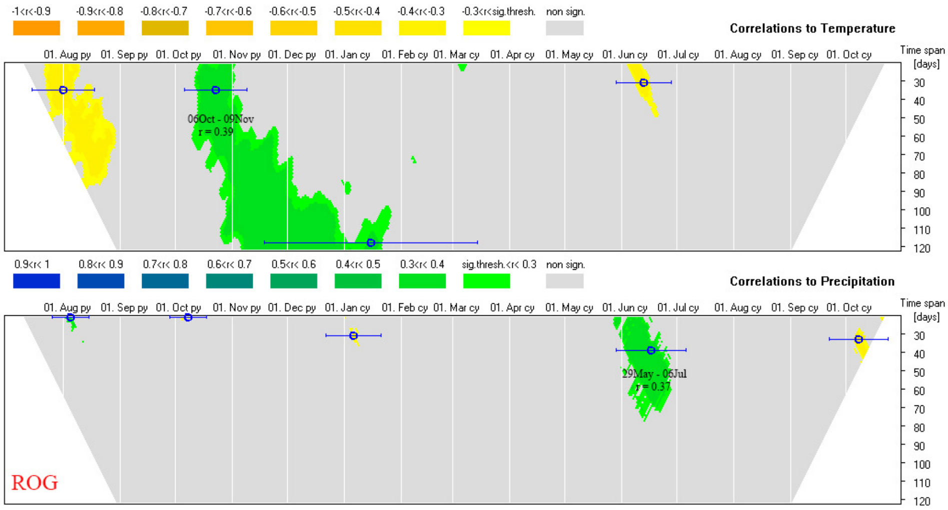

Fig. 1. Exemplary results of CLIMTREG program between temperature and precipitation in relation to ROG dendrochronological series

Second chronology analysed in relation to climatic factors is RNG. Regarding precipitation, we notice following periods with significant correlations, listed in descending order of coefficients: 16 May to 30 August current year, meaning 107 days (*r* = *0.66*); 05 July to 24 September previous year (82 days, *r* = *0.49*); 22 February to 14 Mar (21 days, *r* = *0.39*), current year; 20 December previous year to 17 January, current year, meaning 29 days (*r* = *-0.31*), and the last period since 06 April to 28 April

(23 days, *r = 0.30*). Although the connection between precipitation and tree ring growth is relatively high, the temperature in contrast, feels very week significant correlation only in two periods. First begin to 11 July of previous year to 18 August, respectively 39 days, with a correlation coefficient *r = -0.32*. Second start in 06 May and ends after 40 days, on 14 June current year (*r = 0.31*).

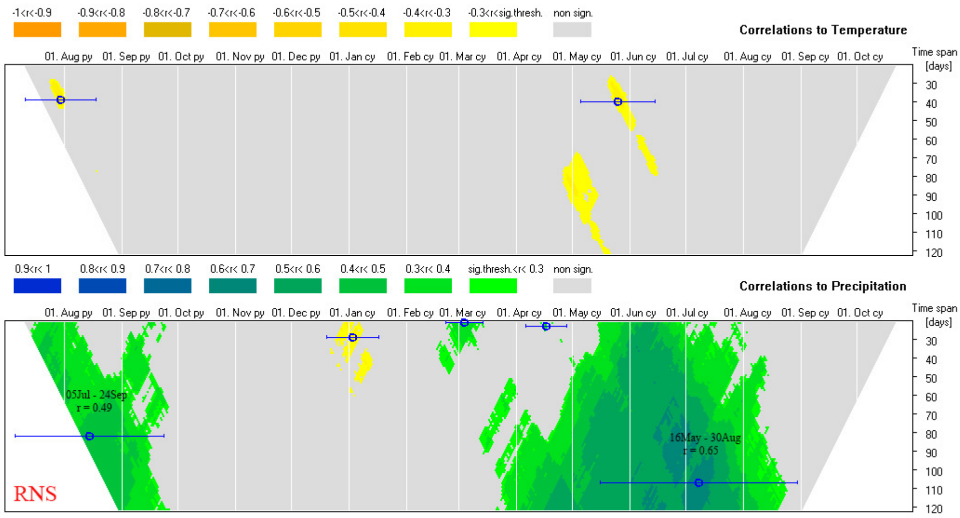

Fig. 2. Exemplary results of CLIMTREG program between temperature and precipitation in relation to RNS dendrochronological series

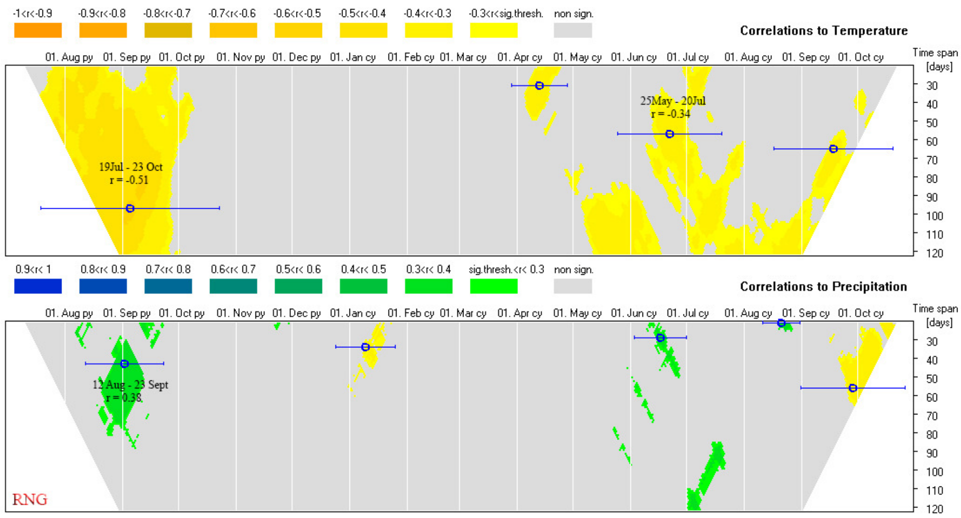

Fig. 3. Exemplary results of CLIMTREG program between temperature and precipitation in relation to RNG dendrochronological series

The third site analysed RNG was significantly correlated with both temperature and precipitations. The correlation coefficient, regarding precipitation ranges from 0.39 (12 August to 23 September of previous year) to $r = -0.37$ obtained for the period 01 September – 26 October current year). This correlation for late summer and early autumn don't have biological support and is pure statistic. Other intervals are 11 August to 31 August current year, meaning 21 days ($r = 0.35$); 03 June to 01 July (29 days, $r = 0.33$); 24 December previous year to 26 January current year (34 days, $r = - 32$). In relation to temperature the intervals found are 19 June to 23 October previous year ($r = -0.51$); 29 March to 28 April (31 days, $r = -0.38$); 25 May to 20 July (56 days, r = -0.34) and the last one starts from 17 August until 20 October (65 days, $r = -0.33$). Similar observation for the last period can be made as in case of precipitation.

CONCLUSIONS

This study is a new approach for understands response of oak trees species to variability of climate parameters based on daily climatic data. The relationship climate-growth is different according with tree species, and in case of the same species differences appear according to site characteristics. For the beginning, statistical parameters of chronologies have differences only in terms of correlations along all radii. This shows a uniformity of responses of trees to the environmental factors.

The significance correlation between growth and climate parameters highlights the different patterns between species, both in terms of intensity and period. Thus, the oak and sessile oak from the same site the precipitations are the main factor for tree ring formation, in particular to RNS chronology and less for sessile oak (RNG). The period interval and intensity of correlation are much higher for oaks. This is explained by the fact that here oak is at the upper limit of altitudinal distribution. The influence of temperature on the growth is not significantly except for short periods in the current year of tree ring formation.

Intraspecific analysis of oak trees shows different behaviours at regional level. The RNG series is weak correlated with precipitation from previous year and only for specific site. Instead temperature is significant and negative correlated on long periods especially for period from previous year. In current growing season the temperature does not show a relatively homogeneous influence, which reflects that this dependence is not constant every year. Climate-growth dependence occurs only in years with climatic extremes very obvious.

The sessile oak at an altitude of 669 m is not significantly influenced by precipitations and temperature. It should be noted that temperatures during October – November from previous autumn in this case is a stimulating factor of annual growth ring formation.

In conclusion, the response of tree rings of Quercus species from Rona region, Maramures, to the main climatic factors (temperature and precipitation) is different in relation to species, and within species in relation to specific sites. Interspecific differences occur even for shorth distances among chronologies. Even if intensity of correlation surprised has the same value, distinctions appear regarding the field of correlation. This can be homogeneous and continuous, case from Rona oak, during the vegetation period of the current year or batch in case of temperature in the current growing season.

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REFERENCES

1. Andersson M., Milberg P., Bergman K.O., 2011, Low pre-death growth rates of oak (Quercus robur L.) – Is oak death a long-term process induced by dry years? Annals of Forest Science, 68, pp.159-168
2. Fang K., Gou X., Peters K., Li J., Zang F., 2010, Removing biological trends from tree-ring series: testing modified Hugershoff curves. Tree-Ring Research, 66(1), pp.51-59
3. Friedrichs A.D., Büntgen U., Frank D.C., Esper J., Neuwirth B., Löffler J., 2009, Complex climate controls on 20th century oak growth in Central-West Germany. Tree Physiology, 29, pp.39-51
4. Schweingruber F.H., 1996, Tree-Rings and Environment. Dendroecology. Swiss Federal Institute for Forest, Snow and Landscape Research, Paul Haupt Verlag, Vienna, 609 pp.
5. Stajić B., Vučković M., Janjatović Ž., 2015, Preliminary dendroclimatological analysis of sessile oak (Quercus petraea (Matt.) Liebl.) in „Fruška Gora" National Park. Serbia, Baltic Forestry, 21(1), pp.83-95