# THE RELATIONSHIP BETWEEN CLIMATE AND RADIAL GROWTH FOR THE OAK (QUERCUS ROBUR *L.*) IN THE WESTERN PLAIN OF ROMANIA

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**Abstract:** By applying methods of dendrochronology we separated the influence of the factors limiting the growth, having direct reference to climatic factors. According to forecasts made on the basis of different models a strong global warming for the near future was determined. *Quercus robur L.* presents a high economic importance in the Romanian forest, therefore the below study is to make a sensitivity analysis to action of oak to "climate as limiting factor". The obtained result was used for the reconstruction of a climatic parameter called the standardized precipitation index combined for three months (SPI 3). The analysis shows a high sensitivity achieved in the previous year's rainfall formation of growth rings (September and October) and early season rainfall associated to the current growing season (May, June). The importance of this study resides in the need to know by further analysis how this species adapts itself to these climate changes knowing that the species within the area are threatened by extinction if it fails to adapt.

## 1. INTRODUCTION

The global changes, the global warming and the climate change have become quite common expressions (Christensen et al., 2007). These scientific concepts have been studied during the last years from different perspectives and by using different instruments.

Knowing the relation between the climate and the radial growth is very important for the determination of the way of influencing the growth by the climate factor and especially for the embracement of durable management solutions for the forestry fund. Most of the times a dendrochronological series has a coverage superior to 100 years and thus it is offered the possibility to compare the variation of the climate factors and the way the growths are influenced under different conditions. Based on the obtained results, we can formulate hypotheses and even forecasts.

Although the forestry eco-systems from the Carpathian space have an economic and ecologic major value, few studies and researches aimed the quantification of the relation between the climate factors and the auxological processes (Popa, 2003; Popa, 2004; Popa & Kern, 2008).

The radial growth rings contain information regarding the climate conditions influencing the growth of those trees, respectively influences of the competition between the trees (Fritts, 1976; Rozas, 2005). It is known the fact that the trees' response to the climate changes is relatively constant in time (Fritts, 1976, Schweingruber, 1996).

In Europe, the *Quercus robur L.,* oak is an extremely valuable species for the dendrochronological studies since it proved to be part of the trees faithfully responding to the climate changes.

The correlation between the radial growth and the precipitations is strong and it is related to the species' habitat. There have been performed climate reconstructions for long periods using wood from old buildings, fossil wood, etc., calibrated using carbon radioactive isotopes (Becker, 1993).

This study represents a different approach aiming to explain the climate influence upon the growth of the oak trees (*Quercus robus L.*) in the Western Plain of Romania. We have had in mind the analysis of the oak's sensitivity to the action of the main climate factors and the determination of the most influencing factor (the restrictive factor).

We can find a strong correlative relation between radial growth and climate in the reached results. The main restrictive factor in this region is represented by precipitations, even if the test area is located in Bârzova alluvial plain and flooding determining excessively humid soil was not present on rare occasions. The important variation of precipitations is found in the radial growing rings.

In order to maximize the effect of atmospheric precipitations, we have calculated the correlation between the standardized index of precipitations cumulated for a period of 3 month (SPI 3), and the radial growth during the period 2006-1901. It thus have resulted an important correlation index equivalent to 0.44 for June, seen as optimum for the reconstitution of the deficit/excess of humidity during the period 2006-1852. The analysed statistical indexes indicate a strong sensitivity of the oak to the action of the climate factors.

Since 1960 we have observed an evolution of the drying phenomenon to the oak species, with serious consequences upon the evolution of those ecosystems. It is important to know the conditions essentially influencing growth; based on the information we have got, we can give answers and formulate hypotheses.

The future studies involving an intra-annual analysis for the formation of the growing ring (early wood, late wood) are necessary for the explanation of the studied phenomenon.

## 2. MATERIAL AND METHOD

### 2.1. The study area

The study area (Fig. 1) is represented by a forestry ecosystem of meadow oak from the Banat region, Banloc city (45º47′N, 21º17′E), located at 90 m altitude. The samples come from an oak ecosystem with a relatively low human influence.

### 2.2. The data set

For the elaboration of the dendrochronological series in the experimental area we have chosen randomly, according to the dendrochronological principles (Fritts, 1976; Cook & Kairiukstis, 1990; Popa, 2002), a number of 25

trees for which we have extended the growth samples at the height of 1.30 m from the ground. The area where the samples were taken was chosen so that to minimize the effects of the disturbances inside and outside the ecosystem (Popa, 2003). The cores have been mounted on standard wooden plates and then polished in order to underline the annual growths.
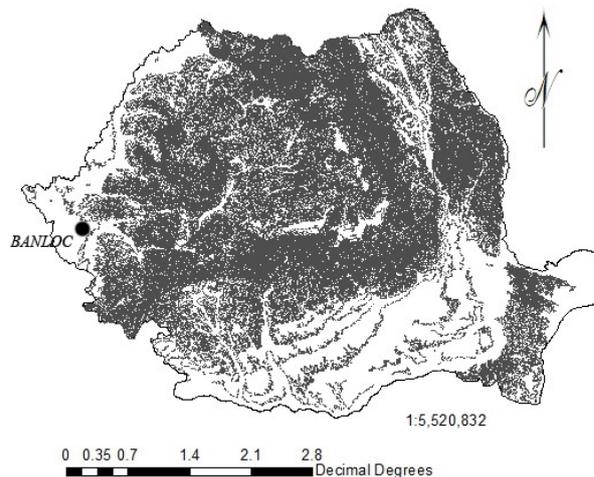


Figure 1. The location of Banloc study area.

The measurement of the annual ring was done by the LINTAB - system composed of a highly accurate digital position meter and a very performing binocular. The registration in electronic format of the measurements was done by the TSAP programme - that makes the connection between Lintab and the computer (Rinn, 1996).

The accuracy of the measurements of the radial grow rings was of 0.001 mm. The registration were individually saved for each core and the final file was saved in the classical Heidelberg format (*.fh).

The time series obtained where thus visually and statistically cross-dated using the TSAP and COFECHA programs (Holmes, 1983). This program performs a statistical control upon the correct positioning in time of each individual measurement compared to all the measurements introduced into the analysis.

The ARSTAN win program (Cook, 1985) was used in order to obtain the standardized growing indexes. Arstan program offer a correction of annual ring for the modifications caused by the change of the tree geometry, the age, the non-climate external factors etc. By the application of the varied mathematical model used for standardization, we can eliminate the influences that are not making the object of the analysis, influences called noise.

By the standardization of the dendrochronological series we removed the signal induced by the age factor by applying a cubic spleen function with a periodicity equal to 67% from the length of the series (Cook & Kairiukstis, 1990). The length of the variation period was chosen as being 2/3 of the total length of the growth index series since it is considered as being optimally related to the maximizing of the signal-noise balance (Popa, 2002).

In the dendroclimate analysis we have used a dendrochronological series of residual type, RES. Residuals series are indexes obtained by the application of an autoregressive model to the standard dendrochronological series in order to eliminate auto-correlation.

### 2.3. Climate data

We have used a set of climate data from the international climate database *CRU TS 3* (Jones & Haris, 2008) for the analysis of the correlative relation between the radial growth and the climate, for the period 1901 – 2006. This data resulted through the interpolation of the climate records from the local weather stations thus creating a grid with a resolution of 0.5°. From the weather stations are records missing and a lot of them began to record their data after 1950. Due to these aspects there are sometimes major errors in the CRU database, especially for the precipitations parameter, since these ones have a local action, unlike the temperatures that are homogeneous at the regional level.

The instrumental data obtained from the Timisoara weather station (45°46' N, 21°15' E, elevation 90 m), for the period 1961-2007, were used to check the CRU climate data. The correlation between the two sets of data exceeded 0.85. The climate diagram was done for the period 1901-2006 (Fig. 2).

The climatic data are characterized by a multi-annual average temperature of 11.7° C and an annual level of precipitations of 625 mm. The precipitations conditions are low during the first two months of the year: January and February, after that they constantly increase, until the June, they decrease again until September and after that we can notice a slight increase. The most humid month is June (286 mm) and the hottest is July with a temperature of 22.3° C. The months with the lowest pluviometric conditions are February and March.

We have also introduced in the analysis a synthetic index for the precipitations deficit/excess– the standardized precipitation index – SPI calculated for cumulated periods of 3 months (Barbu & Popa, 2001).

### 2.4. The analysis of the climate-radial growth relation

The quantification of the influence of the climatic condition, respectively the thermal condition was done through the correlation coefficient. The analysis of the temporal stability of the correlative relation was calculated using the Dendroclim 2002 program (Biondi & Waikul, 2004). The analysis period is comprised between the June of previous year and September of the current vegetation season. By the linear regression method we have proceeded to the reconstruction of the historical variation of SPI3 for the period 1852-2007 in the Banloc area.
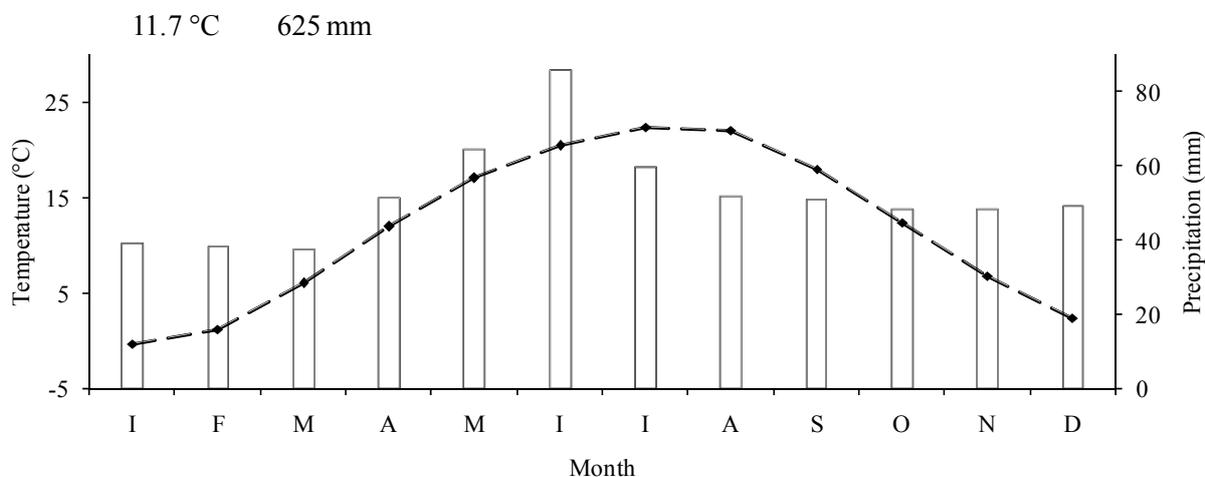


Figure 2. Precipitations and monthly average temperatures for the Timisoara weather station. Monthly mean precipitation (wait bars); monthly mean temperature (black dotted line).

## 3. RESULTS

### 3.1. The dendrochronological series

The time period covered by the individual chronologies is comprised between 1852 and 2007, covering more than 10 series after 1872 (Fig. 3). The average age of the analysed trees is of 138 years, with a minimum of 116 years and a maximum of 156 years. The average width of the annual ring varies from 1.37 mm·year$^{-1}$and 6.41 mm·year$^{-1}$, with an average of 2.53 ± 0.77 mm*year$^{-1}$.

The autocorrelation of the 1$^{st}$ degree is of 0.71 ± 0.11, in the case of the growing series and it drops to the value of -0.13 for the residual indexes, respectively 0.34 for the standard indexes.

The response of the trees to the annual changes of the environmental conditions is reflected in the average sensitivity which varies between 0.19 and 0.32 with an average of 0.24 ± 0.03, representative values for the radial growth series. The average standard error of the residual indexes expressed the sensitivity of the trees to the growing conditions and it has the value of 0.26 ±0.04.

The correlation between the individual chronologies and the dendrochronological series is of 0.57. The correlation between the radial growths is of 0.30, the one between the radial growth series (Y variance) is of 0.31 and the correlation between the annual values of the same series is of 0.28. The variance explained by the first main component is of 34.92%.
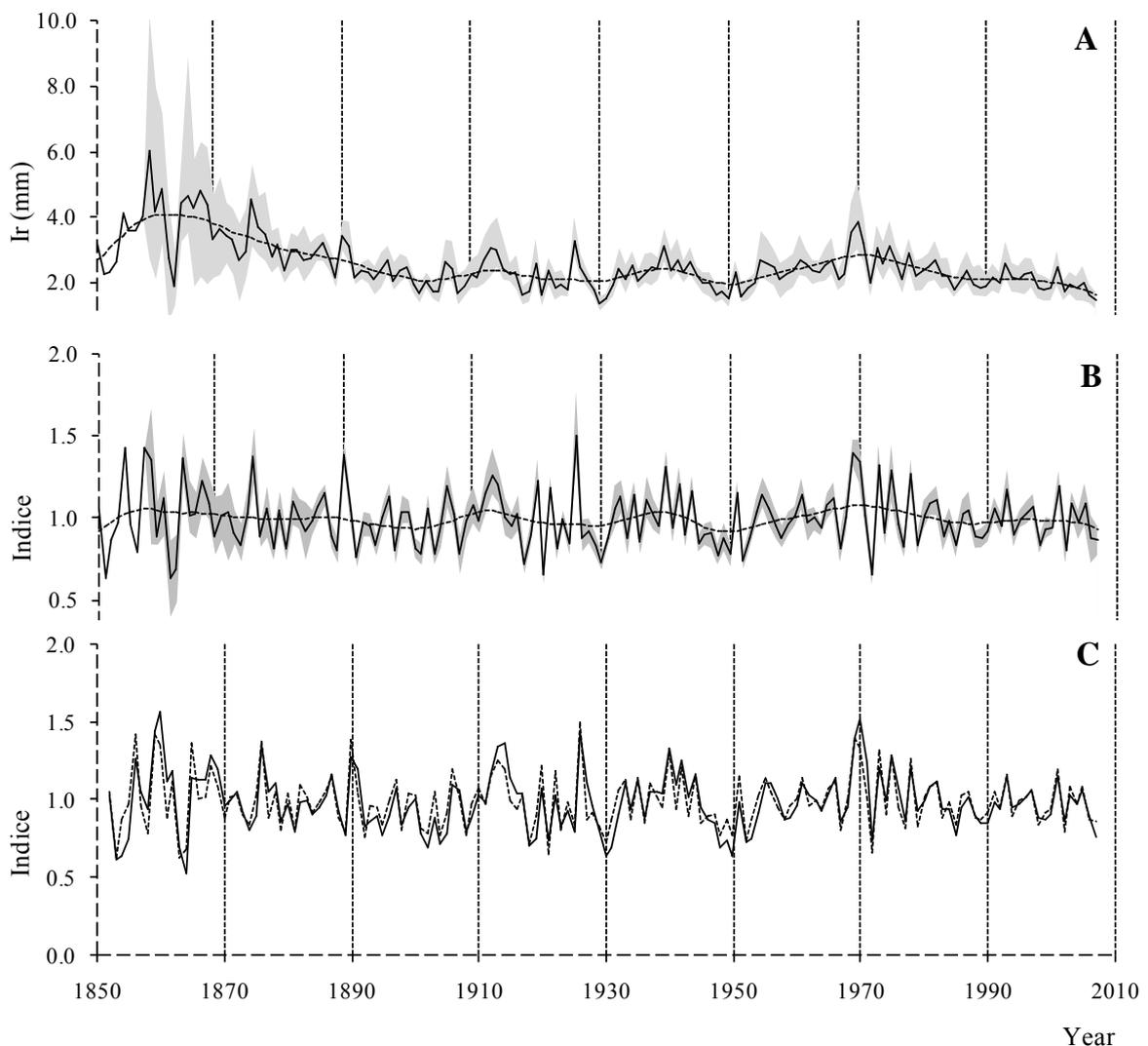


Figure 3. The oak dendrochronological series for the Banloc region (A – the average radial growing series: black – annual values, black dotted line – the spline curve, grey – the confidence interval; B – the residual dendrochronological series: black – annual index values, black dotted line – the spleen curve, grey – the confidence interval; C – the comparison of the index series: black continuous line – standard index series, black dotted line – residual index series).

The proportion between the signal and the noise (SNR) is of 15.86. The ESP value is superior to the value of 0.85 after the year 1877, having an average value of 0.93, values calculated for the residual growing indexes.

From the comparative analysis of the residual series and of the standard one several differences can be noticed, especially during the period with values of the indexes below the average.

The main negative years are: 1853, 1863, 1874, 1879, 1881, 1888, 1889, 1892, 1902, 1904, 1908, 1918, 1921, 1923, 1930, 1936, 1948, 1958, 1967, 1972, 1977, 1979, 1994, 1998, 2002, the positive years are: 1856, 1859, 1865, 1876, 1882, 1887, 1890, 1897, 1906, 1920, 1922, 1926, 1940, 1942, 1944, 1951, 1955, 1969, 1975, 1993, 2001. For calculate this year's we use the program Weiser (Gonzalez, 2001). It can be noticed a correlation between the characteristic positive and the negative years, analysed for the appearance period. Thus, the positive years precede the negative years. The explanation is that after a stressful period the bioaccumulation capacity is greater.

### 3.2. The climate – radial growth response

The dynamics of the average radial growth reported at a certain age shows a trend characteristic for the brush lacking intense competition processes or significant modifications of the structure. If until 1875 we could notice great variations of the radial growth curve due to the small number of series, after that year the dynamics is approximately linear until 1970 and after that the trend becomes exponentially decreasing. It can be noticed in the same context a

decrease and stabilization of the confidence interval corresponding to the average radial growth curve after 1890, induced by the number of samples.

A variation of the radial growth dynamics can be seen compared to the studied climatic data, respectively the rainfalls, the temperature and the standardized index of precipitations (Fig. 4). Thus the precipitations in the current vegetation season (May-June) are the basics for the formation of the oak's annual ring. From the analysis of the correlation between the precipitations and the residual series it resulted the following values for the months taken as reference: May (0.28), June (0.45). The rainfalls corresponding to those months are the main climate variables controlling the growth.

From the analysis of the correlation between the temperature and the residual growth it results a negative influence upon the beginning of the bioaccumulation process during the months of Mach (-0.23) and April (-0.24). The correlation between the standardized precipitations index and the dendrochronological series presents the same trend as the influence of the precipitations upon the growth, except from the correlation values which are higher, due to the commutation of the values for a period of 3 months in the SPI3 case.

The SPI case is illustrated by the months of May (0.25), June (0.44) and July (0.44). The climatic conditions at the end of the vegetation season participate to the formation of early wood and they influence in the growth variation next year. The months with influence of the precipitations upon the radial growth from the previous year are September and October.
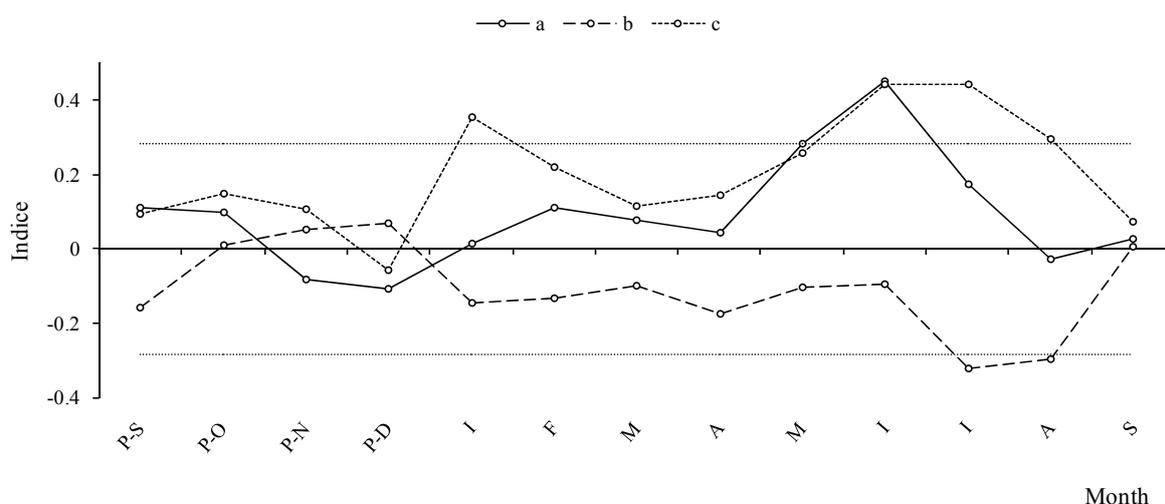


Figure 4. The correlation between the residual indexes series and the climate factors (a – correlation between the precipitations and the RES series; b – correlation between the temperature and the RES; c – correlation between the SPI 3 and RES; ··· the superior limit of the confidence interval; ··· the inferior limit of the confidence interval) to the oak expressed by the use of the correlation coefficients.

The temperatures are those that can affect the assimilation of the resources necessary to the maintenance during the winter period and to the reset of the bioaccumulation process next spring.

### 3.3. The reconstruction of the standardized precipitation index

For the reconstruction of the precipitation standardized index (SPI 3) for the month of June we have used the classical process, by dividing the set of data with the values of the known standardized precipitation index in two equal parts. The first set of data is used for the adjustment of the mathematical model used for the reconstruction, choosing the period 1959–1983 since the anthropic influences upon the environment have been tighter, eliminating the climate abnormalities further the pollution more obvious after 1980, and the second one for verification (Fritts, 1976; Popa & Kern, 2008).

The linear regression was chosen as variant for reconstruction after having calculated the variation of the standardized precipitations index for a period of time equal to the length of the dendrochronological series. The mathematical model used has the form of SPI3 (t) = 3.436 Ir (t) – 3.268.

The correlative bond between the residual growth and the standardized precipitation index is 0.586. The correlation coefficient between the real SPI 3 and the estimated SPI 3 by the mathematical model for the verification period (1984-2006) is of 0.430.

From the graphic (Fig. 5) we can tell that the SPI3 restoration follows the minimum and maximum years, which shows the high level of influence of the precipitations in the formation of the annual ring. The highly pluviometric periods oscillate almost constantly compared to the ones presenting a deficit of precipitations.

The reconstruction of the standardized precipitation index was tested by using the correlation Pearson (r) coefficient for the adjustment periods and for the verification one (Fritts 1976; Popa & Kern, 2008)

## 4. DISCUSSIONS AND CONCLUSIONS

According to the above mentioned, there can be easily distinguished an obvious separation of the spring precipitations from the year current of the annual ring formation as a dominant limitative factor for growth of the oak in the studied region.

The regional or even sub-regional signal reflected by this dendrochronological oak series proved to be mainly climate. The homogeneity of the individual series expressed by a correlation index of 0.57 compared to the master series shows that the oak is sensitive and it reacts in group, not individually to the disturbing factors.

The hyper-sensitivity to the precipitation deficit makes this species especially interesting since by the global warming the precipitations are reduced, thus being indirectly influenced.

The average sensitivity is a measure of the relative variability expressed by growing indexes characterizing the adjacent rings; the great values indicate a great variability (Fritts, 1976; Rozas, 2004), in the analyzed case we can notice quite homogeneity, its value being of 0.24.
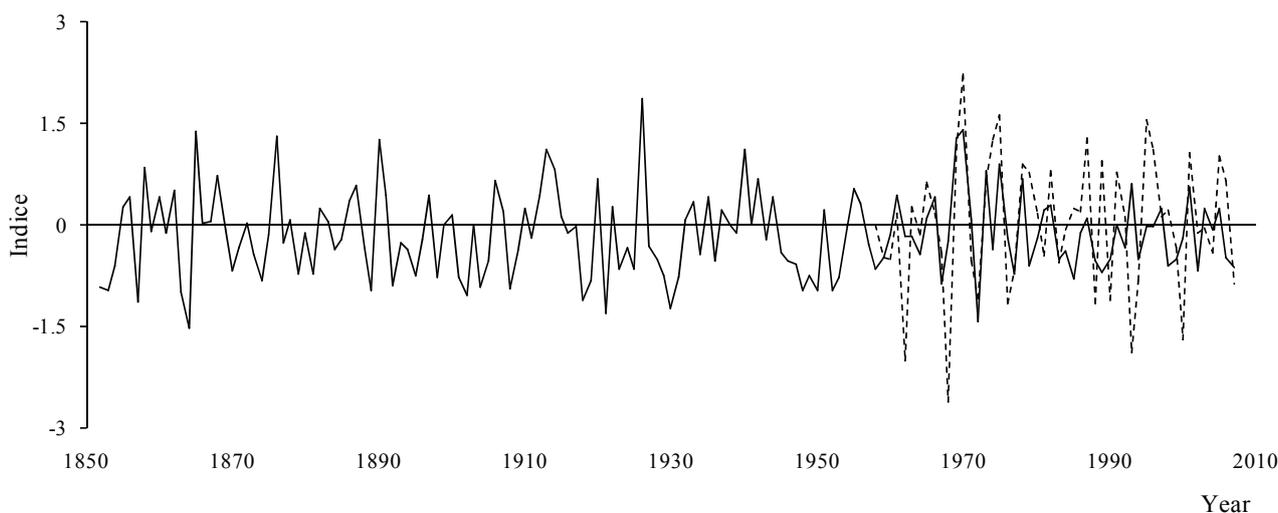


Figure 5. The reconstruction of the SPI3 variation in the month of June based on a residual dendrochronological series for the oak species (black dotted line – SPI 3 June real; black – SPI 3 June reconstituted).

The autocorrelation of the 1st degree indicates how strongly the growth is influenced by the conditions from the previous year (Fritts, 1976), and here we can observe the strong influence represented by the coefficient of 0.71. Similar responses were obtained by (Fonti & Garcia-Gonzales, 2007), respectively the months of September and October are the ones controlling the growth from the perspective of the beginning of the bioaccumulation process.

Constantly we have observed that the limitative climate factor is represented by the precipitations. Thus, the climate conditions from the beginning of the radial growth period can be limitative for the oaks, phenomena also observed in Europe (Fonti & Garcia-Gonzales, 2007).

The spring precipitations (July) are determinant in the bioaccumulation phenomenon at the oak from the Western Europe (Tessier et al., 1994; Nola, 1996), unlike the Romanian oak for which the May and June precipitations are significantly correlated to the growth. The weak positive correlations were met in the March and May temperatures for the beginning of the vegetation season, respectively with the values of the thermal index in the months of August and less in September from the end of the bioaccumulation period.

Unlike other studies where the climate-radial growth relation is analyzed from the perspective of the limitative factors we can notice the clear influence of a single factor represented by the pluviometric condition permitting to the oak in this region to offer precise data for the reconstitutions of the precipitation variations based on the radial growth.

The wood formed during the vegetation season is the one differentiating the annual radial growths and the formation of this one is mainly based on the precipitations of the months of May - July. Previous studies in different sites dispose the same orientation, the period being variable, different according to the region, so that in Slovenia (Cufar et al., 2008) the bioaccumulation active period is restrained at the level of the months of May and June.

The snowfalls and the temperatures (Cufar et al., 2008) are also admitted as limitative main factors for certain regions (Slovenia) but they are excluded for the Banloc region.

We can notice from the analysis of the studied factors a strong correlative bond between the radial growth (expressed by the growing indexes) and the precipitations. The precipitations of the months of May and June offer the optimum conditions for the biomass production, the accumulations being maximal and submitted to the influence of these variables.

The limitative character of the precipitation deficit is suggestively highlighted by the correlation between the dendrochronological series and the precipitation standardized index SPI3.

The response of the oak to dryness permits the successful use of this species to the climate reconstruction, faithfully following the inter-annual „precipitation calendar".

Mode of the variation for main predictor, respectively precipitation, in this area can be very important from ecological point of view, because variations beyond a certain point negative or positive can determine phenomena of growth reduction or even partial and total drying of trees.

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