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Dendroecological analysis of Scots pine (P*inus sylvestris* L.) stands in Vitosha Mountain, Bulgaria

N. Zafirov

University of Forestry, Sofia, Bulgaria

Introduction

Current state

Scots pine (*Pinus sylvestris* L.) is one of the most widely distributed tree species in Europe, and the Balkan Peninsula is its southern tree limit. In Bulgaria pine stands cover one sixth of the woodland and more than 50 per cent of the land occupied by coniferous forests. It is also the main species that has been used in the large scale afforestration for the last 50 years. However, nowadays many of these plantations are affected by the widespread forest decline, and more than 20 per cent of them have already degraded. Unfortunately, the causes leading to the declining health condition of pine plantations are not fully clarified. Some of the scientists attribute it to fungal diseases, others – to insect infestations but most of them suppose that abiotic factors and mainly the ongoing climate change is the trigger leading to the worsening of plantations' condition (Innes, 1993).

The most precise way to investigate the influence of the variety of environmental factors on trees is by considering the dimension of time. The environmental situation is shown in true light only by tree rings (Schweinguber, 1996), which makes dendrochronological methods the most suitable for studying the impact of the factors affecting tree health.

Objective and research tasks

The objective of this study is assessing the state and dynamics of the condition of Scots pine plantations in Vitosha Mountain and evaluating the impact of climate conditions. For this purpose, several research tasks were planned to be achieved:

1. To establish mean index series for the radial increment of several pine plantations and to assess the impact of climate conditions, mainly mean monthly temperatures and monthly precipitation,
2. To analyze the dynamics of the mean indices during the growth periods of the stands and to ascertain the effect of the tree age, altitude and slope exposure on the health condition of the stands, and
3. To build models for the radial increment of the sites that show similar changes in the established series.

Materials and methods

Objects of this study are pine plantations in Vitosha Mountain which is located in the centre of the Balkan Peninsula near Sofia, the capital of Bulgaria. It has an area of 311 km^2 and an unusual, dome like shape which makes it suitable for studying the impact of the slope exposure on tree growth.

Samples were taken from seven pine plantations at different ages and growing under different ecological conditions. On the eastern slope at 1200 m altitude three stands were sampled, each at different age – 50, 70 and 90 years old. Samples were also collected from stands on the other slopes of the mountain at the same elevation and also from one stand at 1600 m altitude.

Twelve to seventeen trees per sample site were sampled and one or two cores per tree were extracted. Dendrochronological methods, as described by Fritts (1976), Cook and Kairiukstis (1990), were used for sampling the trees, processing and cross-dating the cores. Tree-ring widths were measured by using a tree-ring measuring table with Dendrostat computer program in the University of Forestry, Sofia. Exponential, modified exponential and power functions were used for detrending the increment series. For better visual analysis the mean index chronologies were smoothed with five-year moving average curves and were plotted on joint graphs.

After the autocorrelation of each index series was removed, a multiple regression analysis was performed for assessment of the climate impact on tree growth. As predictors in the model the following variables were used: mean monthly temperatures and monthly precipitation over a period of twelve months – from September of the previous year to August of the current year. Climatic data was provided for the Cherni Vrah meteorological station which is the nearest available for all of the stands. The period from 1955 to 2003 was used for developing the models because this is the common time span for the mean index series.

For building a model which can be used for prediction of the current year health condition of the trees, stepwise regression was used. The variables, which are used as predictors in such models, must precede the period of the growth season (Mirtchev *et al.* 2000). So the following variables were used: mean index for the previous year and mean monthly temperatures and monthly precipitation from September of the previous year to March of the current year.

Results and discussion

By cross-dating the cores, one missing and several partially missing rings were found which shows that the environmental conditions in the studied sites rarely became so unfavorable for Scots pine trees to cease their radial growth.

For establishing mean index series, between 20 and 30 cores per site were used. The calculated chronology signal (Expressed Population Signal) for the different stands has values between 0.85 and 0.92 which shows that the number of sampled trees was sufficient for establishing mean index series.

The multiple regression analysis, where monthly precipitations and mean monthly temperatures were included as predictors together, showed that there is a strong climatic signal in all of the series. The coefficients of determination (R^2) vary from 0.45 for the Northern site to 0.63 for the Southern site (Tab. 1).

Table 1: Coefficients of determination from multiple regressions with both mean monthly temperatures and monthly precipitations as predictors

Study site	East, 1200 m a.s.l., 90-year-old	East, 1200 m a.s.l., 70-year-old	East, 1200 m a.s.l., 50-year-old	East, 1600 m a.s.l.	North	West	South
R^2	0.60	0.62	0.54	0.62	0.45	0.62	0.63

In order to determine which climatic factor has greater effect on the increment of the trees, multiple regression analyses were performed separately with the mean monthly temperatures and with the monthly precipitations. Again, great difference between the reactions of the separate sites was not established (Tab. 2). Almost all index series showed greater correlation with the mean monthly temperatures than with the monthly precipitations. The age of the trees does not modify the climate-growth relationship. Minor differences were established for trees growing on differing slopes of the mountain. The Southern plantation is the most influenced by the temperature variation, and showed the same dependence upon both of the factors. Unlike it, the Northern plantation is the least influenced by the temperature variation, and has the highest difference in the dependence upon these factors. The absence of great differences in the impact of the two factors on the different sites is probably due to the fact that these plantations are neither at the high nor at the low tree line of the Scots pine distribution.

Table 2: Coefficients of determination from separate multiple regressions with only precipitations or only mean temperatures as predictors

	East, 1200 m a.s.l., 90-year-old	East, 1200 m a.s.l., 70-year-old	East, 1200 m a.s.l., 50-year-old	East, 1600 m a.s.l.	North	West	South
R^2 (T)	0.40	0.45	0.32	0.44	0.37	0.44	0.37
R^2 (P)	0.22	0.28	0.30	0.32	0.14	0.33	0.37

Through the graphical analysis of the smoothed index chronologies for the stands at different ages, several differences between them were established (Fig. 1). The two longer chronologies have a common stress period from the beginning of the 40-s to the beginning of the 50-s of the last century. Then an improvement in their condition is observed until the beginning of the 90-s when the index series steadily drop below average. The indices of the youngest trees vary around one during the 70-s, and after the beginning of the 80-s they reach their lowest level. The great differences between the sites are found when the stands reach an age of about 50 years. At that age their indices generally reach their highest values: for the 90-year-old stand – in the 60-s, for the 70-year-old stand – in the 80-s and for the 50-year-old stand – at the end of the century. It is very interesting that in spite of the unfavorable climatic conditions during the last decade that affected the two older stands, the youngest stand is in good condition. Clearly, Scots pine trees in this area are most vital at 50 to 60 years of age, when they are less affected by the adverse influence of the environmental factors. After this period, they gradually become more vulnerable to adverse influences. This fact can be used in forestry practices for determining the age at which Scots pine trees have to be felled.

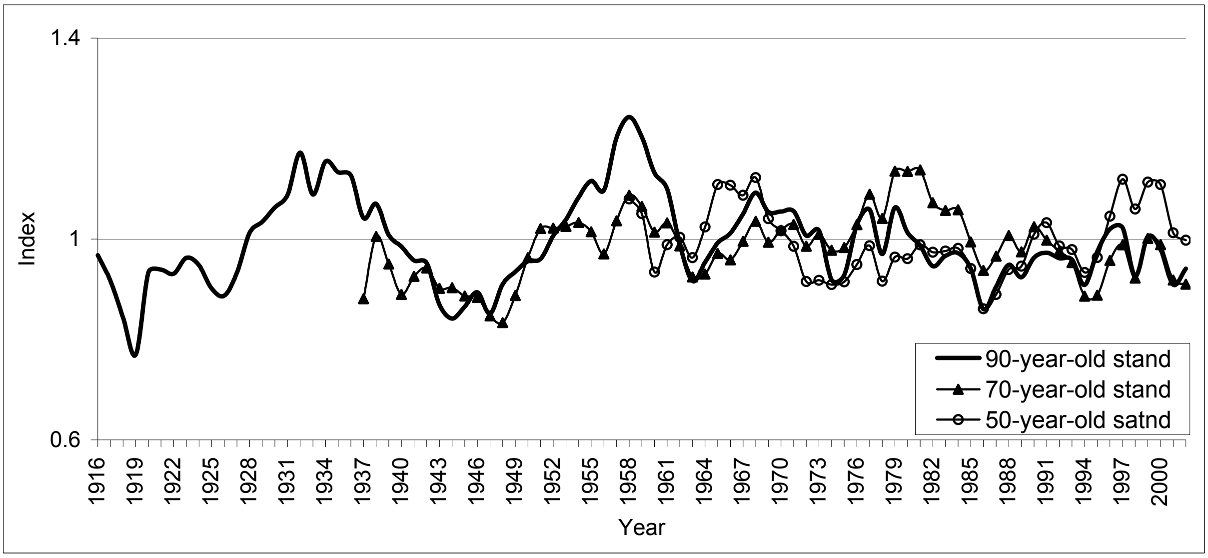

Figure 1: Mean indices dynamics of pine trees at different ages growing at 1200 m altitude on the eastern slope of Vitosha Mountain

The morphological analysis of the temperature-precipitation regime confirmed the conclusions made by the regression analyses. The established stress periods for the pine plantations at lower elevations, during the 40-s and after the 80-s of the last century, correspond to periods with mean monthly temperatures above average (Fig. 2). There is not clearly visible relationship between the dynamics of the mean indices and monthly precipitations, with the latter being above average for the first period and below average for the second one.

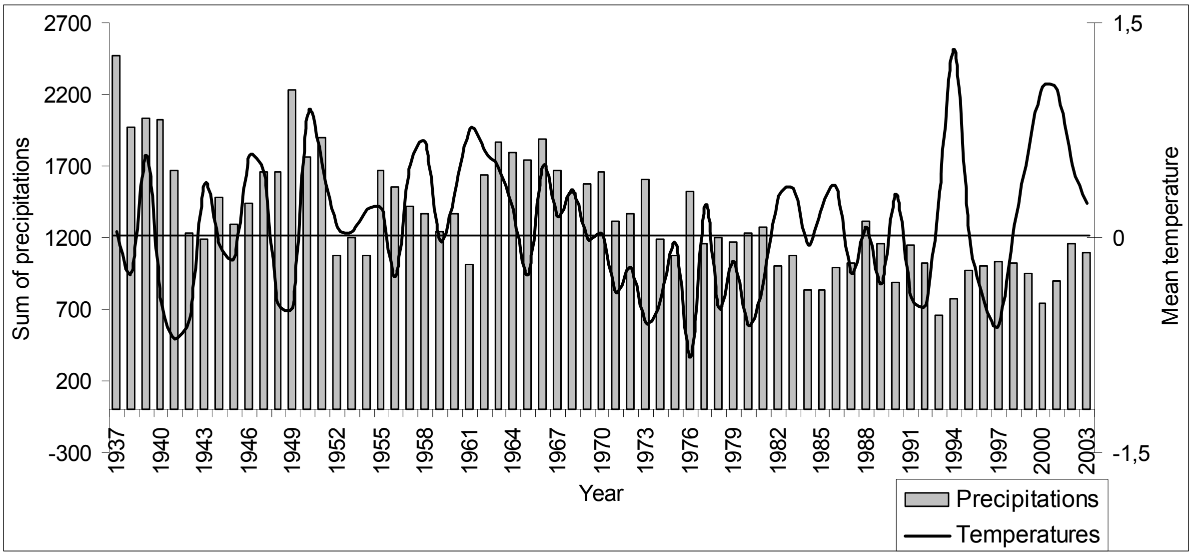

Figure 2: Monthly precipitation and mean monthly temperature dynamics for the Cherni Vrah Meteorological Station

The mean index series of the stand at high altitude, together with the series of the stand at low altitude at the same age are shown on Figure 3. It is noticeable that the two curves have opposite trends, with the periods below one for one of the chronologies corresponding to periods above one for the other. At 50 years of age only, both of the stands are in good condition, and the indices for the stand at a higher elevation reach their higher values. This shows that although the two stands are affected in the same degree by the climatic factors, as established by the regression analyses, the way in which they exert influence on them is probably opposite.

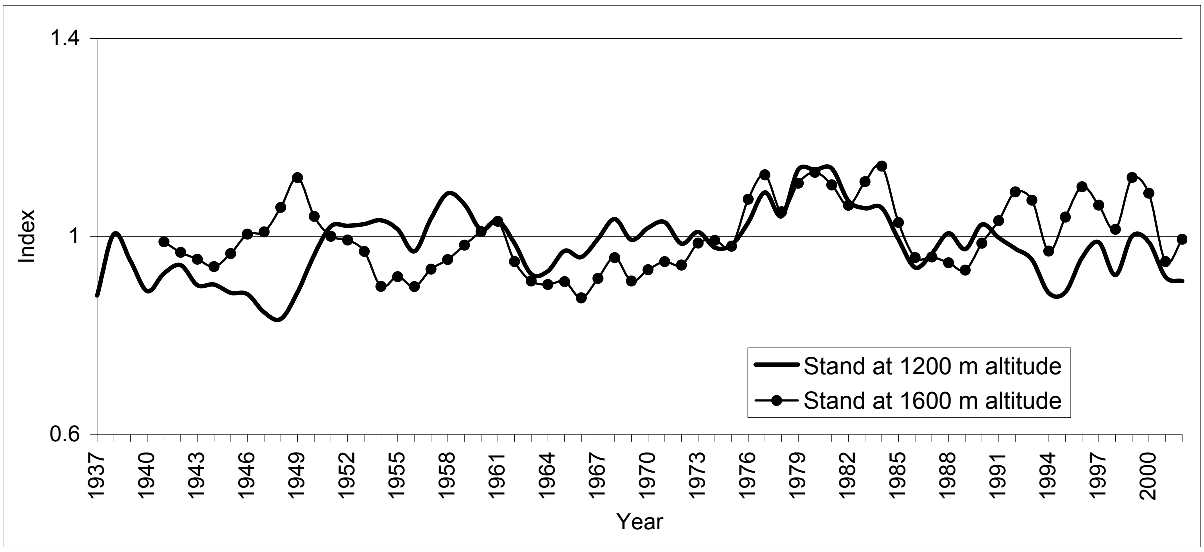

Figure 3: Mean indices dynamics of 70-year-old pine trees growing at different altitudes

The index chronologies for the western and southern stands have the same pattern as these for the eastern stands at 1200 m altitude. Nevertheless, the series for the stand on the northern slope resembles more the one from the stand at a higher altitude. During the 40-s and after the 90-s its indices are above the average and between these periods they are below the average.

The same results were established using correlation analyses between the mean index series of the different stands. All of the chronologies, except the one at a higher altitude and the one on the Northern slope, have high correlation coefficients, raging from 0.39 to 0.66 (Table 3). At the same time the two remaining index series have high correlation, with r being 0.56. These results allowed the mean indices for these two groups to be averaged for the further analysis.

Table 3: Correlation matrix for the mean index series of stands at 1200 m altitude at Eastern, Western and Southern slopes

Study site	East, 90-year-old	East, 70-year-old	East, 50-year-old	West	South
East, 90-year-old	1	0.57	0.41	0.57	0.62
East, 70-year-old		1	0.52	0.50	0.39
East, 50-year-old			1	0.62	0.50
West				1	0.66
South					1

In forestry and forest protection practices it is useful to have a model for predicting the increment of the trees for the next growth period. The most valuable models are those that include just several variables as predictors which are from the period before the growth season. Because of that, stepwise regression analysis was performed with the two built mean index series as dependent variables and the climatic factors until the beginning of the growth period as independent variables. Sufficient significance level (below 0.05) had only the increment of the previous year and the mean temperatures for two months for both of the chronologies and the precipitation for one month for the chronology of the lower sites. The models can be expressed as:

$$I_1 = 0.623 + 0.576 \times PrI_1 - 0.03 \times T_{October} + 0.038 \times T_{March} + 0.001 \times P_{December}$$

and

$$I_2 = 0.843 + 0.516 \times PrI_2 + 0.021 \times T_{January} + 0.035 \times T_{March} ,$$

where I_1 is the index for the radial increment of the trees growing on eastern, southern and western slopes of the mountain; I_1 is the index for the radial increment of the trees growing at 1600 m elevation and trees growing on the northern slope of the mountain; PrI_1, PrI_1 are the indices for the radial increment of the previous year; T is the mean monthly precipitation for the previous October and the current January and March and P is the mean precipitation for the previous December.

The coefficients of determination for the models are high – 0.69 for I_1 and 0.59 for I_2. However, these models can be used only for Scots pine trees, growing in the region of Vitosha Mountain. That is why, for prediction of the increment of the plantations in different areas, other models must be established.

Summary

The influence of the temperature-precipitation regime on the radial increment of Scots pine plantations in Vitosha Mountain is strong. However, at the studied sites the temperature affects the variability of the mean index series in a greater degree than the precipitation does.

The chronologies of trees at different ages, growing at similar ecological settings are well correlated among each other and show common stress periods for the stands. The trees are also identically affected by the climatic factors. However, differences in the trends of the radial increment at around 50 to 60 years of age of these trees were established. This shows that pine plantations in this region are most vital at this age, and prematurely felling of the trees is not needed. However, to determine the right age at which trees must be felled in different areas, such analyses must be done.

The relief is also an important factor, affecting the health condition of pine trees in the studied area. Trees growing at different elevations have opposite trends in their health condition. The periods of good health condition for the trees growing at a lower elevation correspond to periods of bad health condition for the trees growing at a higher elevation. The slope exposure also affects the health condition of the trees. Although tees growing on the Eastern, Western and Southern slopes of Vitosha Mountain have common stress periods, the ones growing on the Northern slope of the mountain differ from them and have a common signal with trees at a higher altitude.

References

Cook, E.R., Kairiukstis, L.A. (eds.) (1990): Methods of Dendrochronology: Applications in the Environmental Science. Kluwer Academic Publishers, Dordrecht. 394 p.

Fritts, H.C. (1076): Tree rings and climate. London, New York, San Farncisco, Academic Press. 576 p.

Innes, J. (1993): Forest Health: Its Assessment and Status. CAB International, Wallingford. 513 p.

Mirtchev, St., Lyubenova, M., Schikalanov, Al., Simeonova, N. (2000): Dendrochronology. Pensoft, Sofia. 198 p. (in Bulgarian)

Schweingruber, F.H. (1996): Tree Rings and Environment. Dendroecology. Berne, Stuttgart, Vienna: Paul Haupt, Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research. 609 p.