EFFECTS OF CLIMATE CHARACTERISTICS ON THE DIAMETER INCREMENT OF CEDAR IN THE CITY OF BELGRADE (SERBIA)

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Abstract

The paper presents the results of research dealing with the influence of climatic factors on the size of earlywood and latewood and the total diameter increment of cedar (Cedrus atlantica (Endl.) Man. ex Carr.). Samples taken from 30 trees at a height of 1.3 m were used in the analysis. The values were correlated with the mean monthly air temperature and precipitation sums (from April to September). In addition, the tree age expressed in years was included as an important factor. The analysed parameters explained 53.9% of the current diameter increment, 30.7% of the latewood and 51.6% of the earlywood share.

Keywords: cedar, earlywood, latewood, diameter increment, climatic factors

INTRODUCTION

Climate change has intensified the issue of introducing non-native tree species as part of an adaptive forest management strategy [1]. Changing climate has become a tough challenge for forests and forestry [2]. Although the extent of climate change is difficult to predict at the regional level [3], it is beyond any doubt that the forests of southern Europe, especially in the Balkans, will be strongly affected by climate change with unforeseeable consequences [4]. One of the solutions is to establish mixed stands of tree species that are more adaptable to warm climatic conditions characterised by a reduced amount of soil moisture during the growing season [5]. Based on climate models and changes in forest ecosystems [4], most autochthonous tree species are assumed not to be able to adapt to future climatic conditions. Therefore, allochthonous species should be introduced into the urban forests of Belgrade. As these species are more adapted to future climatic conditions than autochthonous species, they are expected to increase the number of species in this area. A species commonly recommended for the Belgrade area is the Atlas cedar.

The Atlas cedar originates from the Atlas Mountains of Morocco (Middle Atlas, High Atlas), the Rif and the Tell Atlas in Algeria. A lot of authors consider it a separate species –

Cedrus atlantica [6,7], while some believe it is a subspecies of Lebanese cedar *Cedrus libani* subsp. *atlantica* [8]. In natural habitats, it builds forests at altitudes from 1370 to 2200 meters in pure stands or in mixed with *Abies numidica*, *Juniperus oxicedrus*, *Quercus ilex* var. *ballota* and *Acer opalus*. The most extensive diebacks have been recorded in the area of Belezma National Park, where large areas are occupied by *Fraxinus xanthoxyloïdes*. In some parts, Atlas cedar has been completely replaced by *Quercus ilex*.

Cedar was introduced to Serbia at the beginning of the 19th century, but some authors believe that it was an integral part of European forests during the Last Glacial Period [9]. Cedar is a species that is resistant to industrial and urban pollution [10].

MATERIALS AND METHODS

The research was performed in an artificially raised Atlas cedar stand in Šuplja Stena near Belgrade (Serbia). The investigated stand was established in 1961 in the site of (*Quercetum farnetto-cerris aculeatetosum*). It is located at an altitude of 276 meters with a slope of 50º and a western aspect. It grows in eutric cambisol, 60 cm deep, overlying serpentine bedrock. The stand has a complete canopy closure and is well preserved.

We used statistical modeling to determine the relationship between stand characteristics and growth elements, on the one hand, and site factors, on the other. The ability of the model to adapt to the character it describes was the criterion used to select the most appropriate model. For this purpose, we used an improved forward "STEPWISE" regression.

Principal Component Analysis (PCA) was applied to determine the variability of data between and within the analysed climate characteristics in order to select the best variables for discrimination. The results of these analyses are presented numerically and graphically.

RESULTS AND DISCUSSION

General data on the artificially established cedar stand are shown in Table 1. As can be seen, the total number of trees is 458 per ha. The maximum number of trees (or 50.2%) is in the diameter degree of 37.5 cm. The mean stand height amounts to 24.6 m, and the mean diameter is 39.7 cm. It has a tree distribution line typical of even-aged stands. The volume distribution line is also typical of even-aged stands. The total basal area is 56.4 m^2 ha^{-1} and the total wood volume is 341.9 m^2 ha^{-1}. The distribution of tree volume by diameter class results from the distribution of the number of trees. The maximum is in the diameter class of 37.5 cm.

The dependence of the current diameter increment and the width of earlywood and latewood on climatic characteristics (monthly precipitation sums and mean monthly air temperature in the growing season – from April to September) was examined (Table 2). The independent variables were:

- precipitation sums in April (AP_P), May (MA_P), June (JU_P), July (JL_P), August (AU_P) and September (SE_P) and
- mean air temperature in April (AP_T), May (MA_T), June (JU_T), July (JL_T), August (AU_T) and September (SE_T).

Table 1 *General data on the artificially-established cedar stand*

Diameter class (cm)	N		H_{mean}	G		V (m^3)	
	1 ha	%	(m)	(m^2 ha^{-1})	%	1 ha	%
27.5	35	7.6	19.9	2.2	3.7	10.1	3.0
32.5	53	11.6	22.2	4.3	7.7	23.8	7.0
37.5	230	50.2	24.0	25.1	44.7	148.8	43.5
42.5	53	11.6	25.4	7.4	13.2	46.6	13.6
47.5	53	11.6	26.0	9.3	16.5	59.6	17.4
52.5	17	3.7	26.6	3.7	6.5	23.9	7.0
57.5	17	3.7	27.0	4.3	7.8	29.1	8.5
∑	458	100.0		56.4	100.0	341.9	100.0

Table 2 *The influence of age and analysed climatic factors on current diameter increment (Zi), share of latewood (Ka) and share of earlywood (Ra)*

Independent variable	Dependent variable					
	Zi		Ka		Ra	
	Parameters	Error	Parameters	Error	Parameters	Error
CONSTANT	3.51507	5.49560	0.40177	1.06784	4.60545	5.06950
Year	-0.05312	0.02647	-0.00260	0.00215	-0.04263	0.02442
AP_P	-0.00936	0.00732	0.00126	0.00135	-0.00684	0.00675
MA_P	0.00597	0.00456	0.00133	0.00130	0.00487	0.00421
JU_P	-0.00318	0.00440	-0.00152	0.00123	-0.00445	0.00406
JL_P	-0.00613	0.00449	0.00176	0.00177	-0.00517	0.00414
AU_P	0.00747	0.00625	0.00284	0.00181	0.00517	0.00577
SE_P	0.00257	0.00615	-0.00214	0.03691	-0.00063	0.00567
AP_T	-0.07113	0.14174	0.05849	0.04727	-0.10590	0.13075
MA_T	0.24427	0.15941	0.02157	0.04902	0.19210	0.14705
JU_T	-0.26011	0.17639	-0.00320	0.05031	-0.31356	0.16271
JL_T	0.19227	0.18462	-0.09588	0.04509	0.18134	0.17031
AU_T	-0.16232	0.15925	0.03514	0.03989	-0.08750	0.14690
SE_T	0.08442	0.13470	0.40177	1.06784	0.05476	0.12426
R		0.7344		0.5539		0.7181
R^2		53.9372		30.6822		51.564
Standard error		1.12969		0.33522		1.0421
F-test		2.88		1.22		2.62

According to this regression method, the total volume increment decreases with increasing age and increases with increasing precipitation in August. The August precipitation sums have the greatest influence on the size of the latewood. The size of the earlywood decreases with age (Table 3).

Five components were isolated in the principal component analysis (PCA). The results of this analysis are shown in Table 4. According to the eigenvalues and percentage values obtained, the first five components (coordinates) are sufficient to explain 74.762% of the total variability of data. The value of each variable (climatic factor) contributes to the overall variability of data (according to the first, second and third axes), as shown in Table 4. The scatter plot shows the geometric distance between the studied climate parameters and the variability between them. According to the first breakpoint, two components were further analysed in PCA.

Table 3 *Influence of age and analysed climate factors on current diameter increment (Zi), share of latewood (Ka) and share of earlywood (Ra) (Stepwise regression)*

Independent variable	Dependent variable					
	Zi		Ka		Ra	
	Parameters	Error	Parameters	Error	Parameters	Error
CONSTANT	2.95369	0.52792	0.33436	0.08749	2.99967	0.40623
Year	-0.05300	0.01272			-0.05133	0.01188
AV_P	0.01037	0.00447	0.00289	0.00128		
R		0.6118		0.3210		0.5457
R^2		37.4134		10.3059		29.7796
Standard error		1.1359		0.3302		1.0701
F-test		12.85		5.060		18.66

There is a significant positive correlation between the temperature (June and September) and the diameter increment due to the influence of the first and second components. The effect of the first component brought about the positive correlation between the tree diameter increment and the temperature in May, April, July and August, while the correlation between the mentioned months and the tree growth was negative under the influence of the second component.

Table 4 *Eigenvalues and percentage values with the share of each coordinate in describing the total variability of data*

Component number	Eigenvalue	Variance percentage	Cummulative percentage
1	4.0862	31.432	31.432
2	1.6509	12.699	44.131
3	1.5234	11.719	55.850
4	1.3817	10.629	66.479
5	1.0768	8.283	**74.762**
6	0.8240	6.339	81.100
7	0.7573	5.825	86.925
8	0.5349	4.115	91.040
9	0.3544	2.726	93.767
10	0.3213	2.471	96.238
11	0.2101	1.616	97.854
12	0.1560	1.200	99.054
13	0.1230	0.946	100.000

A negative correlation was found between precipitation (April, June, August and September) and the diameter increment under the influence of the first and second components.

The effect of the second component determined the positive correlation between the precipitation (May and July) and the diameter increment, and a negative correlation was found between the measured precipitation and the tree growth due to the influence of the first component.

Under the influence of the first and second components, a positive correlation was found between the age and the tree growth. Based on the sharpness of the vector angle for the age of cedar trees, a positive highly significant influence of the first component on the diameter increment was stated.

CONCLUSION

The exploitation of introduced species arouses significant interest because it provides information about their climate adaptability. Some species, especially tree species, could adapt to more diverse climatic conditions than they are known to be able to in their natural range of distribution.

The size of the diameter increment of Atlas cedar is most influenced by precipitation variability, while temperatures proved to be secondary climate variables. The increase in precipitation in the period from August to September is crucial for the growth of Atlas cedar [11].

For forest management purposes, new growth models that are sensitive to climate characteristics and their changes in forest ecosystems need to be developed.

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