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

Tatjana Dimitrijević[1], Gordana Šekularac[2*], Mihailo Ratknić[3], Miroljub Aksić[4]

[1]Institute of Forestry, Kneza Višeslava 3, 11000 Belgrade, SERBIA

[2]University of Kragujevac, Faculty of Agronomy,
Cara Dušana 34, 32000 Čačak, SERBIA

[3]Earthe Climate Change Team (ECCTeam), New Jersey, USA

[4]University of Priština, Kosovska Mitrovica, Faculty of Agriculture,
Kopaonička nn, 38219 Lešak, SERBIA

*gordasek@kg.ac.rs

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 red oak (Quercus rubra L.). 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 54.1% of the current diameter increment, 32.9% of the latewood and 49.4% of the earlywood share.

Keywords: red oak, 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 characterized 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 red oak.

The red oak is native to North America and is distributed in the eastern and central United States (from the northern end of the Great Lakes, east to Nova Scotia, south to Georgia, Mississippi, Alabama, and Louisiana, and west to Oklahoma, Kansas, Nebraska, and

Minnesota) [6] as well as in south-eastern and south-central Canada. Table 1 shows the characteristics of red oak in natural habitats.

***Table 1** Characteristics of red oak in natural habitats*

Regions	ST	SM	pH	RG	L	NR	PS
Algonquin park region, Ontario	I	d		r	M	vd	S
Southern Ontario	M-I	d-m		r-a	S	e	P
New York and New England	I	m	N	r	L	e	S

Symbols: Shade tolerance (ST): intolerant (I), medium (M); Soil moisture (SM): dry (d), medium (m); Soil reaction (pH): neutral (N); Rate of growth (RG): rapid (r), average (a); Longevity (L): medium (M), short (S), long (L); Natural regeneration (NR): very difficul (vd), easy (e); Place in succession (PS): pioneer (P), subclimax (S).

Introduced to Europe in the 1700, it has been naturalized in most of western and central Europe [7]. Across western and central Europe, northern red oak has become the fourth most important invasive species, colonizing several regions across Belgium, Germany, northern Italy, Lithuania, Poland, Ukraine, European Russia [7], the Urals and Western Siberia. The wide distribution of red oak is based on its economic productivity. On the other hand, considering its impact on the habitats it is introduced to, it is identified as an invasive species that can change the structure of forest ecosystems [8].

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 293 m with a slope of 5º 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.

In the models obtained using “STEPWISE” regression, the effect of individual independent variables on the values of diameter increment was determined using the net regression calculation procedure.

RESULTS AND DISCUSSION

General data on the artificially established cedar stand are shown in Table 2. As can be seen, the total number of trees is 508 per ha. The maximum number of trees (or 33.5%) is in the diameter degree of 37.5 cm. The mean stand height amounts to 22.3 m, and the mean diameter is 38.9 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 56.17 m^2 ha^{-1} and the total wood volume is 658.5 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.

Table 2 *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	%
22.5	17	3.3	19.9	0.68	1.2	6.6	1.0
27.5	68	13.4	21.4	4.04	7.2	41.9	6.4
32.5	153	30.1	22.9	12.69	22.6	139.2	21.1
37.5	170	33.5	24.2	18.78	33.4	215.9	32.8
42.5	34	6.7	25.3	4.82	8.6	57.8	8.8
47.5	15	3.0	26.5	2.66	4.7	33.0	5.0
52.5	17	3.3	27.5	3.68	6.6	47.3	7.2
57.5	34	6.7	28.5	8.83	15.7	116.9	17.7
∑	508	100.0	/	56.17	100.0	658.5	100.0

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 3). 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).

A linear regression model of the effects of age and the analyzed climatic factors on the current diameter increment (Zi), the share of latewood (Ka) and the share of earlywood (Ra) was constructed. The parameters of the model are given in Table 3. Applying the stepwise regression procedure, we determined a negative effect of September precipitation (SE_P), June temperature (JN_T) and July temperature (JL_T) (on the total volume increment (Zi), a negative effect of temperature on the width of the latewood in August (AV_T) and a negative effect of July precipitation (JL_P) and temperature (JL_P) on the width of earlywood (Table 4).

Table 3 *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	16.73000	6.01027	5.05060	3.07033	11.67940	3.40557
Year	-0.11618	0.02611	-0.05094	0.01334	-0.06524	0.01480
AP_P	-0.00238	0.00812	0.00215	0.00415	-0.00452	0.00460
MA_P	0.00049	0.00504	-0.00034	0.00258	0.00083	0.00286

Table 3 *continued*

JU_P	-0.00127	0.00490	-0.00110	0.00250	-0.00017	0.00278
JL_P	-0.00027	0.00449	0.00048	0.00229	-0.00075	0.00254
AU_P	-0.00741	0.00675	-0.00354	0.00345	-0.00387	0.00383
SE_P	-0.01239	0.00703	-0.00479	0.00359	-0.00760	0.00398
AP_T	0.09820	0.13833	0.07004	0.07067	0.02816	0.07838
MA_T	0.06641	0.16823	0.04136	0.08594	0.02504	0.09532
JU_T	-0.19403	0.18393	-0.06782	0.09396	-0.12621	0.10422
JL_T	0.05533	0.20030	0.09928	0.10232	-0.04394	0.11349
AU_T	-0.06043	0.17596	-0.08316	0.08989	0.02272	0.09970
SE_T	-0.32218	0.14883	-0.11072	0.07603	-0.21145	0.08433
R		0.87		0.82		0.88
R^2		75.81		66.53		77.97
Standard error		1.2957		0.6619		0.7341
F-test		8.19		5.20		9.26

Table 4 *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	31.49920	3.81984	7.77490	1.28520	16.41900	2.08272
SE_P	-0.01640	0.00767				
JN_T	-0.43537	0.15989				
JU_P					-0.00679	0.00269
JU_T	-0.38190	0.17473			-0.57903	0.08750
AV_T			-0.26744	0.05633		
SE_T	-0.45459	0.15454				
R		0.74		0.57		0.70
R^2		54.13		32.88		49.37
Standard error		1.58630		0.80581		0.96750
F-test		12.69		22.54		21.94

The net regression equations are presented in Table 5 and Figure 1.

Table 5 *Net regression equations for total diameter increment, latewood and earlywood*

Net regression equations for		
Total diameter increment	**Latewood**	**Earlywood**
5.30111 – 0.01640 * SE_P	7.77490 – 0.26744 * AV_T	15.97358 – 0.57903 * JU_T
13.55918 – 0.43537 * JN_T		3.10132 – 0.00679 * JU_P
13.15657 – 0.38190 * JU_T		
12.60095 – 0.45459 * SE_T		

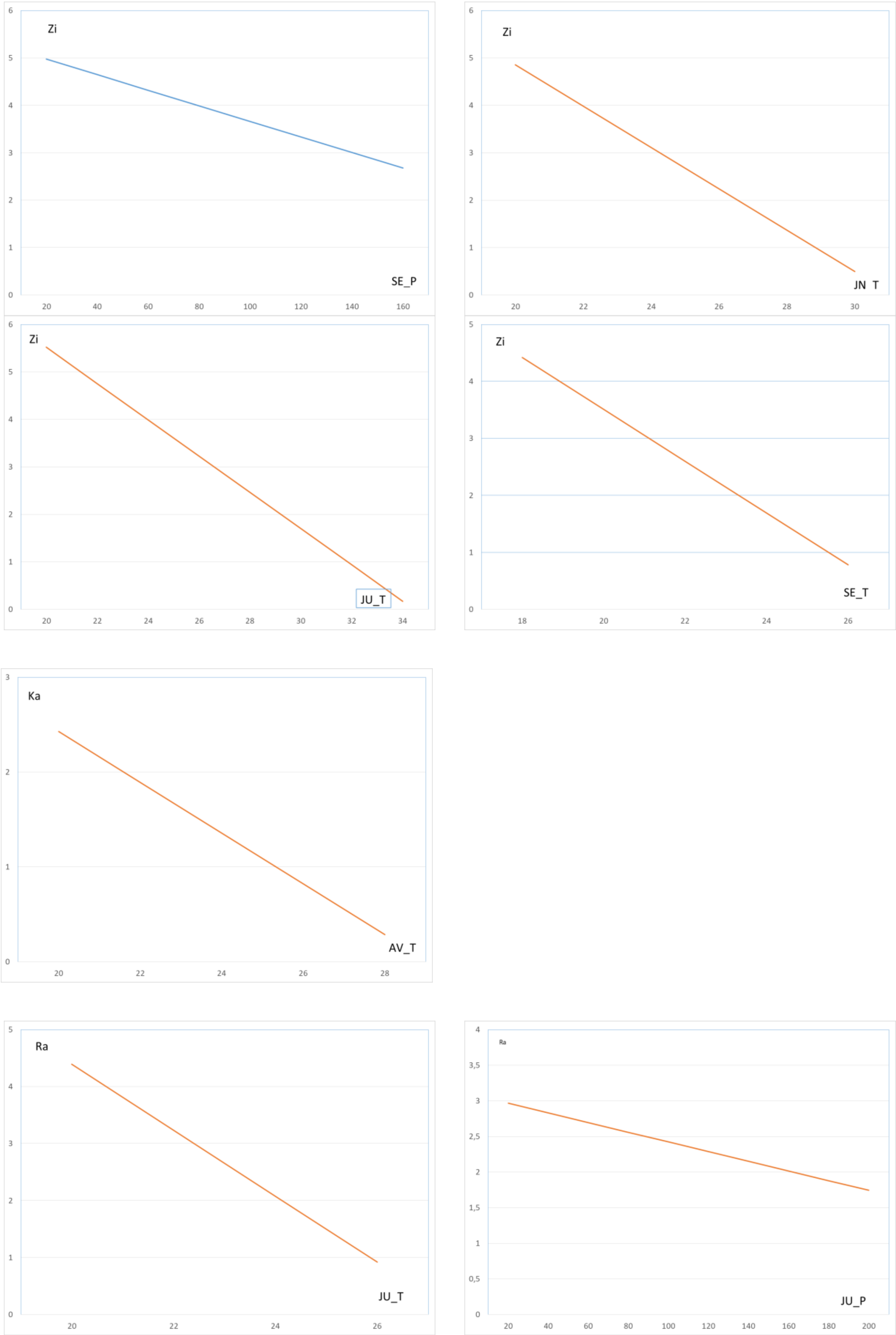

Figure 1 *Net regressions*

CONCLUSION

The study of the impact of climate factors on the diameter increment of introduced species (size of earlywood, latewood and total increment) provides the necessary information about the adaptability of the species to new conditions.

According to the obtained regression models, September precipitation and June, July and September temperatures have a negative statistically-significant impact on the total diameter increment. These factors account for 54.13% of the variability.

The size of the latewood is most negatively affected by the temperature in August which accounts for 32.88% of the variability. The size of earlywood is negatively affected by the sum of precipitation and air temperature in June. This model explains 49.37%.

Bearing in mind that the red oak is distinguished as an invasive species susceptible to the adverse effects of climate factors, its introduction into natural habitats within forest ecosystems should be reconsidered.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for financial support (451-03-47/2023-01/ 200027, 451-03-47/2023-01/200088 and 200189).

REFERENCES

[1] Ennos R., Cottrell J., Hall J., *et al*., Forest Ecol. Manag. 432 (2019) 718–728.

[2] Lindner M., Maroschek M., Netherer S., *et al.*, Forest Ecol. Manag. 259 (4) (2010) 698–709.

[3] Hemery G. E., Int. Forest Rev. 10 (2008) 591–607.

[4] Ratknić, T. Application of adaptive measures in the adaptation of forest ecosystems to climate change in the City of Belgrade, Final Report, Institute of forestry, Belgrade (2021).

[5] Milad M., Schaich H., Konold W., Biodivers. Conserv. 22 (5) (2013) 1181–1202.

[6] Forbes R. D. Forestry handbook, Ronald Press, New York (1955), ISBN-10: 1114202614; ISBN-13: 978-1114202610.

[7] Quercus rubra, European Forest Genetic Resources Programme, *Available on the following link*: https://www.euforgen.org/species/quercus-rubra/.

[8] Stanek M., Piechnik L., Stefanowicz A., Forest Ecol. Manag. 472 (2020) 118253.