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CLIMATE CHARACTERISTICS AND DIAMETER INCREMENT OF EASTERN WHITE PINE: POTENTIAL USE IN AFFORESTATION IN THE BELGRADE AREA (REPUBLIC OF SERBIA)

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Abstract: *The impact of climate change on forest ecosystems is becoming increasingly apparent. Research indicates that rising air temperatures affect the state of biodiversity, a range of ecological processes, as well as the dynamics of developmental characteristics of individual trees (Ratknić T. et al., 2019a; Dimitrijević T. et al., 2022; Dimitrijević T. et al., 2023). This study investigates how climate affects the size of earlywood, latewood, and the total current increment of *Pinus strobus* trees in Belgrade. Data related to site changes are compared to site characteristics in its natural sites in North America. The climate model REG_IN indicates that newly emerging site conditions will hinder the establishment of new pine plantations in the urban forests of Belgrade. According to the aridity index (FAI) for the period 2081-2100, the FAI is estimated to reach 7.4, indicating a forest-steppe climate. All the analyses suggest that the emerging conditions will prevent the introduction of *Pinus strobus* into the urban forests of Belgrade.*

Keywords: *Pinus strobus*, climate change, REG_IN model, earlywood, latewood, total increment

KLIMATSKE KARAKTERISTIKE I DEBLJINSKI PRIRAST BOROVCА: POTENCIJALNA UPOTREBA U POŠUMLJAVANJU NA PODRUČJU BEOGRADA (REPUBLIKA SRBIJA)

Sažetak: *Uticaj klimatskih promena na šumske ekosisteme je sve vidljiviji. Istraživanja ukazuju da povećanje temperature vazduha utiče na stanje biodiverziteta, veliki broj ekoloških procesa, kao i dinamiku razvojnih karakteristika pojedinanih stabala (Ratknić T. et al., 2019a; Dimitrijević T. et al., 2022; Dimitrijević T. et al., 2023). U radu je vršeno istraživanje na koji način klima utiče na veličinu ranog, kasnog drveta i ukupnog tekućeg prirasta stabala *Pinus strobus* na području grada Beograda. Podaci promene staništa poređeni su sa karakteristikama staništa na prirodnim nalazištima na području Severno Američkog kontinenta. Na osnovu klimatskog modela REG_IN ukazuje se da se stvaraju stanišni uslovi koji će onemogućiti uspešno podizanje novih plantaža borovca u urbanim šumama grada Beograda. Na osnovu indeksa aridnosti (FAI) za period 2081-2100., procena*

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je da će FAI vrednost iznositi 7,4, odnosno da će klima imati odlike šumsko-stepske klime. Sve ove analize ukazuju da se stvaraju uslovi koji onemogućavaju unošenje Pinus strobus u urbanim šumama Beograda.

Ključne reči: Pinus strobus, klimatske promene, REG_IN model, rano drvo, kasno drvo, ukupni prirast

1. INTRODUCTION

Climate change undoubtedly gives rise to the development of new approaches in forestry. These approaches have been triggered by the effects of global and regional climate changes (different climate scenarios, changes in greenhouse gas concentrations, the state of the ozone layer, changes in ultraviolet radiation intensity, etc.).

According to the latest IPCC Report (2023), the mean global air temperature of the planet is estimated to be 1.09 [from 0.95 to 1.20]°C higher in the period 2011–2020 than in 1850–1900, with a greater increase over its land area (1.59 [from 1.34 to 1.83]°C) than over the oceans (0.88 [from 0.68 to 1.01]°C). The mean global air temperature in the first two decades of the 21st century (2001–2020) was 0.99 [from 0.84 to 1.10]°C higher than in 1850–1900. The mean global surface temperature has risen faster since 1970 than in any other 50-year period in at least the last 2000 years (high confidence) (IPCC AR6 SYR, 2023). The concentration of carbon dioxide, the most important greenhouse gas, has increased by 50% compared to the pre-industrial period and is now at 415.7 parts per billion (ppb). The concentration of methane has increased more than 2.5 times (1908 ppb), and the concentration of nitrogen compounds by 25% (334.5 ppb).

Based on the ND-GAIN index of Serbia's vulnerability to climate change and other global challenges, combined with its readiness to improve resilience, Serbia ranks 76th out of 182 ranked countries. The goal of this index is to assist governments, businesses, and communities in better prioritizing investments for a more efficient response to the immediate global challenges ahead (Notre Dame Global Adaptation Initiative, 2023). These changes will have a striking impact on forest ecosystems. Human activities have already led to the destruction of numerous habitats, leaving them mostly fragmented or damaged by long-term pollution from various sources (Ratknić T. et al., 2019b). Existing and future vegetation in the Belgrade area will be developing under conditions of elevated temperatures compared to previous conditions. The isotherms of mean annual air temperatures have shifted by about 160 km to the north, and by the end of the 21st century, the extent of the shift will exceed the ranges of many tree species, leading to their extinction in the areas they are currently present (Barns, B.V., 2009; Iverson et al., 2008; Kirschbaum, M. and Fischlin, A., 1996; Joyce D. and Rehfeldt G., 2012). Climate change will modify forest ecosystems of Belgrade as they will not be able to adapt to the new climatic conditions (Dimitrijević T. and Ratknić M., 2023).

Climate change poses challenges in selecting the most appropriate forest management practices. The rate of climate change hinders the ability of forest ecosystems to adapt to these changes, thereby jeopardizing their sustainable utilisation. One possible solution to address the impact of climate change on forests

is through the concept of climate niches (Joyce D. and Rehfeldt G., 2012). The use of climatic conditions to describe a species' niche has become central to much "ecological reasoning and theory" (Pulliam, 2000, based on Joyce D. and Rehfeldt G., 2012). The dependence of growth and increment parameters on climatic factors is one of the elements used in developing species niches and selecting suitable sites with regard to future climate changes (Dimitrijević T. and Ratknić M., 2023). "The central premise of this approach is that the currently realised niche of a species provides the best available metric for projecting the future distribution of suitable habitats" (Pearson, 2007, based on Joyce D. and Rehfeldt G., 2012).



Figure 1. *Range of Eastern white pine trees – in the eastern part of North America (in the United States and Canada)*

Based on climate models and changes in forest ecosystems (Ratknić T. at al., 2019b), it is assumed that most native tree species will not be able to adapt to future climatic conditions. This is the reason to introduce non-native species in the urban forests of Belgrade that are more adaptable to future climate conditions than native species, and thus increase the diversity of species in this area. The influence of climatic characteristics has been determined for the Belgrade urban forests of

Douglas fir (Ratknić T. et al., 2019a), larch (Dimitrijević T. et al., 2022), and red oak (Dimitrijević T. et al., 2023). Regarding Eastern white pine cultures in Serbia, two-way volume tables have been constructed (Ratknić M. et al., 1987), and habitat indices have been developed (Ratknić M., 1994).

Eastern white pine (*Pinus strobus*) is distributed across southern Canada, ranging from Newfoundland, Anticosti Island, and the Gaspé Peninsula of Quebec, westward to central and western Ontario, and extreme southeastern Manitoba. Its range extends south to southeastern Minnesota and northeastern Iowa, eastward to northern Illinois, Ohio, Pennsylvania, and New Jersey. In the southern part of its range, it is found mostly in the Appalachian Mountains, reaching down to northern Georgia and northwestern South Carolina. It can also be found in western Kentucky, western Tennessee, and Delaware. A variety of Eastern white pine grows in the mountains of southern Mexico and Guatemala (Wendel G.W. and Smith C., 1990).

This species adapts to a wide range of soils but is most competitive on well-drained sandy soils of low to medium quality sites (Wendel G.W. and Smith C., 1990). It grows in pure stands, although it has also been found in mixed stands with other coniferous and broadleaved species, particularly with *Pinus resinosa* and *Pinus bankiana*, *Abies balsamea*, *Picea rubens*, *Picea glauka*, *Betula papyrifera*, as well as in mixed forests with *Tsuga canadensis*, *Acer saccharinum*, and *Betula lutea*. The characteristics of Eastern white pine in its natural sites are presented in Table 1.

Table 1. Characteristics of Eastern white pine in natural sites

Regions	Shade Tolerance (ST)	Soil moisture (SM)	Soil reaction (pH)	Rate of growth (RG)	Longevity (L)	Natural Reproduction (NR)
Algonquin Park Region, Ontario	Young – M Old - I	d-w		s	L	d
Southern Ontario	I-M	d-w		r	L	m-e
New York and New England	M	d	N	m	L	e
Southeastern United States	M	m	A-N	r	L	m

Symbols: Shade Tolerance (ST): intolerant (I), medium (M); Soil Moisture (SM): dry (d), medium (m); wet (w); Soil Reaction (pH): (A) acid, neutral (N); Rate of growth (RG): rapid (r), medium (m); average (a); Longevity (L): long (L); Natural Regeneration (NR): difficult (d), easy (e); medium (m);

Source: Forbes R., 1955

In Europe, Eastern white pine was first recorded in 1553 in the Royal Garden of Fontainebleau, France, but further mentions regarding its introduction into parks and forests emerged much later, at the beginning of the 18th century. In 1705, it was planted by the Duchess de Bofor at Badminton in Great Britain, and a few years later in Longleat (Kent) on the estate of Lord Weymouth. Successive introductions into other European countries were reported by various authors as follows: in Germany in 1770; in the former Czechoslovakia in 1773; in Switzerland in 1850; in Poland in 1876; in Austria in 1886; and in Bulgaria in 1903. Its rapid growth rate, high-quality wood and good yield, great adaptability to different locations and climatic conditions, and its remarkable ornamental value, were among the main reasons for its introduction (Radu S.. 2008).

It has been frequently used in afforestation in Western Europe but has shown susceptibility to blister rust attacks (*Cronartium ribicola*). In Serbia, it has been used

in the reclamation of degraded and deforested areas. Eastern white pine tolerates low winter temperatures and urban conditions well. It grows in moderately moist, acidic soils (calcifuge) but is found to be sensitive to snow breakage.

This study analyses Eastern white pine (*Pinus strobus* L.) as another potential species for planting in the urban forests of Belgrade.

2. MATERIAL AND METHODS

The study was conducted in an artificially established stand of Eastern white pine at the locality known as Šuplja Stena. The coordinates of the experimental field are X=7464033; Y=4947582; and Z=283. The study stand is located at an elevation of 283 meters, with a slope of 5° and a westward aspect. The stand is 50 years old, well-preserved, with a complete canopy. Apart from Eastern white pine, individual specimens of spruce (17 trees per hectare) and field maple (8 trees per hectare) were recorded in the stand.

The dependence of the current diameter increments and width of earlywood and latewood on climatic characteristics was examined. The climatic variables included monthly precipitation sums and mean monthly air temperatures during the growing season (from April to September). The independent variables were:

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

3. RESULTS

3.1. Soil Characteristics

Soil Type: Luvisol (ilimerized soil), profile structure A (0-2 cm) – E (2-40 cm) Bt (40->60 cm).

The surface layer of the soil belongs to the loam textural class. As the soil depth increases, the content of clay increases, and the deeper analysed layers belong to the class of clayey loams. Regarding the reaction of the soil solution in water, the soil is between strongly and very strongly acidic throughout the analysed depth. Regarding the degree of base saturation, the surface layer at 0-20 cm and the layer at 20-40 cm depth are dystrophic, while the deepest analysed layer is eutrophic. This results from base leaching into deeper layers preceding illuviation. The soil is weakly humic throughout the depth of the soil. The availability of total nitrogen in the surface layer is good, while it is moderate in the deeper layers. The availability of plant-accessible forms of phosphorus is poor throughout the depth of the soil, and the quantity of plant-accessible forms of potassium barely exceeds 10 mg/100 g, which is the threshold between poor and moderate availability (Miletić Z. and Eremija S., 2019). The chemical properties of the soil on this experimental field are presented in Table 2, and the physical properties in Table 3.

3.2 Phytocenological Characteristics

The site belongs to the forest community of Italian oak and Turkey oak with *butcher's-broom*, a variant of hornbeam (Ass. *Quercetum farnetto-cerris* Rud. *aculeatetosum* Job.). The following species were recorded in the stand (Stajić S., 2019):

- Tree layer: Canopy (0.8); *Pinus strobus* (4.2); *Quercus cerris* (1.1); *Acer pseudoplatanus* (1.1).
- Shrub layer: Canopy (0.4); mean height 3.0 m; *Acer pseudoplatanus* (3.3); *Acer campestre* (1.1); *Fraxinus ornus* (1.1).
- Grond flora layer: Coverage (0.8); *Rubus hirtus* (5.5); *Hedera helix* (2.3); *Galium aparine* (2.3); *Acer pseudoplatanus* (1.2); *Dryopteris filix-mas* (1.1); *Fraxinus ornus* (1.1).

Table 2. Chemical Properties of the Soil

Depth	pH		Adsorptive complex					Total		Accessible	
	H ₂ O	KCl	T	S	T-S	V	Y1	humus	N	P ₂ O ₅	K ₂ O
cm			cmol/kg			%	cm ³	%	%	mg/100g	
0-20	5.04	3.60	27.97	11.59	16.39	41.42	25.21	2.81	0.16	3.53	13.40
20-40	5.02	3.66	24.97	12.35	12.62	49.45	19.42	1.88	0.11	2.26	10.70
40-60	5.05	3.28	23.82	14.66	9.16	61.55	14.09	1.18	0.07	2.79	11.30

Source: Miletić Z. and Eremija S., 2019

Table 3. Physical Properties of Soil

Depth	Coarse sand	Fine sand	Silt	Clay	Total sand	Total clay	Textural class
cm	%	%	%	%	%	%	
0-20	0.90	32.70	38.90	27.50	33.60	66.40	Loam
20-40	0.60	32.80	36.60	30.00	33.40	66.60	Clayey loam
40-60	0.50	29.00	38.30	32.20	29.50	70.50	Clayey loam

Source: Miletić Z. and Eremija S., 2019

3.3 Stand Characteristics

General data about the artificially established stand of Eastern white pine are presented in Tables 4 and 5. The total number of trees amounts to 557 per hectare. The maximum number of trees (39%) is in the diameter class of 27.5 cm. The mean stand height is 20.9 m, and the mean diameter is 31.7 cm. The stand has distribution lines of trees and volume by diameter classes typical of even-aged stands. The total basal area is 59.1 m²ha⁻¹, while the total wood volume amounts to 342.6 m³ha⁻¹. The maximum volume is in the diameter class of 32.5 cm.

Table 4. Statistical Indicators of Diameter (D), Height, and Volume Distributions

Size	X_{mean}	Min.	Max	Quartile		σ	V	sd	Coefficient of distribution	
				Q1	Q3				α_3	α_4
D (cm)	31.7	21.2	44.8	28.0	35.0	4.82	15.22	0.58	0.274	-0.287
H (m)	20.9	16.7	27.2	19.6	21.7	3.47	1.86	0.23	0.976	2.708
V (m ³)	0.6	0.2	1.2	0.4	0.7	0.04	0.21	0.03	0.885	1.060

Source: Original

Table 5. Basic Data on the Eastern White Pine Stand

Diameter degree (cm)	N		H	G	V	
	per ha	%	(m)	m ² /ha	m ³ /ha	%
22.5	26	4.7	17.5	1.54	8.9	2.6
27.5	222	39.9	21.81	18.42	106.6	31.1
32.5	168	30.2	21.86	18.55	107.3	31.3
37.5	124	22.3	21.08	17.59	101.8	29.7
42.5	17	3.1	22.5	3.12	18.0	5.3
Σ	557	100.0		59.1	342.6	100.0

Source: Original

Turkey oak is represented by 17 trees, with a total basal area of 2.41 m²/ha. Its mean diameter is 37.5 cm, while the mean height amounts to 18.1 meters. Field maple is represented by 8 trees, with a total basal area of 1.13 m²/ha. The quadratic mean diameter is 42.5 cm, while the mean height amounts to 22.2 meters. The total volume is 342.6 m³/ha.

3.4 Impact of Climate Factors on Current Diameter Increment

By applying the correlation method for weight estimation, a model was constructed to assess the influence of age and analysed climate factors on the total current diameter increment, size of latewood (Ka), and size of earlywood (Ra). The parameters of these models are provided in Table 6. The size of earlywood is negatively influenced by age (AGE), total precipitation in April (AP_P), total precipitation in July (JL_P), total precipitation in August (AU_P), as well as mean air temperatures in April (AP_T), May (MA_T), June (JU_T), July (JL_T), and August (AU_U). Positive influence is observed with total precipitation in May (MA_P), June (JU_P), September (SE_P), and mean air temperature in September (SE_T). The correlation coefficient is 0.615, explaining 37.8% of the earlywood values. The F-test value indicates significance at a 0.01 level.

The size of latewood is negatively influenced by age (AGE), total precipitation in April (AP_P), June (JU_P), July (JL_P), and September (SE_P), as well as the mean monthly air temperature in June (JU_T) and September (SE_T). Positive influence is determined for the total precipitation in May (MA_P) and August (AU_P), and mean air temperature in April (AP_T), May (MA_T), July (JL_T), and August (AU_T). The regression coefficient is 0.803, explaining 64.5% of the latewood values. The F-test value indicates significance at a level of 0.05.

The size of the total current diameter increment is negatively influenced by age (AGE), total precipitation in April (AP_P), July (JL_P), and August (AU_P), as well as the temperature in April (AP_T), May (MA_T), July (JL_T), and August (AU_T). Positive influence is observed with total precipitation in May (MA_P), June

(JU_P), and September (SE_P), as well as mean air temperature in June (JU_T) and September (SE_T). This data are presented in Table 7.

Table 6. *The Influence of Age and Analysed Climatic Factors on Current Diameter Increment (Zi), Share of Latewood (Ka) and Share of Earlywood (Ra) (Ra)*

Independent variable	Dependent variable					
	Ra		Ka		Zi	
	Parameters	Error	Parameters	Error	Parameters	Error
CONSTANT	14.876	4.960	0.453	1.661	16.652	5.490
AGE	-0.068	0.254	-0.865	0.222	-0.322	0.234
AP_P	-0.300	0.206	-0.142	0.140	-0.324	0.190
MA_P	0.179	0.242	0.259	0.143	0.253	0.223
JU_P	0.076	0.201	-0.102	0.139	0.180	0.185
JL_P	-0.385	0.281	-0.066	0.163	-0.440	0.258
AU_P	-0.521	0.281	0.183	0.164	-0.334	0.259
SE_P	0.040	0.211	-0.010	0.150	0.740	0.195
AP_T	-0.339	0.209	0.304	0.166	-0.179	0.192
MA_T	-0.129	0.225	0.117	0.173	-0.158	0.207
JU_T	-0.065	0.264	-0.181	0.191	0.100	0.243
JL_T	-0.260	0.332	0.191	0.221	-0.258	0.306
AU_T	-0.373	0.349	0.070	0.225	-0.298	0.321
SE_T	0.045	0.235	-0.230	0.163	0.240	0.217
R	0.615		0.803		0.688	
R ²	0.378		0.645		0.473	
Standard error	24.574		0.329		27.196	
F-test	1.356		4.056		2.001	

Table 7. *Type of Effect on the Size of Earlywood (Ra), Latewood (Ka), and Total Current Volume Increment (Zi)*

Effect	Size		
	Earlywood	Latewood	Total current diameter increment
Positive	<ul style="list-style-type: none"> • Precipitation sums in June • Precipitation sums in September • Mean air temperature in September 	<ul style="list-style-type: none"> • Precipitation sums in May • Precipitation sums in August • Mean air temperature in April • Mean air temperature in May • Mean air temperature in July • Mean air temperature in August 	<ul style="list-style-type: none"> • Precipitation sums in May • Precipitation sums in June • Precipitation sums in September • Mean air temperature in June • Mean air temperature in September
Negative	<ul style="list-style-type: none"> • AGE • Precipitation sums in April • Precipitation sums in May • Precipitation sums in July • Precipitation sums in April • Mean air temperature in May • Mean air temperature in June • Mean air temperature in July • Mean air temperature in August 	<ul style="list-style-type: none"> • AGE • Precipitation sums in April • Precipitation sums in June • Precipitation sums in July • Precipitation sums in September • Mean air temperature in June • Mean air temperature in September 	<ul style="list-style-type: none"> • AGE • Precipitation sums in April • Precipitation sums in July • Precipitation sums in August • Mean air temperature in April • Mean air temperature in May • Mean air temperature in July • Mean air temperature in August

Source: Original

The climate prevailing in the natural sites of Eastern white pine in North America is cold and moist. It extends in areas with the mean July temperature ranging between 18° and 23°C. Comparing these data with the July temperature date for the Belgrade area, we can see that it is mostly at the upper limit of the ecological niche or significantly above it (Graph 1). This indicates that, in terms of temperature, the Eastern white pine plantation was established in conditions that corresponded to its natural sites, but due to climate change, the temperature conditions have become unfavorable for its normal growth.

The annual precipitation sums in the natural sites range from about 510 mm in northern Minnesota to about 2030 mm in north-western Georgia. In the Great Lakes region, about two-thirds of the precipitation occurs during the warm season, from April to September. In other locations, half of the precipitation occurs during the warm season. Comparing these data with the precipitation in the Belgrade area, it is evident that it is below the lower limit of the ecological niche (except in a few years) (Graph 2).

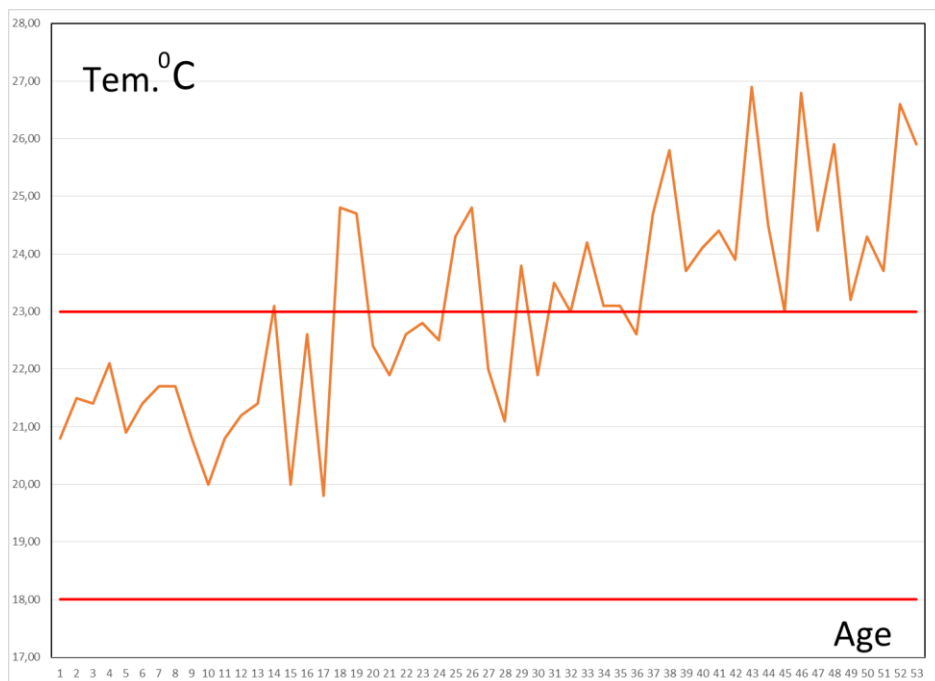


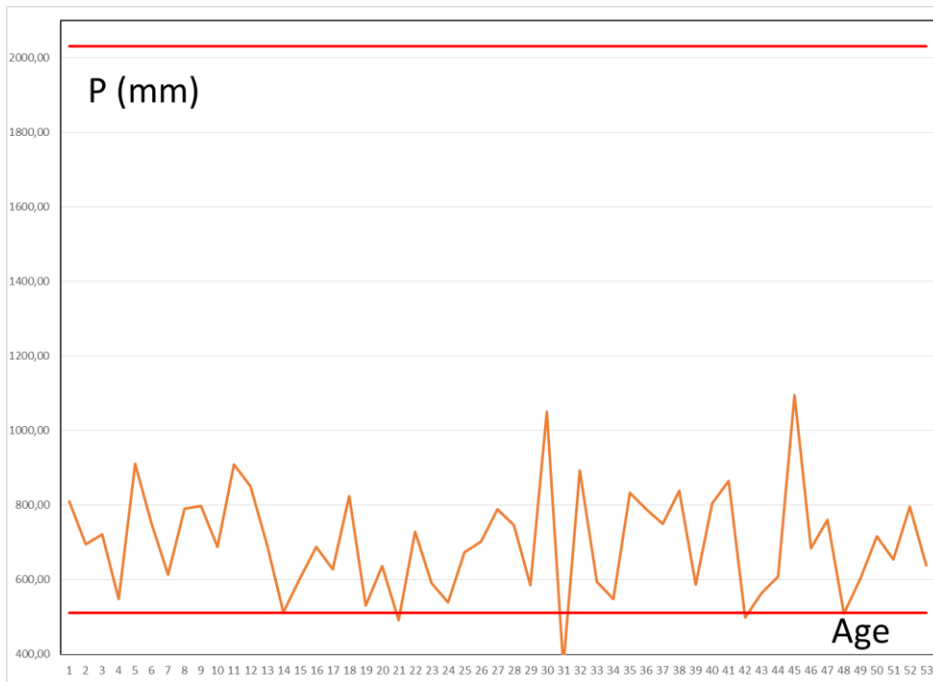
Chart 1. Air temperature values in July at the habitat in Belgrade. The red lines are the ecological temperature niche in July in natural habitats

Recent climate change projections for Serbia predict a trend of increasing temperatures for the A1B and A2 scenarios for the three observed periods (2011-2040, 2041-2070, and 2071-2100) (Ministry of Agriculture and Environmental Protection, 2015). The expected temperature changes for the observed periods are as follows:

1. 2011-2040 – an increase in temperature of 0.5-0.9°C for A1B, and 0.3-0.7°C for the A2 scenario;

2. 2041-2070 – an increase in temperature of 1.8-2.2°C for A1B, and 1.6-2.0°C for the A2 scenario;
3. 2071-2100 – an increase in temperature of 3.6-4.0°C for A1B, and 3.2-3.6°C for the A2 scenario.

The most pronounced warming, exceeding 4.0°C by the end of the century, is expected for the summer and autumn seasons (MAEP, 2015). The region of Serbia is an area where the air temperature rise will significantly exceed the global average, with an increased incidences of severe droughts and intense precipitation. Summer warming in the Balkans and western Turkey is projected to be 5-6°C for the period 2071-2100 under scenario A2 (Giorgi F. et al., 2009). Applying the ICTP-RegCM3 model for the period 2071-2100, scenario A2 predicts an increase of 7.0°C above the Balkan countries, including Serbia (Önol B. and Semazzi F., 2009). These parameters indicate that site conditions are being created that will hinder the successful establishment of new Eastern white pine plantations in Serbia and the urban forests of Belgrade.



Graph 2. Values of the annual sum of precipitation in the habitat in Belgrade. The red lines are the ecological niche of the annual sum of precipitation in natural habitats

3.3 Forest Aridity Index – FAI

The potential for further introduction of Eastern white pine into urban forests was analysed based on the Forest Aridity Index (FAI). FAI is determined by the ratio of the mean temperatures during critical months (July and August) to the sum of precipitation in the main growing cycle (from May to June) plus the sum of

precipitation in the critical growing cycle (from July to August) (Führer E., 2008; 2010). The Forest Aridity Index (FAI) classifies forest regions, allowing for the definition of the distribution areas of certain tree species. Increased values of the Forest Aridity Index (FAI) indicate dry weather conditions during the growing season and critical months, while lower values indicate a cooler and more humid climate (Führer E. et al., 2011). The meteorological characteristics of forest climate categories are: <4.75 (beech climate), 4.75-6.00 (oak-hornbeam climate), 6.00-7.25 (Turkey oak climate), and >7.25 (forest-steppe climate). The values of the Forest Aridity Index (FAI) according to the REG-IN model are shown in Table 8 (Dimitrijević T. et al., 2022). The period 1871-1900 had the lowest FAI value, at 5.4. The values of the index estimated according to the REG-IN model are above 6 and show a rising trend. The FAI value for 2081-2100 is estimated to be 7.4, indicating a climate with forest-steppe characteristics (Table 6). According to this analysis, the ongoing conditions will prevent the introduction of *Pinus strobus* into the urban forests of Belgrade.

Table 8. FAI Values by Analysed Periods and Estimated Values According to the REG-IN Model

Periods	Estimated values according to the REG-IN model		
1871-1900	2021-2050	2051-2080	2081-2100
5.4	6.4	6.9	7.4

Source: Dimitrijević et al., 2022

3.6 Potential Evapotranspiration

Throughout the ecological niche in natural Eastern white pine sites, precipitation is approximately 1 to 1.5 times greater than evaporation from shaded free water surfaces (Wendel G.W. and Smith C.). Annual potential evapotranspiration ranges from 430 to 710 mm, with 56 to 68 per cent occurring in the warm season. There is an excess of moisture in all seasons.

Due to a lack of data on solar radiation, relative air humidity, and wind speed, reference evapotranspiration for the Belgrade City area was calculated using the Hargreaves equation (Hargreaves G.H. and Samani Z.A., 1985). Estimated annual ET values according to the REG-IN model for all three periods are higher compared to the periods from 1871 to 2018, as expected due to the rise in mean annual air temperatures. Annual ET values according to the REG-IN model show a rising trend (Table 9).

Table 9. Reference Evapotranspiration (mm) calculated by the Hargreaves Method

Periods	Months												Year
	J	F	M	A	M	J	J	A	S	O	N	D	
1871-1900	17.0	26.1	55.7	89.8	127.3	145.9	161.4	142.3	96.9	58.3	27.1	15.8	963.6
	Estimated values according to the REG-IN model												
2021-2050	21.6	32.5	53.9	90.8	132.3	152.6	164.1	150.7	100.2	63.0	34.3	19.7	1015.7
2051-2080	24.1	35.5	57.4	87.1	127.1	148.3	165.6	160.9	103.5	67.9	38.4	20.9	1036.7
2081-2100	26.9	39.8	57.4	82.4	117.3	167.8	169.8	170.2	107.4	72.9	42.3	22.5	1076.7

Source: Dimitrijević T. et al., 2022

4. CONCLUSION

The size of latewood is negatively influenced by age (AGE), total precipitation in April (AP_P), June (JU_P), July (JL_P), and September (SE_P), as well as the mean monthly air temperature in June (JU_T) and September (SE_T). Positive influence is determined for the total precipitation in May (MA_P) and August (AU_P), and mean air temperature in April (AP_T), May (MA_T), July (JL_T), and August (AU_T). The regression coefficient is 0.803, explaining 64.5% of the latewood values. The F-test value indicates significance at a level of 0.05.

The size of the total current diameter increment is negatively influenced by age (AGE), total precipitation in April (AP_P), July (JL_P), and August (AU_P), as well as the temperature in April (AP_T), May (MA_T), July (JL_T), and August (AU_T). Positive influence is observed with total precipitation in May (MA_P), June (JU_P), and September (SE_P), as well as mean air temperature in June (JU_T) and September (SE_T). This data are presented in Table 7.

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CLIMATE CHARACTERISTICS AND DIAMETER INCREMENT OF EASTERN WHITE PINE: POTENTIAL USE IN AFFORESTATION IN THE BELGRADE AREA (REPUBLIC OF SERBIA)

Tatjana DIMITRIJEVIĆ, Mihailo RATKNIĆ, Sabahudin HADROVIĆ

Summary

The size of earlywood is negatively influenced by age (AGE), total precipitation in April (AP_P), total precipitation in July (JL_P), total precipitation in August (AU_P), as well as mean air temperatures in April (AP_T), May (MA_T), June (JU_T), July (JL_T), and August (AU_U). Positive influence is observed with total precipitation in May (MA_P), June (JU_P), September (SE_P), and mean air temperature in September (SE_T). The correlation coefficient is 0.615, explaining 37.8% of the earlywood values. The F-test value indicates significance at a 0.01 level. The size of latewood is negatively influenced by age (AGE), total precipitation in April (AP_P), June (JU_P), July (JL_P), and September (SE_P), as well as the mean monthly air temperature in June (JU_T) and September (SE_T). Positive influence is determined for the total precipitation in May (MA_P) and August (AU_P), and mean air temperature in April (AP_T), May (MA_T), July (JL_T), and August (AU_T). The regression coefficient is 0.803, explaining 64.5% of the latewood values. The F-test value indicates significance at a level of 0.05. The size of the total current diameter increment is negatively influenced by age (AGE), total precipitation in April (AP_P), July (JL_P), and August (AU_P), as well as the temperature in April (AP_T), May (MA_T), July (JL_T), and August (AU_T). Positive influence is observed with total precipitation in May (MA_P), June

(JU_P), and September (SE_P), as well as mean air temperature in June (JU_T) and September (SE_T). The climate model REG_IN indicates that newly emerging site conditions will hinder the establishment of new pine plantations in the urban forests of Belgrade. According to the aridity index (FAI) for the period 2081-2100, the FAI is estimated to reach 7.4, indicating a forest-steppe climate. All the analyses suggest that the emerging conditions will prevent the introduction of *Pinus strobus* into the urban forests of Belgrade.

**KLIMATSKE KARAKTERISTIKE I DEBLJINSKI PRIRAST BOROVCA:
POTENCIJALNA UPOTREBA U POŠUMLJAVANJU NA PODRUČJU
BEOGRADA (REPUBLIKA SRBIJA)**

Tatjana DIMITRIJEVIĆ, Mihailo RATKNIĆ, Sabahudin HADROVIĆ

Rezime

Veličina ranog drveta je pod negativnim uticajem starosti (AGE), sume padavina u aprilu (AP_P), sume padavina u julu (JL_P), sume padavina u avgustu (AV_P), kao i srednje temperature vazduha u aprilu (AP_T), maju (MA_T), junu (JU_T), julu (JL_T) i avgustu (AU_U). Pozitivan uticaj je konstatovan sa sumom padavina u maju (MA_P), junu (JU_P), septembru (SE_P) i srednjom temperaturom vazduha u septembru (SE_T). Koeficijent korelacije iznosi 0,615 i objašnjeno je 37,8% vrednosti ranog drveta. Veličina kasnog drveta je pod negativnim uticajem starosti (AGE), sumom padavina u aprilu (AP_P), junu (JU_P), julu (JL_P) i septembru (SE_P), kao i sa srednjom mesečnom temperaturom vazduha u junu (JU_T) i septembrom (SE_T). Pozitivan uticaj utvrđen je sa sumom padavina u maju (MA_P) i avgustu (AV_P), i sa srednjom temperaturom vazduha u aprilu (AP_T), maju (MA_T), julu (JL_T) i avgustu (AV_T). Koeficijent regresije iznosi 0,803 i objašnjeno je 64,5% vrednosti kasnog drveta. Veličina ukupnog tekućeg debljinskog prirasta pod negativnim uticajem je starosti (AGE), sume padavina u aprilu (AP_P), julu (JL_P) i avgustu (AU_P) kao i temperature aprilu (AP_T), maju (MA_T), julu (JL_T) i avgusta (AU_T). Pozitivan uticaj konstatovan je sa sumom padavina u maju (MA_P), junu (JU_P) i septembru (SE_P) i sa srednjom temperaturom vazduha u junu (JU_T) i septembru (SE_T). Na osnovu klimatskog modela REG_IN ukazuje se da se stvaraju stanišni uslovi koji će onemogućiti uspešno podizanje novih plantaža borovca u urbanim šumama grada Beograda. Na osnovu indeksa aridnosti (FAI) za period 2081-2100., procena je da će FAI vrednost iznositi 7,4, odnosno da će klima imati odlike šumsko-stepske klim. Sve ove analize ukazuju da se stvaraju uslovi koji onemogućavaju unošenje *Pinus strobus* u urbane šume Beograda.