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RESEARCH OF ECOLOGICAL CONDITIONS OF SPECIAL-PURPOSE FOREST TO ASSESS THE ENVIRONMENTAL STATE OF THE BELGRADE AGGLOMERATION

Marina Vukin[158], *Milun Krstić*[159], *Violeta Babić*[160],
Branko Kanjevac[161], *Slobodan Stefanović*[162], *Vladica Ristić*[1163]

Abstract

The paper covers research in the fields of urban forestry and environmental ecology. The research results on ecological factors in forest habitats in the periurban zone of Belgrade are presented. The studied complex is classified into forests with a priority protective function and forests intended for recreation and cultural functions. The paper aims to assess the ecological potential of habitats in relation to the purpose and ecosystem services of forests. Based on the research results, it will be possible to reconstruct parts of the forest complex that are underutilizing the habitat's potential. The climate character was determined based on the climate index using the Thornthwaite method. Based on air temperatures and precipitation amounts (2002-2016), the soil moisture deficit and surplus, potential and actual evapotranspiration, aridity and humidity indices, and the climate index were calculated. The habitat is characterized as: a habitat of submontane beech forest (*Fagetum submontanum*) on eutric brown soil on loamy sediments; a habitat of Hungarian and Turkey oak forest with manna ash (*Quercetum frainetto-cerridis ornetosum*) on eutric brown soil on loamy sediments, and a habitat of a typical Hungarian and Turkey oak forest (*Quercetum frainetto-cerridis typicum*) on illimerized eutric brown soil on loamy sediments. The objective of management is to develop silvicultural measures that facilitate the regeneration of introduced tree species.

158 Marina Vukin, PhD, Assistant Professor, Correspondence Academician of IRASA, Belgrade, Republic of Serbia, marina.vukin@futura.edu.rs, ORCID 0009-0007-4664-4089
159 Milun Krstić, PhD, Full Professor retired, Academician of IRASA, Belgrade, Republic of Serbia, milun.krstic@sfb.bg.ac.rs, ORCID 0000-0003-3012-2546
160 Violeta Babić, PhD, Full Professor, Academician of IRASA, University of Belgrade, Faculty of Forestry, Belgrade, Republic of Serbia, violeta.babic@sfb.bg.ac.rs, ORCID 0000-0001-6848-8442
161 Branko Kanjevac, PhD, Assistant Professor, Correspondence Academician of IRASA, University of Belgrade, Faculty of Forestry, Belgrade, Republic of Serbia, branko.kanjevac@sfb.bg.ac.rs, ORCID 0000-0002-5940-3600
162 Slobodan Stefanović, PhD, Assistant Professor, Faculty for applied ecology Futura, Metropolitan University, Belgrade, Republic of Serbia, slobodan.stefanovic@futura.edu.rs, ORCID 0009-0007-7386-6365
163 Vladica Ristić, PhD, Full Professor, Academician of IRASA, Faculty for applied ecology Futura, Metropolitan University, Belgrade, Republic of Serbia, vladicar011@gmail.com, ORCID 0000-0002-8605-1698

Key words: *Ecological conditions, Belgrade forests, environment, reconstruction.*

Introduction

In the southeastern peri-urban zone of the Belgrade agglomeration, along the state road E75, there is the forest complex 'Stepin Lug', constructed between 1956 and 1961 on former bare land and agricultural areas [1]. In this area, there has been a pronounced anthropogenic impact on the forest habitat's conditions. According to the authors [2]: '*The initial vegetation and soil cover of this region were (except the climatogenic forest of Hungarian and Turkey oak) conditioned by the relief. The developed relief not only enabled the arrival of various forest communities but also significantly 'changed' the character of the geographical position of this terrain*.' The authors believe that the previous climate of this area, once covered in forest and unaffected by urban development, was considerably colder and wetter. Today, this area is characterized by exceptional floral diversity and high environmental and aesthetic value, due to the presence of over 43 autochthonous and allochthonous deciduous and coniferous species. The reason for the existence of such many tree species is the favorable ecological conditions. The current artificially established stands represent suburban forests categorized as special-purpose forests in the subcategory of forests of special importance [3, 4, 5]. The Institute for Nature Conservation of Serbia recommends preserving the current state of tree species and suggests that the management goal should focus on restoring the forest's native characteristics [6]. The paper aims to examine key synecological characteristics and identify the fundamental ecological conditions of the studied stands. The aim of the work is also to assess the ecological potential of the forest habitat, considering the global and primary purpose of the forest complex and the need to provide ecosystem services of a typical suburban forest. The final goal is to create a basis for the development of a new vegetation map of the research area as a model of the potential of local habitats expressed through basic ecological characteristics. Based on the research results, it will be possible to reconstruct those parts of the forest complex that are not sufficiently utilizing the habitat potential.

Materials and methods

The object of the research is artificially established stands of broadleaves within the management unit 'Stepin lug', in the suburban zone of the city of Belgrade (Figure 1). According to the global purpose [6], the complex is classified into forests with a priority protective function and forests intended for recreation and general cultural and educational functions. The main purposes are soil protection from erosion, as well as recreational and tourist purposes [6]. The complex occupies an area of 471.95 ha. Artificially established stands are present on an area of 133.08 ha (28.2%). Field research was carried out on 3 permanent experimental plots (Figure 2), in an artificially established stand of silver linden (*Tilia tomentosa* Moench.) - EF 1 and EF 2; and an artificially established stand of the northern red oak (*Quercus borealis* Misch. f.)

- EF 3; in the period 2014-2019. The stands are 65 years old. The size of the experimental fields was 5 ares. Research into orographic, climatic, and edaphic conditions was carried out, along with vegetation reconnaissance and comparison with data from the Titov Gaj Forest Park potential vegetation map [2]. The altitude and exposure were determined using the base map of the management unit 'Stepin Lug' [6]. The slope was determined using a Vertex III altimeter. The coordinates of the experimental fields were determined using the Pidion BIP-6000 device and the ArcGIS software package. To study climate conditions, data from the Republic Hydrometeorological Institute of Serbia, for the Belgrade Observatory meteorological station (130 m a.s.l.), for the period 2002-2016, were used [7]. The climate character was determined based on the calculation of the climate index using the Thornthwaite method [8,9]. To research the edaphic characteristics, 1 pedological profile was opened in each experimental field, to a depth sufficient to define the soil characteristics. Phytocoenological affiliation and typological definition of the habitat are presented based on terrain reconnaissance and detailed research [2,10,11,12]. The definition of the ecological-typological affiliation of the habitat was carried out based on the typological definition of the habitat in which the stands are located, and not based on the ecological-typological characteristics of the stands themselves, given that these are artificially established stands.

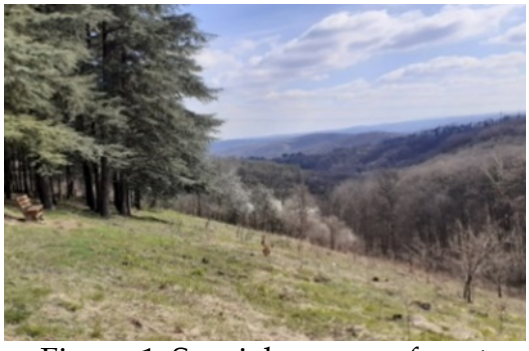

Figure 1: Special-purpose forest 'Stepin Lug'

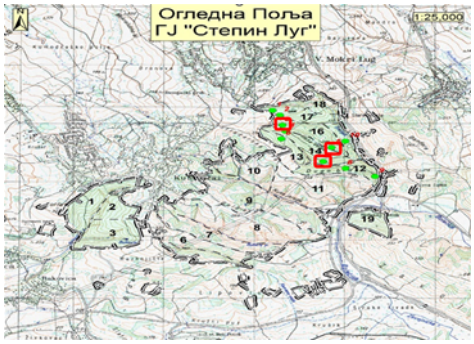

Figure 2: Research area with locations of experimental fields

Research results and discussions

Orographic conditions

The management unit "Stepin Lug" extends between 44°30' and 45°30' north latitude and 18°30' and 17°30' east longitude [6]. The forest complex is characterized by a recognizable developed relief (Figure 1). The lowest point is at 99 m a.s.l., while the highest point is at 332 m a.s.l., so the elevation difference is 233 m.

Climatic conditions

The general characteristics of the climatic conditions in the research area follow the climate characteristics of the wider area of the city of Belgrade. According to the

climatic zone, the Stepin Lug forest complex is located in the III climatic zone and the III D area [9]. The area is characterized by a temperate-continental climate. The region is influenced by the Mediterranean Sea and the Atlantic Ocean, and the subregion is influenced by cold continental air from the northern and northeastern parts of Europe.

Air temperature

The average annual air temperature for the observed period (Table 1) is 13.4°C, with large oscillations, from 11.8°C to 14.5°C. The average temperature during the growing season is 19.0°C. According to the average mean air temperature values of the seasons, it can be stated that winters are moderately cold, springs are fresh, summers are moderately warm, and autumn is relatively warm. The average monthly temperature shows regularity in movement, with the minimum temperature in January and the maximum in July. The annual temperature fluctuation is large and reaches 61.2°C in extreme cases.

Table 1: Average monthly and average annual air temperatures in the study area in the period 2002-2016 (°C)

Year	Meteorological station: Belgrade Observatory				Latitude 44°48N			Longitude 20°28E		Altitude 132 m a.s.l.			Avg. year temp.
	Months												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2002	1.2	8.5	10.3	12.1	20.1	22.9	24.3	22.2	11.1	13.2	10.6	1.3	13.2
2003	0.3	-2.1	7.1	12.1	21.5	25.0	23.1	25.6	17.8	10.8	9.2	2.8	12.8
2004	-0.3	3.6	7.7	13.1	16.0	20.6	23.1	22.0	17.2	15.1	7.6	3.7	12.5
2005	1.7	-1.3	5.8	12.7	17.7	20.3	22.6	20.6	18.4	12.8	6.7	3.4	11.8
2006	-0.5	1.9	6.5	13.7	17.4	20.2	24.7	20.9	19.2	15.2	8.9	4.3	12.7
2007	7.6	7.2	10.2	14.9	19.5	23.8	25.8	24.2	17.9	11.8	5.2	1.1	14.1
2008	3.2	6.3	9.1	13.8	19.3	23.0	23.7	24.0	17.0	14.8	9.1	4.6	14.0
2009	-0.2	2.9	7.9	15.8	19.9	21.0	24.1	24.1	20.6	13.1	9.9	4.7	13.7
2010	0.6	3.7	8.2	13.5	18.1	21.3	24.4	24.1	17.8	10.6	12.2	2.5	13.1
2011	1.6	1.0	9.0	14.4	17.5	22.2	24.0	24.7	22.6	12.1	4.4	5.5	13.3
2012	2.1	3.0	10.1	14.5	17.9	24.9	27.0	26.3	21.5	14.7	10.5	2.0	14.5
2013	3.3	4.6	6.6	15.0	19.1	21.4	24.5	25.3	17.2	15.3	10.1	3.2	13.8
2014	5.3	7.8	10.8	13.7	17.2	21.4	23.0	22.5	18.3	14.1	9.6	4.6	14.0
2015	4.0	4.1	9.2	13.5	19.1	21.9	26.8	26.0	20.0	12.4	9.2	4.3	14.2
2016	2.5	9.0	9.1	15.5	17.5	22.5	24.4	22.3	19.7	11.1	7.7	0.9	13.5
Average	2.2	4.0	8.5	13.9	18.5	22.2	24.4	23.7	18.4	13.1	8.7	3.3	13.4

Precipitation regime

The average value of the total annual precipitation for the observed period is 723.8 mm (Table 2). This value represents a fairly favorable amount of precipitation, considering the location of Belgrade and its surroundings on the edge of the Pannonian Plain and the temperate-continental climate. The least precipitation occurs in winter (21% of the total annual amount), and the most in spring and summer (53%). It very often happens that during two consecutive years, precipitation amounts oscillate from the lowest to the highest in a certain period (or vice versa), which is one of the characteristics of the precipitation regime in the Belgrade area and beyond [10,11,12,13]. In the observed period, the minimum annual precipitation was 499.2 mm (2011), and the maximum was 1095.1 mm (2014). There are large oscillations in the

amount of precipitation for the observed period. The minimum precipitation is recorded during November and December, and the maximum occurs in May and June. During the growing season, 456.9 mm of atmospheric precipitation falls, which is 63% of the annual precipitation. The height of the snow cover is highly variable from year to year, both in terms of thickness and duration. The maximum varies from 5-70 cm, and the duration is up to 42.7 days. The relative humidity is 64%.

Table 2: Precipitation regime in the study area in the period 2002-2016 (mm)

Year	Meteorological station: Belgrade Observatory			Latitude 44°48N			Longitude 20°28E		Altitude 132 m a.s.l.				Avg. year precip. amount
	Months												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
2002	15.1	14.0	14.8	53.7	20.9	79.6	60.7	106.8	51.9	88.3	35.8	52.8	594.4
2003	62.9	26.5	11.4	23.1	39.5	33.4	111.8	6.4	57.6	115.2	23.4	36.7	547.9
2004	93.5	29.4	18.9	71.7	63.3	113.8	94.6	89.3	45.0	32.9	129.5	50.3	832.2
2005	52.2	84.2	33.9	54.7	47.4	95.1	91.4	144.3	54.1	28.6	23.5	78.8	788.2
2006	43.2	59.1	104.4	97.0	42.3	137.8	23.3	120.6	24.3	20.9	24.5	51.3	748.7
2007	49.3	56.0	99.6	3.8	79.0	107.6	17.5	72.5	84.1	103.6	131.5	34.5	839.0
2008	44.6	8.3	79.7	34.9	60.6	43.3	53.0	45.6	68.5	18.4	51.0	79.0	586.9
2009	55.1	95.2	64.9	6.1	34.7	151.0	90.0	44.5	3.9	98.9	59.5	120.6	824.4
2010	91.6	112.8	47.2	43.7	96.4	181.7	41.4	53.5	51.8	48.8	45.2	61.4	875.5
2011.	47.8	55.6	27.9	14.1	66.9	41.1	95.0	14.0	47.7	36.1	5.0	48.0	**499.2**
2012	97.2	61.5	2.4	66.9	127.9	16.0	39.0	4.5	30.7	44.9	28.1	55.1	574.2
2013	76.9	53.4	95.4	21.3	104.4	50.1	2.9	44.3	58.7	52.0	40.0	7.9	607.3
2014	24.1	19.9	48.7	85.3	280.4	60.3	250.6	63.5	126.0	61.2	8.8	66.3	**1095.1**
2015	48.6	52.4	132.9	30.7	80.7	38.6	10.6	49.5	101.4	71.8	63.4	3.8	684.4
2016	46.3	38.5	102.6	53.9	71.3	152.2	35.0	60.8	47.8	76.8	71.8	2.6	759.6
Sum	848.4	766.8	884.7	660.9	1215.7	1301.6	1016.8	920.1	853.5	898.4	741.0	749.1	/
Average	56.6	51.1	59.0	44.1	81.0	86.8	67.8	61.3	56.9	59.9	49.4	49.9	**723.8**

Hydric balance and climate classification according to Thornthwaite

The Thornthwaite climate classification was carried out based on the presented values of the calculated water balance (Table 3). Actual evapotranspiration (SET) is 76% of potential evapotranspiration (PET), which indicates a deficit of water in the soil. Deficit of water occurs during the vegetation period, in the summer months. In contrast, the excess water is 16% of the total amount of precipitation and occurs in the winter months.

Table 3: Hydric Balance according Thornthwaite in the study area in the period 2002-2016 (mm)

Year	Meteorological station: Belgrade Observatory			Latitude 44°48N			Longitude 20°28E		Altitude 132 m a.s.l.				Year value
	Months												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
t	2.2	4.0	8.5	13.9	18.5	22.2	24.4	23.7	18.4	13.1	8.7	3.3	13.4
i	0.29	0.71	2.23	4.70	7.25	9.55	11.02	10.55	7.19	4.30	2.31	0.53	60.64
PET	3.1	6.6	27.5	60.0	106.2	134.8	162.2	143.6	82.8	47.3	21.3	5.1	800.5
P	56.6	51.1	59.0	44.1	81.0	86.8	67.8	61.3	56.9	59.9	49.4	49.9	723.8
R	100	100	100	84	59	11	0	0	0	13	41	85	/
SET	3.1	6.6	27.5	60.0	106.2	134.8	78.7	61.3	56.9	47.3	21.3	5.1	608.8
M	0	0	0	0	0	0	83.5	82.3	25.9	0	0	0	191.7
V	39.0	44.5	31.5	0	0	0	0	0	0	0	0	0	115.0
Humidity Index: 12.374				Aridity Index: 23.947					**Climate index: -1.994**				
									Climate type: subhumid arid C_1				

Legend: i – Caloric Index; PET – Potential Evapotranspiration; R – Soil Water Storage; SET – Actual Evapotranspiration; M – Soil Water Deficit; V – Soil Water Surplus

The climate index is -1.994, which indicates that within the studied area, subhumid dry climate C_1 prevails.

Microclimatic conditions

The pronounced hilliness of the terrain and the highly developed microrelief, large differences in altitudes, and the existence of numerous valleys and alluvial plains significantly influenced the fact that the researched area is much fresher than other parts of the Belgrade area. Temperature inversions are common, occurring as a result of changes in altitude and exposure of the terrain to different parts of the world. According to previous research [10], elements of the hydric balance, in the slightly earlier period of 1990-2009, indicate that the research area has a subhumid wetter climate of type C_2. The climate index shows large fluctuations, from 41.06 during 1999 (humid temperate climate B_2) to -49.76 during the following year 2000 (arid climate type E). Hydric balance studies for the Belgrade area for the long-term period 1888-1958 [12], as well as the wider area of central Serbia that includes the altitudinal belt of Hungarian and Turkey oak forests [13], indicate approximately the same values of the humidity index, aridity index and climate index, which indicates slight oscillations of climatic conditions, over several previous decades, for the climate of Belgrade and the surrounding area. Based on the above, comparing the values of basic and derived climate factors (air temperature, precipitation, hydric balance, climate index), as important factors for forest growth and survival, for different previous periods, it is difficult to assert with certainty that macroclimatic conditions in a given area have changed significantly so far. But, in any case, less favorable microclimatic conditions are created for the growth of forest vegetation.

Edaphic conditions

The studied area belongs to the post-pontic fluvial forms [14]. The complexity of the geomorphology and petrography of this area has resulted in the occurrence of almost all sediments characteristic of the wider Belgrade area in such a small area: tertiary and cretaceous limestones, sandstones, clays, marls, and serpentinites [15]. Alluvium occurs in stream valleys. The hilly relief and the complexity of the parent substrate have led to the presence of a large number of soil formations [10, 11, 15]. The most common soils are eutric brown. Despite forming under thermophilic oak forests, eutric brown soils are represented here most often as medium-deep to deep soils. The soils of this part are of somewhat lighter mechanical composition and belong to loams and light loams in which the colloid fraction does not exceed 20%. This mechanical composition is conducive to maintaining good water capacity. The chemical characteristics of these soils show that they are mild to moderately acidic soils. The degree of base saturation is 2/3 of the possible total capacity. They are characterized by a high presence of base cations, which indicates high potential productivity. The presence of humus and assimilatives (N, P, K) shows relatively low values due to many years of agricultural exploitation.

Artificially established stand of silver linden (*Tilia tomentosa* Moench) - experimental field 1

Experimental field 1 (EP1) is located in section 16b (Figure 2), at an altitude of 265 m. The coordinates of the sample field are: 7463313.6 E and 4955971.7 N, Gauss-Krüger projection zone 7. The exposure is northeast, the slope is about 20˚. The geological base is composed of clayey sediments. The soil cover is represented as eutric-brown soil with a structure of profile A-(B)-C (Table 4, Figure 3). The vegetation is represented by the potential vegetation of the hilly beech forest (Ass. *Fagetum submontanum*). The tree floor is characterized by the following species: beech (*Fagus moesiaca*) as an edificator, sessile oak (*Quercus petraea*), Turkey oak (*Quercus cerris*), large-leaved linden (*Tilia platyphyllos*), silver linden (*Tilia tomentosa*), цер (*Quercus cerris*). In the shrub layer, due to the strong shade of the tree layer, there are a smaller number of species, mainly woody species that are also found in the first layer: beech (*Fagus moesiaca*), sessile oak (*Quercus petraea*), Turkey oak (*Quercus cerris*), hornbeam (*Carpinus betulus*), wild cherry (*Prunus avium*), aspen (*Populus tremula*), wild service tree (*Sorbus torminalis*), common hazel (*Corylus avellana*), and common ivy (*Hedera helix*). In the herbaceous plant layer, there are: *Anemone ranunculoides, A. nemorosa, Hedera helix, Corydalis cava, C. solida, Asarum europeum, Isopyrum thalictroides, Euphorbia amygdaloides, Asperula odorata, Viola silvestris*, *Dentaria bulbifera, Athyrum filix-faemina,* etc. The habitat where the studied stand is located, according to its affiliation with the typological classification system of forests [16], is defined as an ecological type: habitat of hilly beech forest (*Fagetum submontanum*) on eutric-brown soil on loamy sediments.

Artificially established stand of silver linden (*Tilia tomentosa* Moench) - experimental field 2

Experimental field 2 (ОП 2) is located in section 14s (Figure 2), at an altitude of 185 m. The coordinates of the experimental field are: 7463763.3 E and 4955349.4 N, Gauss-Krüger projection zone 7. The exposure is south to southwest, and the slope is up to 15˚. The geological base is composed of clayey sediments. The soil cover is defined as: eutrophic brown soil with an A-(B)-C profile structure and a profile thickness of about 55 cm (Table 4, Figure 3). The exposure of the terrain to the south plays a crucial role in defining favorable edaphic conditions for deciduous forest vegetation, so this soil is warmer than other eutric brown soils. The vegetation is represented by the potential vegetation of the Hungarian and Turkey oak with manna ash (Ass. *Quercetum frainetto-cerridis ornetosum*). The tree floor is characterized by the following species: Hungarian oak (*Quercus frainetto*), Turkey oak (*Quercus cerris*), manna ash (*Fraxinus ornus*), European wild pear (*Pyrus piraster*), and service tree (*Sorbus domestica*). In the shrub floor, there are: Hungarian oak (*Quercus frainetto*), Turkey oak (*Quercus cerris*), manna ash (*Fraxinus ornus*), wayfarer (*Viburnum lantana*), cornel (*Cornus mas*), common buckthorn (*Rhamnus cathartica*), *Crataegus* sp., *Rosa* sp. In the herbaceous plant layer, there are: *Lathirus niger, Cytisus supinus, Viola hirta, Vincetoxicum officinale, Rubus tomentosus, Lithospermum purpureo-coeruleum, Polygonatum officinale, Allium pulchelum, Brachypodium pinatum,* etc. The habitat where the studied stand is located, according to its affiliation with the typological forest classification system [16], is

defined as an ecological type: forest of Hungarian and Turkey oak with manna ash (*Quercetum frainetto-cerridis ornetosum*) on eutric-brown soil on loamy sediments.

Artificially established stand of northern red oak (*Quercus rubra* L.) - experimental field 3

Experimental field 3 (EP 3) is located in section 16y (Figure 2), at an altitude of 230 m. The exposure is northeast, the slope is about 10°. The geological base is composed of clayey sediments. The coordinates of the experimental field are: 7463857.8 E and 4955588.3 N, Gauss-Krüger projection zone 7. The soil is described as an ilmerized eutric-brown soil with an A-(B)-C profile (Table 4, Figure 3). The initial appearance of clay leaching in the cambium horizon is noticeable. The presence of roots in the upper parts of the profile indicates good water-air characteristics. These properties decrease with soil depth. Given that the experimental field is located on a wider ridge, where there is no modification of microclimatic characteristics due to the influence of the rugged relief, but rather the terrain is under the influence of the macroclimate, the vegetation characteristics are characterized by the potential vegetation of the climatogenic community of Hungarian and Turkey oak (Ass. *Querceto frainetto-cerridis typicum*). The tree floor consists of the following species: Hungarian oak (*Quercus frainetto*), Turkey oak (*Quercus cerris*), silver linden (*Tilia tomentosa*), downy oak (*Quercus virgiliana*), wild service tree (*Sorbus torminalis*), Tatar maple (*Acer tataricum*), and manna ash (*Fraxinus ornus*). In the shrub floor, there are: cornel (*Cornus mas*), hornbeam (*Acer campestre*), *Rosa* sp., wild privet (*Ligustrum vulgare*), Italian woodbine (*Lonicera caprifolium*), wayfarer (*Viburnum lantana*), and European spindle (*Evonymus europaeus*). The ground flora floor contains: *Dactylis polygama*, *Galium pseudoaristatum, Carex verna, Silene viridiflora, Genista ovata, Lathyrus niger, Citysus supinus, Calamintha clinopodium, C. officinalis, Festuca va;llesiavca, F. heterophylla, Lapsana communis, Rubus tomentosus,* etc. The habitat where the investigated stand is located, according to its affiliation with the typological forest classification system [16], is defined as an ecological type: habitat of a typical Hungarian and Turkey oak forest (*Quercetum frainetto-cerridis typicum*) on illimerized eutric-brown soil on clayey sediments.

Table 4: Physical characteristics of the soil in the experimental fields

Experimental field	Horizon	Depth (cm)	Shape of the structural aggregate	Texture	Soil type	Vegetation
EP1	A	32	nut to prismatic	sandy-loamy	Eutric brown soil on loamy sediments	Ass. *Fagetum submontanum*
	(B)	32-85	prismatic to polyhedral	loamy		
	C	>85				
EP2	A	20	coarse-grained to prismatic	sandy-loamy	Eutric brown soil on loamy sediments	Ass. *Quercetum frainetto-cerridis ornetosum*
	(B)	20-55	prismatic to polyhedral	loamy		
	C	>55				
EP3	A	20	lumpy	loamy	Eutric brown soil on loamy sediments	Ass. *Quercetum frainetto-cerridis typicum*
	(B)	20-80	lumpy to polyhedral	loamy-clay		
	C	>80				

Figure 3: Morphology of soil profiles

With a highly developed relief, the studied area exhibits a pronounced microclimatic diversity of habitat conditions, accompanied by temperature inversions with increasing altitude and large temperature differences at various exposures. The presence of the hilly beech forest community (Ass. Fagetum submontanum) on EP1 highlights the significant impact of the ecological factors analyzed in the area, including the developed relief, microclimate, and soil conditions of the habitat. The presence of valleys, characterized by lower air temperatures and increased relative humidity, has led to the formation of a mesophilic habitat, which is suitable for the emergence of beech forests. The macroclimate of the studied area, unchanged by the relief, is reflected by the climatogenic community of Hungarian and Turkey oak (Ass. *Quercetum frainetto-cerridis*), with numerous variants (EP2 and EP3). A certain humidity of the macroclimate indicates that forest communities have sufficient amounts of accessible soil moisture throughout the year. Research into the physical characteristics of the soil cover indicated the existence of favorable conditions for the growth of forest vegetation in all sample areas, taking into account that several decades ago, there were agricultural areas and bare land in the same area. The established favorable soil texture provides optimal conditions for the growth of introduced autochthonous and allochthonous forest tree species. The health status of introduced broadleaf species is very satisfactory, with no recorded diseases or pests. Similar results related to achieving ecological stability and adaptability of introduced autochthonous and allochthonous broadleaf tree species to secondary habitats in special-purpose forests, 50 years old, in the Belgrade area, were obtained by the authors [5,17]. The high degree of adaptability and naturalization of red oak, as a species geographically very distant from the habitat of this part of Europe, indicates an extremely promising broadleaf species for introduction into the habitats of the oak belt in the area of Belgrade and central Serbia [17]. The bioecological characteristics of these species, along with their environmental conditions, contribute significantly to their aesthetic and ecological value. This, in turn, enhances the environmental quality of this section of the urban area, particularly given its proximity to the busy E 75 road and the city center.

Conclusion

Research on the ecological characteristics of primary forest habitats in the Stepin Lug complex near Belgrade, where stands of silver linden and red oak have been established, reveals a remarkable potential for supporting biodiversity. Additionally, these habitats offer valuable protective, regulatory, and social ecosystem services for suburban forests. The developed 'anarchic' relief is one of the decisive factors that

enabled the achievement of the environmental harmony of a typical suburban park-forest, but it also caused microclimatic differences over short distances. The favorable macroclimatic and microclimatic conditions, particularly characterized by a subhumid dry climate, play a crucial role in the forest vegetation of the oak belt in Serbia. Additionally, the gradual rise in air temperature and the relatively mild effects of climate change suggest that the local climate potential will be a key factor in the development of the forest. These circumstances impose the need, in the context of sustainable development, to minimize risks and take all necessary measures to protect biodiversity, the environment, and more rational use of available natural resources in the Belgrade area. Understanding the orographic, climatic, and microclimatic conditions of a habitat, along with the physical characteristics of the soil, is crucial for selecting suitable woody species that will thrive optimally. Considering the age of the stands, the compatibility of bioecological characteristics with the habitat conditions of primary forest types, as well as the current state of the stands, it can be concluded that the basic protective, regulatory and social functions of a special-purpose forest are provided in the studied part of the forest complex. The conducted research represents a contribution to the formation of a new model of the potential of local habitats expressed through basic ecological characteristics. Future silvicultural measures should focus on the regeneration of silver linden and red oak, considering the high aesthetic, decorative, and environmental value of these species. This approach aims to enhance the environmental conditions in this part of the peri-urban zone of Belgrade.

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