



Measuring dendrofloristic diversity in urban parks in Novi Sad (Serbia)

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ABSTRACT

Urban parks provide many ecosystem services, and conserving biodiversity is one of the most important among them. Keeping track of biodiversity indices and their evolution over time is a useful procedure for preserving biodiversity within urban habitats. The paper presents an application of the R programming language and the R package “vegan” for calculating alpha and beta diversity indices for dendroflora in urban parks. The case study includes five major parks in the city of Novi Sad, Serbia: Danube, Futog, Kamenica, Liman and Railway park. The alpha indices calculated in the paper are the richness, Simpson, Shannon, Berger-Parker and Fisher indices, and they have been used to quantify the diversity of dendroflora in each park separately. The beta indices in this research were the Jaccard distance and Sorensen indices, and these have been used to estimate the overlap in dendrofloristic composition among parks. These analyses have been supported with additional analysis related to the dendrofloristic elements such as the ratio of native to non-native species of trees and shrubs, family spectrum, analysis of prevailing native species, abundance of invasive species, etc. This research has shown that the Danube, Futog and Kamenica parks are highly valuable from a biodiversity perspective, but also that there are distinct differences in plant composition among the five parks. This research demonstrates application of the R program in measuring dendrofloristic diversity, and creating comprehensive databases of floristic elements in urban parks. Beyond its utility for calculation purposes and processing of numerical data related to individual plant species, R can be used for the analysis of spatial data and creating maps, making its scientific applications to ecological problems even more attractive.

Introduction

Urban parks have an important role in maintaining biodiversity within cities, because they provide habitat for native vegetation and support the natural processes of ecosystems (Lepczyk et al., 2017; Srdjevic et al., 2019). Maintaining biodiversity is a challenging task in which the main threats to biodiversity loss are defined by the HIPPO concept (Torrance (2010): (1) Habitat alteration, (2) Invasive species, (3) Pollution, (4) Population growth and (5) Overexploitation, which Torrance proposed as the main causes for biodiversity loss in both urban and natural areas. To preserve biodiversity, it is important to keep track of existing species and analyze the factors that threaten their survival (Volis, 2018; Shilling et al., 2020). Two primary quantitative measures of biodiversity are richness (Lelli et al., 2019; Myllyviita et al., 2019) and evenness (Parisi et al., 2021; Phillips and Lindquist, 2021), referring to the number of species and the evenness of their distribution over space, respectively. Biodiversity indices provide key information for monitoring species diversity, and numerous contemporary software tools

have been developed to support these calculations (Zhang and Jim, 2014; Lopucki and Kiersztyn, 2015; Basnou et al., 2020; Kumdet et al., 2021). For example, EstimateS is a well-known software tool that provides simple procedures for calculating biodiversity indices (Colwell et al., 2012), but in recent times the R programming language, and the R package “vegan” in particular, have become popular alternatives for these biodiversity calculations (Lakicevic et al., 2020). The basic input data needed for calculating biodiversity indices are the number of species, and the number of individuals belonging to each species (see Supplement 1), but all other data related to individual plants can also be processed in R and subsequently used for monitoring or forecasting purposes. Two useful R packages for additional modeling purposes are “plant” and “ForestFit,” both of which offer diverse types of analysis and simulation regarding plant communities and their “size and trait-structured demography, ecology and evolution” (Falster et al., 2016). The R language is already well known as a freely-available, open-source tool for ecological applications, but here we also highlight its added value, considering that the R program also offers tools for creating high-

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quality maps and other visualizations of spatial data [Rahlf \(2017\)](#).

Defining biodiversity indices dates back to the early 20 th century, and from that period on, many indices have been defined, discussed and analysed. We still use the “old” ones, but the calculation procedure is far more sophisticated and facilitated by the use of contemporary software.

This paper focuses on measuring dendrofloristic diversity (diversity of woody plants such as trees and shrubs) in parks in Novi Sad, Serbia, but the methods are easily extended to calculating the diversity of fauna and other life forms at other spatial extents as well. The calculation procedures were performed with the R program, applying the R package “vegan”.

Materials and methods

The paper analyses dendrofloristic diversity in five major parks in Novi Sad: Danube, Futog, Kamenica, Liman and Railway park ([Fig. 1](#)). Kamenica park is located on the right bank of the Danube River, while the four other parks are located on the left bank of the river. Environmental conditions are similar for the Danube, Futog, Liman and Railway parks, and are typical of urban parks exposed to nearby high population density, pollution from transportation systems, development of commercial facilities, and residential housing and schools, while the Kamenica park is more isolated and lies adjacent to the Danube River ([Fig. 1](#)), but it is not classified as a riparian forest, being very similar to a typical European broadleaf forest community, considering its structure and floristic elements (see Supplement 1). Climate conditions in the area have typical continental climate features; there are four distinct seasons, with an average annual temperature of 10.9 °C, and rainfall totalling 578 mm per year. The south- western wind can be quite strong during the late fall and winter seasons, so plants can be exposed to mechanical damages. The climatic conditions and terrain configuration (lowland and plain area) determine the floristic composition – the main elements being broadleaf species, typically helophytes and mesophytes.

[Table 1](#) presents basic information regarding the size and protection

Table 1

Parks evaluated in the Novi Sad biodiversity study.

Park	Area [ha]	Protection status ^a	Year of protection
Danube park	3.9	Natural monument	1998
Futog park	12.0	Natural monument	2005
Kamenica park	42.0	Natural monument	2006
Liman park	12.9	None	–
Railway park	4.2	None	–

^aThe Law of Nature Protection of the Republic of Serbia defines a natural monument as a small and well-preserved landscape area with unique and recognizable natural values, which can be both natural or created by human activities (e. g. botanical gardens, parks, etc.).

status of the parks. All five parks are classified as urban parks, and the three parks, Danube, Futog and Kamenica, have been designated as natural monuments. More detailed information on the five parks can be found in [Lakićević and Srđević \(2017\)](#).

Research for this study was conducted in two phases, with the first phase involving fieldwork to determine basic properties of all tree and shrub species in each park, and with the second phase processing all collected park data in the R programming language. The fieldwork was conducted from October 2019 to December 2020. The first phase of the analysis obtained general information regarding floristic elements, including ratio of gymnosperms and angiosperms in overall species composition, origins of tree and shrubs species (i. e., native versus non-native), plant family spectrum ([Useni et al., 2021](#)), most dominant native species, etc. The second phase of analysis calculated biodiversity indices, using the R programming language. The input data for calculation of diversity indices were a list of all woody species (trees and shrubs) and the number of individuals belonging to each species, for each park separately (Supplement 1). The number of trees was determined by the so- called “stem count.” The number of shrubs was counted: a) by counting each specimen if they were planted as single shrubs or in a group or b) by taking into account the corresponding planting

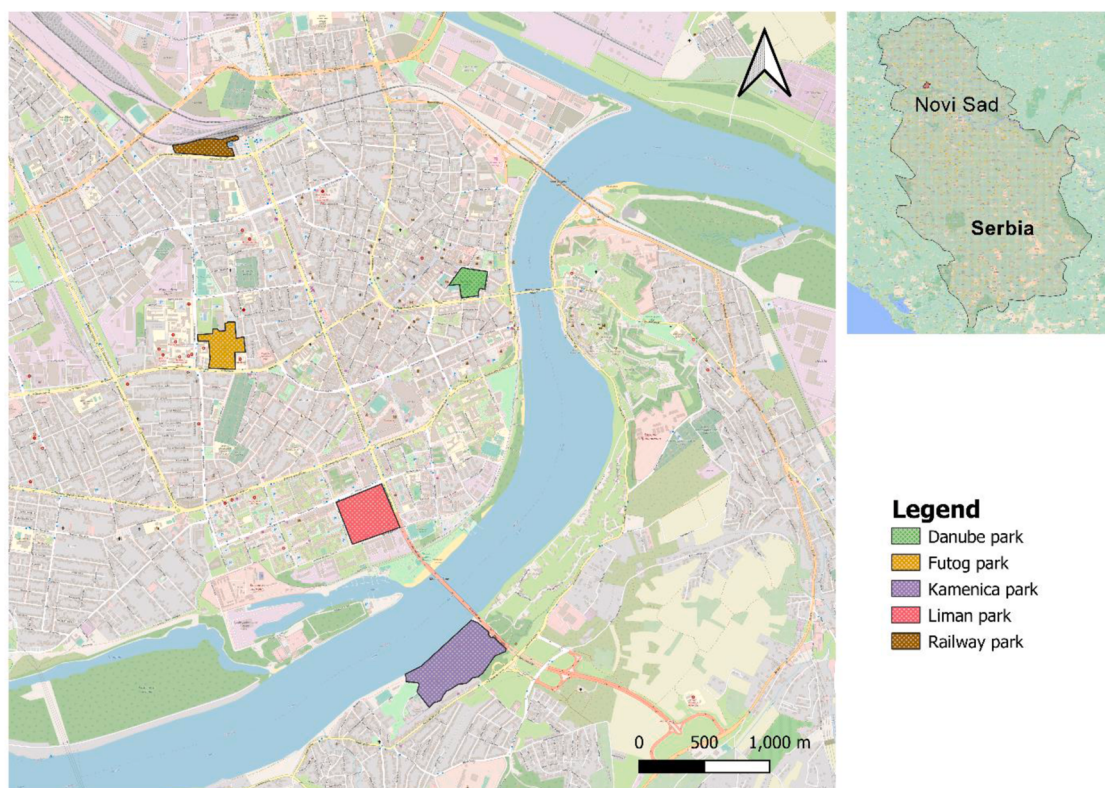


Fig. 1. Locations of parks in Novi Sad, Serbia diversity study.

distance for the shrubs planted in hedges. For both trees and shrubs, the number of individuals was counted equally – regardless of plant size.

The calculated indices were: alpha indexes (richness, Simpson, Shannon, Berger- Parker and Fisher) and beta indices (Jaccard distance and Sorensen index). The alpha diversity indices quantify diversity within each particular park, whereas the beta diversity indices serve for comparison purposes, usually between two or more habitats/areas or, less frequently, within the same habitat/area over different time periods. More about biodiversity indices and corresponding formulas can be found in Magurran (2004) or Fedor and Zvaríková (2019), but we briefly describe them here. Richness (Braun-Blanquet, 1932) is a diversity index that measures the number of species within a habitat. The Simpson index Simpson (1949) measures evenness, and its value varies in the interval from 0 to 1, where values closer to 1 demonstrate better evenness among species. The Shannon index (Shannon, 1948) measures both richness and evenness and its usual values vary in the interval 1.5–3.5 with values greater than 3.5 indicating that habitat is highly important in biodiversity terms Magurran (2004). The Berger- Parker index (Berger and Parker, 1970) measures the relative abundance of the most dominant species and takes values in the interval (0, 1]. The Fisher index Fisher (1921), unlike those previously described, is a non- parametric index, based on the assumption that abundance of species follows a log distribution and does not have fixed threshold values, but a higher number of this index corresponds to higher species diversity. Jaccard distance Jaccard (1901) measures the dissimilarity in plant composition in two or more datasets, and takes values in the interval [0, 1], where values closer to 0 indicate a greater overlap in the plant composition between communities. The Sorensen index Sørensen (1948) measures similarity in plant composition among communities, taking values in the interval [0,1], where values closer to 1 correspond to greater similarity in plant species composition. Both the Jaccard distance and Sorensen indices are prominent in the ecology literature, but the Jaccard distance has generally been preferred (Useni Sikuzani et al., 2019), as a metric one (while the Sorensen index is being semi metric). We summarize basic properties of the indices used in Table 2.

In addition to calculating biodiversity indices, the research included analysis of invasive and non- native species in the park, because they may affect biodiversity loss in the long term. The determination of invasive species was done in accordance with the list of invasive and

potentially invasive species in Serbia proposed by Stojanović and Jovanović (2018).

For the purposes of calculation and visualization of the results, we used the freely available, open- source R program (version 3.5.3), its RStudio interface (version 1.2.1335, also open source), and the R package “vegan” (version 2.5–3, Oksanen et al., 2018). More specifically, the indices for Simpson, Shannon, Fisher, Sorensen and Jaccard distance were calculated using the “vegan” package, whereas, for the two remaining indices (richness and Berger- Parker index), the authors wrote their own R code.

Results and discussion

This section is divided into the following subsections: Preliminary analysis of dendroflora, Alpha diversity indices, Beta diversity indices and Applications of R.

Preliminary analysis of dendroflora

Considering the percentages of Angiospermeae and Gymnospermae dendroflora in all parks together, representatives of the angiosperms dominated in comparison to gymnosperms (89% versus 11%). These percentages correspond well with the natural and potential vegetation of the area, because gymnosperms do not naturally occur frequently in this lowland area (Orlović et al., 2017; Caspersen et al., 2018), which has an average altitude of 75 m above sea level. Next, considering species origins, we found that native and non- native trees are equally represented (50:50%), while non- native shrubs dominate over the native ones (62% versus 38%) in the five urban parks. Previous research has shown that replacement of native shrubs happens more frequently than replacement of native trees in urban plantings (Lanta et al., 2013), and this is the case in the parks analyzed in this study as well.

The analysis of the plant family spectrum considered the three most dominant families that belong to the Angiospermeae and Gymnospermeae divisions (Fig. 2)

Fig. 2 shows basic statistics for the most dominant plant families using the “boxplot” representation. The plant families Rosaceae, Oleaceae and Berberidaceae are the most dominant angiosperms, while Pinaceae, Cupressaceae and Taxaceae are the most dominant families among gymnosperms.

As a sequel to the analysis of plant family spectrum, we also investigated the most dominant species of trees and shrubs in the five parks. The most dominant native trees in the parks are (1) *Tilia tomentosa* Moench, (2) *Acer campestre* L., (3) *Ulmus carpinifolia* Gled., (4) *Pinus nigra* Arn. and (5) *Tilia platyphyllos* Scop. The only species from this list that does not belong to the natural vegetation of the area is black pine; this species was commonly used when designing and reconstructing parks in Novi Sad, as a native conifer which has shown good adaptive capacity in the urban environment. All other species – linden trees, field maple and European elm - are typical representatives of native, local flora in this area.

The most dominant native shrubs in the parks are (1) *Pyracantha coccinea* Roem., (2) *Taxus baccata* L., (3) *Buxus sempervirens* L. (4) *Syringa vulgaris* L. and (5) *Ilex aquifolium* L. Common yew and boxwood were used for hedges, while the others have been selected due to their high ornamental values. Some native shrubs, for example, *Cornus sanguinea* L., *Euonymus europaeus* L., and *Viburnum opulus* L. are rarely seen in the territory of Novi Sad, but are present in nearby protected areas – National park “Fruska gora” and Special natural reserve “Koviljsko- petrovaradinski rit”.

Alpha diversity indices

The value of the richness index shows that the lowest number of woody plant species occurs in the Railway park (46), and the highest number occurs in the Futog park (99) (Table 3). Apart from analyzing

Table 2
Biodiversity indices used in the study of Novi Sad parks.

Index	Author	Type	Scale range	Description (component quantified)
Richness	Braun-Blanquet, 1932	α (parametric)	≥ 1	richness
Simpson index	Simpson, 1949	α (parametric)	1.5 - 3.5 ^a	richness and evenness
Shannon index	Shannon, 1948	α (parametric)	(0,1]	evenness
Berger- Parker index	Berger and Parker, 1970	α (parametric)	(0,1]	evenness
Fisher index	Fisher, 1921	α (non-parametric)	> 0	richness and evenness
Jaccard distance	Jaccard, 1901	β (metric)	[0,1]	dissimilarity between communities
Sorensen index	Sørensen, 1948	β (semi-metric)	[0,1]	similarity between communities

^a The Simpson index does not have a fixed range of values. Here, we show the typical range, indicating where values closer to the lower threshold indicate poorer richness and evenness components of floristic elements in an area, and values close to upper threshold and above it indicate that the area has a great importance from biodiversity perspective (due to the high richness and fair evenness of species in the area).

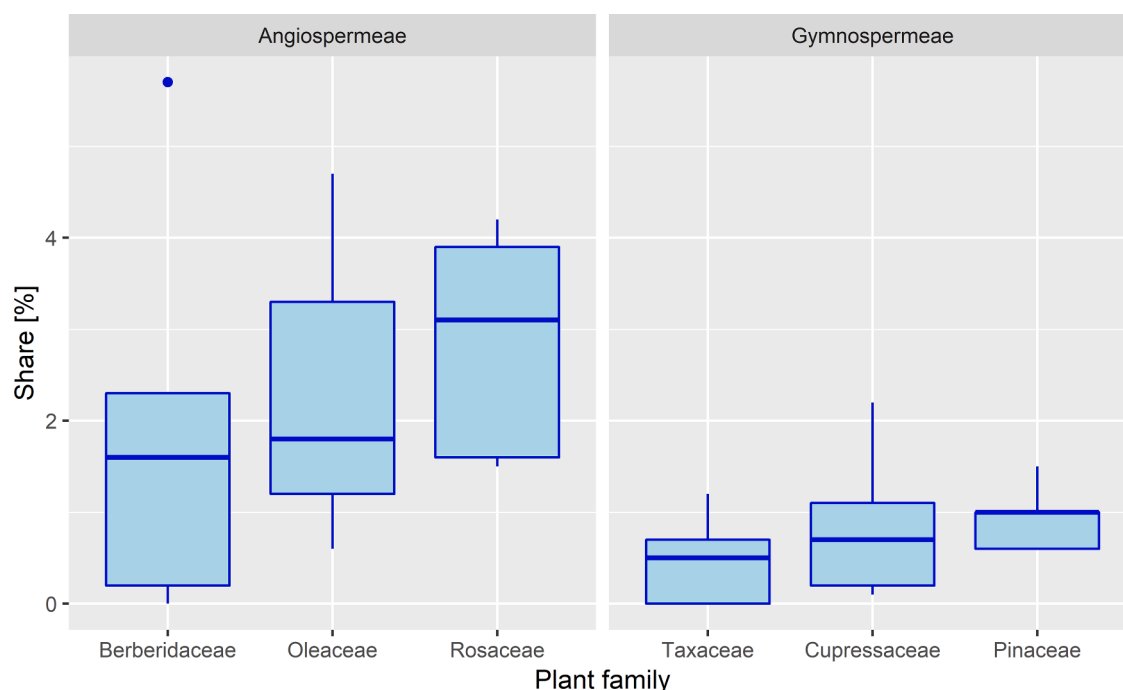


Fig. 2. The most dominant plant families by park in Novi Sad study parks.

Table 3

Alpha diversity indices^a computed in R for Novi Sad parks.

Park	Richness	Simpson	Shannon	Berger-Parker	Fisher
Danube park	85	0.958	3.574	0.083	17.143
Futog park	99	0.964	3.752	0.087	18.895
Kamenica park	87	0.956	3.514	0.094	15.625
Liman park	66	0.923	3.272	0.216	11.913
Railway park	46	0.915	2.963	0.171	9.120

^aIndices are described in the text and Table 1.

the absolute number of species, it is also informative to biodiversity analyses to consider their evenness. The Simpson index had high values in all five parks (the values vary from 0.915 to 0.964), which indicates a highly homogeneous distribution of the plant species in all five parks. The Shannon index varies in a higher range, from 2.963 in the Railway park to 3.752 in the Futog park. The value of the Berger - Parker index is the highest in the Liman park (0.216); this high abundance of the most dominant species and lower value of richness resulted in the slightly lower value of the Shannon index in this park (3.272). The Fisher index estimates the number of taxa expected to be found in a sample with a smaller number of individuals, and again this value is the highest for the Futog park, and lowest for the Railway park.

The results from this research can be compared with a comprehensive study by Galle et al. (2021), which discusses the values of the Shannon and Simpson indices for urban greening in cities around the globe (Amsterdam, Vancouver, Bologna, Cambridge, Melbourne, Oslo, Buenos Aires and Paris). This latter research found that the values for the Shannon index vary from 2.0 to 3.41 in the center of the above- listed cities, and in the range from 2.89 to 4.18 for zones outside city centers. Considering that values of the Shannon index greater than 3.5 indicate an area highly valuable from a biodiversity perspective Magurran (2004), the Futog, Danube and Kamenica park stand out, and are recognized as urban parks with valuable dendrofloristic elements to be monitored and preserved. The Shannon values for the Liman and Railway park have values similar to those discussed in Galle et al. (2021), and are considered typical ones (Table 2). The same research considered values of the Shannon index and their results varied from 0.67 to 0.93 in

the central city zones, and in the interval of 0.84 to 0.97 in zones away from the city centers. Results from our research confirm that the value of the Simpson index is high in all parks in Novi Sad, and this is further interpreted as a favourable evenness of plant species, similar to zones away from city centers (Galle et al., 2021).

The analysis of alpha diversity indices is further informed by the analyses of the share of non- native and invasive species in each of the five parks (Fig. 3).

The smallest proportion of non- native species occurred in the Kamenica park (equal to 40%). In all other parks, the share of non- native species is very similar and varies in a narrow interval, from 54 to 57%. The analysis of invasive species shows that the highest proportion of invasive species was detected in the Kamenica park (10%) and the lowest in the Danube park (5.9%). It is suggested that occurrences of invasive species should be carefully monitored in the future, because they have the potential to affect biodiversity loss in the longer term (Josefsson et al., 2021), and appropriate measures may need to be applied, preferably including mechanical removal of the most aggressive invasive species, to control their further spread. This suggestion especially applies to the three parks which are proclaimed natural monuments, but also to the Liman and Railway parks.

We found that the most aggressive invasive species are mainly present in the Kamenica and Futog parks (Table 4). The species *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle and *Ulmus pumila* L. are frequent invasive species in the entire territory of Serbia, and they could be originating from the surrounding landscapes. The species *Celtis occidentalis* L. and *Robinia pseudoacacia* L. were mainly introduced in with the course of the design and reconstruction projects, and the smaller number of individuals that was initially planted has transformed into larger populations over time, due to the high spread potential of both species (Lakićević and Mladenović, 2017).

Beta diversity indices

The matrix containing the values of the Jaccard distance values for the five parks shows the pair- wise comparisons among parks (Fig. 4). Note that the matrix is symmetrical, with the values equal to 0 on the main diagonal, because these represent self comparisons for which these

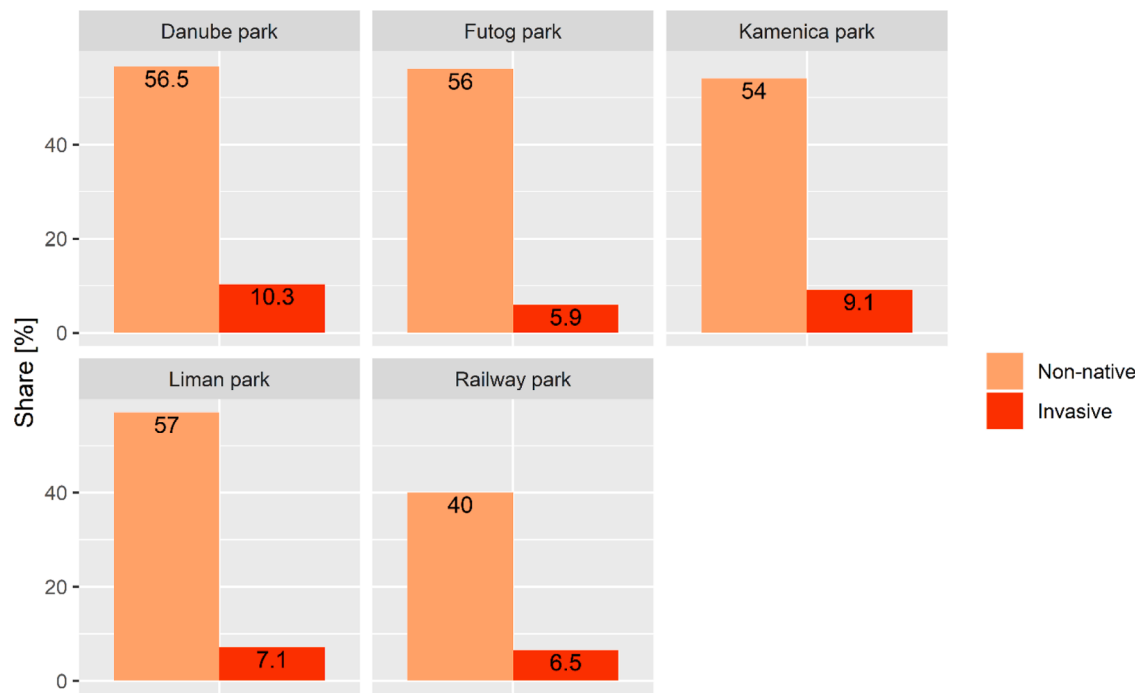


Fig. 3. Percent occurrence of non-native and invasive species by park in Novi Sad study.

Table 4

Invasive species (total number of individuals (N) and their percent distribution among the parks).

Species ^a	N	Distribution in the parks [%]				
		Danube	Futog	Kamenica	Liman	Railway
Acer negundo L.	64	3.1	28.1	31.3	37.5	0.0
Ailanthus altissima (Mill.) Swingle	131	3.8	5.3	48.9	42.0	0.0
<i>Amorpha fruticosa</i> L.	3	0.0	0.0	100.0	0.0	0.0
<i>Broussonetia papyrifera</i> (L.) Vent.	52	0.0	0.0	100.0	0.0	0.0
Celtis occidentalis L.	167	3.0	40.1	16.2	25.1	15.6
<i>Gleditsia triacanthos</i> L.	64	1.6	0.0	98.4	0.0	0.0
<i>Juglans nigra</i> L.	23	0.0	43.5	8.7	47.8	0.0
<i>Koeleruteria paniculata</i> Laxm.	41	2.4	48.8	0.0	43.9	4.9
<i>Maclura aurantiaca</i> Nutt.	36	0.0	19.4	80.6	0.0	0.0
<i>Pinus nigra</i> Arn.	298	8.4	29.2	36.2	15.1	11.1
<i>Populus x euramericana</i> Dode (Guinier)	115	0.0	0.0	0.0	100.0	0.0
<i>Rhus typhina</i> L.	15	0.0	0.0	0.0	53.3	46.7
Robinia pseudoacacia L.	178	9.6	12.9	77.5	0.0	0.0
<i>Syringa vulgaris</i> L.	183	24.6	61.7	0.0	13.7	0.0
Ulmus pumila L.	19	0.0	26.3	73.7	0.0	0.0

^a The most aggressive invasive species are given in bold. These species are characterised by rapid spread, high potential for colonizing different types of habitats, and rapid replacement of elements of the local native flora (Stojanović and Jovanović, 2018).

would show no differences (Fig. 4).

On one hand, the highest overlap in dendrofloristic composition occurred between the Danube and Futog parks, i.e., the value of the Jaccard distance was the lowest and equal to 0.414 (Fig 4). On the other

hand, the results show that the dendrofloristic composition differed the most between the Kamenica and the Railway parks, with the value of the Jaccard index equal to 0.724. The high overlap in plant species composition between the Danube and the Futog park is likely due to the fact that both parks were reconstructed in the 1960ies by the same landscape architect, Dr. Ratibor Đorđević, who chose the same species for both parks' reconstruction. The highest difference in dendrofloristic composition between the Kamenica and Railway parks, can be interpreted as a consequence of the existing remnants of natural flora in Kamenica, characterized by a larger number of species, and on the other hand, a low richness of species in the Railway park.

The general conclusion is that the combination of climatic conditions and management practices (i.e., selecting plant species by urban park designers) determined the overlap in floristic composition the most. The Kamenica park, as the only one lying right on the Danube riverbank, has more hydrophilic elements and therefore differs the most from all other parks (Fig. 4). All other parks are situated in the city zone with very similar environmental conditions, and the overlap in their floristic composition is a consequence of selecting plant material by the landscape and urban park designers during park establishment and subsequent reconstructions.

Complementing the Jaccard distance metrics, the beta diversity as quantified by the Sorrensen index (Table 5), shows the lower triangle of the pair-wise scheme, with the value of 1 on the main diagonal, as the floristic composition in the same park overlaps completely.

The values presented in Table 5 were further processed by a clustering algorithm, and are presented in a dendrogram (Fig. 5), which makes the results more graphical and visually appealing.

The results obtained for the Sorrensen index correspond to the ones discussed for the Jaccard distance. The highest overlap and difference is again demonstrated for the same pairs of parks. From a biodiversity perspective, it is more favorable when having parks with a more diverse plant composition, than having more uniform plant components, which is why it is useful to include the analysis of beta indices for different habitats.

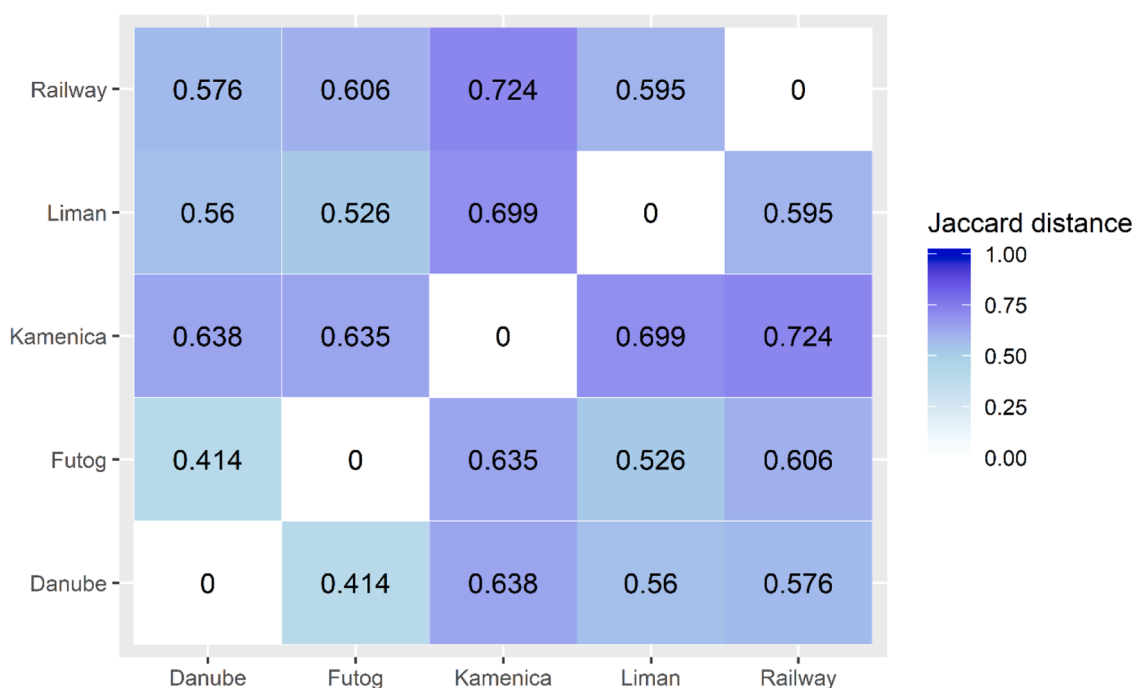


Fig. 4. Matrix of Jaccard distance.

Table 5
Sorensen index of beta diversity^a.

Sorensen index	Danube park	Futog park	Kamenica park	Liman park	Railway park
Danube park	1				
Futog park	0.739	1			
Kamenica park	0.532	0.535	1		
Liman park	0.611	0.643	0.462	1	
Railway park	0.595	0.566	0.433	0.576	1

^a The Sorensen index is described in the text and Table 1.

Application of R

This research included the analysis of diversity indices and applied one of the R packages, “vegan.” In addition, the authors wrote a variety of other complementary scripts in R for performing the preliminary analysis of dendrofloristic elements and producing all graphical visualisations of the results presented here, which highlights the utility of the R program for customized and diverse urban landscape analyses. A direction for future research could be to expand the analyses by including additional data and corresponding R packages. For example, expanding on the present study, we could apply the package “rredlist” [Chamberlain \(2018\)](#) to create a database with the endangered, rare, and protected species in the parks in Novi Sad. Such a database can be

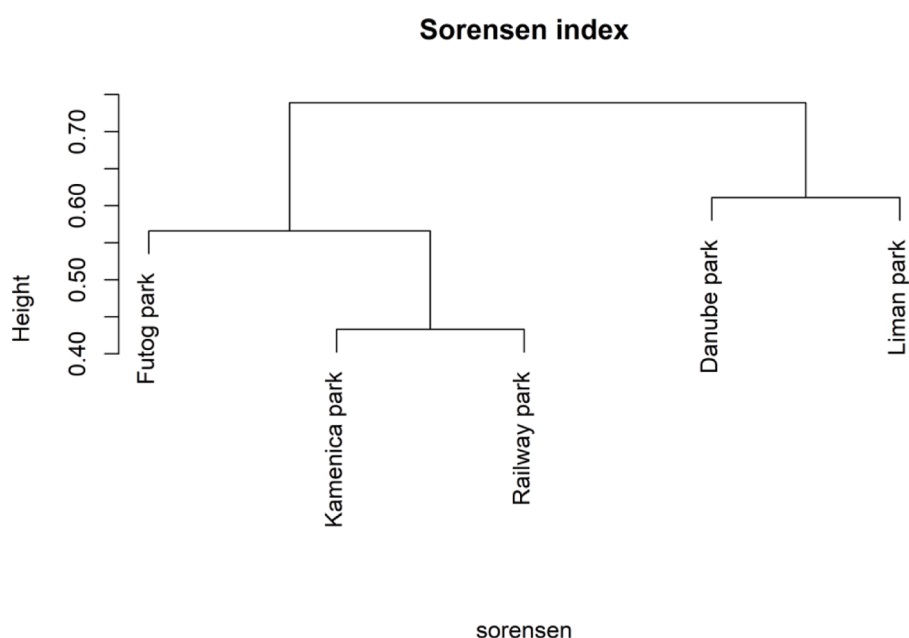


Fig. 5. Dendrogram of Sorensen index.

associated with spatial data, starting with obtaining geographic coordinates for each individual plant, and in this way it would be possible to obtain diverse types of additional basic and thematic maps. The R packages recommended for creating maps are “leaflet” (Cheng et al., 2018) and “ggmap” (Kahle and Wickham, 2013), depending on the user’s programming proficiency in R. More advanced users may want to use the “ggmap” package, because it provides high-quality maps and other graphical outputs (Lakicevic and Reynolds, 2020). Apart from making a more detailed analysis of the urban parks in Novi Sad, future application could include creating comprehensive databases and analyses of dendrofloristic elements in other urban parks in Serbia or even whole regions of Europe.

Conclusion

This research presents the application of the R program in measuring biodiversity indices in urban parks in Novi Sad, Serbia. The analysis of the values of alpha and beta biodiversity indices has been supported with the complementary analyses of dendrofloristic elements, such as the origin of species (native / non - native), form (trees / shrubs), the presence of the most dominant native species, the abundance of invasive species, etc. Urban parks have an important role in maintaining biodiversity within cities, so calculating biodiversity indices can be very helpful in the process of monitoring for, and managing, plant species diversity. Biodiversity indices can be calculated by numerous open-source and commercial applications that have been developed over the past 50 years, but here we have demonstrated that the open-source R program and its package “vegan” are also especially useful for this type of task, and the project presented here is easily extended to include analyses over much larger landscapes as well as including a broader range of lifeforms.

Endnotes

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Lakićević, 2020, Lakićević, 2018

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare the following financial interests / personal relationships which may be considered as potential competing interests: None. Dr. Milena Lakicevic.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tfp.2022.100239.

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