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QUANTITATIVE AND QUALITATIVE ANALYSIS OF URBAN GREEN AREAS USING NON-PARAMETRIC TESTS

Abstract

This paper analyzes the presence and quality of urban green areas in two local communities in the City of Banja Luka, namely: Lazarevo 1 and Lazarevo 2. The aim is to examine which categories and types of green areas are most represented in the study area and what is the quality of existing tree-lines. Two research questions were asked: whether all species are equally presented in the study area and whether the linden species present in this area get sick more often than other species. Part of the results was presented using descriptive statistics (frequency) methods, and to the other part non-parametric tests were applied, Pearson's χ^2-test using two basic forms: distribution shape test and χ^2 test of independence.

Keywords: urban green areas, non-parametric tests, Pearson's χ^2 test

КВАНТИТАТИВНЕ И КВАЛИТАТИВНЕ АНАЛИЗЕ УРБАНИХ ЗЕЛЕНИХ ПОВРШИНА ПРИМЈЕНОМ НЕПАРАМЕТАРСКИХ ТЕСТОВА

Сажетак

У овом раду анализирани су заступљеност и квалитет урбаних зелених површина у двије мјесне заједнице у Бањој Луци: Лазарево 1 и Лазарево 2. Циљ је да се испита које су категорије зелених површина најзаступљеније на овом подручју и какав је квалитет постојећих дрвореда. Постављена су два истраживачка питања: да ли су све врсте подједнако заступљене на подручју истраживања и да ли присутне врсте липе подлијежу болестима чешће од осталих врста. Дио резултата добијен је примјеном метода дескриптивне статистике (учесталости), а други дио добијен је примјеном непараметарских тестова, Пирсонов χ^2 тест и његова два основна облика: тест облика дистрибуције и χ^2 тест независности.

Кључне ријечи: урбане зелене површине, непараметарски тестови, Пирсонов χ^2 тест

1. INTRODUCTION

Over the past decades, rapid urbanization with consequent loss and degradation of green spaces has caused various environmental problems such as habitat fragmentation, biodiversity loss, air pollution, heat islands and heat waves, as well as negative impacts on human health and quality of urban life. In order to respond to this challenge and achieve urban sustainability, the concept of green infrastructure (GI) has been introduced. Sustainability and resilience of urban areas are closely linked to green spaces in urban areas [1]. Currently, landscapes are associated with several major challenges. Among them are dominant: climate change, high species extinction, ecosystem degradation, and the abolition of ecosystem services. There is a great deal of scientific research on the impact of human activities on these phenomena. In particular, land use can change not only the composition of landscapes and habitats, but also the function of ecosystems and their ecological potential, as well as the availability of natural resources [2]. Sustainable land use is key to protecting, recovering, and improving natural resources. Also, urban and landscape design can have a big impact on climate change. As a special element of urban and landscape design, urban open public spaces play an important role in reducing high temperatures, but also in overcoming the impact of climate change [3].

Cities around the world increasingly see urban greening (the use of urban green spaces) as an effective measure to mitigate the harmful effects of the effects of urban heat islands. Many studies have been done on this topic. In general, it is accepted that a larger amount of urban green areas gives a greater cooling effect. However, Masoudi and YokTan argue that this knowledge is inadequate to fully optimize the value of urban green spaces to mitigate the effects of urban heat islands, as the size, shape, and distribution of urban green spaces should also affect their ability to cool neighboring areas [4]. In other words, in addition to the amount of urban green space, their spatial pattern of location (neighborhood, settlement, city, region, etc.) is also important. The spatial pattern of urban green spaces refers to their spatial distribution and characteristics, and is generally described as having two independent components: configuration and composition. The configuration describes the spatial character and layout of urban green areas (for example, shape complexity, connectivity, and fragmentation), while the composition refers to measures of spatial characteristics that are not related to the layout of urban green areas (for example, diversity and abundance of different types). Different aspects of spatial composition and configuration can be quantified using mathematical constructions called landscape metrics. Landscape metrics are widely used in studies describing landscape patterns and their relationship to land use (cover changes), biodiversity distribution, ecological processes, and ecosystem functions [5].

Considering the quality and accessibility of urban green spaces has proven to be more important than considering only the amount of green space. Both planners and scientists have recognized that involving citizens through public participation and understanding their perceptions and preferences is an essential component of designing and managing inclusive and functional green spaces [6]. Here lies an important challenge: quality is subjective and can vary between different user groups [7]. Namely, green areas also provide social benefits, which are essential for the health and well-being of urban residents [8, 9]. Humans are social beings who need accessible green spaces where they can gather, socialize, walk, and relax. They will spend time in public space if they feel nice, comfortable and safe, and thus will provide mental restoration [10]. The quality characteristics of green areas are difficult to measure objectively [11]. There is a gap in knowledge about how to measure the quality of green spaces and whether they meet the needs of urban residents [12]. What constitutes good quality green space is usually unclear in planning processes. Planners have been criticized for relying on outdated, inconsistent, and low green space standards [13]. Various parametric methods, such as logistic regression, can be used to analyze data in studies about quality of life in urban areas. However, these methods have specific assumptions and predefined functions for describing the relationships between variables. Non-parametric models are used in the study of the quality of life of urban residents, in order to select the main variables that affect the quality of life, among the large amount of data collected [14].

Understanding how people perceive and appreciate different landscapes is essential for informing about landscape policies that reflect societal needs [15]. The importance of assessing the contribution of nature and the landscape to people's quality of life is increasingly recognized through frameworks such as ecosystem services and nature's contributions to people. The concept of ecosystem services (ES) is often used in the literature to represent the functions of green infrastructure. In this field, the multifunctionality of the ecosystem stands out, i.e., the capacity of green infrastructure to provide multiple ecosystem services [16].

Cities are major contributors to climate change, but at the same time, urban areas are also among the most vulnerable in the world. Many studies have been done that deal with the impact of urban public spaces on climate change. Thus, for example, authors in paper [17] analyze the potential for improving the comfort of open public spaces by introducing new elements of green infrastructure in order to meet the challenges of climate change. Special attention is paid to the analysis of the continuity of the green infrastructure network, analyzing the comfort of public space using clustered indicators that include greenery, urban equipment, water characteristics and urban morphology, and simulating microclimatic characteristics of the actual and proposed state of a particular public space (lower Dorćol in Belgrade), with the aim of presenting new elements of the process of designing open public space, which was developed at the Faculty of Forestry, University of Belgrade. They could be characterized as appropriate design tools, which will be used in response to challenges such as increased heat wave intensities, temperature thresholds, and the effects of urban heat islands. Urban greenery contributes to the urban environment as an individual element in a small space, but also at the city level as an element of the green infrastructure network. It offers a simple and precise design of the thermal comfort of an open public space. The simulation of climatic conditions on the segment of Jevrejska Street in Belgrade showed that by simply introducing tree lines and natural paving materials, adequate thermal settings for staying outdoors can be achieved. Research in the field of horticulture design and engineering, which will focus on issues of species selection and their characteristics and behavior in extreme weather conditions, has been recognized as important in the further process of this research [17].

Statistical methods, together with GIS and remote sensing data, can be used as an efficient and cost-effective option for analyzing urban growth and urban sprawl. The use of conventional methods of urban analysis is really difficult, time consuming, and expensive. Thus, for example, Al-Sharif et al. chose Tripoli, the capital of Libya, for their study. This study used Pearson's Chi-Square statistics and urban expansion intensity index (UEII) statistical models for quantitative analysis of urban sprawl in Tripoli [18].

The Chi-square statistic is a non-parametric (non-distributive) tool designed to analyze group differences when a dependent variable is measured at the nominal level. Like all non-parametric statistical methods, Chi-square is robust in terms of data distribution. In particular, it does not require equality of variables among research groups or homoscedasticity in the data. It enables the evaluation of both dichotomous independent variables and multiple group studies. Unlike many other non-parametric and some parametric statistics, the calculations required to calculate the Chi-square provide significant information about how each of the groups behaved in the study. This wealth of detail allows the researcher to understand the results and thus extract more detailed information from these statistics than from many others [19].

A similar methodology was used to research informal green spaces in a post-industrial city in Poland, Łódź [20]. Data were collected using orthophotos and a land use database. Then, interviews were conducted with local residents about their perception of undeveloped green areas, which are present in the immediate vicinity. The Chi-Square test was also used to analyze the relationship between the identified environmental services and the variables that characterize green areas. The results are presented using diagrams, after a tabular overview of all collected data.

Environmental heterogeneity affects biodiversity patterns such as species richness and community composition. Through the gradient of environmental heterogeneity, generated by different management treatments, Dornelas et al. (2009) analyzed weed communities in the United States. They used the statistical Pearson's Chi-Square test on the collected data. Their study showed that the distribution of the number of species is an informative indicator of environmental heterogeneity in modified landscapes. She suggests that creating heterogeneity of the environment, through different management treatments, throughout the landscape can be an effective way to promote biodiversity and reduce problematic species [21].

In the context of all the above in the experimental research, on the example of green areas in the urban area of the City of Banja Luka, the initial research questions will be examined using Pearson's Chi-Square test.

2. MATERIALS AND METHODS

The methodology of the research includes research through two phases: theoretical and experimental part. The first part of the paper (Introduction) presents the literature on the use of statistical methods in research on the quality of urban life, with special emphasis on the presence and quality of green spaces in cities and their impact on reducing the negative consequences of intensive urbanization, such as thermal islands. The method of content analysis was used. The literature review covers the time frame from 2005 to 2021 and includes publications, studies, books, scientific and research papers focusing on topics such as: green areas, urban environment and quality of life in it, statistical methods for large quantity analysis data and modern software technologies used in spatial data research, such as geographic information systems (GIS). The first part of the paper provides an overview of the literature and research on similar topics, explains how a large amount of data can be analyzed and how to find the relationship between variables. This section describes the field of research, the methodology used, and an overview of previous research.

The second part of the paper includes experimental research on the example of public green areas on the territory of two local communities, Lazarevo 1 and Lazarevo 2, in the wider urban area of the City of Banja Luka. The basic data classes that were analyzed can be divided into two groups, namely urban green areas and tree-lined trees. The first question that will be examined using the shape distribution test is: Are all types of green areas equally represented in the study area. The second question refers to the health condition of the trees and reads: Is small-leaved linden much more susceptible to diseases than European plane tree in the researched area? This question will also be examined using Pearson's χ^2-test, using contingency tables.

2.1. STUDY AREA

Banja Luka is known as a city of greenery - there are 22,000 trees planted in alleys, parks and settlements, which are obliged to maintain the City Administration. The city has 150 hectares of lawns, 40 kilometers of green fences, 31,000 pieces of ornamental shrubs and 5,000 pieces of roses, and a large number of seasonal flowers. The total area of landscaped park areas in the City of Banja Luka is 78,233 m^2 [22]. A complete exact analysis of the state of vegetation in Banja Luka has not been done, but there are several partial studies on the arrangement of certain urban areas and the protection of park-forests. A new approach to the analysis and observation of data related to urban greenery is given as a basis for future research in this field. Each category of greenery, according to its specifics, is maintained in different ways and by different methods. That is why the green areas of the city are systematized and classified by categories: parks and other smaller areas in the center; lanes along roads, greenery in settlements; tree lines and trees in block greenery; the greenery of the Kastel fortress; greenery memorials; Banj Brdo and picnic areas Trešnjik and Šibovi; weeds; flower beds; rose gardens; ornamental shrubs; hedges; surfaces that are cut in order to control ragweed according to the categorization defined in [23].

The pilot area investigated in this paper belongs to the urban part of the City of Banja Luka in two local communities: Lazarevo 1 and Lazarevo 2, and covers a total area of 11.25 km^2 [24]. The study area is shown in Figure 1.

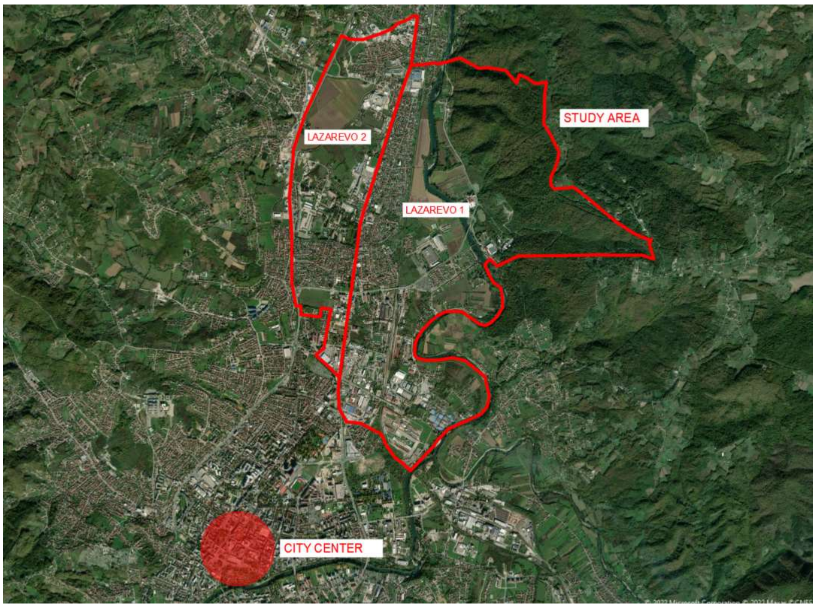

Figure 1. Study area location and boundaries

2.2. DATA COLLECTION AND ANALYSIS

The data analyzed in this paper has been collected during the development of the project entitled "Establishment of GIS database of urban green areas using AreaCAD-GIS platform" implemented by the company GeoINOVA – Informatički inženjering within the innovation challenge "Banja Luka - Future City". The first author was the project coordinator and participated in data collection and processing. Namely, data were collected for 5 groups of green areas in the pilot area Lazarevo 1 and Lazarevo 2; namely green areas, groups of trees, shrubs, hedges and trees. Due to the fact that green areas and tree-lines are the most represented in this area (other groups are insignificantly present), the subject of research in this paper will be only these two groups of data. Data on green areas has been collected from various sources (orthophotos and spatial planning documentation) and during field work. On this occasion, the following attributes are included: category, species, vitality rating, and area. The share of representation in the total area was obtained subsequently, by entering data into Excel spreadsheets. All data on trees (a total of 1328 individuals) were collected during fieldwork (September, 2020). These include: quantitative attributes (tree height, canopy width and trunk diameter) and qualitative attributes (species name, damage, disease, vitality rating, decorativeness rating, degree of protection, and additional description).

For data collection, the INOVA iGEO platform was used, on which the results were graphically presented (spatial arrangement of green areas with the possibility of viewing all attributes). The collected data is exported to shape format (.shp) which is further analyzed in Autodesk AutoCAD Map 3D software from where excel tables are created. Each descriptive attribute is assigned a code to speed up the process of entering data into the IBM SPSS (Statistical Package for the Social Sciences) statistical analysis software. The final phase included the creation of summary tables for green areas and trees from which various indicators were obtained. Distribution shape tests for green areas and contingency tables for trees were performed. Among the outputs, there are tables and graphs that will be presented in the experimental part of this paper. This examined the research questions asked, and the results were presented using formulas, tables and graphs.

3. RESULTS AND DISCUSSION

In order to reach the set goal, which refers to determining the representation of certain categories and types of green areas and analysis of the health status of trees in the study area, two research questions were asked:

- Are all types of green areas equally represented in the research area;
- Is small-leaved linden much more susceptible to diseases than European plane tree.

3.1. QUANTITY ANALYSIS OF GREEN AREAS

The study area (local communities Lazarevo 1 and Lazarevo 2) belongs to the wider urban area of the City of Banja Luka and covers a total area of 11.25 km^2 [24]. 28% of area belong to public green areas, with the largest share belonging to the Trapisti Park Forest (21.67%), and the rest are different types of green areas for public, limited and special purposes.

Of the total public green areas, the largest part belongs to green areas for public use, 89%. These are those areas whose scope of use is not limited by anything, in terms of working hours, entrance fees, etc: city parks, squares, boulevards, greenery of public buildings, tree lines, greenery along the coast, quays, squares, picnic areas, national parks, street greenery [23]. Limited green areas occupy 10%. These are areas that are in some way limited for use, whether it is the working hours of the building next to them or another factor: block greenery, greenery around schools, kindergartens, universities, hospitals, sports and recreational complexes, monuments, as well as private green areas [23]. Special purpose green areas occupy only 1%. These are protection zones and belts, cemeteries, roadside orchards, nurseries, botanical gardens [23]. This result is positive because the users (primarily local, and then the population from other settlements) have at their disposal permanent areas for active and passive rest.

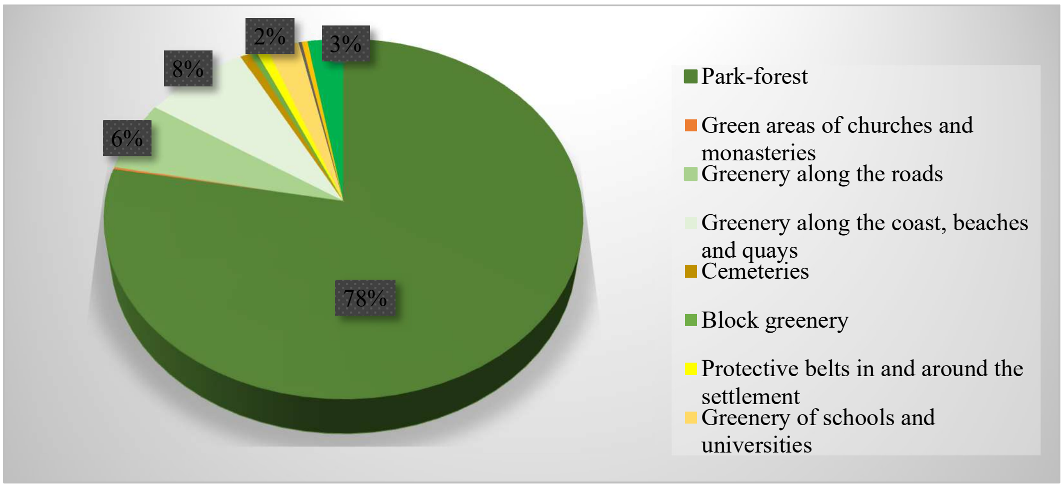

Figure 2. Percentage of individual types in the total green area

From all the above, it can be concluded that the present types of green areas are not equally represented in the study area, which was proven by the test of the form of distribution, which is shown below. A total of 109 green areas have been recorded in the study area, with 12 different types. This is shown in Table 1.

Table 1. Distribution of green areas by types

The area type	**8**	**34**	**16**	**6**	**22**	**12**	
Number	1	2	56	16	1	17	
$\frac{(m_i - np_i)^2}{np_i}$	7.19	5.52	242.33	5.27	7.19	6.90	
The area type	**7**	**13**	**14**	**19**	**4**	**23**	**Total**
Number	7	3	1	1	3	1	**109**
$\frac{(m_i - np_i)^2}{np_i}$	0.48	4.07	7.19	7.19	4.07	7.19	**304.61**

Types of green areas are marked with the following codes: 8 - Park-forest; 34 - Green areas of churches and monasteries; 16 - Greenery along the roads; 6 - Greenery along the river coast; 22 - Cemeteries; 12 - Block greenery; 7 - Protective belts in and around the settlement; 13 - Greenery of schools and universities; 14 - Greenery of kindergartens; 19 - Greenery of sport centers; 4 - Greenery in front of public buildings and 23 - Greenery around public administration buildings.

With a significance level of α = 0.05, it was examined whether the number of present green areas differs significantly by types; i.e., whether all 12 recorded types can be considered equally represented. The set of events (types) is denoted by S_i, i = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. The null hypothesis assumes that they are equally represented, as observed in previous analyses:

$$H_0 : P(S_i) = p_i = \frac{1}{12},\ i = 1, \ldots, 12 \quad (1)$$

$$H_1 : P(S_i) \neq \frac{1}{12},\ \text{for at least one i} \quad (1.1)$$

Therefore, it is necessary to test the compliance of the sample with a discrete uniform distribution, where:

$$np_i = 109 \cdot \frac{1}{12} = 9{,}08,\ i = 1, \ldots, 12 \quad (2)$$

The number of individual types of green areas, i.e., the frequency of realization of the S_i event, is denoted by m_i, i = 1,. . . , 12. Within the realized sample, these values are as follows:

$$m_1=1,\ m_2=2,\ m_3=56,\ m_4=16,\ m_5=1,\ m_6=17,\ m_7=7,\ m_8=3,\ m_9=1,\ m_{10}=1,\ m_{11}=3 \text{ i } m_{12}=1 \quad (3)$$

The values of the χ²-test for each of the events given in the previous table were obtained according to the formula:

$$\chi^2 = \frac{(m_i - np_i)^2}{np_i} = \frac{(m_i - 9{,}08)^2}{9{,}08} \tag{4}$$

$$\text{Than } \chi^2 = \sum_1^{12} \frac{(m_i - np_i)^2}{np_i} \tag{5}$$

When all 12 events are added up, the total value is obtained: $\chi^2_{12\text{-}1} = 304.61$. From the table χ²-distribution [25], the critical value of the test $\chi^2_{11;\,0.05} = 19.675$, and the critical area is C = [19.675; + ∞]. Since 304.61 > 19.675, hypothesis H_0 is rejected and with a risk of 5% it can be argued that there is a significant difference in the distribution of green areas in the study area.

3.2. TREE-LINES QUALITY ANALYSIS

In the researched area, during field data collection, a total of 1328 trees were recorded, with 27 different species. All attributes, including the names of tree species, have been replaced by codes, for easier analysis and statistical presentation of data. The six most present species are marked with the following codes: 19 - Pedunculate oak (*Quercus robur*); 25 - Norway maple (*Acer platanoides*); 26 - European plane (*Platanus x acerifolia*); 31 - Large-leaved linden (*Tilia platyphyllos*); 39 - Small-leaved linden (*Tilia cordata*) and 41 - Silver linden (*Tilia tomentosa*) (Figure 3).

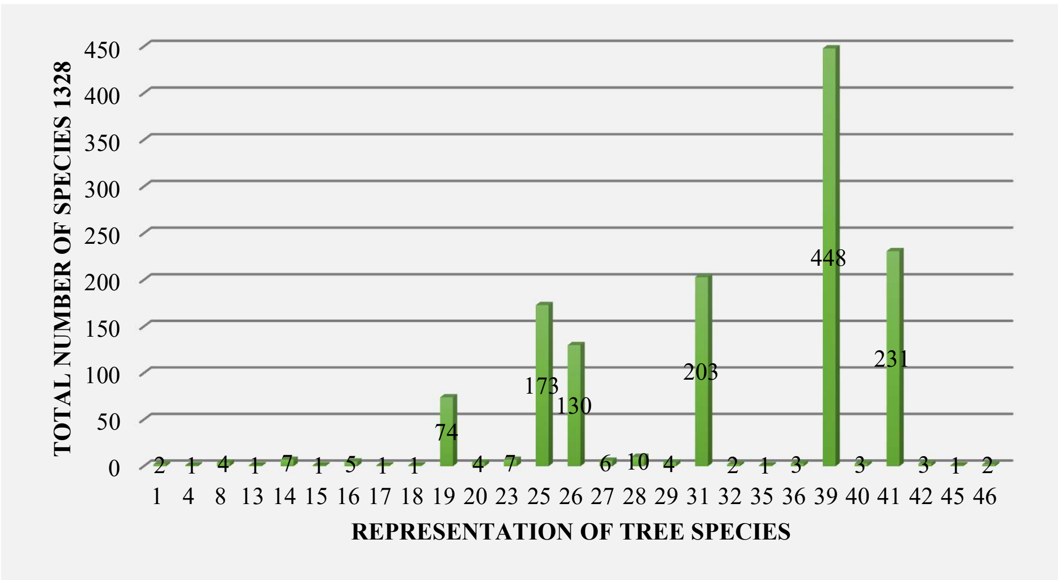

Figure 3. Representation of individual tree species in the total number of trees

As in the entire territory of the City of Banja Luka, so in the study area, the following species are most represented in tree lines: large-leaved, silver and small-leaved linden (882 trees), followed by Norway maple (173), European plane (130) and pedunculate oak (74). Their share in the total number of all trees is 95%, of which 3 species of linden occupy a percentage of 66%.

Among the attributes related to trees, there are also qualitative assessments of the general condition, both mechanical damage and phytopathological (fungal) or other types of diseases. Of the total number of trees, 297 trees (22%) were rated with the lowest vitality rating (1 - nearly dead tree to be removed). One part of the trees has certain damages/diseases, but there is a possibility of remediation, i.e., it is possible to apply phytosanitary measures to improve their health (10%). Of the total number of trees, healthy trees account for 68%.

Given the fact that small-leaved linden is the most numerous species and that during field work it was noticed that there are a large number of trees where the disease is present, especially in young trees, further analysis relates to health for all three species of linden present in study area: small-leaved, large-leaved and silver. Of the total number of trees (882), healthy trees account for 56%, diseased trees that need phytosanitary measures 14% and diseased trees that need replacement 30%. The number of linden species according to health status is shown in Table 2. Codes 0 and 1 imply healthy trees, code 2 diseased (those that need replacement) and code 3 also diseased, but by applying certain measures they can be preserved in tree-lines. The results are presented using the contingency tables.

Table 2: Number of linden species by health status

Species	0 - there is no additional description (healthy tree)	1 - young seedling (healthy tree)	2 - dry / diseased tree (replacement required)	3 - diseased tree (necessary phytosanitary measures)	Total
Large-leaved linden	12	147	18	26	203
Silver linden	144	17	29	41	231
Small-leaved linden	127	42	220	59	448
					882

From the Table 2, it can be concluded that the number of trees that need replacement predominates in small-leaved linden (220 trees, or 49%). Most of the diseased trees have phytopathological (fungal) disease, which was found during field work, in the form of small spots on the leaves of trees. For that reason, it was decided to analyze the number of these trees in more detail, so that further planning and replacement with new seedlings could be done. Also, the distribution of small-leaved linden trees according to health status shows that 59 diseased trees need phytosanitary measures or 13%, while 169 are healthy trees or 38% (young seedlings occupy 10% of healthy trees). A research question was asked: Is the small-leaved linden much more susceptible to diseases than the European plane? The first step was to use the method of descriptive statistics to do cross-tabulation, i.e., the table of contingency for these two species, taking into account only the assessment of vitality, i.e., their health status. The obtained results are shown in Table 3.

Table 3: Number of species of small-leaved linden and European plane tree according to health status

Tree species	**Health status**			
	Healthy trees	**Diseased trees (necessary phytosanitary measures)**	**Sick / dry trees (replacement required)**	**Total**
39 Small-leaved linden (*Tilia cordata*)	169	59	220	448
26 European plane (*Platanus x acerifolia*)	123	0	7	130
Total	292	59	227	578

With a risk of $\alpha = 0.02$, the χ^2 test of independence was used to test whether there is a significant difference in the types of linden and European plane seedlings, when it comes to their health condition. As attributive (descriptive) features X and Y are marked by tree species and health status, respectively. In this case, Hypothesis H_0 argues that there is a significant difference between these two features, ie. that features X and Y are independent. Table 3 also contains aggregate values, i.e., absolute frequencies of modality frequency of both characteristics:

$$n_{1.} = 448 \text{ i } n_{2.} = 130,\ n_{.1} = 292,\ n_{.2} = 59 \text{ i } n_{.3} = 227 \tag{5}$$

By applying equality, the expected number of pairs of all modalities is determined:

$$n_{11} = \frac{448 \cdot 292}{578} = 130{,}2;\ n_{21} = \frac{130 \cdot 292}{578} = 65{,}7;\ n_{12} = \frac{448 \cdot 59}{578} = 45{,}7;\ n_{22} = \frac{130 \cdot 59}{578} = 13{,}3;\ n_{13} = \frac{448 \cdot 227}{578} = 175{,}9;\ n_{23} = \frac{130 \cdot 227}{578} = 51{,}0 \tag{6}$$

Then the realized value of the statistical test was obtained, which reads:

$$\chi^2_{(2\text{-}1)(3\text{-}1)} = \frac{(169-130{,}2)^2}{130{,}2} + \frac{(59-45{,}7)^2}{45{,}7} + \frac{(220-1\quad{,}9)^2}{175{,}9} + \frac{(123-65{,}7)^2}{65{,}7} + \frac{(0-13{,}3)^2}{13{,}3} + \frac{(7-51)^2}{51} = 127{,}72 \quad (7)$$

According to the tables used [25], the critical value of the test is $\chi^2_{(2\text{-}1)\,(3\text{-}1);\,0.02} = 7.824$. It follows that the critical area of the test is C = [7,824, + ∞]. Since the obtained result is 127.72 > 7.824, H_0 is accepted and with a risk of 2% it is claimed that there is a relationship between tree species and health status. A comparison of these two species is also shown in Figure 4.

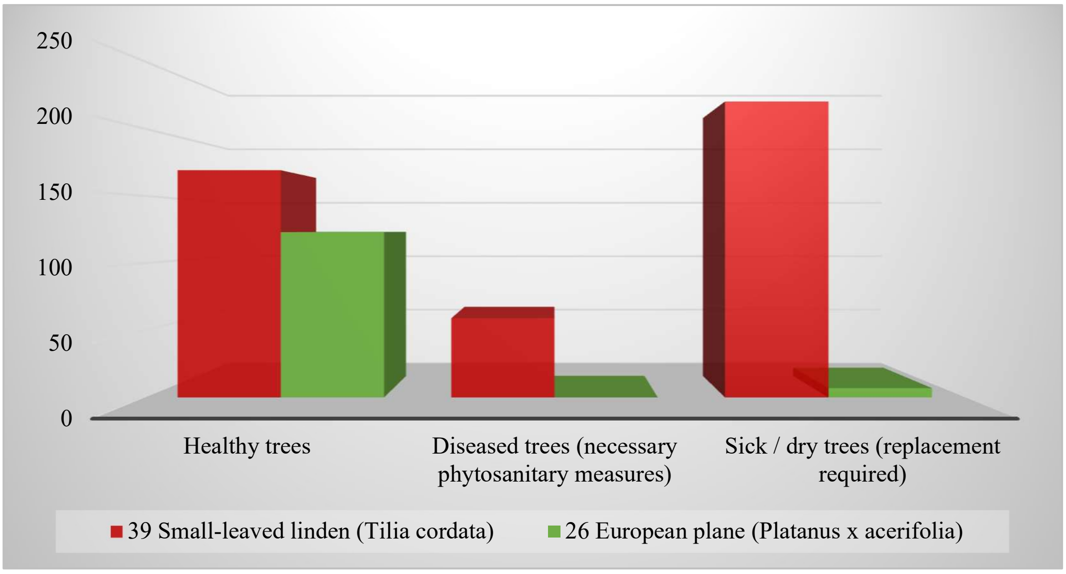

Figure 4. Comparison of the health condition of small-leaved linden and European plane

Based on all the above, it has been shown that the species of small-leaved linden tree gets sick more often than other species of trees. In this example, a comparison was made with the species of the European plane. Almost one half of the total number of this species (49%) have a certain type of disease and need replacement. Having in mind the health condition of plane trees and other species present in this area, recommendations can be given to the competent services of the City Administration of the City of Banja Luka for raising and maintaining green areas, to use them instead of linden, when building new tree-lines or do the reconstruction of existing ones.

4. CONCLUSIONS

This paper analyzes the representation and quality of urban green areas in two local communities of Banja Luka. Part of the results are presented using the methods of descriptive statistics (frequency), and for the second part, non-parametric tests, Pearson's χ^2-test using two basic forms: the test of the distribution form and the χ^2 test of independence were applied. When it comes to the quality of green areas, the health status of trees was examined, as the most sensitive category of all green areas. A research question was asked: Is the small-leaved linden (*Tilia cordata*) much more susceptible to diseases than the European plane (*Platanus x acerifolia*)? The obtained results are shown in table 3. Bearing in mind the health condition of plane trees and other species present in this area, recommendations can be made to the competent services of the City Administration of the Banja Luka for the establishment and maintenance of green areas. It was established that of all the species present, linden is more common than the others and much more susceptible to diseases than the European plane. For future activities in this area, it is recommended to use more permanent species, such as sycamore, oak, maple, etc., when filling existing rows of trees and building new ones. The stated concluding considerations as offered recommendations need to be supplemented. It is necessary to specify the limitations of the planning settings for the replacement of linden. The focus should be on the morphological characteristics of *Tilia cordata* and *Platanus x acerifolia*, which differ significantly, primarily in the domain of the crown and root system. Infrastructural profiles, street fronts as well as small urban gardens of single-family housing that dominate the location of Lazarevo 1 and 2 determine the interpolation of a certain dendrological type. Reconstructions of tree row in many locations cannot be replaced by trees with large habitus. RP (Regulatory Plan) Lazarevo

1 and 2, based on the projected number of inhabitants of 7,600 in the planning horizon, as well as planned areas under public greenery in chapter IX Environment, 1. Public green areas 1.1. Tree rows, 1.2. Park and 1.3. The green block determines the following settings. For planting material it is necessary to use:

Conifers: *Taxodium distichum, Metasequoia glyptostroboides, Abies concolor, Abies nordmanniana, Pinus strobus, Pinus wallichiana Picea omorika, Picea pungens, Cupressus arizonica, Cedrus atlantica, Cedrus libani*.

Deciduous trees: *Gingko biloba, Liriodendron tulipifera, Magnolia sp., Quercus robur, Quercus palustris, Quercus borealis, Fraxinus angustifolia, Ulmus laevis, Acer palmatum, Betula papyrifera, Sorbus torminalis and others, Sorbus torminalis*.

The selection of dendrological species from RP, intended for the landscape arrangement of the greenery system and the formation of tree rows can be used for recommendations, and of course it also includes the sycamore, for which research on the vital characteristics was determined in this paper. For example, in RP, a row of trees (*Liriodendron tulipifera*) with a length of 1,500 m is planned along the road parallel to the railway line Banja Luka – Slunja [26].

After conducting all phases of the research, several important conclusions were reached when it came to green areas. During the examination of the first research question, it was concluded that different types of green areas are not equally represented in the research area. There are a large number (and therefore a large occupied area) of green road belts, which cannot be classified as usable free areas, in terms of the using them by local population. On the other hand, the positive fact is the presence of the Trapisti Forest Park in this settlement, which occupies the largest part of the total green areas. Its preservation and arrangement are of great importance, not only for the local population, but also for users who come from other parts of the city of Banja Luka.

When it comes to the quality of green areas, the health condition of trees was examined, as the most sensitive categories of all green areas, because they are constantly influenced by negative factors: smoke, dust, exhaust fumes, salinization, construction works, wind and vandalism. It was stated that of all the present species, linden is more common than others, and it is recommended for future activities in this area to use more durable species, such as plane, oak, maple and the like, when filling existing tree-lines and building new ones.

The general conclusion reached during the research is that very little attention is paid to the analysis of greenery in the city of Banja Luka, especially when it comes to qualitative analysis, such as the health of tree-lines. Their role in the overall system of green areas of cities is to connect all existing areas into one functional unit, so that this system has multiple benefits for the urban environment. This is especially important at a time when more and more is being invested in preserving the environment, reducing global warming and sustainable development. As one of the most important categories in urban areas, green areas need to be constantly maintained, nurtured and increase their share in total areas, preceded by a detailed analysis of the current situation, so that further steps in this area can be planned.

LITERATURE

[1] A. Wardekker, „Contrasting the framing of urban climate resilience," *Sustain. Cit. and Soc.,* vol. 75, no. 103258, December, 2021, doi: https://doi.org/10.1016/j.scs.2021.103258.

[2] J. A. Foley, R.S. Defries, G. P. Asner, „Global Consequences of Land Use," *Sci.,* vol. 309 (5734), pp. 570-574, August, 2005, doi: http://dx.doi.org/10.1126/science.1111772

[3] A. Djukic, M. Vukmirovic, S. Stankovic, „Principles of climate sensitive urban design analysis in identification of suitable urban design proposals. Case study: Central zone of Leskovac competition," *En. and Build.,* vol. 115, pp. 23-25, March, 2016, doi: https://doi.org/10.1016/j.enbuild.2015.03.057

[4] M. Masoudi, P. YokTan, „Multi-year comparison of the effects of spatial pattern of urban green spaces on urban land surface temperature," *Land. and Urb. Plan.,* vol. 184, pp. 44-58, April, 2019, doi: https://doi.org/10.1016/j.landurbplan.2018.10.023

[5] E. Uuemaa, U. Mander, R. Marja, Trends in the use of landscape spatial metrics as landscape indicators: a review," *Ecol. Ind.,* vol. 28, pp. 100–106, May, 2013, doi: https://doi.org/10.1016/j.ecolind.2012.07.018

[6] E. Rall, R. Hansen, S. Pauleit, „The added value of public participation GIS (PPGIS)for urban green infrastructure planning," *Urb. For. and Urb. Green.*, vol. 40, pp. 264–274, April, 2019, doi: https://doi.org/10.1016/j.ufug.2018.06.016

[7] M. Riechers, J. Barkmann, T. Tscharntke, „Diverging perceptions by social groups on cultural ecosystem services provided by urban green," *Land. and Urb. Plan.*, vol. 175, pp. 161–168, July, 2018, doi:

[8] https://doi.org/10.1016/J.LANDURBPLAN.2018.03.017

[9] A. Andersson, E. Langemeyer, S. Borgström, T. McPhearson, D. Haase, J. Kronenberg, J. Barton, D. N. Davis, M. Naumann, S. Röschel, L. Baró, „Enabling green and blue infrastructure to improve contributions to human well-being and equity in urban systems," *BioScience*, vol. 69, no. 7, pp. 566-574, July, 2019, doi: 10.1093/biosci/biz058

[10] X. Chen, S. DeVries, T. Assmuth, J. Dick, T. Hermans, O. Hertel, A. Jensen, L. Jones, S. Kabisch, T. Lanki, I. Lehmann, L. Maskell, L. Norton, S. Reis, „Research challenges for cultural ecosystem services and public health in (peri)urban environments," *Sci. of the Tot. Env.*, vol. 651, pp. 2118-2129, 15 February 2019, doi: https://doi.org/10.1016/j.scitotenv.2018.09.030

[11] U. K. Stigsdotter, P. Grahn, „Stressed individuals' preferences for activities and environmental characteristics in green spaces," *Urb. For. & Urb. Green.*, vol. 10 (4), pp. 295–304, 2011, doi: https://doi.org/10.1016/J.UFUG.2011.07.001

[12] R. Hansen, A. S. Olafsson, A. P. N. van der Jagt, E. Rall, S. Pauleit, „Planning multifunctional green infrastructure for compact cities: What is the state of practice?," *Ecol. Ind.*, vol. 96, pp. 99–110, January 2019, doi: https://doi.org/10.1016/j.ecolind.2017.09.042

[13] A. Meyer-Grandbastien, F. Burel, E. Hellier, B. Bergerot, „A step towards understanding the relationship between species diversity and psychological restoration of visitors in urban green spaces using landscape heterogeneity," *Land. and Urb. Plan.*, vol. 195, no. 103728, March, 2020, doi: https://doi.org/10.1016/j.landurbplan.2019.103728

[14] C.Y. Jim, K. C. van den Bosch, W.Y. Chen, „Acute challenges and solutions for urban forestry in compact and densifying cities," *Jour. of Urb. Plan. and Develop.*, vol. 144, no. 3, pp. 1–12, June, 2022, doi: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000466

[15] M. Moeinaddini, Z. Asadi-Shekari, M. Aghaabbasi, I. Saadi, M. Zaly Shah, M. Cools, „Applying Non-Parametric Models to Explore Urban Life Satisfaction in European Cities," *Cit.*, vol. 105, 102851, October, 2020, doi: 10.1016/j.cities.2020.102851

[16] A. Butler, „Dynamics of integrating landscape values in landscape character assessment: the hidden dominance of the objective outsider," *Land. Res.*, vol. 41, no. 2, pp. 239–252, 2016

[17] Y. Wang, „A framework to integrate multifunctionality analyses into green infrastructure planning," *Land. Ecol.*, vol. 36, pp. 1951–1969, June, 2020

[18] M. Vukmirović, S. Gavrilović, D. Stojanović, „The Improvement of the Comfort of Public Spaces as a Local Initiative in Coping with Climate Change," *Sustain.*, vol. 11, no. 23, 6546, November 2019, doi: https://doi.org/10.3390/su11236546

[19] A. Al-sharif, B. Pradhan, H. Shafri, S. Mansor, „Quantitative analysis of urban sprawl in Tripoli using Pearson's Chi-Square statistics and urban expansion intensity index," *7th IGRSM International Remote Sensing & GIS Conference and Exhibition IOP Publishing*, IOP Conf. Series: Earth and Environmental Science 20, 2014, doi: 10.1088/1755-1315/20/1/012006

[20] L. Mary, M.L. McHugh, „The Chi-square test of independence," *Bioch. Med.*, vol. 23, no. 2, pp. 143–149, May, 2013, doi: http://dx.doi.org/10.11613/BM.2013.018

[21] R. Włodarczyk-Marciniak, D. Sikorska, K. Krauze, „Residents' awareness of the role of informal green spaces in a post-industrial city, with a focus on regulating services and urban adaptation potential," *Sust. Cit. and Soc.*, vol. 59, no. 102236, August, 2020, doi: https://doi.org/10.1016/j.scs.2020.102236

[22] M. Dornelas, A. C. Moonen, A. E. Magurran, P. Barberi, „Species abundance distributions reveal environmental heterogeneity in modified landscapes," *App. Ecol.*, vol. 46, pp. 666–672, April, 2009, doi: https://doi.org/10.1111/j.1365-2664.2009.01640.x

[23] Development Consulting Group (Beograd), Institut za hidrotehniku (Sarajevo), *Strategija razvoja Grada Banja Luka u periodu 2018-2027. godine*, Grad Banja Luka (in Serbian), 2018.

[24] N. Anastasijević, *Podizanje i negovanje zelenih površina*, Beograd, Šumarki fakultet u Beogradu (in Serbian), 2011.

[25] Institut za građevinarstvo „IG" Banja Luka, Projekt a.d., *Prostorni plan Grada Banja Luka do 2030. godine*, Banja Luka (in Serbian), 2014.

[26] I. Aranđelović, Z. Mitrović, V. Stojanović, *Verovatnoća i statistika*, Beograd, Zavod za udžbenike (in Serbian), 2011.

[27] Urbanistički zavod Republike Srpske a.d. Banja Luka, Regulacioni plan stambenog naselja „Lazarevo" u Banjaluci (Lazarevo 1 i 2), Banja Luka (in Serbian), 2006.