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# STRUCTURE AND DIVERSITY OF URBAN PARK STANDS AT KRYVYI RIH ORE-MINING & METALLURGICAL DISTRICT, CENTRAL UKRAINE

## SUMMARY

The present study examines the relationships between structure (floristic composition, dendrometric parameters), diversity (diversity and evenness indexes) of urban forest park stands and the ecological (soil fertility, soil moisture), environmental factors (air pollution). The study is based on the forest park stands inventory data, performed from 2012 to 2017 in Kryvyi Rih City, Central Ukraine. The floristic compositions of the urban forest park stands are poor. There are only 23 species that belong to 14 families and 12 genera. More families were represented by at least more than 2% of taxon diversity. While Ulmaceae (2 genera, 4 species–17,39 %), Fabaceae (3 genera, 2 species–17,39 %), Aceraceae (1 genera, 4 species–17,39 %) were the most representative families. It was established that at forest park the values of stand density varied from 490 to 660 trees*ha$^{-1}$, stem heights were from 26 to 31 m, stem diameters were from 13 to 17 cm, stand basal area were from 32 to 49 m$^{2}$*ha$^{-1}$, stand volume were from 200 to 415 m$^{3}$*ha$^{-1}$. the values of relative stem heights were from 0,63 to 0,82 m*year$^{-1}$, relative stem diameters were from 0,31 to 0,43 cm*year$^{-1}$, relative stand basal area were from 0,80 to 1,19 m$^{2}$*ha$^{-1}$*year$^{-1}$, relative stand volume were from 5,45 to 10,28 m$^{3}$*ha$^{-1}$*year$^{-1}$. The varied values of the forest park stands index (Shannon-Wiener diversity index from 0,75 to 1,61, Pielou's evenness index from 0,53 to 0,86, Simpson's diversity from 0,24 to 0,60, Margalef's diversity index from 0,87 to 6,97) indicate the ecological instability of these woody plant communities. Current state of the urban forest park stands determined by the combined influence of ecological (soil fertility, soil moisture) and environmental factors (air pollution).

**Keywords**: Floristic Composition, Dendrometric Parameters, Stand Basal Area, Stand Volume, Diversity and Evenness Index.

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## INTRODUCTION

Unfortunately, exploding human populations, 6 billion people are degrading the environment at an accelerating rate, especially in developing and undeveloped countries (Janhäll, 2015; Kim, 2016; Verma and Raghubanshi, 2018). Besides, anthropogenic activities have triggered unprecedented environmental changes on a global and on a local scale. Especially anthropogenic activities strictly available in metallurgical and mining areas (Carvalho, 2017; Urošević et al 2018) such as Kryvyi Rih basin (Bielyk et al 2020; Savosko et al., 2019a; Savosko et al., 2020).

It should also be noted that, due to increasing congested cities all over the world, people's well-being and people's health are at stake. That's why, over the past few decades, there have been intensive efforts to "green cities", reflected in a surge of interest in innovations such as "green walls" (Janhäll S., 2015; Nowak et al, 2018; Rode et al, 2016). Therefore, it is so important to ensure the sustainable existence of the urban forest park stands.

As known urban forest park stands have a great importance in terms of nature and landscape protection. They represent a natural habitat for a wide range of other organisms, serve public welfare, and contribute to popularization, planting and maintenance of plants. Besides, they play an important role in improving various environmental factors in urban areas, such as: temperature, humidity, and dust/pollution content. They also provide sustainable development of the city, either through local climate regulation, carbon sequestration or reduction of stormwater runoff (Anguluri and Narayana, 2017; Rode et al, 2016). Generally, urban forest park stands which are integral to human health represent a complex and necessary feature of the urban landscape, as well as areas provide ecosystem services.

In recent decades, ecosystem services is widely used among scientists and policy makers to highlight the importance of the environment in sustaining human livelihoods in industrial areas (Olander et al, 2018; Rode et al, 2016), especially in metallurgical and mining basins such as Kryvyi Rih City, Central Ukraine (Savosko and Tovstolyak, 2017; Savosko et al, 2019a).

Ecosystem services are generally defined as goods and services that are of value to people, provided wholly or in part by ecosystems services including and urban forest park stands (Lykholat et al, 2016a; Song et al 2018). These three attributes are as well defining ecosystems services of the urban forest park stands: 1) floristic composition, 2) dendrometric characteristics, 3) diversity and evenness indices (Booth 2018; Ebrahimigajoti et al, 2013; Kolbe et al, 2016; Lykholat et al, 2016b; Liquete et al 2016). Floral composition is the oldest and most common way of assessing the structure of the forest stands. The dendrometric characteristics of trees at stands are usually evaluated using a set of variables such as diameter at breast height, tree height, crown projection area, crown length and height of the crown base. Species and biological diversity have always been some of the most frequently used evaluation measures for forest communities in the general forestical monitoring work (Chivulescu et al, 2018; Solomou and Skoufogianni, 2016).

Numerous studies have analyzed the modern state of the urban forest park stands (Verma and Raghubanshi, 2018; Voigt et al, 2014). Nevertheless, these studies are limited by the lack of research on one attribute (or floristic composition, ore dendrometric characteristics, ore diversity and evenness indices). Moreover, the estimates of forest park stands in urban environments mainly rely upon methodologies developed for trees in traditional forests. More exact quantification of urban forest park stands may depend on development of comprehensive research especially at different habitats.

It is widely accepted that understanding conservation targets and sustainable development of the urban forest park stands, including a full description of woody species floristic composition, dendrometric parameters and diversity and evenness indexes (Martins and Pereira, 2018). Furthermore, description and analysis of urban forest park stands through floristic and dendrometric, diversity and evenness characterization provide means to analyse the relation between woody vegetation and edaphic, topographic and human factors (Dan et al, 2016; Lykholat et al 2019a; Lykholat et al 2019b).

The main objectives of this work were to (i) analyze of urban forest park stands floristic composition in the Kryvyi Rih City (Central Ukraine), (ii) estimate their dendrometric parameters and (iii) assess their diversity and evenness indexes. As no detailed ecological information is available on the urban forest park stands, it was not possible to set ecological hypotheses. However, assuming that the pattern of woody species and stands types results from different stochastical events, it was hypothesized that current state of the urban forest park stands determined by the combined influence of ecological (soil fertility, soil moisture) and environmental factors (air pollution).

## MATERIALS AND METHODS

Study area.

This study was conducted in the forest park woodlands, which is located in the Kryvyi Rih City (Ore-mining and metallurgical basin, Central Ukraine). The study area is located between 47°53'54" and 48°8'52" north latitude and 33°19'52" and 33°33'38" west longitude (Figure 1). The climate of the study area is characterized by a short spring, dry summer, little snowy cold winters. The air temperatures average–3,5 and 21,8°C in January and July, respectively. Precipitation falls primarily as rain averaging 400-450 mm year$^{-1}$.

Research design and data collection.

During 2012-2017 we performed a comprehensive study of Kryvyi Rih District parks: 1) studied the history of parks, 2) analyzed the evolution of parks (their progress / regress), 3) studied the ecological conditions in parks, 4) studied the floristic composition of all plant trees in parks, 5) identified treys plantations similar to forest (woody stands, park stands), 6) studied of the structure and diversity of urban park stands.

Map of Ukraine


Map of Kryvyi Rih City

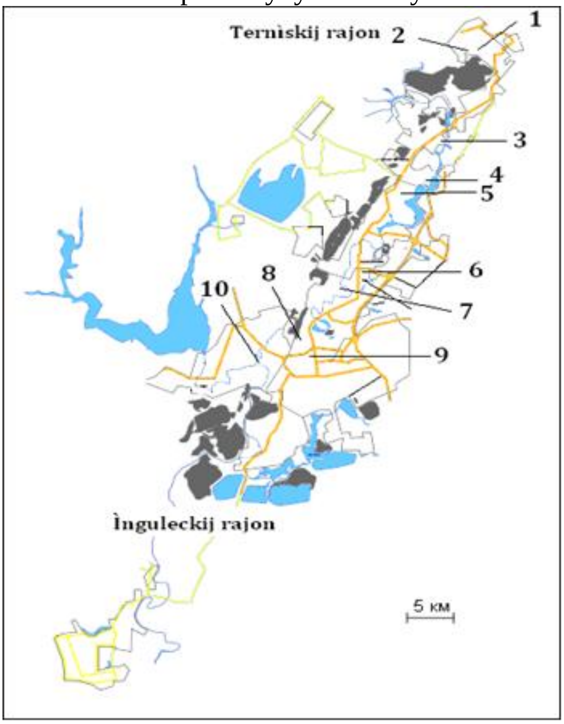


Figure 1. Location of study areas

1 – Pivnichnyi Park, 2 – Pershoho Travnia Mine's Park, 3 – Ternivskyi Park,
4 – Shakhtarskyi Park, 5 – Zatyshok Park, 6 – Cinema Iunist's Park,
7 – Palace of Culture of Mine's Rodina Park, 8 – Rudanivskyi Park,
9 – Bohdan Khmelnytskyi's Park, 10 – Fedor Mershavtsev's Park

Therefore, we choose only ten city parks for the purpose of this study: Pivnichnyi Park, Pershoho Travnia Mine’s Park, Ternivskyi Park, Shakhtarskyi Park, Zatyshok Park, Cinema Iunist’s Park, Palace of Culture of Mine’s Rodina Park, Rudanivskyi Park, Bohdan Khmelnytskyi’s Park, Fedor Mershavtsev’s Park (Figure 1).

Each of these parks combining a contrasting ecological & environmental condition of their areas, diverse floristic composition and have forest woodlands. Summing up of the soil factors actions (fertility and moisture) and of the air pollution actions three ecological areas were identified: 1) environmentally friendly area (Background), 2) relative environmentally friendly area (Buffer), 3) relative environmentally not friendly area (Impact) (Savosko et al, 2019b).

A forest park woodland inventory was made a random sampling scheme. During 2012-2017, the 22 research plots (20*20 m) were established in the park’s ecosystems: from 1 plot to 5 plots per park. Field data were collected through direct enumeration and measurement of all trees in every plot. In each plot, all woody stems of diameter at breast height (dbh) > 10 cm were recorded and: 1) their diameter at 1,3 m above ground (in two perpendicular directions by a caliper); 2) their height (by a hypsometer) were measured (West, 2009). The binomial nomenclature of each tree species was recorded following the Modern botanical nomenclature (IPNI, 2020) as a well as the number of trees per species.

*Dendrometric parameters*

For each research plot the following dendrometric parameters were computed: tree-density of the stand (N), i.e. the average number of trees per sample plot, expressed as trees per hectare (West, 2009).

For each tree the following absolute dendrometric parameters were computed:

– *basal area of the tree* (Gabs), i.e. the cross-sectional area at 1.3 m above ground level of tree, expressed as ($m^2$):

$$Gabs = \frac{\pi * D * 2}{40000} \quad (1)$$

where, $\pi$ is constant (3,142), d is the diameter (in cm) of the tree;

– *volume of the tree* (Vabs), expressed as ($m^3$):

$$Vabs = K * Gabs * H \quad (2)$$

where, K is constant (0,415), Gabs is basal area of the tree ($m^2$), H is the height of the tree (m).

For each tree the relative dendrometric parameters were computed using the following formula:

- $$Hrel = \frac{Habs}{N} \quad (3)$$

where, Hrel is relative height of the tree ($m*year^{-1}$), Habs is absolute height of the tree (m), N is stand age (year);

– $Drel = \frac{Dabs}{N}$ (4)

where, Drel is relative diameter of the tree (cm*year$^{-1}$), Dabs is absolute diamete of the tree (m), N is stand age (year);

– $Grel = \frac{Gabs}{N}$ (5)

where, Grel is relative d basal area of the tree (m$^2$*year$^{-1}$), Gabs is absolute basal area of the tree (m$^2$), N is stand age (year);

– $Vrel = \frac{Vabs}{N}$ (6)

where Vrel is relative volume of the tree (m$^3$*year$^{-1}$), Vabs is absolute volume of the tree (m$^2$), N is stand age (year).

*Diversity and evenness indexes calculation*

The Shannon-Wiener's diversity index, Pielou's evenness index, Simpson's diversity index and Margalef's richness index was used in order to study.

The Shannon-Wiener's diversity index (H') is defined by (Shannon and Wiener, 1949):

- $H' = -\sum_{i=1}^{S} pi * \ln pi$ (7)

where, H' – Shannon-Wiener's diversity index, S – number of species, pi – proportion of total sample belonging to the *i*th species, ln – natural logarithm.

The Pielou's evenness index (Eq) is defined by (Pielou, 1966):

- $Eq = \frac{H'}{\ln(S)}$ (8)

where, Eq – Pielou's evenness index, H' – Shannon-Wiener's diversity index, S – number of species.

The Simpson's diversity index (E) is defined by (Simpson, 1949):

- $E = \sum_{i=1}^{S} (pi)^2$ (9)

where, E – Simpson's diversity index, S – number of species, pi – proportion of total sample belonging to the *i*th species.

The Margalef's richness index (Ma) is defined by (Margalef, 1958):

- $Ma = \frac{(S-1)}{Ln(N)}$ (10)

where, Ma – Margalef's richness index, S – number of species, N – total number of individuals.

For diversity and evenness indexes calculated data of forest park woodlands stand density, stand volume and stand basal area were used (Kaufman et al, 2017; Spake and Doncaster, 2017).

*Statistical analysis*

The data were submitted to descriptive statistics and analysis of variance (ANOVA). The statistical analysis was performed using the program SPSS for Windows, version 11.0.0. For all statistical analysis, significance was considered P < 0,05 (McDonald, 2014).

## RESULTS

*Characteristics of the parks*

At Kryvyi Rih ore-mining & metallurgical district city parks (in the modern sense) began to be created in the late XIX and early XX centuries, simultaneously with "iron fever". However, these parks were small and in fact they have not survived to this day. In the 20's and 30's of the twentieth century, the rapid industrialization of the former USSR led to the powerful development of the Kryvyi Rih City and surrounding mining villages. At this time, the erection of industrial enterprises and the creation of numerous city gardens and parks were begun. The first City Parks, which include massive stands, were establishment in the 20-30s of the twentieth century (Table 1).

It was during this time stands formation was implemented in the following parks: Fedor Mershavtsev's Park (1929), Rudanivskyi Park (1930), Bohdan Khmelnytskyi's Park (1935) and Palace of Culture of Rodina Mine's Park (1938). However, during World War II, their stands were severely damaged. In the post-war years, the reconstruction of old parks and the creation of new parks (mostly between 1945 and 1965) were made. Among the studied parks of this region, the stand of Cinema Iunist's Park (established in 1975) are the youngest.

In most cases, the City Parks at Kryvyi Rih District are located on Interfluve plateau the so-called plakor (Table 1). In these areas, zonal climatic and soil conditions are best manifested. In addition to the interfluve plateau among the landforms and surface of City Parks it was also found seepage slope and midslope. In these areas, very extreme soil conditions are manifested. On the territory of two parks (Ternivskyi Park and Shakhtarskyi Park) among the landforms floodplain of small stream are also deployed. In these areas, good soil conditions are manifested. Only one park (Fedor Mershavtsev's Park) is located on Foodplain, with alluvial toeslope. In these areas, very good soil conditions are manifested.

At Kryvyi Rih District soils were classified as Chernozems by International Soil Classification Systems (SCS) (World reference base for soil resources, 2014), Chernozems Ordinary by Ukrainian SCS (Polupan et al 2005) and Mollisols by USDA SCS (Soil Survey Staff, 2014).

Table 1. The main characteristics of the parks at Kryvyi Rih District

| Park | Year of establishment | Area, ha | Ecological factors | | | | Environmental factors, levels of the air pollution |
|---|---|---|---|---|---|---|---|
| | | | Landforms and surface | Soil | | | |
| | | | | Texture | Moisture | Fertility | |
| Pivnichnyi Park | 1963 | 27,0 | Interfluve plateau, seepage slope, midslope | Clay loam | Dry, slightly moist, moist | Good fertility | Moderate |
| Pershoho Travnia Mine's Park | 1949 | 8,0 | Interfluve plateau, seepage slope | Clay loam | Dry, slightly moist | Good fertility | Moderate |
| Ternivskyi Park | 1963 | 7,7 | Interfluve plateau, seepage slope, midslope, floodplain of small stream | Clay loam | Dry, slightly moist, moist | Good fertility | Low |
| Shakhtarskyi Park | 1950 | 42,8 | Interfluve plateau, seepage slope, midslope, floodplain of small stream | Clay loam | Dry, slightly moist, moist | Good fertility | Low |
| Zatyshok Park | 1962 | 3,6 | Interfluve plateau | Clay loam | Dry, slightly moist | Good fertility | Low |
| Cinema Iunist's Park | 1975 | 3,5 | Interfluve plateau, | Clay loam | Dry, slightly moist | Good fertility | Low |
| Palace of Culture of Rodina Mine's Park | 1938 | 4,9 | Interfluve plateau | Clay loam | Dry, slightly moist | Good fertility | Moderate |
| Rudanivskyi Park | 1930 | 14,0 | Midslope, colluvial footslope | Clay loam | Slightly moist | Good fertility | Moderate |
| Bohdan Khmelnytskyi's Park | 1935 | 42,0 | Seepage slope, midslope | Clay loam | Dry, slightly moist | Good fertility | High |
| Fedor Mershavtsev's Park | 1929 | 36,0 | Foodplain, alluvial toeslope | Sandy clay loam | Moist | Very good fertility | Very low |

Soil texture (such as loam, sandy loam or clay) as known, refers to the proportion of sand, silt and clay sized particles that make up the mineral fraction of the soil. In its turn, soil texture significantly effects on soil fertility and on the growth / development of woody plant species. The results of our research showed that in City Park at Kryvyi Rih District, the soil texture was represented by the following classes. The first class, the clay loam soil, was found in most parks. The second class, sandy clay loam soil was found in only one park (Fedor Mershavtsev's Park). Generally, soil texture in City Parks at Kryvyi Rih District is favorable for woody plants. As we noted earlier, Kryvyi Rih District is located in arid areas. Therefore, moisture status of soil is very relevant for our research of the City Parks. We found that in most cases soil moisture can be estimated as dry-slightly moist. In some cases (Ternivskyi Park and Shakhtarskyi Park), soil moisture can be estimated as slightly moist-moist. Only in one case soil moisture can be estimated as Slightly-moist (Rudanivskyi Park) and moist (Fedor Mershavtsev's Park). Generally, soil moisture in City Parks at Kryvyi Rih District is a few and a slightly favorable for woody plants. Therefore, in the future it is very important to reconstruct old irrigation systems and create new irrigation systems. The soils of the Kryvyi Rih District (Chernozems by Internutional SCS and Mollisols by USDA SCS) are some of the most fertile soils in the World. That is why the soil fertility of City parks can only be assessed as "Good fertility" (in most cases) and "Very good fertility" (Fedor Mershavtsev's Park).

At Kryvyi Rih District, the presence of a significant number of powerful mining and metallurgical enterprises causes significant air pollution, which worsens the ecological conditions for the growth of tree species. According to the common classification scheme, there are the following levels of air pollution: 1) very low, 2) low, 3) moderate and 4) high. For very low level of air pollution the following concentrations are available: Carbon monoxide (CO) from 0,600 mg*m$^3$ to 1,500 mg*m$^3$; Nitrogen dioxide ($NO_2$) from 0,008 mg*m$^3$ to 0,020 mg*m$^3$; Sulfur dioxide ($SO_2$) from 0,010 mg*m$^3$ to 0,025 mg*m$^3$; Dust from 0,030 mg*m$^3$ to 0,075 mg*m$^3$. For low level of air pollution the following concentrations are available: Carbon monoxide (CO) from 1,500 mg*m$^3$ to 3,000 mg*m$^3$; Nitrogen dioxide ($NO_2$) from 0,020 mg*m$^3$ to 0,040 mg*m$^3$; Sulfur dioxide ($SO_2$) from 0,025 mg*m$^3$ to 0,050 mg*m$^3$; Dust from 0,075 mg*m$^3$ to 0,150 mg*m$^3$. For moderate level of air pollution the following concentrations are available: Carbon monoxide (CO) from 3,000 mg*m$^3$ to 6,000 mg*m$^3$; Nitrogen dioxide ($NO_2$) from 0,040 mg*m$^3$ to 0,080 mg*m$^3$; Sulfur dioxide ($SO_2$) from 0,050 mg*m$^3$ to 0,100 mg*m$^3$; Dust from 0,150 mg*m$^3$ to 0,300 mg*m$^3$. For moderate level of air pollution the following concentrations are available: Carbon monoxide (CO) from 6,000 mg*m$^3$ to 12,000 mg*m$^3$; Nitrogen dioxide ($NO_2$) from 0,080 mg*m$^3$ to 0,160 mg*m$^3$; Sulfur dioxide ($SO_2$) from 0,100 mg*m$^3$ to 0,200 mg*m$^3$; Dust from 0,300 mg*m$^3$ to 0,600 mg*m$^3$. Generally, the very low level of air pollution is typical for the area of one City Park, the low level of air pollution is typical for the area of for City Parks, the moderate level of air pollution is typical for the area of for City Parks and the High level of air pollution is typical for the area of one City Park (Table 1).

*Floristic composition*

Table 2. Occurrence of the woody plant species in parks at Kryvyi Rih District

| Scientific name | Common name | In parks | | In research plots | |
|---|---|---|---|---|---|
| | | Np | % | Nsp | % |
| *Acer negundo* L. | Ashleaf maple | 3 | 30 | 3 | 13,64 |
| *Acer pseudoplatanus* L | Sycamore maple | 2 | 20 | 2 | 9,09 |
| *Acer saccharinum* L | Silver maple | 1 | 10 | 1 | 4,55 |
| *Acer platanoides* L. | Norway maple | 10 | 100 | 15 | 68,18 |
| *Aesculus hippocastanum* L. | Horse chestnut | 6 | 60 | 6 | 27,27 |
| *Celtis occidentalis* L. | Common hackberry | 1 | 10 | 1 | 4,55 |
| *Cotinus coggygria* Scop. | European smoketree | 1 | 10 | 1 | 4,55 |
| *Crataegus × kyrtostyla* Fingerh. (known in Ukraine as *Crataegus fallacina* Klokov) | Oneseed hawthorn | 1 | 10 | 2 | 9,09 |
| *Fraxinus americana* L. | White ash | 2 | 20 | 2 | 9,09 |
| *Fraxinus excelsior* L. | European ash | 5 | 50 | 7 | 31,82 |
| *Gleditsia triacanthos* L. | Honey locust | 2 | 20 | 4 | 18,18 |
| *Juglans regia* L. | English walnut | 1 | 10 | 1 | 4,55 |
| *Morus nigra* L. | Black mulberry | 4 | 40 | 4 | 18,18 |
| *Populus nigra* L. | Black cottonwood | 1 | 10 | 1 | 4,55 |
| *Quercus robur* L. | English oak | 5 | 50 | 7 | 31,82 |
| *Robinia pseudoacacia* L. | Black locust | 4 | 40 | 7 | 31,82 |
| *Robinia viscosa* Michx. ex Vent. | Clammy locust | 1 | 10 | 1 | 4,55 |
| *Styphnolobium japonicum* (L.) Schott | Japanese pagoda tree | 1 | 10 | 1 | 4,55 |
| *Tilia cordata* Mill. | Littleleaf linden | 4 | 40 | 5 | 22,73 |
| *Tilia platyphyllos* Scop. | Largeleaf linden | 3 | 30 | 4 | 18,18 |
| *Ulmus glabra* Huds. | Mountain elm | 8 | 80 | 9 | 40,91 |
| *Ulmus laevis* Pall. | European white elm | 2 | 20 | 4 | 18,18 |
| *Ulmus minor* Mill. | European field elm | 6 | 60 | 7 | 31,82 |

Np – total number of parks, Nsp – total number of research plots, % – frequency of occurrence.

According to our research (Savosko and Tovstolyak 2017; Savosko et al., 2018; Savosko et al., 2019b) and data other authors (Fedorovskiy et al., 2013; Terlyga et al., 2015), more than 150 species of trees and shrubs grow in parks, but, in park sand only 23 tree plant species was found. These species belonged to 14 families and 12 genera. More families were represented by at least more than 2% of taxon diversity. While Ulmaceae (2 genera, 4 species – 17,39 %), Fabaceae (3 genera, 2 species – 17,39 %), Aceraceae (1 genera, 4 species – 17,39 %) were the most representative families (Table 2 and Figure 2).

The tree plant species has different incidence among research plots in forest park stand at Kryvyi Rih City. Such, Norway maple (*Acer platanoides* L.) was distributed in 15 plots (65,22 %). Mountain elm (*Ulmus glabra* Huds.) was distributed in 9 plots (39,13 %). Four tree plant species were distributed in 7 plots(by 30,43 %): Black locust (*Robinia pseudoacacia* L. ), English elm (*Ulmus minor* Mill.), English oak (*Quercus robur* L.), European ash (*Fraxinus excelsior* L.). Horse chestnut (*Aesculus hippocastanum* L.) was distributed in 6 plots (20,69 %). Littleleaf linden (*Tilia cordata* Mill.) was d4stributed in 5 plots (21,74 %). Other 14 tree plant species were distributed only in 1-4 research plots in forest park stand at Kryvyi Rih City. The forest park stand consisted of a small number of tree plant species. Such, 6 research plots (27,27 %) had 2 species, 5 research plots (22,73 %) had 6 species, 4 research plots (18,18 %) had 5 species, 3 research plots (13,64 %) had 3 species. The maximum number of species (7 and 8) was found only in 1 and 2 plots, respectively. It should also be noted that only one species of trees grew on 1 plot.

*Dendrometric* parameters

The results of the statistical analysis and Student test of the absolute dendrometric parameters forest park stand are presented in Table 3. It was established that at Kryvyi Rih forest park the values of stand density varied from 490 to 660 trees $*ha^{-1}$, stem heights were from 26 to 31 m, stem diameters were from 13 to 17 cm, stand basal area were from 32 to 49 $m^{2*}ha^{-1}$, stand volume were from 200 to 415 $m^3*ha^{-1}$. The coefficients of variation of absolute dendrometric parameters were from 15,08 % to 32,19 %, which, according to the criteria established by Pimentel-Gomes and Garcia (2002), indicate medium and too high variability (Pimentel-Gomes and Garcia, 2002).

The values of stand density were significantly differed only between two ecological areas: Impact and Background ($P < 0,05$). In contrast, differences among values of the mean height were found to be not significant ($P > 0,05$). The values of Diameter, Basal area, Volume were significantly differed between all ecological areas: Buffer and Background ($P < 0,001$), Impact and Background, ($P < 0,001$). In compared with Background ecological areas at Buffer ecological areas values of absolute dendrometric parameters of the forest park stand were higher: stem diameters by 10,34 %, stand basal area by 16,41 %, stand volume by

8,77 %. In compared with Background ecological areas at Impact ecological areas values of absolute dendrometric parameters of the forest park stand were less: stem diameters by 11,79 %, stand basal area by 11,05 %, stand volume by 54,79 %.

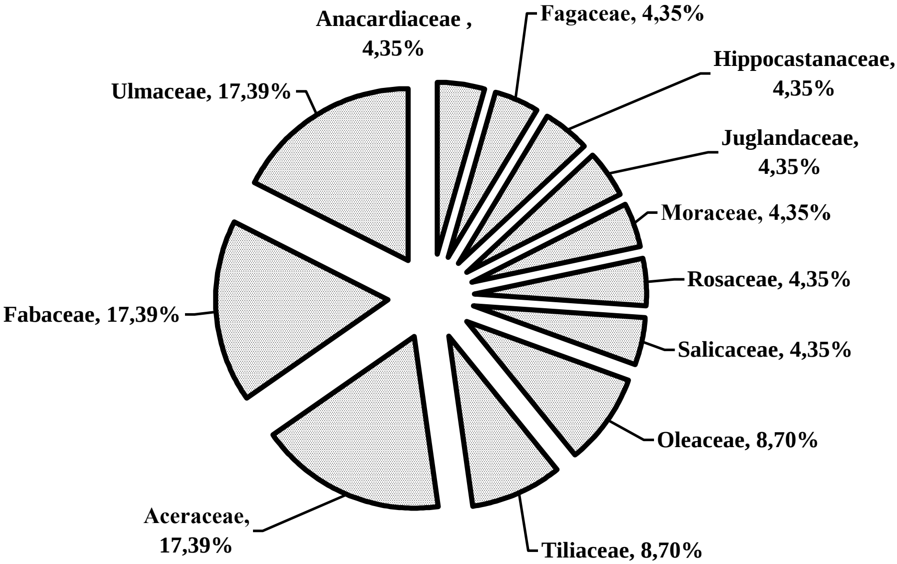


Figure 2. Floristic composition of the forest stands in parks at Kryvyi Rih District

Table 3. The absolute dendrometric parameters of the forest stand in parks at Kryvyi Rih District.

| Ecological areas | Statistical Index | Density (N), trees/ha | Height, m (Habs) | Diameter, cm (Dabs) | Basal area, $m^2$/ha (Gabs) | Volume, $m^3$/ha (Vabs) |
|---|---|---|---|---|---|---|
| Background, n=4 | Mean | 528 | 28,3 | 14,70 | 38,3 | 361 |
| | Std. | 18 | 0,4 | 0,14 | 1,0 | 11,0 |
| | CV, % | 27,32 | 21,45 | 29,96 | 26,74 | 29,61 |
| Buffer, n=11 | Mean | 626* | 29,5 | 16,22** | 44,6* | 393* |
| | Std. | 16 | 0,5 | 0,18 | 2,1 | 10,9 |
| | CV, % | 20,62 | 15,08 | 26,09 | 25,78 | 26,12 |
| Impact, n=7 | Mean | 542 | 26,78 | 13,15** | 34,5* | 233** |
| | Std. | 19 | 0,6 | 0,16 | 1,5 | 15,8 |
| | CV, % | 23,81 | 16,63 | 32,19 | 29,81 | 23,98 |

n – numbers of plots, Mean – arithmetic mean, Std. – standard deviation of mean, CV, % – coefficient of variation; * – are significantly different between Background and another Ecological areas at probability less then 0,05 ($P$ <0,05);** – are significantly different between Background and another Ecological areas at probability less then 0,01 ($P$ <0,01).

As it is known, the forest park stands at Kryvyi Rih City have different ages. Therefore, comparing their absolute dendrometric parameters is not correct. Therefore, we calculated and analyzed the relative dendrometric parameters (Table 4). The findings of this study indicated that at Kryvyi Rih forest park the values of relative stem heights were from 0,63 to 0,82 $m*year^{-1}$, relative stem diameters were from 0,31 to 0,43 $cm*year^{-1}$, relative stand basal area were from 0,80 to 1,19 $m^{2*}ha^{-1}*year^{-1}$, relative stand volume were from 5,45 to 10,28 $m^3*ha^{-1}*year^{-1}$.

Table 4. The relative dendrometric parameters of the forest stand in parks at Kryvyi Rih District

| Ecological areas | Statistical Index | Height, $m*year^{-1}$ (Hrel) | Diameter, $cm*ear^{-1}$ (Drel) | Basal area, $m^2/ha*ear^{-1}$ (Grel) | Volume, $m^3/ha*ear^{-1}$ (Vrel) |
|---|---|---|---|---|---|
| Background, n=4 | Mean | 0,71 | 0,37 | 0,96 | 9,02 |
| | Std. | 0,02 | 0,01 | 0,03 | 0,21 |
| | CV, % | 11,17 | 12,78 | 23,07 | 22,71 |
| Buffer, n=11 | Mean | 0,74 | 0,41** | 1,11** | 9,82* |
| | Std. | 0,04 | 0,01 | 0,04 | 0,23 |
| | CV, % | 15,08 | 16,09 | 20,78** | 16,12 |
| Impact, n=7 | Mean | 0,67 | 0,33** | 0,86 | 5,83*** |
| | Std. | 0,02 | 0,01 | 0,03 | 0,19 |
| | CV, % | 16,63 | 22,19 | 29,8 | 33,98 |

n – numbers of plots, Mean – arithmetic mean, Std. – standard deviation of mean, CV, % – coefficient of variation, * – are significantly different between Background and another Ecological areas at probability less then 0,05 (*P* <0,05), ** – are significantly different between Background and another Ecological areas at probability less then 0,01 (*P* <0,01), *** – are significantly different between Background and another Ecological areas at probability less then 0,001 (*P* <0,001).

The coefficient of variation (CV) was used to evaluate the variability of the data. According to the criterion proposed by Pimentel-Gomes F, Garcia CH. (2002), the CVs were classified as follows: medium (10% <CV≤ 20%) for relative stem heights at all ecological areas, relative stem diameters at Background and Buffer areas relative stand volume at Buffer area; high (20% <CV≤ 30%) for relative stem diameters at Impact area, relative stand basal area at all ecological areas, relative stand volume at Background area and very high (CV> 30%) only for relative stand volume at Impact area.

It was found that differences among values of relative stem heights were not significant (P> 0,05) between Background ecological area (with one hand) and Buffer/Impact ecological areas (on the other hand). In contrast, the values of relative stem diameters, relative stand basal, relative stand volume were significantly differed between all ecological areas: Background and Buffer (P < 0,001), Background and Impact (P < 0,001). In compared with Background ecological areas at Buffer ecological areas values of relative *dendrometric* parameters of the forest park stand were higher: stem diameters by 10,81 %, stand basal area by 15,63 %, stand volume by 8,77 %. In compared with Background ecological areas at Impact ecological areas values of absolute *dendrometric* parameters of the forest park stand were less: stem diameters by 10,81 %, stand basal area by 10,42 %, stand volume by 35,37 %.

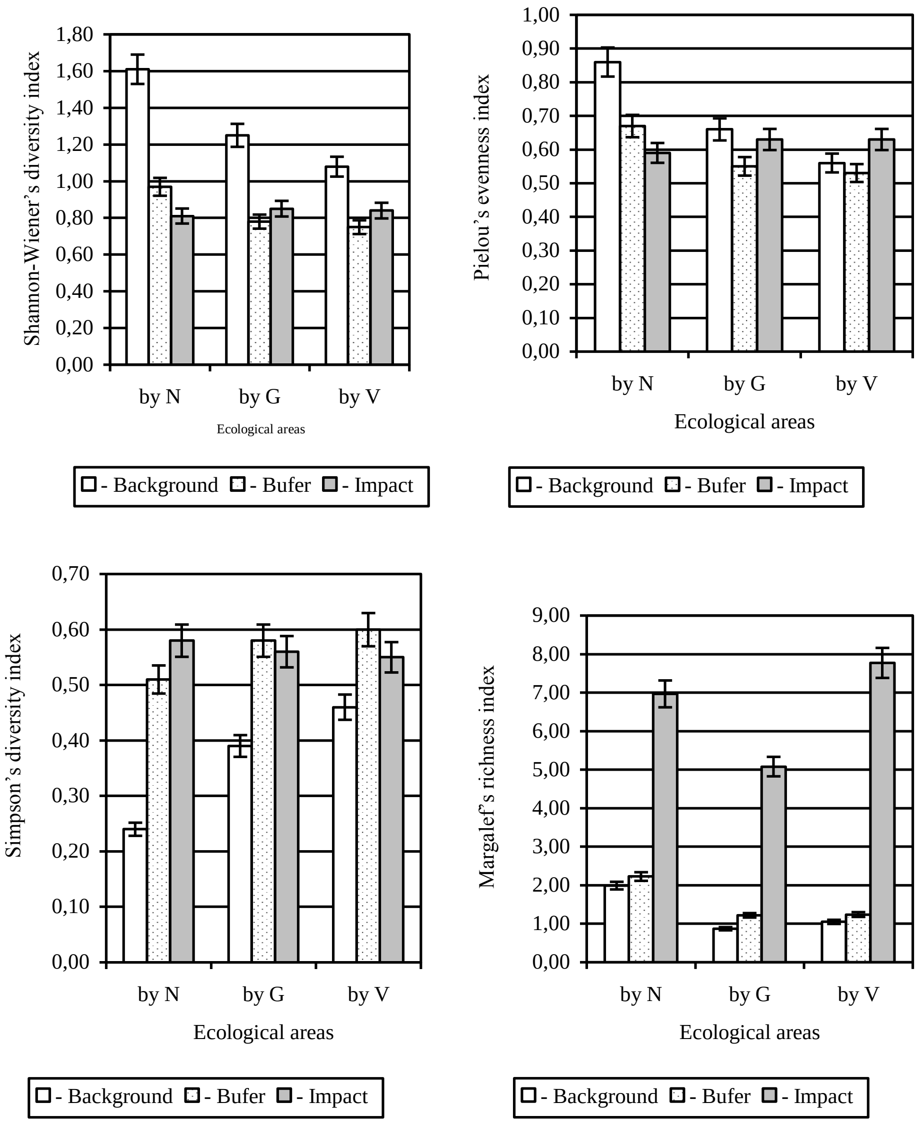


Figure 3. Diversity and evenness indexes of the forest park stand at Kryvyi Rih City, Central Ukraine

N – stem density, V – stem volume, G – stem basal area

Diversity and evenness indexes

Was found that at Kryvyi Rih City forest park stand the Shannon-Wiener diversity index values varied from 0,81 to 1,61 (calculated by stem density), varied from 0,75 to 1,08 (calculated by stand volume) and varied from 0,78 to 1,25 (calculated by stand basal area). For this index calculated by stem density a clear downward trend in ecological areas was installed (Figure 3).

It is important to note that in Background ecological area the maximum values of Shannon-Wiener index were established. The data Figure 3 show that the Pielou's evenness index values varied from 0,59 to 0,86 (calculated by stem density), varied from 0,53 to 0,56 (calculated by stand volume) and varied from 0,55 to 0,66 (calculated by stand basal area). As in the previous case, the maximum values of this index in Background area also were revealed. The results of our calculations showed that the Simpson's diversity index values varied from 0,24 to 0,58 (calculated by stem density), varied from 0,46 to 0,60 (calculated by stand volume) and varied from 0,39 to 0,58 (calculated by stand basal area). According to our research (Figure 3) the Margalef's diversity index values varied from 0,87 to 1,99 (calculated by stem density), varied from 1,22 to 2,23 (calculated by stand volume) and varied from 5,08 to 6,97 (calculated by stand basal area). In all cases, in the Background ecological area the values of this index were maximal.

## DISCUSSION

This paper provides information on forest park stands at Kryvyi Rih City, which are in steppe and technogenesis conditions (a case study at Ukraine). Until now, relatively little information was available on floristic compositions, dendrometric characteristics and diversity / evenness indexes of forest park stands in this region.

At Kryvyi Rih City and at Kryvyi Rih Region there are enough trees and shrubs of the species which had been naturalized in steppe and technogenesis conditions. Such, in Kryvyi Rih Botanic Garden Arboretum about 1000 trees and shrubs species and cultivars grow (Fedorovskiy and Mazur, 2007). In the flora of the Dnipropetrovsk oblast, more than 150 trees and shrubs species are identified (Tarasov, 2012). In Kryvyi Rih City gardens, parks and squares there are about 150 trees and shrubs species (Savosko and Tovstolyak, 2017). It was also established that 80 trees and shrubs species naturally grow on devastating lands at this region (Savosko et al, 2019b). But for green building of the forest park stand at Kryvyi Rih City only 23 trees species were used. Such a small number of species of trees and shrubs is incorrect. Therefore, in the future, it is necessary to increase the biological diversity of trees and shrubs for forest park stand.

As known, steppe ecological conditions (dry climate and lack of moisture), as well as technogenesis environmental conditions (anthropogenic activities, pollution of air and soil) negatively effect on the trees life. However, the dendrometric parameters of forest park stands (stem density, stem height, stem diameter, stand volume, stand basal area) in Background ecological areas were similar to the natural forest (Lafleur et al., 2018; Kuuluvainen and Gauthier, 2018). This phenomenon can only be explained by the location of some parks.

The findings of our study clearly show that in Buffer and Impact ecological areas anthropogenic activities adversely affect to dendrometric parameters. Wherein, in Buffer areas the stem and values were by 10-20% more than in the Background areas. While in Impact areas these values were by 10-30 % lower than in Background areas. Therefore, it can be assumed that small anthropogenic activity and so-so habitat conditions stimulate the dendrometric parameters, and large anthropogenic activity and poor habitat conditions inhibit the dendrometric parameters.

The diversity and evenness have always been some of the most frequently used measures for forest stand and communities (Kaufman et al, 2017; Spake and Doncaster, 2017). The diversity and evenness index has been used as "indicators of the wellbeing of ecological systems". It should also be noted that protection of biodiversity and evenness of forests ecosystem is a strategic for sustainable forestry, understanding and gain an insight of natural forest stand. But the use of these indices is not widespread in modern ecological research.

The Shannon-Wiener diversity index has been the most widely used index in biology and ecology for levels diversity assessment (Kaufman et al, 2017; Santini et al, 2017). The values of this diversity index is usually found to fall from 0.0-5.0, usually between 1,5-3,5 and only rarely surpasses 4,5. The Shannon-Wiener diversity index increases as both the richness and the evenness of the community increase.

On forest park stands at Kryvyi Rih City the Shannon-Wiener diversity index values were ranged from 0,75 to 1,61. The species diversity showed significant variation between Background / Buffer and Background / Impact ecological areas (calculated by stem density). It should also be noted that the biodiversity levels of trees in the city forest park stands are low. The Pielou's evenness index expresses how evenly the individuals are distributed among the different species (Kaufman et al, 2017; Vacek, 2017). Usually this index is constrained between 0 and 1.0 with 1.0 representing a situation in which all species are equally abundant. On forest park stands at Kryvyi Rih City the Pielou's evenness index values were ranged from 0,53 to 0,86. The species evenness showed significant variation between Background / Buffer and Background / Impact ecological areas (calculated by stem density).

Simpson's diversity index calculates a diversity score for a community. It is based on both the number of different species in the community, and the number of individuals present for each of those species. The value of this index will always fall between 0 and 1, where 1 represents complete diversity and 0 represents complete uniformity (Kim, 2016; Santini et al, 2017; Spake and Doncaster, 2017). On forest park stands at Kryvyi Rih City the Simpson's diversity index (raging from 0,24 to 0,60) indicates to moderate trees species diversity.

Margalef's diversity index is a little popular in the current biological and ecological research. But this index measures species richness and it is highly sensitive to sample size and it is a very simple index to apply (Gamito, 2010; Konijnendijk, 2018). On forest park stands at Kryvyi Rih City the Margalef's diversity index values were ranged from 0,87 to 7,77. The species evenness showed significant variation between Background / Impact ecological areas (calculated by all stem density, stand volume and stand basal area).

In generally, compound indices, including variations of all diversity and evenness index, are assumed to intelligibly integrate species richness and evenness into forest park stands. The results of our research (floristic composition, dendrometric parameters, diversity and evenness indexes) differ significantly with the data that were obtained in boreal forest (Darabi et al, 2014; Rapanoela et al, 2016), but they are comparable with the data obtained in the forest park stands (Miller et al, 2015; Ostoić et al, 2018). Our results also show that differences in floristic composition, dendrometric parameters, diversity and evenness indexes are greater between urban land uses than ecological conditions. This fact, as wel as other results support our hypothesis that current state of the urban forest park stands determined by the combined influence of ecological (soil fertility, soil moisture) and environmental factors (air pollution).

## CONCLUSIONS

The floristic compositions of Kryvyi Rih City urban forest park stands (Central Ukraine) are poor. There are only 24 species that belong to 14 families and 12 genera. The absolute and relative dendrometric parameters of the woody plants comparable to forest stand at the boreal zone. Ecological and environmental conditions statistically significant affect these characteristics. At low impact levels, there are stimulations of dendrometric parameters. At high impact levels, there are inhibitions of dendrometric parameters. The Kryvyi Rih City urban forest park stands characterized nasty of diversity and evenness indexes. This indicates the ecological instability of these woody plant communities. Current state of the urban forest park stands determined by the combined influence of ecological (soil fertility, soil moisture) and environmental factors (air pollution).

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