

IMPACT OF PUBLIC PARKS LOCATION IN CITIES ON RICHNESS AND DIVERSITY OF HERBACEOUS VASCULAR PLANTS ON THE EXAMPLE OF CRACOW (SOUTHERN POLAND)

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The richness and diversity of greenery in the classic monocentric model of a city increases with the distance from its center. Some elements of greenery in the layout of urban space do not show this principle, that is, their location in a given zone in the city does not affect their richness. This article tested whether the richness and diversity of herbaceous vascular plants of parks depends on their location, on the example of the city of Cracow. The research indicates that in relation to distance from the city center to parks, the herb layer of Cracow's parks has an azonal character, meaning that its richness does not depend on park location. However, as Cracow does not have a typical monocentric character, taking into account several urban centers around which city has developed, the richness and diversity of the herb layer of parks shows a favorable relationship along with the distance from these centers.

Keywords: plant richness, public parks in Cracow, herbaceous plants

1 Introduction

In the classic monocentric city model, the center is the most transformed and poorest in the spontaneous plant species. The closer to the periphery of the city, the richness increases linearly (Kowarik, 1990; Jackowiak, 1998; Fudali, 2005). Some authors (Chojnacki, 1991) believe that the vegetation in the central part of the city is the result of influence of only urban anthropogenic factors, while on the periphery, vegetation is shaped by habitat factors. It is believed that parks are those elements that have an azonic character, i.e. they do not follow this rule (Olaczek, 1996), do not preserve the zonal distribution of urban flora variation (Jackowiak, 1990; Sudnik-Wójcikowska, 1987; Sukopp, 1990; Fudali, 1994; Sukopp and Herbert, 1998; Hohenwallner, 2000; Fojcik and Stebel, 2001). The aim of the following study is to check whether this rule also applies to the park herb layer and it exhibited azonality, or whether the park's location in the city of Cracow affects its richness and floristic diversity

2 Material and methods

2.1 Study Area

Cracow is a geomorphologically diverse city. Different geographic and phytogeographic regions are in

contact here (Kondracki and Richling, 2001; Kornaś and Medwecka-Kornaś, 1974). It is crossed by the Vistula valley running from east to west. To the southern part of the city, the Carpathian Foothills reach the flysch type, from the north-west the Krakowsko-Częstochowska Upland with the Jurassic limestone rocks, and from the north-east the Miechowska Upland (Proszowicki Plateau) with a chalk base covered with loess. This affects the large floristic richness of the Cracow area. The flora of vascular plants is estimated at about 1,330 species (Trzcińska-Tacik, 1979), the distribution of most of them is reported by Flora Cracoviensis Secunda (Zajac et al., 2006). Around 100 plant communities are known from the area of Cracow (Dubiel, 1991; Dubiel and Schwagrzyk, 2008). The vegetation of the city consists of many different areas of a natural or semi-natural nature, including Sikornik and Sowiniec massif, Tyniecki Forest, Pychowickie Meadows, Nowohuckie Meadows, Skałki Twardowskiego forest, Krzemionki, Bodzów, riparian flora of Vistula, Dłubnia, Rudawa and Wilga river, meadow or scrub communities in undeveloped areas (Dubiel, 1991). The complement of natural, semi-natural and synanthropic vegetation is composed greenery, in which public parks have a significant participation.

The majority of Cracow's public parks are located on flat areas, although some of them contain artificial



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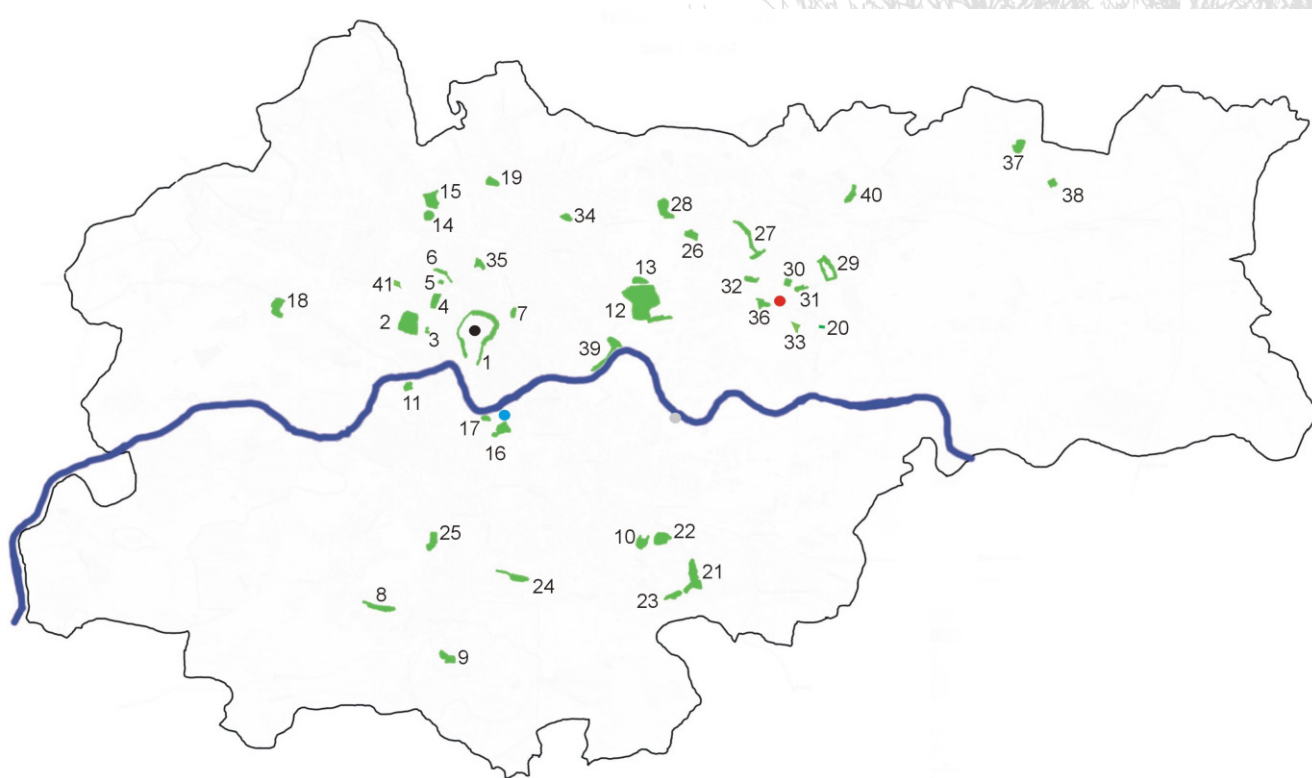
elements of land development, and the habitat and soil conditions are relatively little varied in individual parks. Parks located in the city center occur on anthropogenic soils (Wójcik, 2007) typical for cities, except for the Bednarski Park. The natural character of the habitat has been preserved, for example, in Łuczanowice and partly in Swoszowice. Parks are located in various parts of the city with fewer outlying areas (Figure 1). In most of the parks studied in Cracow, greenery managements are carried out. They are relatively often mowed, although there is variation in the intensity of these activities, sometimes you can observe the most planted bulb plant species, or even the removal of turf and sowing grass.

Cracow is not typically a monocentric city because it consists of three centers around which the city has developed (Bieniarzówna, 1992, 1997). The oldest part, currently the city center, is the Old Town with a centrally located Main Market Square; the history of

this part of Cracow dates back to the 9th century, when a settlement was established in this area. Another center is Podgórze Market Square, which was the center of Podgórze, which was included to Cracow in 1915. The last such center is the Central Square around which the youngest part of Cracow, Nowa Huta, was developed. This part of Cracow was closely related to the steel industry developing in this place after the World War II. This all urban layout was additionally disturbed by included suburban areas and villages during the city growth.

2.2 Data Collection

The number of researched parks was limited to 41 (Figure 1), which, due to their functions, structure and composition, are public parks (eg. Fudali, 2005). A part of various types of urban greenery referred to as parks are omitted because they are:



■ **Figure 1:** The distribution of researched parks in Cracow

- 1 – Planty Krakowskie Park, 2 – Jordan Park, 3 – Park nearby Jagiellonian Library, 4 – Krakowski Park, 5 – Teodor Axentowicz Square, 6 – Młynówka Królewska Park – east part, 7 – Strzelecki Park, 8 – Maccka i Doroty Park, 9 – Swoszowice Park, 10 – Jerzmanowskich Park, 11 – Dębnicki Park, 12 – Lotników Polskich Park – south part, 13 – Lotników Polskich Park – north part, 14 – Wyspiański Park, 15 – Krowoderski Park, 16 – Bednarski Park, 17 – Nowacki Square, 18 – Decjusz Park, 19 – Kościuszki Park, 20 – Klasztorna, 21 Aleksandra Park – south part, 22 – Lilii Wenedy Park, 23 – Rzęska Park, 24 – Kurdwanowski Park, 25 – Solvay Park, 26 – Dywizjonu 303 Park, 27 – Planty Bieńczyckie Park – south part, 28 – Tysiąclecia Park, 29 – Zalew Nowohucki Park, 30 – Ratuszowy Park, 31 – Szwedzki Park, 32 – Wiśniowy Sad Park, 33 – Żeromskiego Park, 34 – Zaczarowanej Dorożki Park, 35 – Kleparski Park, 36 – Kultury Park, 37 – Park in Łuczanowice, 38 – Wadów Park, 39 – Dąbie Park, 40 – Zielony Jar Park, 41 – Saint Vincent de Paul Park.
- Dots on the map: Black – the Main Market Square (Rynek Główny) – middle of the city, grey – geometric middle of the city, blue dot – Podgórze Market Square (Rynek Podgórski) – center of Podgórze district, red dot – Centralny Square (Plac Centralny) – center of Nowa Huta district

- narrow green lanes with the character of squares (eg. Planty Dietlowskie Park, fragments of Vistula Boulevards);
- surroundings of forts (eg. Batowice fort);
- areas occupied by natural and semi-natural vegetation, which are not characterized by a typical layout of public parks such as “Wolski Forest”, “Witkowice Forest Park”;
- which are divided and not available for the public (eg Jalu Kurka Park),

The analyzed parks are located in the historic center of the city, as well as between older and newer housing estates or at the city’s administrative boundaries.

In the analyzed parks, herbaceous vascular plants were noted during observations led in years 2016–2017. Each park was searched no less than 3 times during the growing season, from April to September, in order to obtain the most complete list of species.

In this work, compositional elements such as flower beds, rebates and so-called flower meadows, were omitted. These are the elements intentionally created by men and their richness and diversity is associated with the intentional action of men.

The number of species found in individual parks, the number of families represented, and then the Shannon-Weaver index (Shannon and Weaver, 1963) and the Simpson domination index (Chmiel, 2006) were determined.

For the purpose of checking the hypothesis, distances from the means of parks to individual points were calculated; yielding the following variables:

- distance to the central point defined as the middle of the Main Market Square in Cracow;
- distances to the geometric center of the city,
- distances to the central points of the Main Market Square, Podgórski Market Square and the Centralny Square,
- the shortest distance from the park to the city’s administrative boundaries.

The collected data were presented in the graphs.

2.3 Data Analysis

It was checked whether the tested independent variables regarding the distance of parks have a normal distribution, and their skewness was also tested. Because the variables did not show much skewness and their transformation did not improve, the data was left without transformation. For the number of species, number of families, the Shanon-Weaver diversity index and the Simpson dominance index, a separate regression model was created taking into account

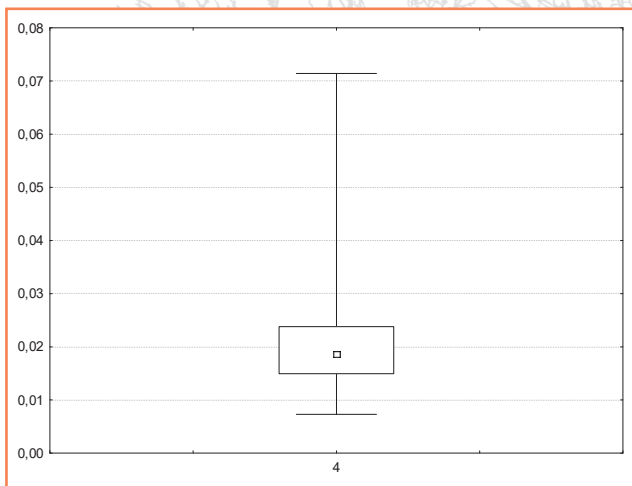
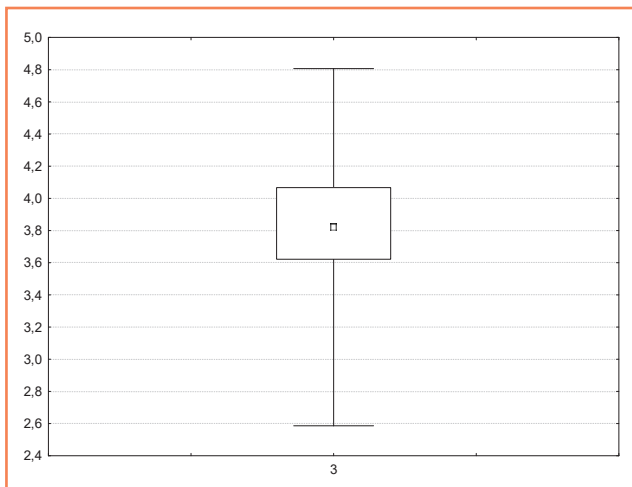
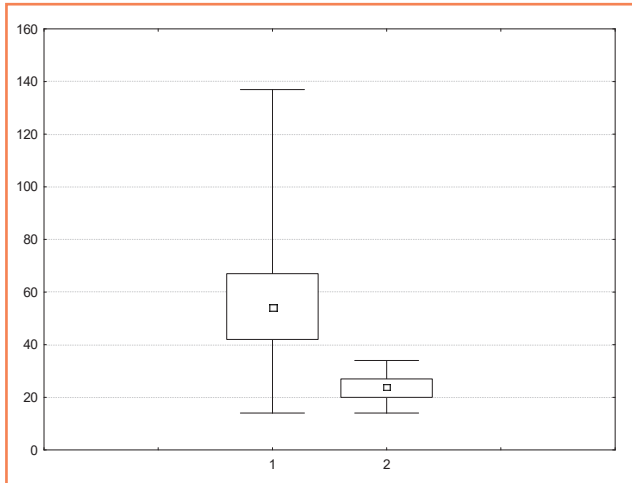
the four independent variables given above. In order to avoid spatial autocorrelation, only results with the highest statistical significance were taken into account.

3 Results and discussion

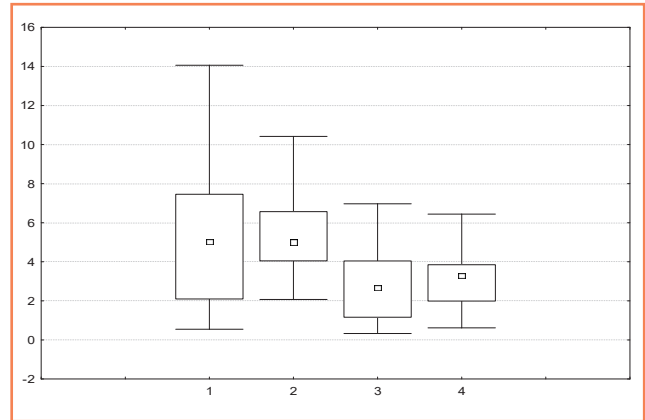
There were noted 273 species of herbaceous vascular plants (Moszkowicz and Krzeptowska-Moszkowicz 2019) in the herb layer of the studied parks in Cracow. Majority of them was found in the southern part of the Lotników Polskich Park – 137 species. The smallest portion (14 species) was identified in Strzelecki Park. On average, 55 species were recorded in the parks and the number of represented families was 24 (Figure 2). While the average number of species and families was closer to the bottom of the chart, the average diversity index almost in the middle (3.8) of its range (2.6–4.8). The dominance index, in turn, was located in the lower part of its values and amounted to 0.02 with values from 0.007 to 0.07. On this basis, it can be concluded that most parks are characterized by lower species richness and average diversity and low species dominance (Figure 2).

Based on Figure 2, it can be concluded that the median distance from the park to the middle of city is about 5 km (1) and 3/4 of them is located within the distance of 8 km from the Main Market Square. They are particularly concentrated near historic development centers (3), and over ¾ occur at a distance not exceeding 4 km from adequate centers. It can also be seen that most parks are located within rather thin compartment of distances from the geometric middle, i.e. from 4 to 6.5 km (2). Therefore, one would expect that more parks have long distances from the city border. A half of Cracow’s parks are just 2 to 4 km (4) from the city limits. To take a closer look at these location features, a scatterplot (variability) with a simple match was made:

As presented in Figure 4, a negative correlation is present, but further location of the park from the adopted center is not always similar with closer distance to the city limits. There are parks whose distances are equal but, for example, smaller as in the case of Planty Bieńczyckie Park (1.7 km and 2.1 km) or similar but larger as in the case of the southern part of the Lotników Polskich Park (4.1 and 3.9). It indicates a certain unevenness of the administrative and urban planning system and the city boundaries. And the visible confidence interval for the linear value of a simple match between distances from centers and to the city limits indicates that larger number of parks in urban space is outside the 95% confidence interval.

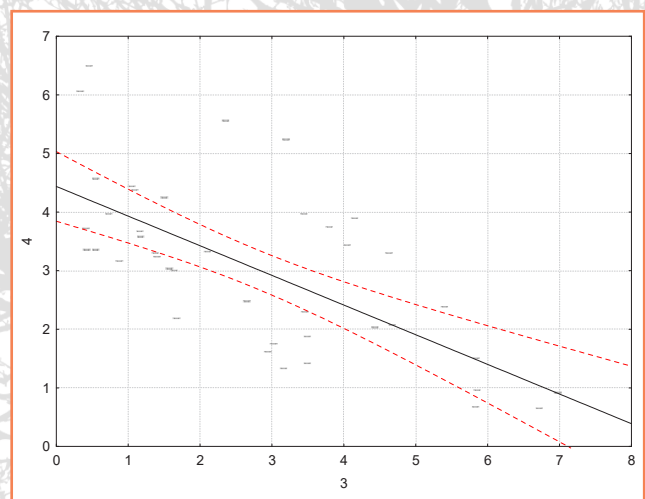


■ **Figure 2:** Median, percentiles (25–75% of the value) and the range of variables for the number of species (1), number of families represented (2), Shannon-Weaver diversity index (3) and Simpson domination index (4) in the herb layer of Cracow parks



■ **Figure 3:** Median, percentiles (25–75% of value) and the range of variables for (X axis): distance of parks from the city center (1), from the geometric city center (2), from centers around which the city grows (3) and the shortest distance from the city limits to the park (4). Distances (Y axis) expressed in kilometers

The impact of the studied factors on selected indicators of richness and diversity is rather small, explaining only between 12% and 24% of volatility (Table 1). It means that the richness and diversity of the herb layer of the parks studied are determined by other factors than the park's location. The distance from the middle of the city and the geometric middle did not show dependence, i.e. they would indicate the azonal nature of the herb layer of Cracow's parks. However, taking into account the historic development centers, there is a statistically highly significant relationship indicating the impact of the park's location in the city on the richness



■ **Figure 4:** Scatter plot of the parks' distance from individual urban centers to the parks (X-axis) and from the parks to the nearest city border (Y axis). Correlation coefficient -0.67, confidence interval 95% – set with dashed lines

Table 1: Results of multiple regression for richness and diversity indicators of park location.

	Number of species	Number of species families	Shannon-Weaver index	Simpson index for species
Distance from urban centers to parks	0.67***	0.76***	0.65***	-0.348266**
Distance from the border of the city to parks	0.47**	0.49**	0.38*	
R ²	0.24	0.32	0.23	0.12

Statistical significance: *0.1 > p > 0.05; **0.05 > p > 0.01; ***p < 0.01

and diversity of its herbaceous vascular plants. The indicators grow according to the increasing distance from urban centers. Therefore, the herb layer of parks in Cracow is not fully attributed to the azonality parks.

Also, a positive relationship shows the distance from the city borders. This is the result of a rather irregular arrangement of greenery and city borders (Figure 1, Figure 3), which could have affected the less statistically significant impact of the distance from the periphery to parks for the richness of herbaceous species and families.

Herb layer of parks is developed by habitat conditions and human activities. The climatic and habitat conditions within the urban space are usually homogeneous, more significant is the local variation that forms the system of microbiotopes (Fundali, 2005). Although the natural location of Cracow causes its large natural diversity and rich flora of vascular plants (Trzcińska-Tacik, 1979; Dubiel, 1991), this influence a little the richness and diversity of vascular herbaceous plants of city parks (Moszkowicz and Krzeptowska-Moszkowicz, 2019). Thus, the suggested azonal nature of parks in urban greenery (Jackowiak, 1990; Sudnik-Wójcikowska, 1987; Sukopp, 1990; Muller, 1993; Fojcik and Stebel, 2001) is also reflected in the park herb layer. This azonality is not observed if we analyze the parks location in relation to the historic centers around which the urban space was developed. Richness and diversity depends on the distance from this center, which can be explained by the less dense buildings and easier inflow of plant diaspores to these parks (MacArthur and Wilson, 1967; Moszkowicz, 2016) which affects the greater richness of park herb layer and more significant contribution of natural factors (Sukopp, 1992; Bianco et al., 2003; Fornal-Pieniak and Wysocki, 2009). This does not mean that all peripherally located parks are surrounded by loose or not build up areas as in the classic model of a monocentric city (Fundali, 2005). Therefore, larger distances from the peripheries influence here to a certain increase in number of species in Cracow. Another reason of that result is the occurrence of the richest and a highly diversified

park near center. Its richness is not only related to the size, but also to its diversified use and the existence of natural and semi-natural elements (Fornal-Pieniak and Wysocki, 2009; Moszkowicz and Krzeptowska-Moszkowicz, 2019). This type of examples could be given more. This also shows that Cracow, in terms of the buildings overlooking the strict center, has no uniform layout, which results from its historical conditions (Bieniarzówna, 1992, 1997).

4 Conclusions

Based on the performed research, the following conclusions were drawn: Cracow as a city does not have a monocentric character and an even urban layout.

The fleet of Cracow's parks in relation to the middle of city and its geometrical center indicates an azonal character, but in relation to the centers around which the buildings were developed, the results shows the dependence of richness and diversity on the park's location in urban space according to the gradient of buildings.

The more peripheral location of parks is not conducive to the greater herb layer richness of parks and does not show any significant connections with diversity.

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