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Effect of Urban Park Reconstruction on Physical Soil Properties

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Abstract. Ecological restoration is an important means of managing urban natural areas with human and ecological values in mind. Urban park restoration involves significant impacts on soil cover. Soil quality is a major concern in urban park management, but little is known about the impact of park reconstruction on soil properties. The effect of urban park reconstruction on physical soil properties was investigated. The study was conducted in the recreational area of the Botanical Garden of the Dnipro National University. Data of remote sensing of the Earth's surface allowed to understand the impact of the park reconstruction on the state of the vegetation cover. The area of territories with high NDVI value, which correspond to dense tree plantations without reconstruction, strongly decreased in the reconstruction zone. The principal component analysis allowed to identify the main trends of the coordinated variability of soil features. The first principal component is obviously a reflection of the transformation of the soil properties, which occurred as a result of the reconstruction of an urban park. In the reconstructed part of the park compared to the area without reconstruction, there is an increase in soil penetration resistance, which occurs from the surface and gradually decays to a depth of 35 cm. The impact on the soil of technological processes that occurred during the reconstruction of the park, caused the compaction of the soil. The decrease in vegetation density occurred after the implementation of the reconstruction project. The consequence was that soil moisture in the reconstructed area was lower than without reconstruction.

Key words: NDVI, principal component analysis, soil compaction, soil moisture, vegetation cover.

Introduction

Urban ecosystems have a particularly critical role in providing services that directly influence human health and safety, such as air purification, noise reduction, urban cooling, and runoff mitigation (Gómez-Baggethun et al., 2013; Romzaykina et al., 2017). Urban soils and vegetation cover are heavily influenced by the human environment (Yang & Zhang, 2015). They can diverge in varying degrees from their natural analogues and vary from pseudo-natural to artificial soils and introduced plant species (Hemkemeyer et al., 2014). Urban soils play multiple roles in urban ecosystems (Setälä et al., 2014). Plant communities and soils that are similar to natural ones are typical for recreational areas and suburban zones. More disturbed plant communities and artificial soils are found in the industrial areas (Burghardt et al., 2015; Huot et al., 2017) and roadsides (Ghosh et al., 2016; Sager, 2020). The basic ecological regimes of plant life, such as soil, rainwater supply, air and light, are greatly altered in the urban environments (Li & Wong, 2007; Xiao et al., 2013; Maamar et al., 2018). Despite the high level of disturbance that characterizes most urban soils, they are able to support plant, animal and microbial organisms and mediate hydrological and biogeochemical cycles (Pavao-Zuckerman, 2008; Santorufo et al., 2012; Pouyat et al., 2020). Vegetation and soils in urban landscapes provide the key ecosystem services for the residents of a city (Pickett et al., 2008; Raciti et al., 2011) such as the biodiversity conservation, water protection, microclimate regulation, carbon sequestration, food production, and cultural and recreational needs (McKinney, 2006; Lovell & Taylor, 2013; Biliaiev et al., 2014).

The soils of urban parks create the conditions for plant growth and development (Czaja et al., 2020). Urban soils are subject to a high level of anthropogenic influence (Lehmann & Stahr, 2007; Seleznev et al., 2020). The urban environment has a unique set of specific features and processes (e.g., soil compaction, functional zoning, settlement history) that affect soil properties and their spatial variability (Vasenev et al., 2013). Temporal dynamics are the result of human-driven processes such as green space management and reconstruction (Van den Berg et al., 2014; Bae & Ryu, 2015; Kunah et al., 2019). After the moment of initial anthropogenic disturbance, the impact of urbanization decreases, which is associated with temporal dynamics of physical, biological and chemical properties of the soil (Scharenbroch et al., 2005). Re-vegetation of urban green space can improve the diversity of urban soil microbiota and bring it closer to near-natural levels by creating more wild habitat conditions (Mills et al., 2020). Urban soils have specific morphological properties (Costa et al., 2019; Prokof'eva et al., 2021). A variety of soil layers with sharp boundaries (Schoonover & Crim, 2015), abundance of anthropogenic inclusions (Sedov et al., 2017) and over compaction (Bezuglova et al., 2018) are typical for urban soils. Urban soils differ in their properties from soils in other systems. The properties of urban soils are very variable in space and time (Wiesner et al., 2016) and also vary within landscape types in urban environments. The spatial variability of soil properties in urban parks depends largely on the types of land cover and functional zoning of the area (Guo et al., 2019; Metwally et al., 2019; Romzaykina et al., 2021). The various practices of land-use and management have a significant effect on the properties of the soil (Spurgeon et al., 2013). Land-use and functional zoning are the key factors determining the spatial variability of vegetation and soils within the city area (Panday et al., 2019). The spatial heterogeneity of urban soils and vegetation within functional zones is also very high (Cadenasso et al., 2007; Mao et al., 2014). The history of land use and current land management practices are factors that determine the heterogeneity of urban soils at various scales (Fraterrigo et al., 2005; Pickett et al., 2017).

Urban green spaces can provide a thermally comfortable environment. In order for them to perform this function, parks must be designed and redesigned with climate conditions and predictions of future climate. A properly designed and reconstructed park can reduce the threat of extreme heat stress hazards (Brown et al., 2015). Urban parks reconstruction is a routine procedure (Li, 2020). Ecological restoration of urban forests is a measure to improve air quality, mitigate urban heat island effects, improve stormwater infiltration, and provide other social and environmental benefits (Johnson & Handel, 2015). Ecological restoration is becoming an important means of managing urban natural areas with human and ecological values in mind. Urban ecological restoration can contribute to a unique and positive relationship between people and nature (Gobster, 2007). The reconstruction of urban parks is associated with a significant impact on the soil cover (Shanahan et al., 2015; Sarah et al., 2015; Kumar & Hundal, 2016).

The soil quality is a major concern in urban park management, but little is known about the effects of park reconstruction on soil properties (Hou et al., 2015). The technological processes of reconstruction, such as excavation, leveling, building paths, planting trees, and adding compost, can significantly modify the spatial variability of soil properties in an urban park. The spatial variability of soil chemical properties in a city park before and after reconstruction was investigated (Romzaykina et al., 2017). However, little is known about the impact of urban park reconstruction on the physical properties of soils. Therefore, the aim of our study was to investigate the effect of urban park reconstruction on the physical properties of soils. We propose the hypothesis that the technological activities in the process of park reconstruction leads to an increase in soil penetration resistance and changes in its aggregate structure. We propose the hypothesis that the technological activity in the process of park reconstruction leads to a change in the physical properties of the soil. To test this hypothesis, it is reasonable to compare the informative indicators of soil physical condition, such as the soil penetration resistance, aggregate structure, bulk density, electrical conductivity, and the soil moisture in the area of the park that was reconstructed and without reconstruction. In order to assess the role of vegetation density change as a result of reconstruction on the physical properties of soil, we used NDVI data for the compared areas before and after reconstruction.

Materials and Methods

The study was conducted in the recreational area of the Botanical Garden of the Oles Honchar Dnipro National University (Ukraine). This artificial tree plantation was created in the 1940s on the location of a natural oak forest. A geobotanical survey of the park in 2013 revealed that plant communities within the study area were represented by 36 species (Table 1). The *Acer platanoides*, *Fraxinus excelsior*, *Gleditsia triacanthos*, *Robinia pseudoacacia* were dominated among the tree plants. The *Alliaria petiolata*, *Chelidonium majus*, *Geum urbanum*, *Viola mirabilis*, *Galium aparine* were dominated among the herbaceous plants.

In 2019, a 2.8 ha area of the park was reconstructed (Fig. 1). During the reconstruction process, walkways were rebuilt, shrubs were removed, old, damaged trees were removed, and tree crowns were trimmed. Juvenile trees were planted in the place of removed old trees. Old outbuildings, which greatly impaired the aesthetic perception of the park, were also removed. An transport and construction machinery was involved in the reconstruction. The works were carried out during the whole warm period of the year.

A study of the physical properties of the soil was conducted in 2020 after the reconstruction of the park was completed. The soil samples were taken within polygons, 2 of which were placed in the reconstruction area and 2 of which were placed in a similar section of the park where no reconstruction was performed. Each polygon consisted of 105 sample points. The points were located along 7 transects with 15 sample points in each. The distance between points in the transect as well as the distance between transects was 3 m.

Soil properties measurement

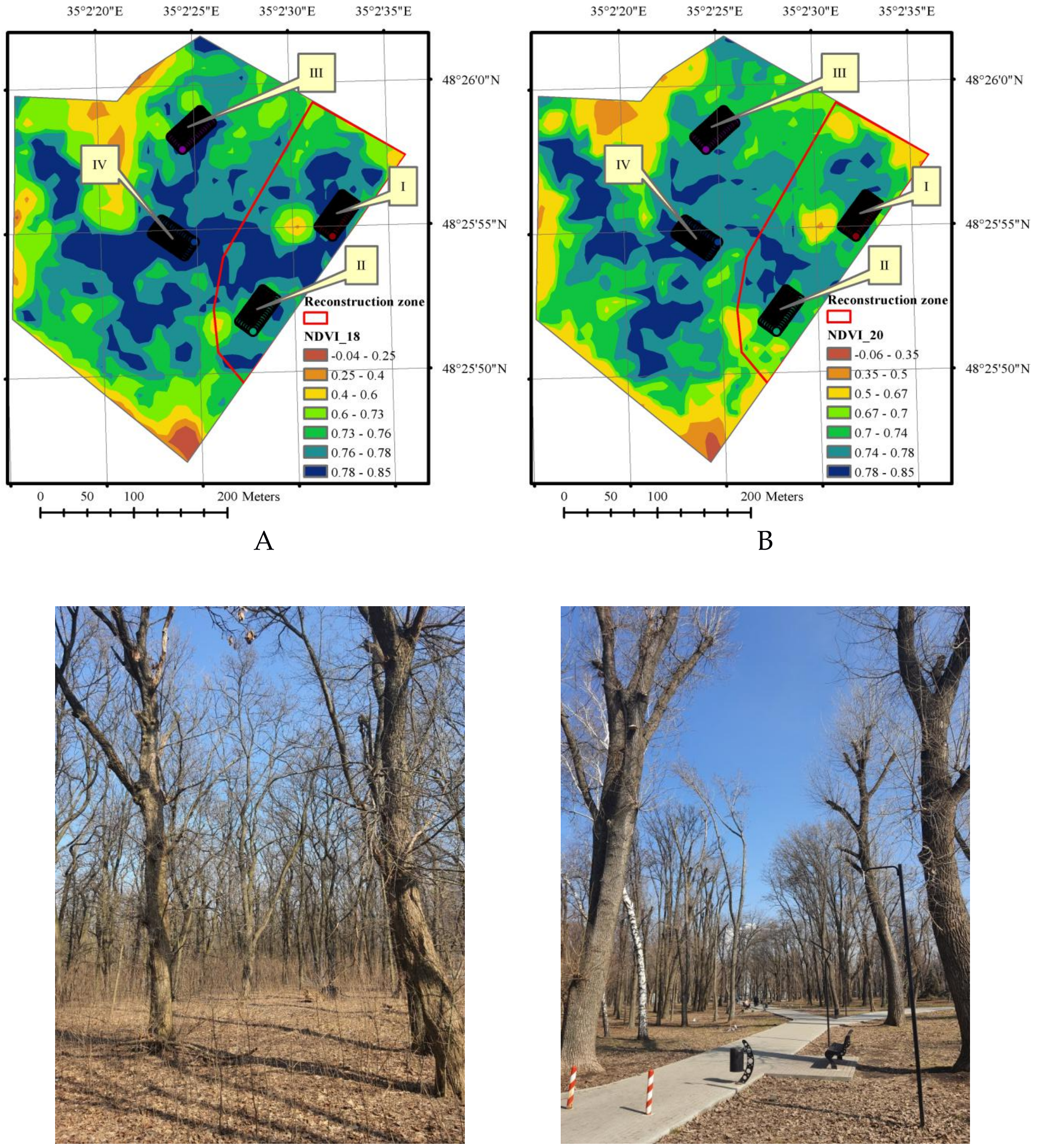
The following soil properties were measured at each test point of the polygons. The soil mechanical resistance was measured in the field using the "Eijkelkamp" manual penetrometer, to a depth of 100 cm at 5 cm intervals (Zhukov & Gadorozhnaya, 2016; Zhukov et al., 2019). The average error of the measurement results of the device is ± 8%.

The measurements were made with a cone with a cross section of 1 cm^2. At each measurement point, the soil mechanical resistance was performed in only one replication. To measure the electrical conductivity of soil *in situ* the HI 76305 sensor (Hanna Instruments, Woodsocket, R. I.), working in conjunction with the portable instrument HI 993310 were used (Yorkina et al., 2018; Kunakh et al., 2020). The soil aggregate fractions size distribution was determined in accordance with the Soil Sampling and Methods of Analysis recommendations (Kroetsch & Wang, 2008). Soil moisture was measured under the field conditions using a dielectric digital moisture meter MG–44. The core method was used for measurement of the soil bulk density (Al-Shammary et al., 2018).

Table 1. Structure of plant communities of polygons (projective coverage of plant species is represented by Braun-Blanquet density scores*) based on 2013 data. *Legend:* * – 1 – <5% cover; 2 – 5–25% cover; 3 – 25–50% cover; 4 –50–75% cover; 5 – – 75 – 100% cover.

Species and Raunkiær plant life-form	Polygon			
	Reconstructed territory		Without reconstruction	
	I	II	III	IV
Phanerophytes				
Acer campestre L.	3	0	0	2
Acer negundo L.	0	0	0	2
Acer platanoides L.	2	2	2	2
Aesculus hippocastanum L.	0	1	0	0
Ailanthus altissima (Mill.) Swingle	0	2	0	0
Betula pendula Roth	2	0	0	0
Fraxinus excelsior L.	2	3	2	2
Gleditsia triacanthos L.	2	2	2	2
Populus nigra L.	3	0	0	0
Pyrus communis L.	0	2	0	0
Quercus robur L.	2	0	0	0
Robinia pseudoacacia L.	4	2	4	2
Ulmus glabra Huds.	2	0	0	2
Nonphanerophytes				
Parthenocissus quinquefolia (L.) Planch.	0	0	0	1
Hemikryptophytes				
Alliaria petiolata (M.Bieb.) Cavara et Grande	2	2	3	2
Anthriscus sylvestris (L.) Hoffm.	0	0	2	0
Arctium minus (Hill) Bernh.	0	2	2	0
Ballota nigra L.	0	0	1	1
Carex melanostachya Bieb. ex Willd.	0	0	1	2
Chelidonium majus L.	2	3	2	2
Daucus carota L.	1	0	0	1
Fragaria viridis (Duch.) Weston	0	0	1	0
Geum urbanum L.	2	3	2	2
Plantago major L.	1	0	0	0
Poa angustifolia L.	1	0	0	0
Poa nemoralis L.	0	0	2	2
Solidago canadensis L.	1	0	0	0
Taraxacum campylodes G.E.Haglund	1	0	1	0
Viola mirabilis L.	4	2	4	1
Terophytes				
Atriplex micrantha C. A. May	1	0	0	0

Galium aparine L.	2	2	2	2
Impatiens parviflora DC.	0	0	0	2
Lactuca serriola L.	1	0	0	0
Stellaria media (L.) Vill	0	0	1	0
Geophytes				
Convolvulus arvensis L.	2	0	2	0
Humulus lupulus L.	2	0	0	0



A B

C D

Fig. 1. A spatial variation of the NDVI on July 6, 2018 (A) and July 6, 2020 (B), as well as landscape images of the area without reconstruction (C) and the area after reconstruction (D) of the park (Date of the photo 23.03.2021).

Evaluating the effects of reconstruction with Sentinel-2 images

Sentinel-2 satellite images of the study area received from Geological Survey (U.S.), & EROS Data Center on two dates: the year before reconstruction on July 6, 2018 and the year after reconstruction on July 6, 2020. Normalized difference vegetation index (NDVI) was calculated based on B8 (wavelength 842 nm) and B4 (wavelength 665 nm) channels with 10 metre spatial resolution:

$$\mathrm{NDVI} = \frac{\mathrm{B8} - \mathrm{B4}}{\mathrm{B8} + \mathrm{B4}}.$$

The value of NDVI varies from –1 to 1 (Saravanan et al., 2019). The values less than 0 indicate no vegetation cover. The values close to zero (–0.1 to 0.1) generally correspond to the barren areas of rock, sand, or anthropogenic surfaces. The values greater than 0 indicate a presence of vegetation. The closer to 1 the NDVI value is, the denser the vegetation cover is (Drisya et al., 2018). The experimental polygons were within the space that was covered by 15–17 pixels of Sentinel-2 images. The NDVI values were extracted from these images and compared using Nested design ANOVA with Reconstruction zone variables (1 – reconstruction zone; 2 – no reconstruction zone) and Polygon nested variables (1, 2, 3, 4) as predictors. The descriptive statistics, ANOVA and Principal Component Analysis were calculated using the program Statistica (Statsoft).

Results

The NDVI values were statistically significantly dependent on the reconstruction effect, year and year interaction and reconstruction effect (Table 2). Areas without reconstruction did not differ in NDVI value in 2018 and 2020, as confirmed by the test of significance for planned comparison ($F = 0.16$, $p = 0.69$). The area within which the reconstruction was conducted, there was a decrease in the NDVI index in 2020 compared to 2018 ($F = 3.81$, $p = 0.05$).

Table 2. ANOVA table between NDVI and the reconstruction effect, year and interrelation between reconstruction effect and year. *Legend:* * – Polygon – effect, which indicates the type of polygon: the polygon is in the reconstruction zone (polygon I and II) or outside the reconstruction zone (polygon III and IV).

Effect	Sum-of-squares (SS)	Degrees of freedom	Mean squares (MS)	*F*-ratio	*p*-level
Total territory comparison ($R^2_{adj} = 0.09$, $F = 290.9$, $p < 0.001$)					
Intercept	349.4	1	349.4	8105.6	<0.001
Year	0.18	1	0.18	4.26	0.04
Reconstruction	37.49	1	37.49	869.9	<0.001
Reconstruction×Year	0.13	1	0.13	2.95	0.09
Error	371.6	8620	0.043	–	–
Polygon comparison ($R^2_{adj} = 0.50$, $F = 19.2$, $p < 0.001$)					
Intercept	75.7	1	75.7	204333.9	<0.001
Polygon*	0.0414	3	0.0138	37.26	<0.001
Year	0.0041	1	0.0041	10.99	<0.001
Polygon×Year	0.0042	3	0.0014	3.79	0.01
Error	0.0441	119	0.0004	–	–

The polygon 2 was distinguished by the lowest level of NDVI, which takes a value of 0.75±0.0032 (Fig. 2). The polygons 1 and 3 did not differ in NDVI value, as confirmed by the test of significance for planned comparison ($F = 0.01$, $p = 0.92$). The polygon 4 had the highest NDVI, which took a value of 0.80±0.0033. The NDVI had a lower value in 2020 than in 2018. This difference was due to a decrease in NDVI in polygons that were in the park reconstruction area. The differences between years in polygons 3 and 4 were not statistically significant, as confirmed by the test of significance for planned comparison ($F = 0.009$, $p = 0.92$).

In turn, the differences between years in polygons 1 and 2 were statistically significant, as confirmed by the test of significance for planned comparison ($F = 21.26$, $p < 0.001$).

The data on soil properties were subjected to the principal component analysis (PCA), and the first three principal components were extracted as a result (Table 3). These components were able to explain 54.4% of the variation in the feature space. The PC 1 was able to describe 26.1% of the variation in the feature space. This component was sensitive to the conflicting directions in the trends of the soil penetration resistance at depths from the surface and up to 35 cm and at 50 cm and deeper: an increase in soil penetration resistance in the upper soil layer was accompanied by a decrease in this indicator in the lower soil layer. The PC1 indicated the presence of an opposite trend in the variability of the proportions of aggregate fractions less than 0.5 mm on one side and more than 0.5 mm on the other. The PC 2 was able to explain 15.0 % of the variability of the feature space. This component indicates consistent variability in the soil penetration resistance within the soil profile to a depth of 90 cm with two local maxima at 30–45 and 75–90 cm. The pattern explained by the PC 2 indicated an increase in aggregate fractions of 2 mm or more in size with an increase in soil penetration resistance. Also, the PC2 was sensitive to the variability in litter height. The PC 3 was able to explain 13.2 % of the variation in the feature space. This component was sensitive to the opposite variation in the soil penetration resistance from the surface to 35 cm depth on the one hand and from 40 cm depth on the other hand. The PC 3 indicated an increase in fractions larger than 2 mm with a decrease in fractions of 0.5–2 mm together with a decrease in the soil electrical conductivity, litter height, and soil density.

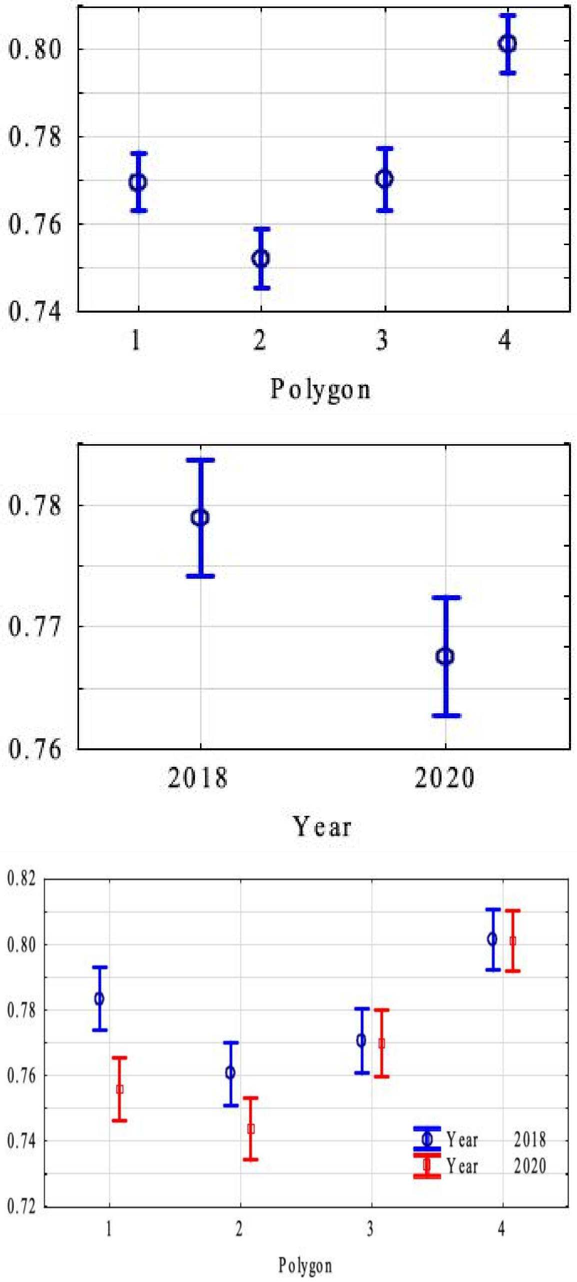


Fig. 2 Dependence of NDVI values (the ordinate axis) on the polygon, year, and interaction of year and polygon according to the results of factorial ANOVA.

The polygons had a specificity of soil properties, which largely depended on the reconstruction of the city park performed (Table 4). These predictors were able to explain 87% of the variation in PC 1. The PC 1 explained the variability of soil properties that were induced by park reconstruction ($F = 23.3$, $p = 0.04$) (Fig. 3). The PC 2 and 3 reflected a specific variation in the soil properties that had a different cause than park reconstruction ($F = 0.013$, $p = 0.92$ and $F = 0.06$, $p = 0.83$, respectively).

Discussion

The reconstruction of the park involved engineering renewal of walkways, clearing the shrub layer and undergrowth of trees, removing old diseased trees and cutting down non-viable tree branches. The technological processes were associated with the presence of a large number of workers and machinery in the park during the performance of the work. As a result, the soil was significantly affected due to compaction. The use of bulk density (BD) measurements taken at depths of up to 14 cm on a city-wide scale to compare the degree of surface soil compaction between different classes of urban green space and agricultural soils showed that in a typical British city, urban soils are in better physical condition than agricultural soils and can contribute to the provision of ecosystem services (Edmondson et al., 2011).

Our results reveal the favorable condition of the soils of the city park by the bulk density indicators in the upper layers. However, the use of the soil penetration resistance indicators shows that the soil compaction occurs to a significant depth up to 35 cm. This result leads to the conclusion that the measurement of soil penetration resistance has an advantage over the measurement of soil bulk density. The best strategy for evaluating soil compaction should be considered a combination of the soil bulk density and soil penetration resistance measurements. The vegetation canopies, especially tree crowns, can significantly regulate a solar energy input to the soil surface in the urban environments. The park reconstruction also included the removal of live branches on the outer canopy and old trees. The thinning of the tree canopy led to an increase in solar energy reaching the soil surface and a greater drying of the soil surface resulting in an increase in soil penetration resistance (Kimes & Smith, 1980; Arboit & Betman, 2017). Data of remote sensing of the Earth's surface allowed to understand the impact of the park reconstruction on the state of the vegetation cover.

The area of territories with high NDVI value, which correspond to dense old-growth tree plantations, strongly decreased in the reconstruction zone. It is also worth noting that such stands have become even more fragmented. The selected polygons are characteristic for assessing the impact of reconstruction on the soil cover. The polygons in the reconstruction zone were distinguished by a significant decrease in the NDVI index, while the polygons in the control zone did not differ significantly in this indicator. Thus, as a result of the reconstruction of the park, the changes in the structure of the vegetation cover lead to an increase in the penetration of solar energy and increase its amount, which reaches the soil surface.

The reconstruction of the park led to a variation in the soil properties, which overlapped with their patterns that existed before the reconstruction. The principal component analysis allowed to distinguish the fractions of soil property variability of the different origins. The principal component analysis revealed to identify the main trends of the coordinated variability of the soil features. The principal component 1 is obviously a reflection of the transformation of the soil properties, which occurred as a result of the reconstruction of an urban park. The principal components 2 and 3 indicate the polygon features that are independent of reconstruction. Thus, the variability induced by the park reconstruction is leading in the degree of influence on the soil properties because the principal component 1 describes the largest fraction of variation in soil features than the other components. A consequence of the effect on soil cover of park reconstruction is an increase in the soil penetration resistance, which takes place from the surface and gradually decays to a depth of 35 cm. There may be two reasons for this phenomenon. The impact on the soil of technological processes that occurred during the reconstruction of the park caused the compaction of the soil. Earlier it was shown, that the technological machines carry out significant impact on the soil, which exceeds in its size the visible boundaries of the wheel track.

This impact is manifested in the increase of the soil penetration resistance by 100–155 % in comparison with the control at the depth of 0–10 cm and by 20–30 % at the depth of 45–50 cm. It cannot be ruled out that the influence of the wheels continues deeper than the tests were conducted. It was also noted that a long period of the soil relaxation after a anthropogenic transformation can create a network of vehicle traces on the soil. In the area where the traces intersect, the negative effects increase significantly (Zhukov, 2015). Thus, the activities of construction and transport equipment during the reconstruction of the park may be the cause of an increase in soil compaction.

Also the reason for the increase in soil compaction may be a decrease in the density of the vegetation cover, which occurred after the implementation of the reconstruction project. The sparser vegetation cover is permeable to solar energy, which contributes to increased temperature and better ventilation. As a result, it is the surface soil layer that quickly dries out, which leads to an increase in the penetration resistance of the upper soil layer. This assumption is confirmed by the fact that the soil moisture in the reconstructed area was lower than that without reconstruction. The peculiarities of the variability of the aggregate structure can be explained by the technological influence on the soil. In the reconstruction zone, the proportion of aggregates less than 0.5 mm in size, which can be classified as microaggregates, increased. The reason for their emergence can be considered destruction of the larger aggregates (meso- and macroaggregates) as a result of technological activity. It should be noted that the increase in the proportion of micro-aggregates is a negative factor that deteriorates the properties of the soil as a habitat for living organisms (Zhukov et al., 2018; Zadorozhnaya et al., 2018).

Table 3. Descriptive statistics of the soil properties and the result of the principal component analysis.

Properties, mean±st. error	**Polygons**				**Correlation coefficient (only significant at $p < 0.05$ presented)**		
	1	**2**	**3**	**4**	**PC1**	**PC2**	**PC3**
Soil penetration resistance at a depth of, cm in MPa							
0–5	1.79±0.04	1.44±0.05	0.83±0.01	0.99±0.01	−0.86	0.17	0.10
5–10	2.45±0.06	1.88±0.07	1.05±0.01	1.2±0.02	−0.85	0.22	0.14
10–15	2.77±0.09	2.06±0.10	1.17±0.02	1.21±0.03	−0.81	0.30	0.19
15–20	2.73±0.09	1.97±0.09	1.33±0.04	1.19±0.03	−0.75	0.40	0.22
20–25	2.43±0.09	1.74±0.08	1.7±0.06	1.27±0.04	−0.53	0.57	0.34

25–30	2.25±0.09	1.75±0.06	2.23±0.08	1.46±0.05	–0.21	0.74	0.33
30–35	2.31±0.09	2.10±0.07	2.74±0.09	1.99±0.08	–	0.75	0.24
35–40	2.83±0.09	2.78±0.08	3.22±0.08	2.58±0.09	–	0.74	–
40–45	3.45±0.09	3.57±0.08	3.56±0.08	3.28±0.09	–	0.58	–0.37
45–50	4.04±0.08	4.13±0.08	3.76±0.07	3.79±0.07	–0.16	0.44	–0.61
50–55	4.33±0.06	4.53±0.06	4±0.07	4.23±0.06	–0.20	0.32	–0.71
55–60	4.64±0.04	4.77±0.05	4.36±0.05	4.53±0.05	–0.21	0.28	–0.77
60–65	4.87±0.04	4.91±0.05	4.62±0.05	4.75±0.04	–0.15	0.32	–0.80
65–70	4.9±0.03	4.99±0.04	4.75±0.04	4.89±0.03	–	0.26	–0.74
70–75	4.79±0.03	5.01±0.04	5.35±0.05	4.85±0.03	0.39	0.46	–0.47
75–80	4.7±0.03	4.88±0.04	5.63±0.06	4.86±0.03	0.59	0.47	–0.24
80–85	4.82±0.03	4.57±0.03	5.67±0.05	4.88±0.03	0.67	0.42	–0.14
85–90	4.99±0.02	4.15±0.03	4.53±0.04	4.98±0.02	0.16	–	–0.32
90–95	4.78±0.02	3.95±0.03	4.64±0.04	5.02±0.02	0.40	–	–0.22
95–100	4.23±0.03	3.95±0.03	4.79±0.04	5.10±0.03	0.69	––	–0.17
Aggregate fraction, in %							
>10 mm	0.06±0.003	0.05±0.002	0.13±0.006	0.07±0.003	0.59	0.36	0.33
7–10 mm	0.24±0.009	0.21±0.01	0.47±0.02	0.25±0.01	0.55	0.44	0.37
5–7 mm	0.31±0.01	0.46±0.02	0.67±0.02	0.37±0.02	0.47	0.42	0.30
3–5 mm	7.65±0.18	8.74±0.37	13.03±0.34	8.52±0.25	0.55	0.47	0.30
2–3 mm	17.84±0.29	17.94±0.41	20.48±0.45	19.94±0.42	0.43	0.26	0.17
1–2 mm	24.08±0.50	24.72±0.52	27.25±0.43	30.05±0.52	0.38	–0.27	–0.16
0.5–1 mm	16.64±0.34	18.53±0.53	19.19±0.50	20.05±0.43	0.11	–0.31	–0.28
0.25–0.5 mm	12.24±0.23	12.27±0.28	9.72±0.25	10.17±0.25	–0.53	–	–
<0.25 mm	21.00±0.76	16.54±0.58	8.82±0.35	10.23±0.47	–0.70	–	–
Other soil properties							
Electrical conductivity, dSm/m	0.45±0.006	0.41±0.008	0.29±0.007	0.35±0.007	–0.54	–	–0.16
Litter	3.47±0.06	2.26±0.06	1.83±0.05	3.54±0.05	–0.17	–0.42	–0.27
Wetness	25.87±0.31	21.57±0.39	30±0.18	27.83±0.21	0.75	–	–
Bulk density	1.01±0.01	1.09±0.008	0.8±0.006	0.89±0.006	–0.82	–	–0.13

Table 4. Nested design ANOVA results examining the effect of polygon and reconstruction (polygon nested in the reconstruction zone).

		Model			**Residual**				
Effect*	R^2_{adj}	**Sum-of-squares (SS)**	**Degrees of freedom**	**Mean squares (MS)**	**Sum-of-squares (SS)**	**Degrees of freedom**	**Mean squares (MS)**	***F*-ratio**	***p*-level**
PC1	0.87	0.75	0.75	2717.2	3	905.7	892.5	416	2.15
PC2	0.50	0.25	0.24	511.9	3	170.6	1566.6	416	3.77
PC3	0.29	0.09	0.08	157.0	3	52.3	1673.2	416	4.02

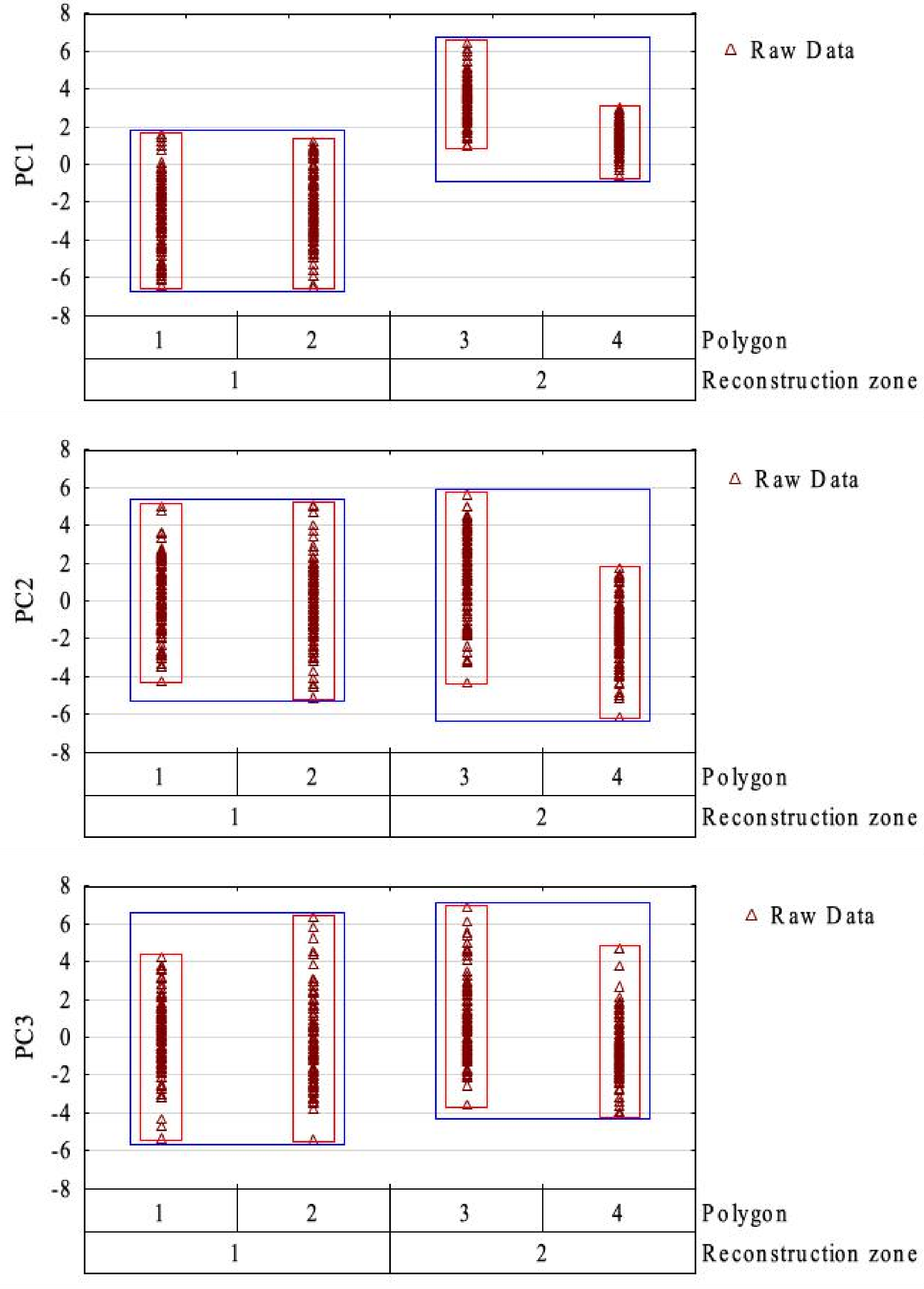


Fig. 3. Variation of the values of the principal components depending on the polygon and the effect of park reconstruction: the mean value and variance of the principal components are presented.

The risks of erosion processes also increase. Erosion can be a factor in the loss of fertility. In an urban environment, erosion processes can also accelerate the migration of toxic substances that are immobilized in the soil, which may have a secondary negative effect (Yorkina et al., 2019). The reconstruction area is located near a highway with active traffic. The electrical conductivity of the soil in this zone is higher, which may be due to the ingress of salt road de-icing agents on the soil surface.

Conclusion

The reconstruction of urban park provides many benefits for the residents of the city. The aesthetic perception of the area is improved and the comfort for recreation increases. The restoration of tree plantations should also be mentioned, which is an important component of the management of artificial forest plantations in the urban environment. However, the reconstruction of parks is associated with a number of negative effects on the soil cover. As a result of the technological processes that are carried out during the reconstruction process, the soil compactness increases to a considerable depth and the aggregate structure of the soil is disturbed. The thinning of the stand and the destruction of the shrub undergrowth greatly alter the microclimatic regime in the city park and increase the risks of excessive evaporation of water from the soil surface. These changes can have the negative consequences for the ecological services performed by the soil. Therefore, the measures to remediate the physical properties of the soil should be an obligatory element of the reconstruction of urban parks.

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