3 LAWN SOILS OF TORUŃ AND BYDGOSZCZ

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Introduction

Green areas are an integral component of urban landscape. Green spaces within cities and towns are created in areas deliberately excluded from construction in order to plant vegetation and create urban greenery units, or they are put aside for housing or industrial development in a distant future. Their location, dimensions and shape are included in the spatial development plans for the urban areas. According to Polish legislation, urban green areas such as parks, lawns and allotments play a recreational, health and aesthetic role. Green areas could be divided into the following groups:

- small and medium, up to 2 ha: backyard lawns, lawns of residential districts consisting of large blocks of flats, children's playgrounds, green squares and flowerbeds, roadside greenbelts and isolated plantings (especially trees);
- large, over 2 ha: parks, sports and recreation areas, cemeteries, arable lands, allotments, hospitals, monastery gardens and the like, educational gardens (zoological, botanical, arboretums) and communal forests.

Vegetation areas placed within the city boundaries play a very important role in functioning of urban ecosystems. Greinert (2000) distinguishes the following functions (among others): recreational, climatic (regeneration of the atmosphere), reserves of genes, separation of areas with different functions (residential, services, industrial, traffic and others), aesthetics (flowerbeds, ornamental lawns, hedges), educational resources for the natural sciences.

Lawns of different size are the most common type of greenery in Toruń and Bydgoszcz, and other Polish cities and towns.

Study area and soil profile documentation

Toruń is situated on flat river terraces, which are the most important element of the relief, together with small groups of dunes. During the expansion of the city, the dunes have been significantly transformed or destroyed by constructions (Niewiarowski, Weckwerth 2006). The largest areas in Toruń are represented by flat lands, which have developed as a result of filling of primary or secondary depressions and flattening of natural convex forms (e.g. dunes). According to Fedorowicz (1993), the thickness of downtown embankments ranges from 2.5 to 4.0 m, or even up to 7–8 m in places of medieval moats. Outside the City Centre, the embankment thickness is relatively smaller and ranges from 1.0 to 2.5 m.

Bydgoszcz is located in the north-western part of the Toruń Basin and in the mouth section of the Brda River Valley. In the north, the city is surrounded by till plains developed during the Weichselian glaciation (Kondracki 2000; Kozłowska, Kozłowski 1990). The central part of the city lies on the river terraces numbered by Galon (1961) from V to VIII. The surface of these terraces is covered by sediments of various grain sizes and ages, like Pliocene clays and silts, Pleistocene tills, sands and gravels (Kozłowska, Kozłowski 1990).

This chapter presents characteristics of eight soil profiles, representative of the lawn soil in Toruń and Bydgoszcz. The location of the study sites was presented in Figure 1. Pedons from Toruń were situated on the right bank of the Vistula River, near the city center. Three pedons from Bydgoszcz came from both banks of the Brda River, also in the city center, and one from the Bydgoszcz Canal Park, 3 km west. Analysis of soil samples collected from horizons and layers was performed according to international standards (van Reeuwijk 2006). In addition, the following parameters were determined:

- total phosphorus (P_t) by Bleck's method, modified by Gebhardt (1982),
- the content of heavy metals dissolved in 2M HNO_3 (Fe, Mn, Zn, Pb, Cd, Cu, Cr, Ni, Co) by atomic absorbance spectroscopy (AAS) after Desaules et al. 2001, the total content of Hg in solid phase on an AMA analyzer, and magnetic susceptibility (κ) determined at the Institute of Environmental Engineering of the Polish Academy of Sciences in Zabrze,
- fractional composition of humus by the method of Kononova and Belchikova (Kononova 1966).

Description of morphology of each profile can be found on next pages. Results of the analyses were presented in Tables 1–10. The studied soils were classified according to World Reference Base for Soil Resources (IUSS Working Group WRB 2007).

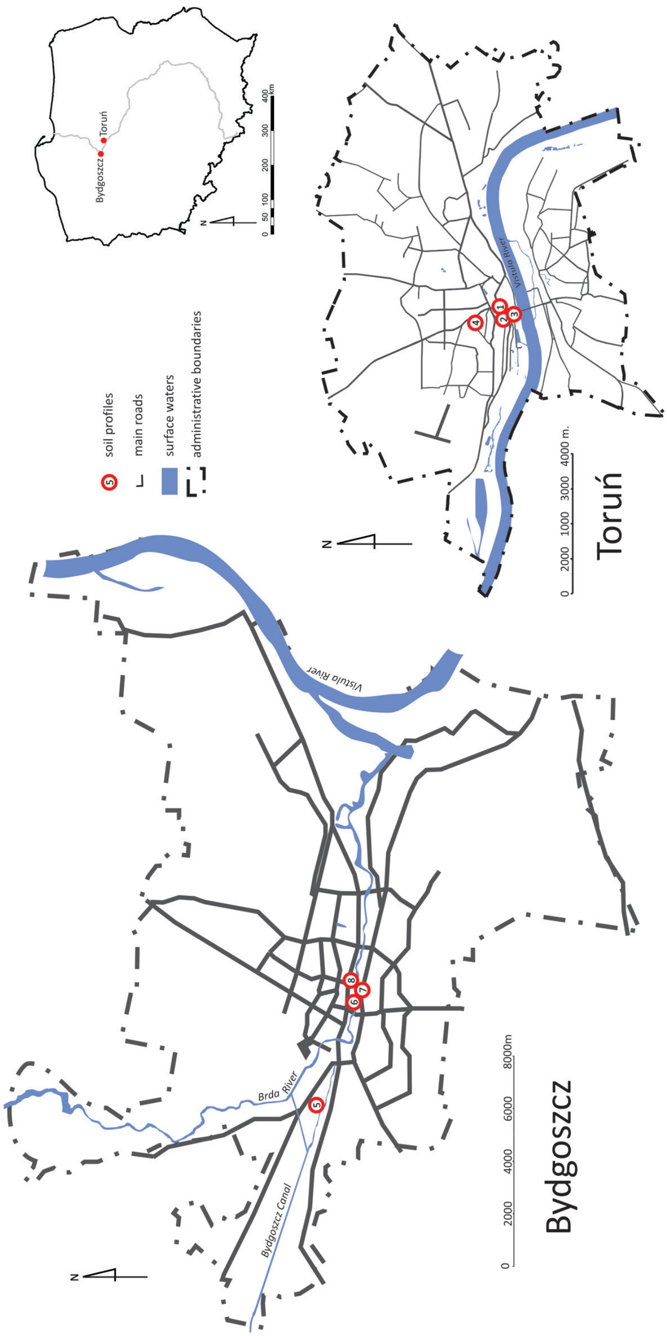
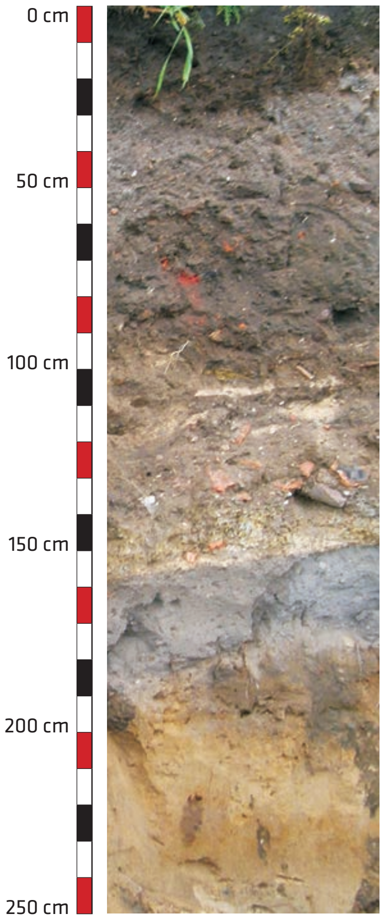


Fig. 1. Location of soil profiles in Bydgoszcz and Toruń Urban Areas

Profile 1

Location:
  Teatralny Sq.,
  Toruń,
  Northern Poland
Coordinates:
  53°00.522' N
  18°35.920' E
Soil classification (WRB 2007):
  Umbric Regosol



A1 – 0–30 cm: loamy sand, very dark greyish brown, granular structure, moist, artefacts (pieces of bricks; 1%), clear boundary.

A2 – 30–90 cm: loamy sand, dark olive grey, granular structure, moist, few artefacts (pieces of bricks, stones, bones; 3%), clear boundary.

Bu1 – 90–120 cm: loamy sand, olive brown, granular structure, slightly moist, interbeddings of loam and sand, few artefacts (pieces of bricks, charcoals; 5%), gradual boundary.

Bu2 – 120–155 cm: loam, light olive brown, blocky subangular structure, slightly moist, interbeddings of loam, common artefacts (pieces of bricks; 15%), abrupt boundary.

Ab – 155–185 cm: loamy sand, dark greyish brown, granular structure, moist, very few artefacts (charcoals; <1%) gradual boundary.

Bw – 185–240 cm: sand, yellowish brown, single grain structure, moist, soft iron concretions, artefacts (charcoals; <1%), gradual boundary.

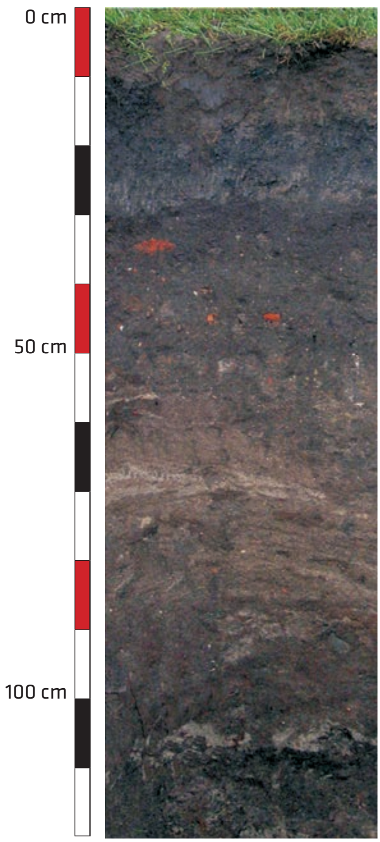
C – below 240 cm: sand, light grey, single grain structure, moist.

Table 1. Selected soil properties – profile 1

HORIZON		A1	A2	Bu1	Bu2	Ab	Bw	C
DEPTH [cm]		0–30	30–90	90–120	120–155	155–185	185–240	< 240
PARTICLE SIZE DISTRIBUTION [%]								
>2 mm		7	9	10	23	4	1	<1
2 mm–50 μm		86	87	84	49	86	94	99
50–2 μm		10	7	11	36	12	2	1
<2 μm		4	6	5	15	2	4	0
TEXTURE CLASS (USDA)		loamy sand	loamy sand	loamy sand	loam	loamy sand	sand	sand
SOIL MATRIX COLOUR	**dry**	2.5Y 3/2	5Y 3/2	2.5Y 4/3	2.5Y 5/4	10YR 4/2	10YR 5/6	2.5Y 7/1
	moist	2.5Y 2/1	5Y 2/2	2.5Y 3/3	2.5Y 4/4	10YR 2/2	10YR 4/6	2.5Y 5/3
BULK DENSITY $[g \cdot cm^{-3}]$		1.40	1.48	1.46	1.57	1.47	1.62	1.71
OC [%]		1.22	0.58	0.49	0.24	0.91	0.04	0.04
N_t [%]		0.100	0.045	0.039	0.029	0.064	0.005	0.004
C:N		12	13	13	8	14	–	–
pH	**in H_2O**	7.7	7.9	8.4	8.2	8,0	8.3	8.2
	in 1M KCl	7.3	7.6	7.7	7.2	7.5	7.6	6.9
$CaCO_3$ [%]		1.6	2.2	3.7	1,0	0.6	0.2	0.1
P_t $[mg \cdot kg^{-1}]$		1440	1540	1185	437	1250	159	80

Profile 2

Localition:
Rapacki Sq.,
Toruń,
Northern Poland
Coordinates:
53°00.661' N
18°36.007' E
Soil classification (WRB 2007):
Umbric Regosol (Humic)



A1 – 0–15 cm: humus horizon, sandy loam, dark greyish brown, granular structure, moist, clear boundary.

A2 – 15–25 cm: humus horizon, sandy loam, very dark grey, massive structure, moist, clear boundary.

Bu1 – 25–55 cm: loamy sand, very dark greyish brown, granular structure, slightly moist, inter-beddings of loam, few artefacts (pieces of bricks and tiles, charcoals; 5%), gradual boundary.

Bu2 – 55–105 cm: sand, very dark greyish brown, week granular structure, slightly moist, inter-beddings of dark loamy and light sandy material, very few artefacts (pieces of bricks; <1%), gradual boundary.

Ab – 105–110 cm: sand, very few iron concretions, gradual boundary.

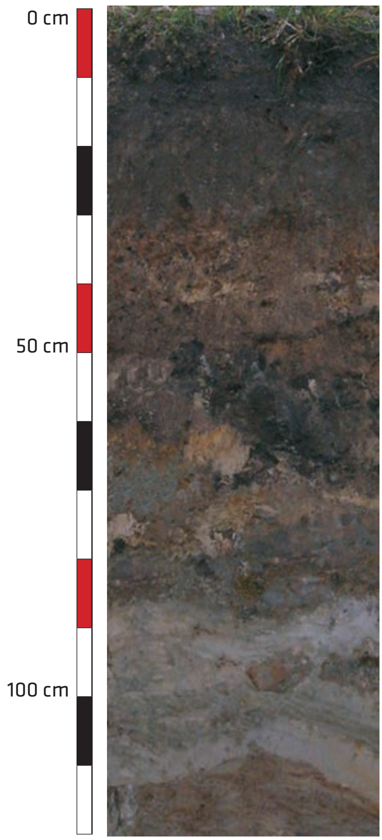
Ab/Bb – 110–120 cm: sand, few iron concretions.

Table 2. Selected soil properties – profile 2

HORIZON		A1	A2	Bu1	Bu2
DEPTH [cm]		0–15	15–25	25–55	55–110
PARTICLE SIZE DISTRIBUTION [%]					
>2 mm		2	10	12	10
2 mm–50 μm		71	48	85	92
50–2μm		24	46	12	6
<2 μm		5	6	3	2
TEXTURE CLASS (USDA)		sandy loam	sandy loam	loamy sand	sand
SOIL MATRIX COLOUR	**dry**	2.5Y 4/2	10YR 3/1	2.5Y 3/2	2.5Y 3/2
	moist	2.5Y 3/2	10YR 2/1	5Y 2/2	5Y 2/2
BULK DENSITY [$g \cdot cm^{-3}$]		1.52	1.21	1.47	1.56
OC [%]		1.44	3.23	0.25	0.82
N_t [%]		0.130	0.331	0.024	0.068
C:N		11	10	10	12
pH	**in H_2O**	7.7	8.0	8.5	8.1
	in 1M KCl	7.3	7.6	8.2	7.7
$CaCO_3$ [%]		1.0	0.4	3.2	3.4
P_t [$mg \cdot kg^{-1}$]		580	1550	636	1070

Profile 3

Location:
'Dream Valley' City Park,
Toruń,
Northern Poland
Coordinates:
53°00.522' N
18°35.920' E
Soil classification (WRB 2007):
Mollic Regosol (Humic)



A – 0–30 cm: loamy sand, very dark greyish brown, granular structure, moist, gradual boundary.

Bu1 – 30–50 cm: sand, olive brown, single grain structure, slightly moist, very homogeneous sandy material, common soft concretions of iron, gradual boundary.

Bu2 – 50–65 cm: loamy sand, dark brown, massive structure, slightly moist, mottling, clear boundary.

Bu3 – 65–85 cm: sandy loam, olive brown, blocky angular structure, slightly moist, few artefacts (pieces of cobblestone; 2%), gradual boundary.

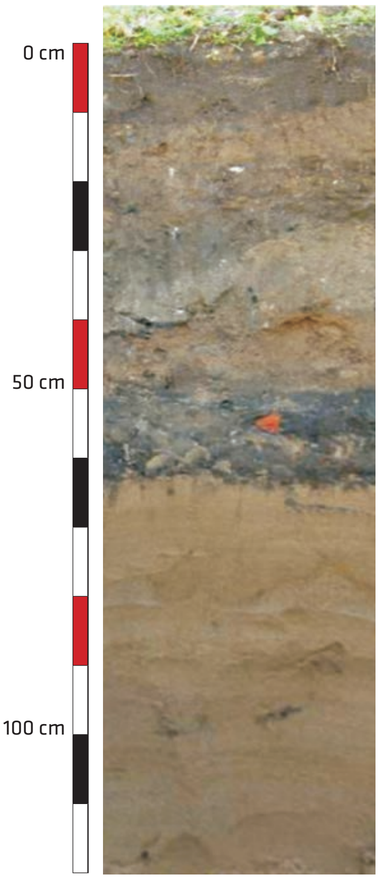
C – below 85 cm: sand, light brownish grey, week granular structure, slightly moist, interbeddings of loam.

Table 3. Selected soil properties – profile 3

HORIZON		A	Bu1	Bu2	Bu3	C
DEPTH [cm]		0–30	30–50	50–65	65–85	< 85
PARTICLE SIZE DISTRIBUTION [%]						
>2 mm		9	15	6	10	1
2 mm–50 μm		80	91	85	64	95
50–2 μm		15	7	11	25	2
<2 μm		5	2	4	11	3
TEXTURE CLASS (USDA)		loamy sand	sand	loamy sand	sandy loam	sand
SOIL MATRIX COLOUR	**dry**	2.5Y 3/2	2.5Y 4/3	10YR 3/3	2.5Y 4/3	2.5Y 6/2
	moist	2.5Y 3/2	2.5Y 3/3	10YR 2/2	2.5 Y 3/3	2.5Y 4/3
BULK DENSITY [$g \cdot cm^{-3}$]		1.60	1.73	1.63	1.80	1.70
OC [%]		1.33	0.17	0.54	0.29	0.05
N_t [%]		0.101	0.017	0.049	0.018	0.003
C:N		13	10	11	16	–
pH	**in H_2O**	7.9	8.1	8.1	8.5	8.9
	in 1M KCl	7.4	7.6	7.6	7.8	8.6
$CaCO_3$ [%]		1.1	0.4	1.1	4.9	3.9
P_t [$mg \cdot kg^{-1}$]		980	972	1450	727	311

Profile 4

Location:
Bema St.,
Toruń,
Northern Poland
Coordinates:
53°01.145' N
18°35.690' E
Soil classification (WRB 2007):
Haplic Regosol (Arenic)



A – 0–12 cm: sand, very dark greyish brown, granular structure, moist, clear boundary.

Bu – 12–50 cm: sand, greyish brown, blocky subangular structure, slightly moist, few artefacts (pieces of bricks, tiles, wire, flakes of dried paint, charcoals; 2%), interbeddings of loam, few roots, clear boundary.

Ab1 – 50–55 cm: sand, dark greyish brown, granular structure, slightly moist, very few artefacts (pieces of bricks, glass, charcoals; 3%), gradual boundary.

Ab2 – 55–63 cm: sandy loam, light olive brown, granular structure, slightly moist, abrupt boundary.

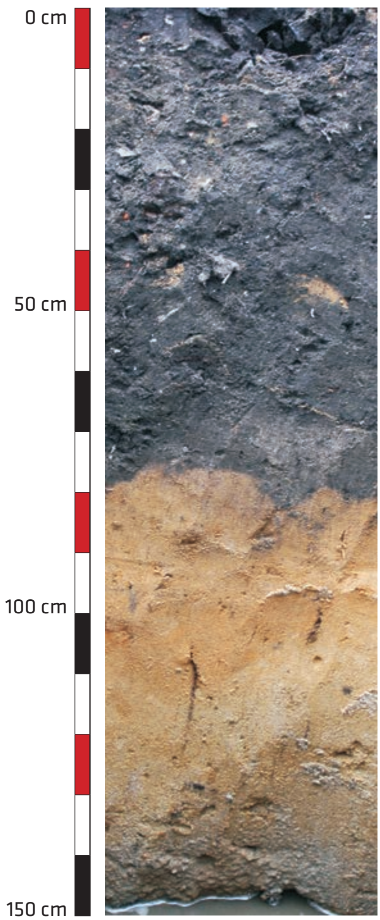
C – below 63 cm: sand, pale yellow, single grain structure, slightly moist.

Table 4. Selected soil properties – profile 4

HORIZON		A	Bu	Ab1	Ab2	C
DEPTH [cm]		0–12	12–50	50–55	55–63	< 63
PARTICLE SIZE DISTRIBUTION [%]						
>2 mm		6	19	15	35	<1
2 mm–50 µm		89	92	88	62	98
50–2µm		11	4	8	30	1
<2 µm		0	4	4	8	1
TEXTURE CLASS (USDA)		sand	sand	sand	sandy loam	sand
SOIL MATRIX COLOUR	**dry**	10YR 3/2	2.5Y 5/2	10YR 4/2	2.5Y 5/3	2.5Y 7/4
	moist	10YR 2/2	2.5Y 3/2	10YR 2/2	2.5Y 4/3	2.5Y 6/6
BULK DENSITY [$g \cdot cm^{-3}$]		1.49	1.53	1.93	1.85	1.74
OC [%]		2.02	0.60	0.88	0.96	0.02
N_t [%]		0.162	0.028	0.044	0.070	0.002
C:N		12	21	20	14	–
pH	**in H_2O**	6.8	8.4	8.2	8.1	8.0
	in 1M KCl	6.4	8.1	7.8	7.4	7.4
$CaCO_3$ [%]		–	3.2	1.8	1.2	1.0
P_t [$mg \cdot kg^{-1}$]		927	390	752	579	109

Profile 5

Location:
‘Bydgoszcz Canal’ City Park,
Bydgoszcz,
Northern Poland
Coordinates:
N 53°07’16.3’’
E 17°57’47.9’’
Soil classification (WRB 2007):
Mollic Regosol (Technic)



Au – 0–6 cm: sandy loam, dark grey, granular structure, moist, clear boundary.

Bu1 – 6–24 cm: sandy loam, dark grey, blocky subangular structure, moist, numerous artefacts (pieces of bricks, concrete, glass, garbage), gradual boundary.

Bu2 – 24–51 cm: sandy loam, dark grey, blocky subangular structure, moist, few artefacts (bricks, concrete, glass), numerous snail shells, gradual boundary.

Bu3 – 51–80 cm: loamy sand, grey, blocky subangular structure, moist, few artefacts and shells, clear boundary.

Bw – 80–98 cm: sand, brownish yellow, single grain structure, moist, homogeneous sandy material, no artefacts and shells, diffuse boundary.

C – 98–126 cm: sand, very pale brown, single grain structure, moist, homogeneous sandy material, no artefacts and shells, gradual boundary.

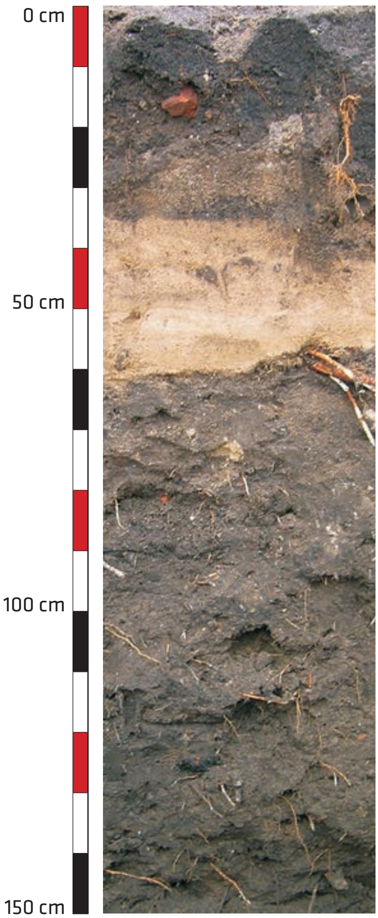
Cg – 126–150 cm: sand, light grey, single grain structure, very wet, homogeneous sandy material.

Table 5. Selected soil properties – profile 5

HORIZON		Au	Bu1	Bu2	Bu3	Bw	C	Cg
DEPTH [cm]		0–6	6–24	24–51	51–80	80–98	98–126	126–150
PARTICLE SIZE DISTRIBUTION [%]								
>2 mm		6	25	11	7	1	6	9
2 mm–50 μm		56	62	59	76	88	89	94
50–2 μm		41	34	38	23	11	10	6
<2 μm		3	4	3	1	1	1	0
TEXTURE CLASS (USDA)		sandy loam	sandy loam	sandy loam	loam sand	sand	sand	sand
SOIL MATRIX COLOUR	**dry**	10YR 4/1	10YR 4/1	10YR 4/1	10YR 5/1	10YR 6/8	10YR 7/4	10YR 7/2
	moist	10YR 2.5/1	10YR 3/1	10YR 3/1	10YR 4/1	10YR 4/6	10YR 5/6	10YR 6/1
OC [%]		3.75	2.15	3.60	1.10	0.19	0.03	0.01
N_t [%]		0.310	0.110	0.262	0.098	0.007	0.005	0.004
C:N		12	20	14	11	27	–	–
pH	**in H_2O**	7.2	7.8	7.6	7.4	7.3	7.4	7.7
	in 1M KCl	7.1	7.5	7.5	7.3	7.2	7.3	7.5
$CaCO_3$ [%]		5.6	4.3	7.5	1.1	0.3	0.3	0.3

Profile 6

Location:
Bernardyńska St.,
Bydgoszcz,
Northern Poland
Coordinates:
N 53°07’15.2’’
E 18°00’24.4’’
Soil classification (WRB 2007):
Haplic Regosol (Technic)



Au – 0–35 cm: sandy loam, very dark grey, granular structure, slightly moist, numerous (>10%) artefacts (pieces of bricks, concrete, glass), clear boundary.

Bu1 – 35–60 cm: sand, light yellowish brown, single grain structure, slightly moist, few artefacts (pieces of bricks, glass, garbage), homogeneous sandy material, abrupt boundary.

Bu2 – 60–97 cm: sandy loam, greyish brown, blocky subangular structure, slightly moist, numerous artefacts (pieces of bricks, concrete, glass) and roots, diffuse boundary.

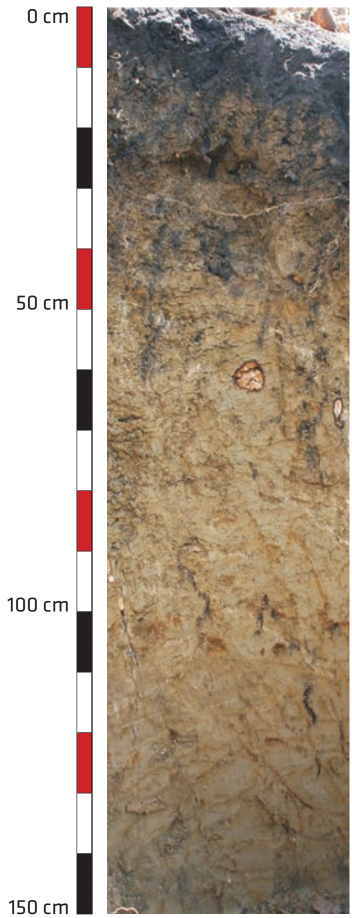
Bu3 – 97–150 cm: sandy loam, greyish brown, blocky subangular structure, slightly moist, a lot of artefacts (pieces of bricks, concrete, glass) and roots.

Table 6. Selected soil properties – profile 6

HORIZON		Au	Bu1	Bu2	Bu3
DEPTH [cm]		0–35	35–60	60–97	97–150
PARTICLE SIZE DISTRIBUTION [%]					
>2 mm		5	4	21	18
2 mm–50 μm		68	96	65	66
50–2μm		30	4	32	31
<2 μm		2	0	3	3
TEXTURE CLASS (USDA)		sandy loam	sand	sandy loam	sandy loam
SOIL MATRIX COLOUR	**dry**	10YR 3/1	10YR 6/4	10YR 5/2	10YR 5/2
	moist	10YR 2/1	10YR 4/4	10YR 3/1	10YR 3/1
OC [%]		2.51	0.01	1.01	1.07
N_t [%]		0.167	0.001	0.066	0.064
C:N		15	10	15	17
pH	**in H_2O**	7.8	8.0	7.9	8.0
	in 1M KCl	6.9	7.8	7.6	7.7
$CaCO_3$ [%]		1.1	0.7	3.0	1.5

Profile 7

Location:
'Wzgórze Wolności' City Park,
Bydgoszcz,
Northern Poland
Coordinates:
N 53°07'02.7''
E 18°00'47.1''
Soil classification (WRB 2007):
Regosol (Siltic)



A – 0–8 cm: silty loam, dark grey, granular structure, slightly moist, clear boundary.

A/B – 8–33 cm: silty loam, light yellowish brown, blocky angular structure, slightly moist, single roots, gradual boundary.

Ck1 – 33–49 cm: silty loam, pale yellow, blocky angular structure, slightly moist, few carbonate coatings on peds, few medium roots, gradual boundary.

Ck2 – 49–97 cm: silty loam, pale yellow, blocky angular structure, slightly moist, a lot of carbonate and iron coatings on peds, common fine roots, diffuse boundary,

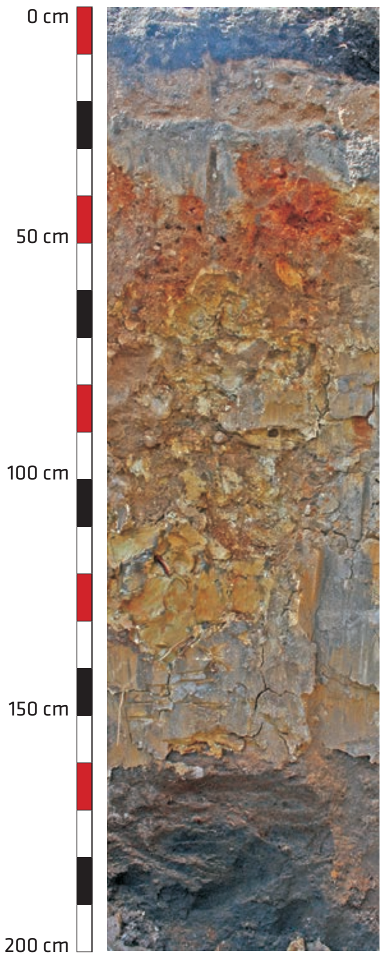
Ck3 – 97–150 cm: silty loam, pale yellow, blocky angular structure, slightly moist, few carbonate and iron coatings on peds.

Table 7. Selected soil properties – profile 7

HORIZON		A	A/B	Ck1	Ck2	Ck3
DEPTH [cm]		0–8	8–33	33–49	49–97	97–150
PARTICLE SIZE DISTRIBUTION [%]						
>2 mm		1	2	1	1	1
2 mm–50 μm		34	31	32	34	32
50–2μm		61	62	61	60	62
<2 μm		5	7	7	6	6
TEXTURE CLASS (USDA)		silty loam	silty loam	silty loam	silty loam	silty loam
SOIL MATRIX COLOUR	**dry**	2.5Y 4/1	2.5Y 6/4	2.5Y 7/4	2.5Y 7/3	2.5Y 7/4
	moist	2.5Y 3/1	2.5Y 4/4	2.5Y 6/4	2.5Y 6/3	2.5Y 6/4
OC [%]		4.49	0.41	0.11	0.26	0.06
N_t [%]		0.316	0.031	0.019	0.026	0.016
C:N		14	13	–	–	–
pH	**in H_2O**	7.1	8.1	8.3	8.3	8.1
	in 1M KCl	6.5	7.2	7.3	7.5	7.5
$CaCO_3$ [%]		0.6	1.3	2.2	4.6	2.3

Profile 8

Location:
'Brda promenade' Jagiellońska St.
Bydgoszcz,
Northern Poland
Coordinates:
N 53°07'16.3''
E 18°01'00.7''
Soil classification (WRB 2007):
Regosol (Endosiltic)



Au – 0–15 cm: sandy loam, very dark grey, granular structure, slightly moist, few artefacts (concrete, bricks, glass, slag, asphalt, charcoals), clear boundary.

Bu1 – 15–28 cm: sand, light yellowish brown, single grain structure, dry, no artefacts, homogeneous sandy material, clear boundary.

Bu2 – 28–36 cm: sandy loam, grey, blocky subangular structure, dry, common artefacts (bricks, glass, slag, asphalt, tar, charcoals), clear boundary.

Bu3 – 36–42 cm: sand, light yellowish brown, single grain structure, dry, no artefacts, homogeneous sandy material, gradual boundary.

Buw – 42–65 cm: sand, yellowish red, single grain structure, dry, dominant iron coatings and concretions, gradual boundary.

Ck1 – 65–109 cm: silty loam, pale yellow, blocky angular structure, moist, many mottles, diffuse boundary.

Ck2 – 109–160 cm: silty loam, pale yellow, blocky angular structure, moist, abundant mottles, clear boundary.

2C – 160–200 cm: sandy loam, dark greyish brown, blocky subangular structure, wet, few iron concretions.

Table 8. Selected soil properties – profile 8

HORIZON		Au	Bu1	Bu2	Bu3	Buw	Ck1	Ck2	2C
DEPTH [cm]		0–15	15–28	28–36	36–42	42–65	65–109	109–160	160–200
PARTICLE SIZE DISTRIBUTION [%]									
>2 mm		14	22	21	9	13	0	0	0
2 mm–50 μm		60	90	71	87	88	15	11	55
50–2μm		37	9	26	11	11	70	69	42
<2 μm		3	1	3	2	1	15	20	3
TEXTURE CLASS (USDA)		sandy loam	sand	sandy loam	sand	sand	silt loam	silt loam	sandy loam
SOIL MATRIX COLOUR	**dry**	2.5Y 3/1	2.5Y 6/4	2.5Y 5/1	2.5Y 6/4	5YR 4/6	2.5Y 7/4	2.5Y 7/4	2.5Y 4/2
	moist	2.5Y 2.5/1	2.5Y 4/4	2.5Y 3/1	2.5Y 5/3	5YR 3/4	2.5Y 6/3	2.5Y 6/3	2.5Y 3/1
OC [%]		11.1	0.01	2.44	0.06	0.16	0.24	0.04	1.73
N_t [%]		0.763	n.d.	0.083	0.006	0.024	0.067	0.064	0.206
C:N		15	–	29	10	–	–	–	–
pH	**in H_2O**	8.0	8.9	8.0	8.2	8.0	7.6	7.7	7.4
	in 1M KCl	7.4	8.5	7.4	7.9	7.7	7.1	7.1	7.1
$CaCO_3$ [%]		4.5	4.2	0.7	0.3	0.4	2.8	0.9	1.8

General properties of the studied soils

All of the tested soils from Toruń had a texture of sand or loamy sand. This is related to Toruń location on sandy terraces of the Vistula River. Loamy or sandy loamy horizons were also present: in topsoil (profile 2) or deeper (from 50 to 150 cm, other profiles) – Tables 1–4. The investigated soils from Bydgoszcz were much more diversified in texture. Profiles 5 and 6 had a texture of sandy loams and sands, profile 7 was silt loam in the entire profile, and profile 8 was the most varied with texture – from sands to silt loam (Tables 5–8). It was the result of lithogenesis and technogenic impact on the Bydgoszcz environment.

According to Munsell Soil Color Charts (2000), the hue of genetic horizons and layers in profiles ranged from 2.5 to 10.5 YR, with 2.5Y as the most common one. This value occurred in 24 samples. Large differences in colour between levels were associated with their large variety and diversity of the material, often even within a single layer (Tables 1–8).

The range of bulk density in tested soils was from 1.21 to 1.93 $g \cdot cm^{-3}$. The relatively high density of subsurface layers can be associated with preparations of the lawn soil (compaction to reduce permeability). Large variability in physical properties is an effect of heterogeneous morphology of the urban soils.

The soil reaction was closely related to the content of organic matter. Values of pH were between 6.8 and 8.9 (in H_2O) and between 6.4 and 8.6 (in 1M KCl). There was no clear vertical pH trend in the examined profiles.

The $CaCO_3$ content in the individual profiles was varied and ranged from 0.1% to 7.5%. No significant relations between the pH values measured in 1M KCl and carbonate content were found.

The highest organic carbon (OC) content was in the surface horizons. The content of OC in non-A horizons varied. The increase in OC content was observed at certain depths in all profiles. It was connected with the presence of material from older surface horizons. The content of total nitrogen (N_t) corresponded with the organic carbon distribution in individual profiles. Values of the carbon to nitrogen ratio were up to 29; in most cases – from 10 to 14. The narrow range of the C:N ratio is an effect of lawn treatments and fertilization. This allows to maintain high biological efficiency of these soils.

The total phosphorus (P_t) content was different in each analyzed soil. The highest value was observed in profile 1 (80–1550 $kg \cdot mg^{-1}$). This pit was located in the direct neighbourhood of the remains of a medieval church and in the area of an old cemetery.

The percentage ratio of humic and fulvic acids in humus horizons of the examined Toruń soils was similar in most of the analyzed samples, and was close to 1:1, with a slight predominance of fulvic acids. Different values were found only in samples from profile 1, the fractional composition of which was dominated by humic acids. A significant difference was found in Ab horizon due to a high level of organic matter decomposition in this buried horizon (decomposed fulvic acids) – Fig. 2.

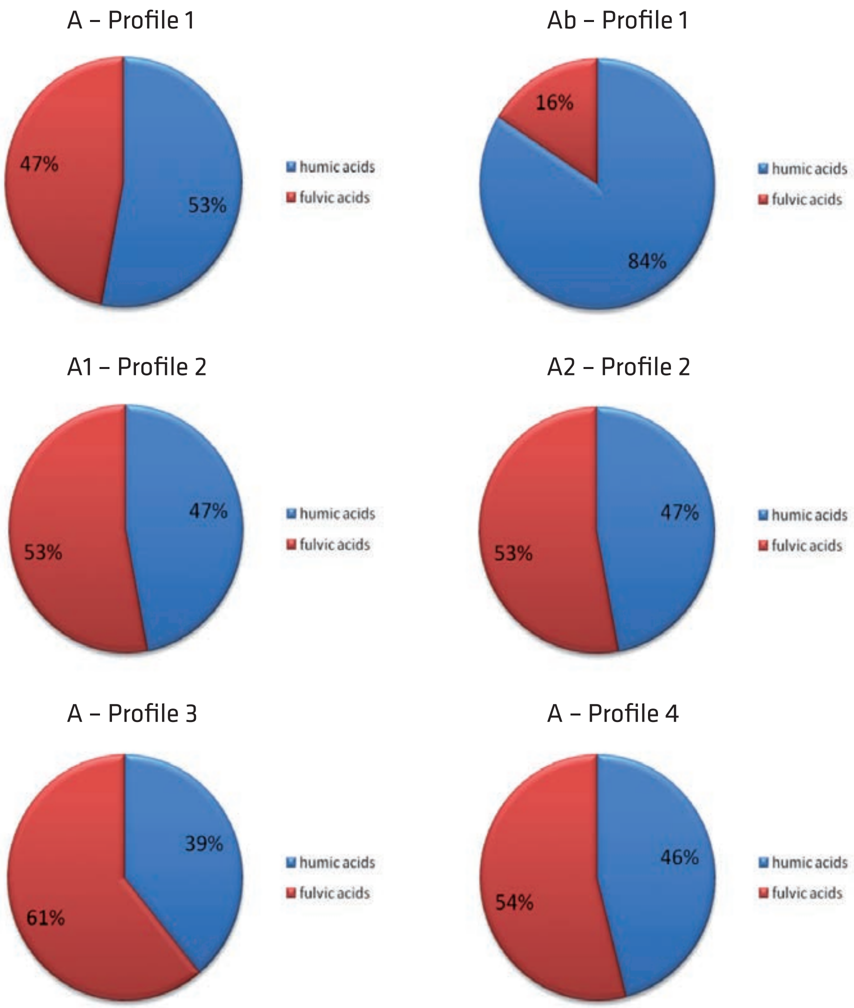


Fig. 2. Percentage of humic and fulvic acids in humus horizons of the examined soils in Toruń

Comparison of the results with similar studies in Germany showed a few differences between German and soils investigated in our study. The bulk density of soil in Stuttgart was almost twice as high in the surface horizons, and in the lower horizons – much lower than in Toruń. The results of total nitrogen analysis also showed some differences. The N_t values were higher in the German city of Stuttgart (Lorenz, Kandel 2005) than in Toruń and Bydgoszcz. Carbon and nitrogen content was also higher in the German city of Kiel, however, the ratio of carbon to nitrogen was at a similar level (Beyer et al. 1994). These differences may result from different methods of lawn cultivation. The increased density may be connected with the use of tractors for mowing and the increased nitrogen content - with the use of higher amounts of fertilizers. Hong Kong urban soils had similar properties as soils in Toruń, especially in the case of pH and the content of OC and N_t (Jim 1998).

Heavy metals and magnetic susceptibility

In most cases, the content of heavy metals (soluble in 2M HNO_3) did not exceed the Polish standards defined in the Regulation of the Minister of the Environment (2002). As shown in tables 9 and 10, the content of zinc and the content of cadmium slightly exceeded the limit values only in profiles 5 and 8, respectively. Local Zn contamination of soils in Bydgoszcz is confirmed in long-term research conducted in the most green areas of the city. The content of this element ranged from 20 to 896 $mg \cdot kg^{-1}$ (Malczyk et al. 1996; Dąbkowska-Naskręt, Różański 2002, 2006, 2009). Among the analysed metals, only Mn, Zn, Pb and Cu were significantly positively correlated (at $p<0.05$) with magnetic susceptibility (κ) – Table 9.

A similar content of heavy metals in urban soils of Gorzów and Zielona Góra (Western Poland) was reported by Greinert (2000, 2003). The origin of these pollutants may be associated with artefacts that often occur in urban soils (pipes, cables, foundations, paints and their components). In the soils of Bydgoszcz, the vicinity of contamination sources, such as heat and power plants and heavy traffic, also influence the content of heavy metals (Dąbkowska-Naskręt, Różański 2007, 2009). Also other parameters of the Zielona Góra soils had characteristics similar to the soils of Toruń and Bydgoszcz (bulk density, pH in H_2O, OC content).

The soils investigated by Sobocká in Bratislava (Sobocká et al. 2004) showed some discrepancies in the content of heavy metals compared to soils in Toruń. The content of cobalt, copper, manganese and nickel was higher in Toruń soils, in contrast to the content of cadmium, chromium and lead, which was higher in Bratislava. However, these differences were not very large. When comparing the studied soils to those from Stockholm, the content of heavy metals was higher in the latter (Linde et. al. 2007). The mean content of Pb, Cu, Ni, Cr and Zn in lawn soils of Toruń was lower than in soils of Nanjing (Lu et al. 2003) and Beijing (Chen et al. 2005). In the case of Pb, it was over 4 times less than in Beijing and 10 times less than in Nanjing. The mean content of Zn was over 2 times higher in Beijing and over 5 times higher in Nanjing. Both Bejing's and Nanjing's soils have a similar mean content of Cu, which was over 6 times higher compared to Toruń. The analyzed lawn soils compared to similar soils in the cities of Tuscany (Bretzel, Calderisi 2006), Uppsala (Ljung et. al. 2006), New Castle (Rimmer 2006) and Xuzhou (Xue-Song, Yong 2006) are less contaminated with heavy metals. This may be related to relatively low industrialization of Toruń, the main function of which are services, especially educational ones.

Table 9. Total content of selected heavy metals (HM) and magnetic susceptibility (κ) in the examined profiles from Toruń, and Pearson correlation coefficient (κ:HM)

Depth [cm]	κ [10^{-8} $m^3 \cdot kg^{-1}$]	Fe	Mn	Zn	Pb	Cd	Cu	Cr	Ni	Co
		HM [$mg \cdot kg^{-1}$]								
Profile 1										
0–30	41	3450	212	39	62	0.33	34.0	2.0	4.5	2.3
30–120	50	3330	227	23	66	0.23	52.0	1.5	4.3	3.0
Profile 2										
0–15	17	3250	151	22	10	0.16	7.9	2.7	4.4	2.4
15–25	44	7470	271	109	30	1.02	60.0	5.0	23.0	9.2
Profile 3										
0–25	42	7830	1047	29	18	0.28	7.0	1.7	6.5	4.7
25–45	10	9070	833	8.8	6.1	0.15	2.3	2.0	4.1	3.7
Profile 4										
0–12	27	5100	215	48	20	0.28	8.5	1.9	2.8	1.8
12–50	57	2073	980	69	19	0.20	8.4	1.4	3.3	1.8
MEAN		5197	492	43	29	0.33	22.5	2.28	6.6	3.6
SD		2597	388	32	23	0.29	22.9	1.17	6.7	2.5
κ:HM		-0.44	0.15	0.52	0.55	0.28	0.50	-0.08	0.20	0.12

In comparison to Toruń soils, only the content of Zn and Ni was significantly higher in Bydgoszcz soils – 4 and 2 times, respectively. Nevertheless, due to alkaline reaction of the analysed soils, most of the heavy metals are represented by immobile forms (Hanna et al. 2009; Martinez, Motto 2000), which was confirmed in the recent research by Dąbkowska-Naskręt and Różański (2009) on Zn and Pb in Bydgoszcz soils. This situation, in contrast to Toruń, may result from the presence of such industry as heat and power plants, chemical plants as well as heavier road and rail traffic compared to Toruń. It is especially visible in the case of mercury content, i.e. 1.40 $mg \cdot kg^{-1}$, a typical value for Bydgoszcz (Dąbkowska-Naskręt, Różański 2007; Różański, Dąbkowska-Naskręt 2011).

Table 10. Total content of selected heavy metals in the examined profiles from Bydgoszcz

Depth [cm]	Fe	Mn	Zn	Pb	Cd	Cu	Ni	Hg
	[mg·kg^{-1}]							
Profile 5								
0–6	2750	288	423	69.6	0.30	37.9	19.1	0.18
6–24	2745	425	436	56.2	0.05	47.1	19.2	0.16
Profile 6								
0–35	3969	141	182	58.6	0.35	46.0	12.7	1.40
35–60	1333	296	8.0	2.2	1.31	3.3	2.9	0.02
Profile 7								
0–8	2912	249	97	29.6	1.35	23.3	24.2	0.13
8–33	2391	254	38	2.5	0.94	15.9	20.1	0.07
Profile 8								
0–15	3561	239	72	34.7	4.77	25.2	14.0	0.29
15–28	1528	271	7.0	0.2	2.18	22.7	0.8	0.02
MEAN	2649	270	158	31.7	1.41	27.7	14.1	0.28
SD	904	79	177	28	1.53	15.1	8.4	0.46

Summary

Except for profile 7, the analysed soils exhibited all the characteristics of urbanosols which were specified by Gerasimova et al. (2003). All these soil profiles were characterized by the presence of horizons (layers), the origins of which can be linked to human activity. These were often heterogeneous, disturbed layers with numerous artefacts, such as fragments of bricks, concrete, asphalt, glass and bones, metal elements. Transitions between levels were often sharp, which proved their artificial origin. Generally, the material in adjacent layers was characterized by different physical and chemical properties, colour, etc., which can also be related to their technogenic origin. Lawn soils have some common features but also some differences. They are basically determined by the history and the type of land use of the area where a given lawn is located. As compared to other cities, in most cases, the content of heavy metals was relatively low, and close to natural values. The increased concentration of metals was recorded only in a few profiles, and in several others, the content was at the contamination level.

This study was partly financed by Polish Ministry of Science and Higher Education (grant No. N N306 463738).

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