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ORIGINAL PAPER

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Impact of urbanisation on soil characteristics

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Abstract Six forest locations were chosen from urban (U) and semi-urban (SU) zones of Sofia, Bulgaria. Soil profiles characterised for their generic physico-chemical properties: particle size distribution, pH, C-content (%) and N-content (%). From the ratio silt/clay and C/N, significant differences were observed for the Ah horizon in the urban and semi-urban locations. Clay formation appeared to be reduced in this horizon in the urban soils and the C-content is higher in semi-urban soils in comparison with the urban soils. On the base of the results obtained, a reduction of the buffering capability is noted for the topsoil of the urban sites compared to the semi-urban sites.

Keywords Urban soils · Silt/clay ratio · C/N ratio

Introduction

The degree of urbanization changes the functioning of natural ecosystems, the ecological balance and provokes the expression of new qualitative characteristics. The specific micro-climate conditions in the cities also contribute the changes in soils as an important component of urban environment (Scharenbroch et al. 2005). The determination of the characteristics and specific properties of soils is of a great importance for the soil science and human health (Simpson 1996). The soils in the cities are very variable and on one hand have characteristics close to the characteristics of natural soils and on the other hand soils formed totally as a result of human activity. Generally the urban soils show differences in comparison with the soils in natural ecosystems (Kabata-Pendias and Pendias 1992) and for many soil quality parameters the intrinsic local scale variability can be significant (Hursthouse et al. 2004). The dynamic nature of the use and reuse of land through urban development also results in the addition of materials from a variety of sources (Rosenbaum et al. 2003; Markiewicz-Patkowska et al. 2005). As a consequence the range of specific indicators of urban impacts in the upper layers of soils could be summarized as: presence of dust and materials from the buildings, imported soils and other materials with low differentiation of clay; changes in physical-chemical properties: lower water capacity and higher compaction of the soil; tendency to become alkaline and higher CEC; enrichment with organic wastes, potentially toxic elements, organic compounds and residues.

There exist numerous data sets on the chemical contamination of urban soils, but with little regard to the soil as a living medium and its response to changes in external factors and role in the urban ecosystem. In particular an assessment of basic soil properties in addition to those potentially hazardous to human health is lacking (Hursthouse et al. 2004).

The purpose of this study was to compare the quality of the soils in urban and semi-urban plots under a similar land use (oak ecosystems), by studying a range of basic soil properties. The indicators used covered features sensitive to soil profile development and readily impacted upon by urban activities. Very little data is available for comparison of the impact of the urban activity on soil. So these sites were selected to reflect areas within and out with strong urban activity.

Experimental

In the study are included six sites, which are chosen as a part of the global biodiversity project "Globnet" (Niemelä et al. 2000). The Sofia region has a plain–hilly relief, temperate climate (mean annual temperature = 13.2°C), with predominance of west and east winds. The soil parent materials are mainly crystalline schist, granodiorites, and Mesozoic sediments (sandstone, dolomites and limestone)

The sampling locations were selected to cover a geographical spread away from the main urban area and where

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urban and semi urban sites could be selected in the same compass direction, within zones containing similar parent material. The three urban forest parks (U1-3) and three semi-urban forest locations (SU1-3) used were

U1—The Boris garden: the largest park in Sofia; distance from the town centre 3.3 km (SE direction); mean elevation 550 m, slope near 4°, with soil characteristics of Haplic Vertisols (FAO, ISSS, ISRIC 1994).
U2—The Loven park: distance from the town centre 3.7 km (SSW direction); mean elevation 570 m, slope near 4°, with soil characteristics of Chromic Luvisols (FAO, ISSS, ISRIC 1994).
U3—The Northern park: distance from the town centre 5.6 km (NW direction); mean elevation 575 m, slope near 4°, with soil characteristics of Anthrosols urbogenic terri-cumulic.
SU1—distance from the town centre 13.2 km (SE direction); mean elevation 650 m, slope near 17°, with soil characteristics of Chromic Luvisols (FAO, ISSS, ISRIC 1994).
SU2—distance from the town centre 11.3 km (SSW direction); mean elevation 950 m, slope near 17°, with soil characteristics of Chromic Luvisols (FAO, ISSS, ISRIC 1994).
SU3—distance from the town centre 20 km (NW direction); mean elevation 780 m, slope near 6°, with soil characteristics of Mollic Luvisols (FAO, ISSS, ISRIC 1994).

The main physical and chemical properties of the soils were determined with standard methods for textural composition; soil organic matter; total *N*; pH (Zhiyanski et al. 2005).

Results and discussion

Soil texture

The main soil characteristics of soils are presented in Table 1. The variations in soil textural properties, based on field observations and analytical data are discussed later.

The Vertisols, (U1) are soils influenced by the parent rock undergoing clay accumulation (FAO-UNESCO 1991). In the profile at U1 the upper A1h-horizon is enriched with fine sand (0.25–0.05 mm) and coarse silt (0.05–0.01 mm), compared with the lower horizon. The soil in plot U3 is an Anthrosol, where anthropogenic activity is the main factor for pedogenesis (FAO-UNESCO 1991). The layer IAh of U3 is enriched with coarse silt (0.05–0.01 mm) and fine silt (0.005–0.001 mm) with the highest content for all horizons studied, in common with soils previously characterised around heavy industrial sites and silt loading may be a significant anthropogenic signature.

In site U2 the silt fractions (coarse silt: 0.05–0.01 mm) are also significant but here the coarse silt is more prevalent in sub-surface horizon (B1) (pH 4.25) and the upper Ah – horizon is enriched with clay (<0.001 mm). The soil is a Luvisol, which are influenced by clay transfer and accumulation (FAO-UNESCO 1991).

The mean content of the coarse silt (0.05–0.01 mm) in the A_h-horizon of the urban sites is higher than the semi-urban sites (U_{ave}=27.12%±7.80 SD=4.51; SU_{ave}=15.93%±6.49, SD=3.74). The fine silt (0,005–0,001 mm) is also higher in the urban soils (U_{ave}=18.09%±10.70, SD=6.17) than in the semi-urban areas (SU_{ave}=12.65±6.67, SD=3.85) and highlights an impact of urban activity on pedogenic processes.

The impact of clay content on the retention of anthropogenic pollution (e.g. Pb) has been noted as an important factor for pollutant impact (Kabata-Pendias and Pendias 1992). In U2 the increase of the clay fraction (<0.001 mm) in Ah-horizon compared to the lower soil horizon was observed (also partially developed at site U3).

In general, the soils from the urban locations exhibit a lower mean clay content (<0.001 mm) in the Ah-horizon compared with the soils from the semi-urban locations.

The clay content depends primarily on the processes of clay formation, which vary with the geographical conditions, soil type and parent materials. The process of rock weathering is to reduce particle size (sand → silt → clay) and can be defined in terms of the ratio silt/clay (FAO-ISSS-ISRIC 1994). The ratio in the conjunction with the physical process of clay accumulation is also termed the coefficient of clay formation (Qa).

Qa = silt/clayor in this case:

$$\text{Qa} = \sum (0.05 - 0,001)/(< 0,001)$$

The mean data for the coefficient of clay formation (Qa) for Ah-horizon of soils from the urban locations show higher values than in the semi-urban soil, and is visually demonstrated in Fig. 1.

For both soil categories, the surface horizons show proportionally lower clay content than deeper in the profiles, however in the urban sites, this trend is more strongly developed. This could be related with the higher total anthropogenic influence at these locations due to the alkalization of Ah-horizon of the urban sites as the surface horizons are

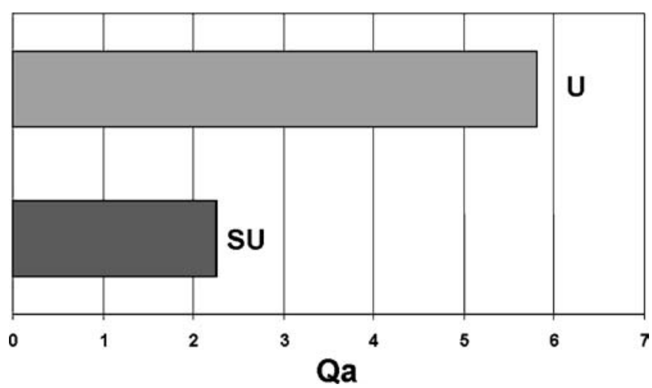

Fig. 1 Average coefficient of clay formation (Qa) for surface horizons (Ah) of urban (U) and semi-urban (SU) soils from Sofia, Bulgaria

Table 1 Basic soil properties for soil profiles collected from urban (U) and semi-urban (SU) locations in Sofia, Bulgaria

Horizon (cm)	Mechanical (fraction) composition (%)						Silt/clay (Qa)	pH	C (%)	N (%)	C/N
	1–0.25	0.25–0.05	0.05–0001	0.01–0.005	0.005–0.001	<0.001					
U1 (mm)											
A_1h 0–10	28.35	18.20	20.92	9.00	8.37	12.55	3.05	6.50	2.92	0.18	16
A_2 10–30	43.61	13.82	12.37	8.24	8.25	12.37	2.33	5.75	1.89	0.07	27
AB 30–53	20.84	16.85	8.64	12.95	17.28	21.60	1.80	5.65	1.41	0.06	23
B_1 53–73	24.25	13.57	4.28	3.73	13.36	38.46	0.56	6.20	0.90	0.05	18
U2 (mm)											
Ah 0–6	33.95	7.67	24.54	8.18	16.36	8.36	5.87	5.30	3.70	0.14	25
B_1 6–34	35.03	7.43	28.53	8.14	16.30	4.07	13.01	4.25	1.81	0.10	18
B_2 34–60	33.68	23.63	8.26	8.27	20.66	4.13	9.00	5.35	0.97	0.05	18
U3 (mm)											
I_{Ah} 0–3	15.95	1.79	35.90	6.34	29.54	8.45	8.49	7.05	5.90	0.21	28
II 3–19	15.53	2.52	29.38	16.79	20.99	12.59	5.33	6.90	3.60	0.11	33
III 19–53	16.28	14.91	4.21	29.41	29.41	4.20	15.01	7.10	2.26	0.10	26
B 53–64	20.46	25.45	16.87	12.66	18.44	4.22	11.37	7.50	1.25	0.09	14
SU1 (mm)											
Ah 0–2	17.70	10.28	8.74	21.86	8.74	30.60	1.29	6.65	4.36	0.28	16
B_1 2–26	11.27	4.33	17.33	13.01	17.33	34.67	1.37	5.70	2.49	0.19	11
B_{2t} 26–68	19.34	2.34	12.68	38.05	12.69	12.68	5.00	6.35	1.93	0.13	15
SU2 (mm)											
Ah 0–4	10.63	28.91	17.71	8.86	8.86	22.15	1.60	5.30	5.57	0.26	21
B_1 4–14	11.23	12.33	13.08	13.09	21.81	26.17	1.83	4.90	2.84	0.10	28
B_2 14–64	11.73	10.66	28.47	8.97	22.29	14.26	4.19	5.20	0.49	0.03	16
SU3 (mm)											
Ah 0–8	16.18	19.89	21.34	8.08	20.35	12.85	3.87	6.50	5.64	0.37	16
ABh 8–29	18.35	24.92	19.35	9.88	17.18	10.32	4.50	6.20	4.17	0.31	13
B_1 29–40	21.17	20.16	18.74	13.40	17.58	10.15	4.90	6.10	2.41	0.24	10

generally more alkaline than the deeper parts of the profile and for the urban sites show higher pH than the semi urban sites (Table 1). As the time of soil formation is assumed to be similar for all sites, the degree of eluviation of clay in the profile should be similar (Scharenbroch et al. 2005). The proportionally lower Qa values in the urban soils reflecting a reduction in the rate of clay mineral formation.

On the base of the mechanical composition results it could be summarized that the urbanization reduces the buffer capacity in topsoil (Ah-horizon).

Organic matter

All soils show a high C% in surface horizons compared to those at depth (Table 1). The C-content of the surface horizon in urban soils is more variable and tends to be lower (2.92–5.90%) when compared to the semi-urban (4.36–5.64%) soils.

When the values of C/N are considered, the ratio shows on one hand the enrichment with organic substances and on the other hand the intensity of mineralization. In natural soils C/N ratios and total C are expected to decrease with depth (Lorenz and Kandeler 2005). The trend is seen for total C in all soils, and for the C/N ratio semi-urban sites. In the urban profiles, the C/N ratio is more variable down the profile. The highest value of C/N is found in soil U3, where the mineralization is lower and the processes of accumulation of organic matter predominate. Despite the fact that Mollic Luvisols (e.g. SU3) have higher carbon contents, the C/N ratio is significantly lower. The differences between U3 and SU3 are indicative of the variation in organic matter quality and not unexpected in urban systems (Lorenz and Kandeler 2005). It could be that the organic matter in U3 has higher content of the anthropogenic organic residues from for example coal dusts, as seen in strongly disturbed soils from urban areas (Beyer et al. 2001). The higher C/N ratio in the soils of U-parts shows that the processes of mineralization of the organic matter have lower intensity in comparison with the processes in soils of the SU locations. The plot SU2 is an exception and the relatively high values of C/N ratio are likely to be due to differences in climate conditions as a result of a higher altitude.

Conclusion

The soils formed under oak ecosystems in urban (U) parks in Sofia show significant differences in the properties of the upper Ah-horizon, where the anthropogenic loading predominates compared with the semi-urban (SU) parts. The differences are summarised as higher content of the coarse silt (0.05–0.01 mm) and fine silt (0.005–0.001 mm) fractions; higher silt/clay ratio; higher C/N ratio, and reduced intensity of mineralization processes of the organic matter. The low clay content and the high content of non-reactive organic matter in the topsoil of the urban locations suggests a reduction in soil buffer capacity and potential impacts from the different pollutants of urban environment.

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