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RESEARCH ARTICLE

Soil quality is key for planning and managing urban allotments intended for the sustainable production of home-consumption vegetables

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Abstract The growing importance of urban allotments in planning and managing urban areas is due to the combined positive effects on ecosystem services, the economy and human well-being, especially of groups of the urban population that can be vulnerable (e.g. the elderly, immigrants, low-income families). Some studies have highlighted the potential risk of contamination by metals of vegetables grown in urban areas and the lack of appropriate site-specific risk assessments. However, surveys are still lacking on the possibilities of using urban soil as a good substrate to produce vegetables for home consumption. We assessed the soil quality in two areas in Pisa (Italy), one intended for urban horticulture and the other already cultivated for that purpose. We analysed the soils for the main chemical and physical characteristics (texture, bulk density, water stability index, pH, cation exchange capacity, organic carbon, total nitrogen, phosphorous) and elements (Pb, Cu, Ni, Cr, Zn, Cd, As, K, Al and Mn). Our results showed that both areas had physical and chemical heterogeneity due to the effects of urbanization and to the different cultivation techniques employed. The metal content was lower than the guidelines limits, and the soil conditions (pH = 8) greatly reduced the metal mobility. Copper concentration in some of the cultivated area samples was higher than the limits, representing a possible stress factor for the microbial biodiversity and fauna. Our findings demonstrate that site-specific surveys are necessary before planning urban cultivation areas, and educating urban gardeners regarding sustainable cultivation techniques is a priority for a safe environment.

Keywords Vegetable gardening · Urban soil · Trace metals · Organic matter · PCA

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Introduction

Urban vegetable gardens (allotments) in towns and cities promote social well-being and health. The benefits of growing vegetables for urban dwellers are widely recognised; an example is the Grow Your Own program in the UK, where Leake et al. (2009) reported that the mental and physical health benefits of growing one's own food largely compensate for the possible environmental urban pollution. In addition, a sense of place in degraded neighbourhoods is developed by the practice of community gardens, as well as improving environmental learning and awareness (Bendt et al. 2013).

Urban allotments are also key elements for improving biodiversity (Colding et al. 2013) and reducing the effects of gas emissions (Kulak et al. 2013) as well as mitigating temperature and promoting water drainage (Wamsler 2014).

Increased interest in allotments means that local councils need to find suitable spaces and planners need to be sensitised and trained in addressing the specific challenges in relation to improving food security (Gerster-Bentaya 2013).

Areas allocated for urban allotments are generally chosen for planning-based reasons, i.e. to use spaces not occupied by buildings or other infrastructures, rather than for cultivation and environmental requirements. As a consequence, soils of these areas show the typical characteristics of urban soils and related problems for plant growth. Urbanization alters the soil dramatically, causing low levels of organic matter, compaction, and a reduction of penetrability by water, air and roots (Craul 1992; Pulford 1991). These soil alterations decrease soil fertility and make it more difficult to grow horticultural plants for food production.

Urban gardeners are often unaware of the causes for these soil properties are unfavourable for plant production. Therefore, they can try to resolve the problem of the poor quality of the soil through the overuse of chemicals thereby impoverishing the soil biota mass and reducing long-term fertility, along with the risk of self-intoxication and ingestion of the residues through the food (Flemming and Trevors 1989).

Many studies have investigated contamination by trace metals in urban allotment soils and in homegrown vegetables. According to Alloway (2004), the most significant hazards in garden soils are likely to come from lead, cadmium, mercury and PAHs, even though the risk of metal exposure for most urban gardeners is minimal, and the highest pollution has been found in allotment soils located near major road, rail and canal junctions (Hough et al. 2004). A study by Vittori Antisari et al. (2015), conducted in Bologna, confirms the importance of the location and the atmospheric contribution to the pollution of the products. According to Samuel et al. (2012), crops grown in city vegetable plots are not automatically ‘healthier’ or ‘safer’ compared to supermarket products.

To reduce contamination levels and health risks, growers should be advised to choose planting sites carefully, based on the knowledge of present and past use of the site (Hursthouse and Leitao 2016) and on the distance from and barriers to traffic, which is often one of the most important sources of soil pollution in urban areas (Bretzel and Calderisi 2011). Samuel et al. (2012) also suggest that the pollution risks must be weighed against the societal benefits of urban horticulture. Hough et al. (2004) thus highlighted the need for specific risk assessments for areas intended for urban cultivation. When urban soils are allocated for urban horticulture, all the physical and chemical properties should be analysed in order to plan successful cultivation techniques, bearing in mind that urban soils can have particular characteristics that are not comparable with the surrounding areas or with pedological maps. Knowledge of the soil properties such as texture, pH and organic carbon content is also necessary for correctly evaluating any potential pollutant translocation in the soil-plant system (Islam et al. 2007).

The above-mentioned literature suggests that localization and agricultural management of urban gardens are crucial for the successful practice of urban agriculture. Therefore, we decided to investigate two urban areas in the town of Pisa, Italy; one is intended to be used for self-production by the local administration, and one area is already in use. We assessed the soil properties influencing the fertility (organic carbon, nutrients, structural stability) and thus the aspects related to the plant production, as well as the presence and mobility of trace metals in order to verify the possible health risks for consumers. The aim was to evaluate the soil conditions and to offer management suggestions for public administrators. We also wanted to contribute to the database of urban allotment soils and provide useful data for the functional planning of resources.

Materials and methods

Site description and soil sampling

The two study areas are located in Pisa, Italy (approximately 90,000 inhabitants). The annual mean air temperature of Pisa is 14.3 °C and the annual mean rainfall is 900 mm.

The first area (A) is approximately 165 × 40 m, situated in a peripheral and populated district urbanised in the 1980s in the southeast part of the town. A is a public area, which has been earmarked by the municipality for municipal vegetable gardens (Fig. 1). No records are kept by the municipality of the former use of this area, which potentially have had an impact on soil quality; however, through interviews with the residents, we discovered that a part of the area had been subject to dumping and subsequent filling with different types of soil. At the moment, the area is not cultivated, just covered by grass and mowed regularly.

The second area (B) is an allotment site situated in a very populated district built in the 1960s, in the east of the town near the river Arno. The allotment area is in the floodplain of the river Arno and slopes 1 m in a south-north and east-west direction (Fig. 2). River floods may occur in autumn and winter; the consequent heavy metal input in the B area can be considered negligible due to the low levels of metals in the river, as reported by the Regional Agency for Environmental Protection (ARPA 2008). The area had been left as unmanaged grassland until 1995, when the municipal vegetable gardens were set up. It is divided into 72 allotment plots, each of about 80 m^2. Agricultural techniques of the gardeners do not include on-site composted biomass.

Both A and B are far from the main roads, isolated from the effects of traffic by distance or buildings.

Soil samples were taken at two depths (0–10 and 10–20 cm) in A, bearing in mind the possible presence of layers of different soils resulting from the previous management of the site. Ten sampling points were selected, which were 15 m away from each other along a diagonal transect. The B soil was sampled in the tilled layer (0–20 cm depth) of ten randomly selected allotments. At each sampling point of both locations, one sample per depth was obtained mixing three sub-samples collected in a quadrate of 100 × 100 cm.

Fig. 1 Images of the area A, isolated from the main roads by buildings. The district was built in the 1980s

Soil analysis

Soil was air-dried at room temperature and sieved. Texture, bulk density (BD), pH(H_2O), cation exchange capacity (CEC), organic carbon (C_{org}), total nitrogen (N_{tot}) and phosphorous (P) were determined on the 0–2-mm fraction by means of methods of ASA-SSSA (1996).Wet sieving was used to determine the stability of the soil aggregates in water: air-dried aggregates (1–2 mm) were placed in 0.25-mm-mesh sieves and moistened by the water rising by capillarity from a layer of wet sand, then immersed in deionised water and shaken at a rate of 60 rpm. A water stability index (WSI) was defined according to Vigna Guidi et al. (1989) as $WSI = 100 (1 - A/B)$, where A and B are the weights of aggregates passing through the sieve after 5 and 60 min, respectively.

The concentrations of Pb, Cu, Ni, Cr, Zn, K, Al, Mn, Cd and As were determined using ICP spectrometry (Liberty Axial Varian, Turin, Italy) after acid attack, following the recommendation no. 3051A of US-EPA (2007). Soil samples with high values of metals underwent chemical extraction with H_2O and 0.01 M $CaCl_2$ (Houba et al. 1996) in order to investigate the potential metal mobility.

Statistical analysis

In this study, principal component analysis (PCA) (Lebart et al. 1984) was applied to the datasets, using the statistical software R (R Core Team 2015). PCA was used to describe the characteristics of the soils to understand the relationships between measured variables and samples. PCA transforms the original coordinate system, and the new coordinates are called principal components (PCs). The score plot is the projection of the data onto the PCs. The scores can be seen as the summary of the relationship among the observations (or samples). The PCs were computed to provide a new space of uncorrelated 'variables' which best carry the variation in the original data and in which to more succinctly represent the original 'samples'. The loading plot visualizes the summary of the variable's structure, and it is a means to interpret the patterns seen in the score plot. Since the analytical values varied greatly among the examined parameters, transformed data were auto-scaled (zero mean and unit variance) before carrying out the statistical analysis.

Results and discussion

Physical and chemical properties in relation to soil quality

The results of the soil in A are reported in Table 1. The soil texture was sandy loam, though samples A1–A6 showed a higher percentage of sand, while samples A7–A10 showed a higher percentage of silt. The mean value of BD (1.55) was in line with the values expected for this particular soil texture. pH was generally moderately alkaline, and CEC ranged between 15.3 and 25.9 cmol(+)/kg. Structural stability varied from

Fig. 2 Images of the area B, near the river Arno, far from the main roads and isolated from traffic. In the *aerial image*, it is possible to see the nearby district built in the 1960s–1970s, where the gardeners live. (UAG photograph by courtesy of ©Francesco Sinni)

Table 1 Soil properties at the A area

Sample	Depth cm	CEC cmol+/kg	pH	BD g/cm^3	Sand %	Silt %	Clay %	WSI	C org %	C inorg %	N tot g/kg	Pb mg kg^{-1}	Cr	Ni	Cu	Zn	K	K av	Al	Mn	P av
A1	0–10	19.6	8.3	1.7	59.2	34.9	5.9	1.0	1.1	1.4	1.6	18	61	39	78	57	3688	130	21040	622	28
	10–20	16.8	8.0	1.6	62.1	32.3	5.6	0.2	0.9	1.3	1.6	13	52	38	75	51	2964	100	17824	595	22
A2	0–10	15.3	8.2	1.6	60.2	34.2	5.7	0.3	0.9	1.0	1.2	28	62	39	57	52	3460	108	20967	543	26
	10–20	18.4	8.3	1.6	55.9	38.4	5.7	0.1	1.0	0.6	1.7	37	51	36	53	49	2489	79.2	16606	606	21
A3	0–10	15.6	8.3	1.7	59.4	34.8	5.8	2.6	1.1	0.7	2.0	35	66	39	56	55	3843	89.8	23477	562	24
	10–20	18.4	8.3	1.5	56.6	37.9	5.6	2.8	1.1	0.5	1.6	36	56	35	43	51	2757	85.2	18414	547	19
A4	0–10	21.5	8.0	1.2	62.0	34.2	3.8	0.8	2.2	0.4	2.9	44	55	39	47	54	2989	106	18531	591	29
	10–20	20.0	8.2	1.7	59.3	36.4	4.3	0.6	1.5	0.3	2.1	50	44	34	41	47	2000	85.4	14136	633	19
A5	0–10	25.5	7.9	1.5	61.7	34.9	3.4	27.3	3.1	0.4	3.4	52	50	36	45	69	2958	113	17119	554	36
	10–20	20.9	8.1	1.6	63.6	32.9	3.5	0.7	2.0	0.3	2.5	49	44	28	33	49	2987	79.1	15098	520	26
A6	0–10	24.9	7.9	1.4	63.1	33.3	3.6	20.8	3.0	0.4	3.4	53	52	42	55	57	2473	107	17826	559	30
	10–20	20.8	8.2	1.4	65.1	31.6	3.4	21.9	1.8	0.4	2.4	53	47	36	62	51	2225	90.3	14373	537	23
A7	0–10	24.0	8.4	1.4	50.6	43.4	6.1	10.2	2.7	0.7	2.8	69	55	50	62	70	2858	134	18342	542	31
	10–20	24.6	8.3	1.4	54.1	40.6	5.3	10.7	2.3	0.7	2.6	49	56	48	79	68	2730	116	18740	574	27
A8	0–10	23.7	8.1	1.8	49.7	44.2	6.1	18.2	2.2	0.8	2.8	79	66	53	59	78	3370	152	21334	570	35
	10–20	24.3	8.2	1.3	49.8	43.4	6.8	29.8	2.1	0.8	3.4	62	66	52	77	86	2729	142	18676	590	26
A9	0–10	25.5	7.0	1.6	51.7	43.6	4.7	22.8	2.9	0.4	3.2	61	52	46	57	69	2793	171	17256	609	34
	10–20	24.0	8.1	1.5	54.5	40.5	5.1	14.4	2.0	0.5	2.8	59	49	42	62	66	2398	95.7	16119	535	26
A10	0–10	25.9	7.9	1.6	57.3	38.6	4.1	18.7	3.6	0.4	3.9	79	54	45	62	143	3042	96	17391	625	46
	10–20	25.6	7.9	1.4	62.2	34.0	3.8	15.7	3.1	0.4	3.2	82	44	40	62	116	2033	72	12924	571	35

poor (WSI = 20–30) or very poor (WSI <20). Organic matter content was higher than in most Italian agricultural soils (Borrelli et al. 2016); P_{av} content was medium to high, while K_{av} was low to medium. The heavy metal content was below the threshold limit values defined by the Italian regulations for soils of public parks and gardens (Italian Legislative Decree no. 152/2006). Cd and As resulted under the detection limits in all the samples.

Most of the chemical parameters (C_{org}, N_{tot}, P_{av}, K, Pb, Zn, Ni) showed little differences between the two sampling depths and a high variability among the sampling points. Sampling points A1–A3 were quite different from the others at both depths. This was confirmed by the PCA, whose results are reported in Fig. 3. The PCA showed a rising gradient for PC1, the main one, due to C_{org}, N_{tot}, WSI and CEC, with the lowest value in relation to sample A1 and the highest in relation to sample A10. Three groups of samples A1–A3, A4–A8 and A9–A10 were identified. PC2 described a secondary gradient, relative to Al, K, Cr and C_{inorg}, which was related to samples, in particular from sample A4 (lower content of these elements) to sample A8 (higher content of these elements). Regarding the deeper layer (10–20 cm), the gradient on PC1 was even more evident: in fact, the samples were evenly distributed along a gradient. In other words, in some points the soil showed similar characteristics both in the surface and in the deeper layer, while in other points the surface soil differed from the deeper one. These findings are consistent with the history of the area, a part of which was reportedly used also as dump, covered by a filling soil taken from elsewhere. The A soil thus has characteristics of heterogeneity that are typical of many urban soils (Craul 1992). This soil can be used for allotments, because it is not polluted, but it needs a structural amelioration to improve its fertility.

The results of the analysis of the soil properties and metals in B are reported in Table 2. The texture of the soil was sandy loam, and CEC values were from 16.3 to 22.5 cmol(+)/kg; pH ranged from subalkaline to alkaline. The C_{org} content was generally low; only sample B6 showed a 3.8 % content, which is a high value for Italian cultivated soils (Borrelli et al. 2016) and could be related to a sporadic use of an organic fertilizer. The N_{tot} content ranged from 1.3 to 2.3 g kg^{-1}, but again in sample B6 it was 2.9 g kg^{-1}. K_{av} was from middle to high for a sandy loam soil. Lead ranged from 15 to 33 mg kg^{-1}, Cr from 50 to 71 mg kg^{-1} and Ni from 42 to 56 mg kg^{-1}; Cu ranged from 50 to 94 mg kg^{-1} in nine samples; only sample B20 showed a significantly higher value; Zn was 61–80 mg kg^{-1} and Mn ranged from 516 to 903 mg kg^{-1}. Also in B soil, Cd and As resulted under the detection limits in all the samples. The soil metal content of Ni, Cr, Pb and Zn at the two sites was lower than that found in the green spaces near the main roads of the town of Pisa, where Bretzel and Calderisi (2006) found a contamination of metals, especially Pb and Zn. The excess of Cu in sample B10 was likely due to fungicide residues, as the gardeners confirmed to have used such pesticides in the recent years. Cu can affect the soil biota and alter the soil cycles of C and N (Flemming and Trevors 1989; Barański et al. 2014) leading to a reduction in fertility. Despite the high total content of Cu, its mobile fraction was under the detection

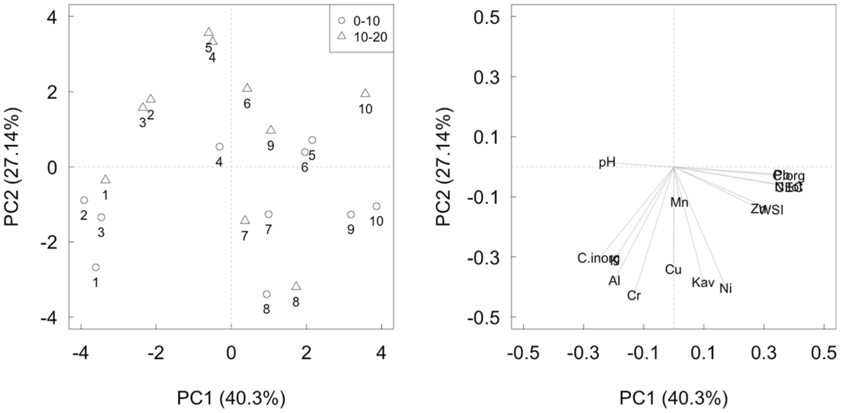

Fig. 3 The PCA analysis of the data regarding A shows that most of the chemical parameters (C_{org}, N_{tot}, P_{av}, K, Pb, Zn, Ni) are almost homogeneous between the two sampling depths, although there is a high variability among the sampling points. The PCA showed a rising gradient for PC1, the main one, due to C_{org}, N_{tot}, WSI and CEC, with the lowest value in relation to *sample 1* and the highest in relation to *sample 10*. PC2 described a secondary gradient, relative to Al, K, Cr and C_{inorg}, which was related to the samples, in particular from *sample 4* to *sample 8* Figure 3-5 contains poor quality of text. Otherwise, please provide replacement figure file.I send the high definition figure as attachment

limit, due to the values of pH, because the solubility of heavy metals in the soil solution tends to decrease with the decrease of the proton activity (Gaulik and Bidoglio 2006).

The score plot of the B dataset (Fig. 4) from PCA highlights that the samples do not show a clear pattern, which means that the allotment soil, considering the whole picture, does not differ greatly among the sampling points. The loading plot, which explains the correlation between variables, depicts a typical frame: C_{org} and N_{tot} are strongly correlated. The mineral part of the soil (i.e. Al, Pb, Ni, Mn) is anti-correlated to organic carbon and nitrogen.

Figure 5 compares samples from both sites, A at two depths and B, by means of the common parameters: Pb, Cr, Ni, Cu, Mn, Al, Zn, K, K_{ass} CEC, pH, C_{org}, C_{inorg} N_{tot} and WSI. The comparison highlights that A was richer in N_{tot}, C_{org} and CEC (especially those from samples A5 to A10, topsoil) compared to B, probably due to the spontaneous vegetation present in A, which enriched the soil with organic matter. A was also richer in Pb, especially from sample A8 onwards, at the surface layer. The higher value of lead could be related to the presence of filling soil, which can come from a more polluted area.

Four samples (B3, B6, B8 and B9) from the B area fall almost within the A area sample clusters, thus demonstrating a similarity with the A area samples due to a lower content of K, Cr, Al, K_{av} and Ni.

Management suggestions for the study sites

The conditions of A and B pose a number of issues that need to be taken into account for management planning.

Location

Both sites were far from potential polluting sources, such as industrial sites or the main roads, isolated from the effects of traffic by the distance or buildings, which reduce pollution risks, as confirmed by the data of metal contents. These locations are in line with the recommendations for the planning of

Table 2 Soil properties at the B area

Allotment	CEC cmol(+)/kg	pH H_2O	Sand %	Silt %	Clay %	WSI	C org g/kg	C inorg g/kg	N tot g/kg	Pb mg kg^{-1}	Cr	Ni	Cu	Zn	Mn	Al	K	K av
B1	21.3	8.4	57.9	36.1	6.0	4.85	1.1	7.2	1.5	25	66	48	55	77	605	19890	4425	150
B2	16.3	8.3	51.6	42.7	5.7	13.16	1.0	7.2	1.4	25	71	51	50	77	644	22746	5064	158
B3	17.5	8.2	60.2	35.1	4.7	10.42	1.0	6.9	1.5	16	58	49	62	71	646	21812	3365	108
B4	17.5	8.4	49.6	43.7	6.7	9.30	1.0	6.2	1.7	33	69	55	47	76	903	18754	4323	162
B5	20.0	8.8	60.6	34.4	5.0	6.54	1.6	10.6	2.1	22	70	50	94	78	661	21957	5464	152
B6	18.8	7.9	49.8	43.3	6.9	3.17	3.8	6.7	2.9	17	58	47	66	80	516	14934	4274	106
B7	22.5	8.6	49.9	41.8	8.3	9.07	1.0	5.5	1.3	25	69	56	62	78	565	20049	4141	137
B8	16.3	8.2	59.9	35.4	4.7	6.52	1.9	7.9	2.2	15	50	46	88	80	569	13245	3542	149
B9	20.0	8.4	60.8	34.6	6.7	7.89	1.2	7.3	1.4	15	53	42	69	61	602	14796	4639	134
B10	20.0	8.2	50.2	42.9	6.9	10.40	1.5	6.0	2.3	15	63	45	161	67	589	17218	4972	139

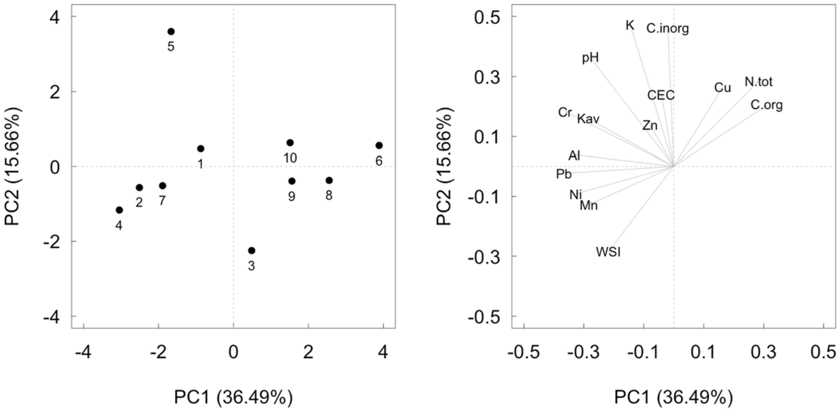

Fig. 4 The PCA analysis of the data related to B highlights that the allotment soil, considering the whole picture, does not differ greatly among the sampling points. On the other hand, the loading plot depicts a typical frame, i.e. C_{org} and N_{tot} are strongly correlated, while the mineral part of the soil (i.e. Al, Pb, Ni, Mn) is anti-correlated to C_{org} and N_{tot}

allotments and gardens for the production of vegetables (Samuel et al. 2012; Vittori Antisari et al. 2015). Therefore, the two areas respond positively to an eligibility requirement to be destined to allotment sites.

Origin of soils

Very often in urban environments, the soil is subject to excavation, movement and filling operations, as reportedly happened in the A area. For this area, and for similar cases, a record should be kept of the historical data and soil analyses should be carried out in order to correctly manage the soils (Mc Clintock 2012).

Heterogeneity of soils

The A area presented a heterogeneity, due to the different origin of the soils. The northern side of the area was potentially more fertile, with higher soil OM and structural stability. Once an area is divided into allotments and assigned, gardeners need to be aware of such differences, which, if not taken into account, could lead to frustration and mismanagement on the part of the gardeners.

Soil fertility

Urban soils can be lacking in OM and structure (Pini et al. 2011), which may be acceptable for managing low-input green areas, but not for growing vegetables, especially for home consumption. In fact, these vegetables need to be managed organically to ensure the health of non-professional gardeners and the quality of the produce, guarantee food security and minimize dependence on external inputs (Mäder et al. 2002).

Soils of both areas had a loose texture generally good for horticulture, as it easily enables the development of vegetable roots, especially the edible roots such as carrots and beetroots; however, this kind of poor soil needs the addition of organic matter to improve the nutrients, structure and water retention. This was evident especially at the B area where some samples showed very low values of C_{org} and N_{tot}, and almost all samples had a very low WSI. The WSI was under the limits for a good soil structure, which is fundamental in understanding the fertility of soil and a criterion for assessing agricultural soil quality (Mueller et al. 2010). The 20-year cultivation in B did not seem to have had a positive effect on the structure of the soil. No organic matter seemed to have been added over the years, therefore the management had not improved the soil, while Edmondson et al. (2014) demonstrated that a proper use

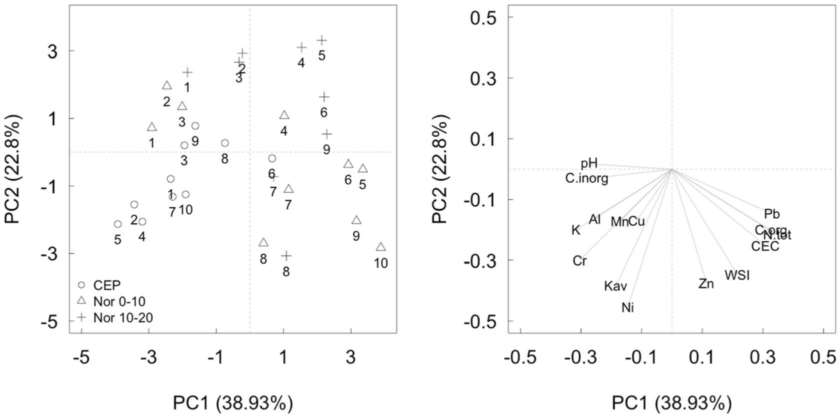

Fig. 5 Score plot (*left*) and loading plot (*right*). Comparison by means of PCA of samples from both sites: A (*NOR*) at two depths and B (*CEP*), using the common parameters: Pb, Cr, Ni, Cu, Mn, Al, Zn, K, K_{av}, CEC, pH, C_{org}, C_{inorg}, N_{tot} and WSI. The comparison highlights that the allotment soil is generally richer in C_{inorg}, K and Cr, compared to A, which was richer in N_{tot}, C_{org}, Pb and CEC (especially those from *samples 5* to *10*, topsoil)

of organic materials resulted in a good fertility of allotment soil.

The low fertility of B for growing vegetables implies that if gardeners are not environmentally aware, they may tend to overuse chemicals or to be frustrated with bad results. This disadvantage can be avoided by using mature compost. The addition of self-produced compost to the cultivation of vegetables can greatly improve the soil structure and is excellent in helping urban gardeners in recycling organic waste from their home and garden. Edmondson et al. (2014) compared soils in urban allotments with soils from the surrounding agricultural areas and found that allotment soils are richer in OM derived from manure and compost. However, still more effort is needed in replacing fertilizers with compost from urban organic waste. Before spreading compost, all the soil properties should be evaluated to avoid detrimental effects, such as the enhancement of metal mobility (Murray et al. 2011), and anti-germinative effects, especially in small seeds (Ligneau and Watt 1995). At B, no gardeners were producing compost correctly, and no organic waste compost piles were detected during our monitoring. In such situations, gardeners could be trained and given advice on how to adopt sustainable good practices. Moreover, municipal guidelines for the allotment management should indicate as mandatory the self-production of compost and its use.

Soil pollution

The values of the metals of A and B were generally low. Soil pH was unfavourable to metal mobility, thus there was extremely low risk of their translocation to the food chain (Islam et al. 2007). Therefore, in these areas, there is no need to ban the production of particular vegetables that can uptake metals. A higher value of Cu found in one B sample suggested attention to the possible overuse of agrochemicals by some gardener. Again, training would help gardeners to correctly manage their soils and avoid environmental risks.

Conclusions

In order to help urban gardeners adopt the agricultural practices adequate for the specific environmental conditions of their garden plots, soils allocated for urban agriculture should be analysed in terms of fertility and presence of pollutants, as well as all the chemical and physical properties involved in the mobility of pollutants. When planning an area for urban horticulture, it is fundamental to consider all the possible sources of pollution nearby, especially traffic, in order to prevent the contamination of soil and vegetables. In addition, the history of the site is important for future landscape developments.

Our study demonstrated the following:

- The soils presented heterogeneous properties between the two areas, but also within the areas, as commonly happens with urban soils.
- The cultivation technique used by the gardeners had not improved the quality of the soil in terms of structure and organic matter content.
- The soils did not present contamination; thus, in the present situation, they are safe from the point of view of the translocation of metals from soil into the food chain.
- The presence of Cu in one allotment may result from the inappropriate use of chemicals by the gardeners.
- The soils can be used for home production; however, they need structural improvement with organic matter to enhance the long-term fertility.

Practical applications could include the following: the soil organic matter content could be increased by quality compost produced by the gardeners or supplied by the municipality; the recovery of soil fertility requires training for gardeners in order to prevent the careless use of chemicals; and training should be continuous and systematic, providing information on soil quality and organic farming. Future perspectives include interviews with gardeners to extend the information on their management practices and compare the results with environmental surveys.

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