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Urban Soil Quality Assessment—A Comprehensive Case Study Dataset of Urban Garden Soils

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1. INTRODUCTION

Soil is the foundation of ecosystem functioning in urban green spaces and provides key ecosystem services for a livable city (Zhu et al., 2018). Urban soils are a mixture of natural soil-forming factors and anthropogenic activities (Shuster and Dadio, 2018). Therefore, they require an adapted set of indicators for a soil quality assessment. Soil quality is one of the three constituents of environmental quality, along with water and air quality (Andrews et al., 2002). It is generally referred to as the capacity of a soil to function within ecosystems and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health, including human health (Doran and Parkin, 1994). Here, we present a comprehensive dataset of 37 soil quality indicators measured at 170 plots in 85 urban gardens within the city of Zurich, Switzerland. They represent all major inherent and dynamic soil properties for a soil quality assessment (Bünemann et al., 2018), including eight physical, nine chemical and eleven biological soil quality indicators, plus nine soil metal properties (As, Ba, Co, Cu, Ni, Pb, Sb, V, Zn). Soil function decomposition was assessed by the tea bag index method (Keuskamp et al., 2013). Results regarding the influence of garden management, local and landscape effects on the distribution of soil quality indicators can be found in Tresch et al. (2018). This dataset is useful for future studies on urban soil quality, ecosystem services or for modeling purposes such as carbon dynamics or greenhouse gas inventory models in cities.

2. MATERIALS AND METHODS

2.1. Study Sites and Design

The dataset of 37 soil quality indicators (**Figure 1**) was measured at 170 plots in 85 urban gardens in the city of Zurich, Switzerland, comprising 42 allotment and 43 home gardens (**Figure S1**). These two garden types are the most frequent in Switzerland, but also comparatively worldwide (Lin et al., 2017). Allotment gardens represent a plot of land rented by gardeners, usually located in urban or semi-urban areas, while home gardens are often situated around private houses. The study design is part of the interdisciplinary project BetterGardens (www.bettergardens.ch) that focuses on soil quality, biodiversity, ecosystem services and human wellbeing in urban gardens in Switzerland. Two plots within each garden were selected according to garden habitat and management practices such as lawn, vegetables or flower and berry beds. Five soil samples

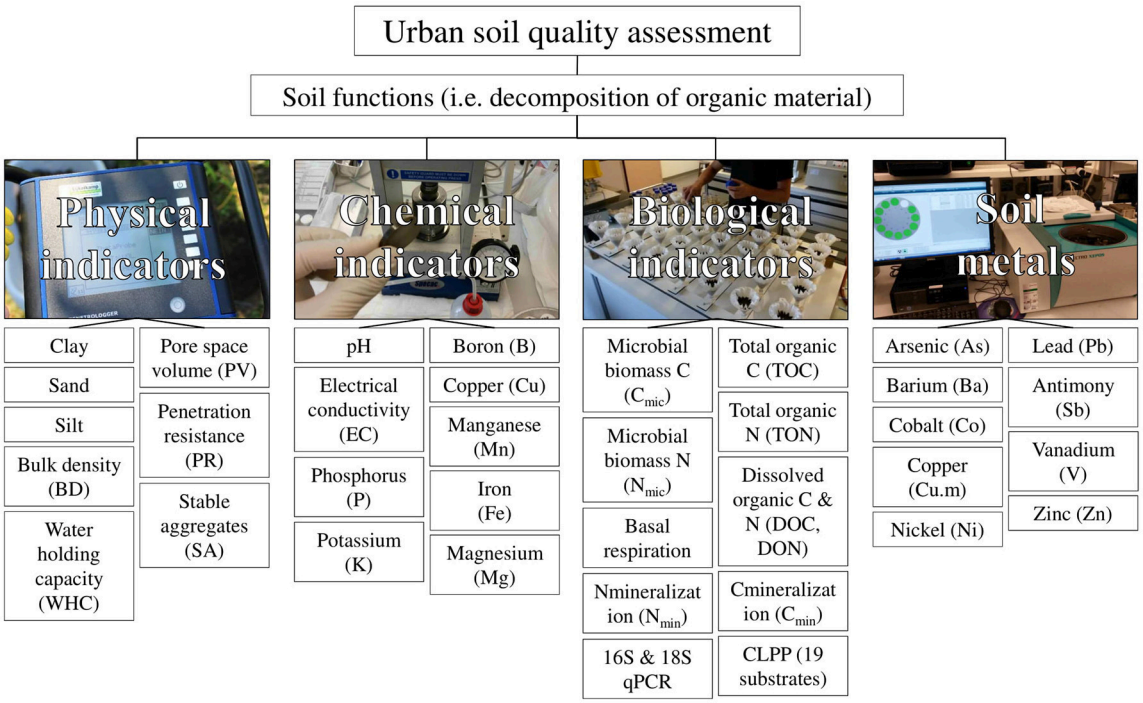

FIGURE 1 | Concept of assessing urban soil quality through the measurements of soil quality indicators related to soil functions. Details about soil quality indicators measured in urban gardens of Zurich, Switzerland can be found in **Table S4**.

(0–20 cm depth, 3 cm wide soil auger Eijkelkamp, NL) were collected randomly within an area of 2 × 2 m on the 170 plots, prior to the first soil gardening practices in March 2015. Soil samples were pooled for each plot, gently air dried, homogenized and sieved at 2 mm then stored at 4°C. Subsamples designated for DNA analysis were frozen and stored at -80°C until analysis. Subsamples for chemical analysis were air dried at 20°C and stored under cool and dry conditions. For physical soil quality indicators, undisturbed samples were collected with three soil cores (5 cm diameter and depth, Eijkelkamp, NL) at a depth of 10–15 cm on each plot. Soil quality analyses were performed in accordance with Swiss standard methods for soil characterization (Agroscope, 2012).

2.2. Physical Soil Quality Indicators

Soil texture was measured by a combined sieving and sedimentation technique (Schinner et al., 1996). Soil water holding capacity (WHC) was determined by a cylinder method on a sand bath (Schinner et al., 1996). Soil aggregate stability (SA) was determined from aggregates in the 1–2 mm fraction by wet sieving for 5 min on a multi-sieve device (42 cycles min^{-1}) and subtracting the sand fraction (Schinner et al., 1996). Soil bulk density (BD) and pore space volume (PV) were determined with the undisturbed soil cores following Swiss reference methods (Agroscope, 2012). Penetration resistance was measured with a Penetrologger (cone type: 100 mm^2, penetration speed: 0.002 ms^{-1}; Eijkelkamp, NL), recording the penetration resistance every 1 cm down to a soil depth of 80 cm. Ten replicated measurements were taken and mean values from 0 to 20 cm soil depth were calculated for the penetration resistance.

2.3. Chemical Soil Quality Indicators

Soil pH and electrical conductivity (EC) were measured in a soil suspension with deionized water (1:2.5 w/v). Soil nutrient contents (P, K, Mg, Cu, B, Mn, Fe) were measured at an external certified laboratory with ammonium acetate-EDTA.

2.4. Biological Soil Quality Indicators

Total organic carbon (TOC) and nitrogen (TON) were determined by a CHN analyzer (Thermo Scientific Flash EA 1112, NL) after removing carbonates with 2 M HCl. Dissolved organic carbon (DOC) and nitrogen (DON) as well as mineralized N (N_{min}), were measured in an extract with 0.01 M $CaCl_2$ (1:4 w/v) (Krauss et al., 2017). Soil microbial biomass carbon (C_{mic}) and nitrogen (N_{mic}) contents were determined by chloroform-fumigation-extraction (CFE) (Fliessbach et al., 2007). Soil basal respiration and C mineralization (C_{min}) were assessed by measuring CO_2 evolution in defined intervals from soil samples using a gas chromatograph (TCD detector; 7890A, Agilent Technologies, USA) as described in Tresch et al. (2018). Basal respiration rates were recorded after 1 week and C_{min} after 4 weeks of soil incubation at 20°C. Community level physiological profiles (CLPP) were assessed with the MicroResp technique (Campbell et al., 2003) using 18 different carbon substrates and water (see **Table S2**). The carbon substrates represent a cross-section of root exudates, ranging from sugars to amino acids, carboxylic acids, amino sugars and hemicellulose

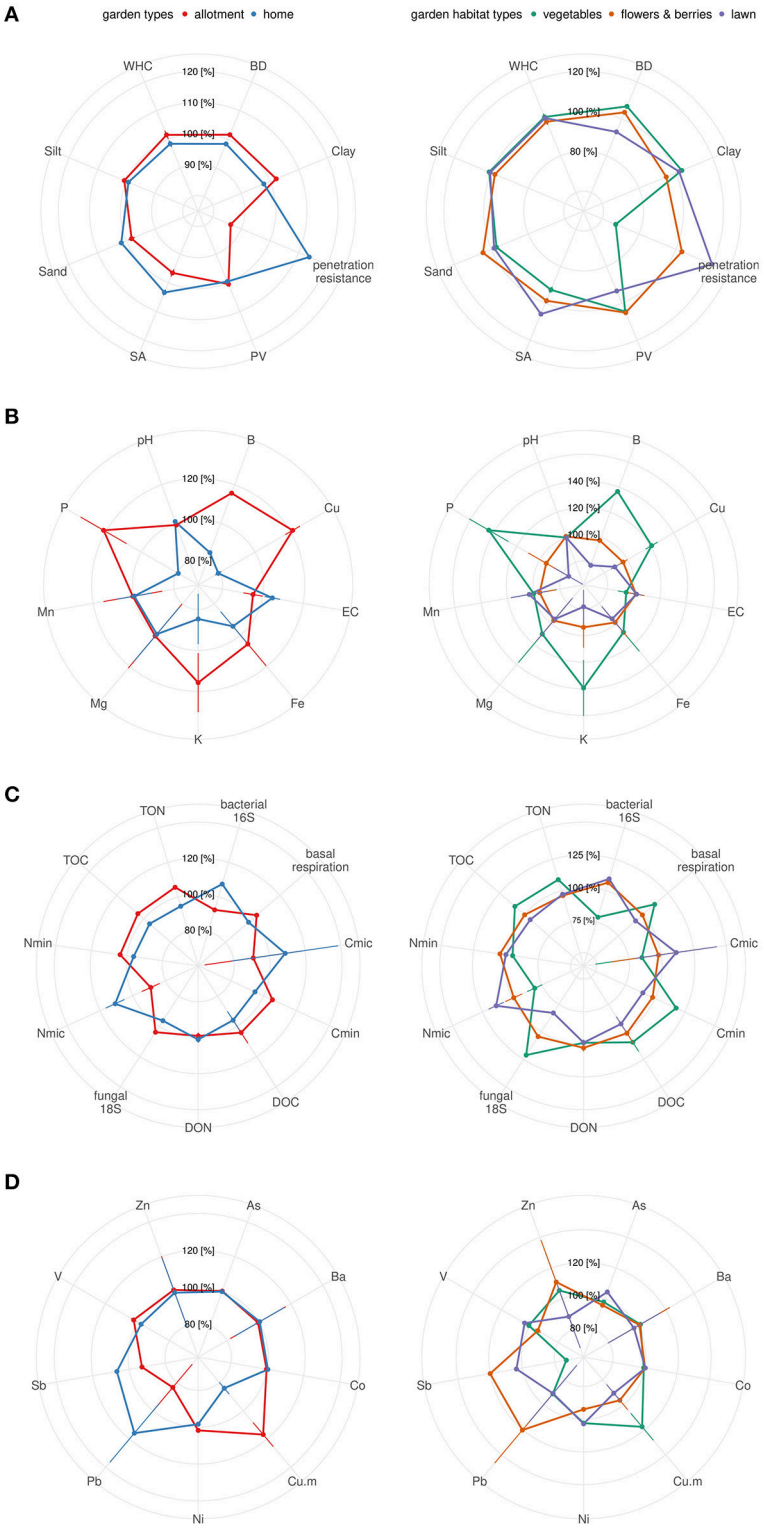

FIGURE 2 | Soil quality indicators per garden type (left) and habitat type (right) consisting of **(A)** eight physical indicators, **(B)** nine chemical indicators, **(C)** eleven biological indicators, **(D)** nine metal measurements. Data points represent the relative deviation [%] from the grand mean (**Table S4**) that is set to 100%. Standard error bars are shown with lines.

typically occuring in soil (Campbell et al., 1997). Quantitative real-time PCR (qPCR) was performed to estimate the bacterial (16S rRNA; BactQuant assay, Liu et al., 2012) and fungal (18S rRNA; FR1/FF390 primer, Vainio and Hantula, 2000 validated by Chemidlin Prévost-Bouré et al., 2011) gene copy numbers (see **Table S3**).

2.5. Soil Metal Contents

Metals contents were measured as total element concentrations analyzed in dried and ball milled soil samples pressed with wax to tablets on an X-Ray Fluorescence device (XRF, X-lab 2000, SPECTRO Analytical Instruments, DE). Although the measurement corresponds to standard soil metal concentrations (Horta et al., 2015), metal concentrations are probably overestimated by 10–20% (Christl et al., 2004) compared to the standard method (i.e., aqua regia). Cu.m refers to copper metal values.

2.6. Soil Function Decomposition of Organic Material

Belowground decomposition was measured by using standardized commercial tea bags following the tea bag index method (Keuskamp et al., 2013). Green tea bags were used as a rapid and rooibos tea as a slowly decomposable material. In total, four tea bags per tea type (170 plots × 2 tea types × 4 replicates = 1,360 tea bags) were burried at a depth of 8 cm for 90 days (mid-October until mid-January 2016). Decomposition, expressed as percentage change in mass before and after decomposition, was calculated after drying at 60°C and subtracting soil particles subsequent to incineration of the tea bags.

2.7. Statistics

All statistics were performed using R software version 3.4.2 (R Core Team, 2017). Descriptive statistics (dplyr) and visualization (ggplot2) were obtained with the data manipulation package tidyverse (Wickham and Grolemund, 2016) and the spatial plot (**Figure S1**) with the package ggmap (Kahle and Wickham, 2013). Example R codes (R project files) including the raw data (csv file) are provided in the **Supplementary Material**.

3. CONCLUSION

The dataset comprises a collection of soil quality indicators for urban garden soils including standardized tea bags representing the soil function decomposition. We measured eight physical, nine chemical, eleven biological soil quality indicators as well as nine metal values (**Figure 1**), that are necessary for a comprehensive soil quality analysis in an urban context. The dataset was sampled at a scale of an entire representative medium-sized European city (**Figure S1**). The data is split according to the two most common urban garden types: allotment and home gardens (**Table S1**). Furthermore, sample plots were assigned one of three garden habitat types: vegetable beds (i.e., annual vegetable plants), flower beds and berry cultivations (i.e., perennial flowers, roses, and berry shrubs), and lawn (i.e., meadows and turf). Descriptive statistics are given in **Tables S4–S6**. A graphical representation of percentage deviations from the overall mean value split by garden and habitat type is given in **Figure 2**. In summary, this dataset provides information about a city-wide soil quality assessment of urban gardens. This data can be used for comparing soil properties among different cities or land use types. Moreover, our study may help to analyze the effect of garden management or urbanization on soil quality (see Tresch et al., 2018) or provide data for modeling of carbon dynamics in urban soils or other soil based ecosystem services.

AUTHOR CONTRIBUTIONS

AF, MM, R-CL, PM, DF, and ST conceived and designed the research. ST, DF, and AZ performed the field work. Lab work was done by ST, AK, AM, and BS. ST analyzed the data. All authors contributed to the writing of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2018.00136/full#supplementary-material

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