U.S. DEPARTMENT OF AGRICULTURE

Technical Note No. 470-03

Soil Health

January 2024

Site Evaluation for Urban Soil Health

Acknowledgments

Joshua Beniston Ph.D., USDA NRCS is the primary author of this technical note.

The following individuals reviewed and contributed to the content of the technical note: Valerie Cohen, USDA NRCS; Kaitlin Farbotnik, USDA NRCS; Arthur Hawkins, USDA NRCS; Michael Higgins, USDA NRCS; Jacob Isleib, USDA NRCS; Zahangir Kabir, USDA NRCS; Rob McAfee, USDA NRCS; Edwin Muniz, USDA NRCS; Randy Riddle, USDA NRCS; Jonathan Russell-Anelli, Cornell University; and Ann Tan, USDA NRCS.

Cover photo: A soil sample taken as part of the NRCS Cropland In-Field Soil Health Assessment protocol at an urban farm in Ft. Worth, Texas. Photo by Joshua Beniston, USDA NRCS.

Table of Contents

Introduction

Urban agriculture and equity are priority areas for the NRCS, and resource conservation work is expanding for urban and small-scale agriculture. Urban agriculture can be broadly defined as gardening and food production taking place in urban areas, including backyard gardens, community and school gardens, and urban farms. Urban resource conservation work includes projects outside of food production, such as rain gardens and habitat plantings. Management and utilization of urban soils offer ecological services to society and opportunities to interact with nature in landscapes that are heavily covered by impervious surfaces. Understanding and optimizing soil health can lead to robust ecological outcomes in all these contexts.

Urban soils are often thought of, and described as, polluted and having poor conditions for plant growth; however, extensive research of urban soils indicates that characterization is not accurate (Pouyat et al. 2020). In fact, urban sites have variable soil conditions and health. Many urban sites contain favorable soil conditions for urban agriculture or ecological restoration projects, while other sites may present degraded soil conditions due to the history of their land use. Often, soil properties and conditions are not consistent across a particular site, where some areas of the site have healthy soil conditions and other areas demonstrate soil degradation.

There are several resource concerns that affect the function and use of urban soils. Compaction, soil organic matter depletion, degradation of soil organism habitat, and sites with soil materials that are unsuitable for plant growth are all frequently encountered in urban areas. Urban soils are also subject to highly elevated concentrations of heavy metals and contamination by organic compounds, which present public health risks. The potential risk for soil contamination is regularly cited as a primary concern for land managers and a motivation for soil testing at urban sites. Another motivation for soil testing is to gather information; for many cities, there is little background information about soils and their geography.

Thus, site evaluations and assessments are an essential step in the process of managing and improving urban soils. Assessment of urban soils will require planners and land managers to ask pertinent questions about site history and soil conditions, gather information with non-invasive field techniques, and perform laboratory tests to understand soils. The goal of this technical note is to present existing strategies and tools to support the assessment of soil health in urban areas.

This technical note provides a summary of the use of existing tools, data sources, and monitoring and testing protocols to conduct robust assessment of urban soil health at the site level. These tools can be used to develop a robust assessment of urban soil conditions (Table 1). This document is intended as a reference for NRCS conservation planners and field staff, but much of the information is relevant for land managers, gardeners, and others interested in evaluating urban soils.

Table 1. A site evaluation process for assessing urban soil health

Stages	Specific actions
1. Review background information on site conditions and land use history	Determine site and management unit boundaries
	Review Web Soil Survey/SSURGO and additional data sources
	Review key questions on site history
2. Field assessment of site and soil conditions	Review site history observation questions
	Review key field observations on soil properties
	Conduct in-field soil health assessment to assess soil physical and biological properties
3. Screening of soil for heavy metal/elemental concentrations – *when available*	Conduct pXRF screening of soil for heavy metal content
4. Laboratory analysis of soil	Laboratory analysis of heavy metal content
	For urban agriculture sites: • Conduct laboratory nutrient test • Consider need for testing soil health indicators
	Determine soil sampling areas and sampling strategy
	Collect samples and submit to laboratory
5. Data interpretation and management planning	Identify presence or absence of resource concerns based on steps 2–4
	Plan appropriate conservation practices for areas with resource concerns

Review Background Information On Site Conditions And Land Use History

Web Soil Survey

One of the first steps of evaluating soils at a new location is to access information about its soil types and properties. In the U.S., this information is typically gathered by using tools produced by the National Cooperative Soil Survey, such as Web Soil Survey (WSS) or SoilWeb. WSS is a comprehensive source of soil maps and information about soil uses and limitations. SoilWeb, developed by University of California, Davis, is a user-friendly interface for exploring soil maps and data outside WSS.

For urban areas, however, the level of detail and availability for soils data varies; only a handful of cities in the U.S. currently have detailed soil surveys available. Furthermore, soil types and properties may change significantly over very small distances due to the complex history of human impacts on urban sites. This makes mapping soils in urban areas difficult. For these reasons, WSS and soil maps may not provide soil information that is appropriate for planning and management of urban sites. Where there is soil information available, it should be considered a baseline and checked against conditions in the field.

Table 2. Some historical land uses at or near urban sites that can lead to soil resource concerns[1]

Type of Site	Lead (Pb)	Other Inorganic Contaminants	Organic Contaminants	Compaction	Topsoil Removed	Large quantities of debris and artefacts
Near coal-fired power plant		X				
Highway corridor or Heavily trafficked road	X	X				
House / building demolition site	X	X		X	X	X
Industrial site	X	X	X	X	X	X
Parking lot	X	X		X	X	X
Farmland		X	X	X		
Storage lot	X	X	X	X	X	X
Vacant urban lot[2]						X

Other Data Sources for Exploring Site History and Conditions

In urban areas, there are several specific historical land use activities often associated with resource concerns and risk (Table 2). Several data sources exist that may clarify land use history, potential resource concerns, and associated risks at urban sites. Data sources that may be useful for understanding land use history in urban areas include the following:

- Google search – Historical, ownership, and land use information for specific addresses.
- Google Earth – historical imagery – Information about past land uses and cover during recent decades.
- EPA Browfields Search Tool – Allows searching of sites where the U.S. Environmental Protection Agency (EPA) has documented contamination.

[1] Table adapted from Crozier et al. (2020).
[2] Depending on site history, vacant urban lots may be subject to any of the resource concerns listed here.

- GIS data from county level agencies – Records of property boundaries, ownership, and past land use.
- Wind history maps – Information about prevailing wind direction to determine potential for atmospheric deposition of contaminants.

An important caveat is that urban land use in most U.S. cities predates these data sources, making a comprehensive understanding of historical land uses and risks based on data unrealistic. Therefore, in addition to background research, field evaluation is necessary to understand the potential impacts of urban land uses on the site. Field evaluation includes questioning landowners, producers, neighbors, and community members about the site history. When determining if there is significant potential for soil contamination at the site, other key questions include:

- Does the site have a history of industrial land uses?
- Are there buildings or houses built prior to 1980 on, or adjacent to, the site that may contain lead-based paint?
- Was there a building on the site previously that was demolished?
- Is the site directly adjacent to a road where salts or other chemicals are applied? Or is it directly adjacent to a road that has been in place prior to 1980, when leaded gasoline was used?
- Is there a facility nearby that could produce a negative impact to the site such as laundromat, garage or other industrial operations? What is the proximity of the site to these locations?
- Based on the proximity of the site to industrial facilities, as well as the direction of prevalent winds, does there appear to be potential for the airborne deposition of contaminants?

If the answer to any of these questions is "yes," then additional level of review, screening, and testing of the site may be necessary. If the answer to all of these questions is "no," then the site has a low risk of soil contamination from historical legacies.

Field Assessment of Site and Soil Conditions

One of the most insightful methods for inventorying soil conditions is by performing a cropland in-field soil health assessment (IFSHA) of the field (Photo 1). The IFSHA is an NRCS protocol designed to help conservation planners (and land managers) evaluate soil conditions and determine if soil resource concerns exist at their sites (USDA NRCS 2019b).

The IFSHA protocol was designed for cropland; however, most indicators in the assessment also apply to urban soils, particularly when crops or landscape plantings are being grown at the site. IFSHA can assess aggregate stability, soil organism habitat conditions, drainage, and the presence of compaction at the site. The IFSHA worksheet provides detailed methods for in-field assessment of soil properties, as well as interview questions about the management history of the site to begin a discussion of soil management. Additional questions that are important for understanding soil conditions at urban sites include:

- Are there plants growing on the site already? If so, how are the roots growing?
- Is the site using raised beds for urban agriculture? If so, do the beds contain mineral soil material or soilless growing media such as potting mix or compost?
- Is there a distinct topsoil layer or has topsoil been removed?

- Does the soil contain large quantities of coarse fragments (rock, human artifacts, building materials, etc.)?
- Is there compaction? If so, to what extent? Does the compaction occur in the soil surface or subsurface layers?
- Does the soil appear to be a more native soil type or highly altered?
- What is the soil texture class of the surface layer?
- Is there evidence or knowledge of impervious surfaces directing water on to the site?
- Is there evidence of flooding, seasonal high-water table, or concentrated erosion?

Photo 1. Conducting cropland in-field soil health assessment (IFSHA) at an urban farm in Fort Worth, TX. (A) **Soil physical and biological properties are assessed by using a spade to remove a cube of soil.** (B) **Soil structure, color, plant roots, biological diversity**, **and biopores are examined visually.** (C) **A penetrometer is used to identify compaction and a strainer tests aggregate stability. Soil cover, residue breakdown, surface crusts**, **and ponding** and **infiltration were assessed visually and through discussion with the producers. This site displayed robust soil health after** 5 **years of intensive management as an urban farm. Photo Josh Beniston, NRCS**.

Observation and assessment of in field soil properties can provide information about the soil physical conditions. However, soil screening procedures and laboratory testing are strongly recommended in the development of urban sites for agriculture, as altered soil chemical properties (including elevated concentrations of heavy metals and contaminants) cannot be determined through visual assessments or background research.

Screening of Soil with Portable X-Ray Fluorescence

For urban soils, portable X-ray fluorescence (pXRF) can be used as a pre-screening procedure to screen for heavy metal content of soils at sites with potential for elevated concentrations. The pXRF is an analytical instrument that can be used in the field or in a laboratory setting for quick and accurate measurement of heavy metal content in soils. It does not detect organic compounds, such as pesticides, herbicides, polycyclic aromatic hydrocarbons.

If the screening results from pXRF indicate heavy metal concentrations above the recommended thresholds, then it is advisable to perform additional laboratory analysis. Soils with elevated heavy metal concentrations benefit from implementation of conservation practices, such as raised beds, that are designed to limit direct exposure to soil.

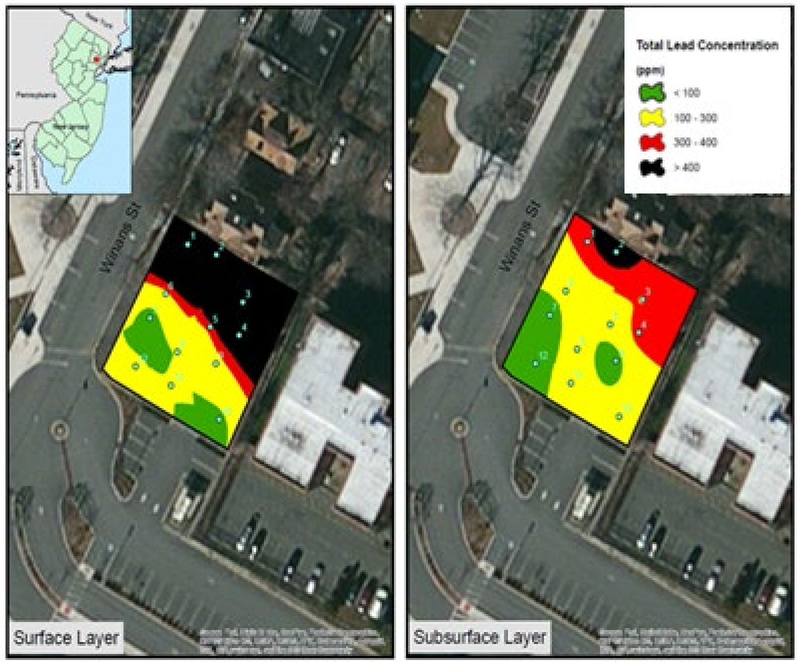

Figure 1. Site map of total lead (Pb) concentrations in soil surface and subsurface layers, generated with pXRF data (courtesy of Edwin Muniz, NJ NRCS).

One of the advantages of using the pXRF is that its ability to efficiently screen multiple areas within a field helps to identify “hot spots,” that is, areas of special concern with elevated levels of a certain elements. Data from pXRF can be used to generate site maps highlighting the spatial distribution of elements (Horta et al. 2021) (Figure 1). These maps can guide further evaluation and management of the site to determine where more intensive soil sampling and analysis are needed and where conservation practices should be implemented based on producer objectives.

Using pXRF for soil screening requires specialized training. Currently within NRCS, the pXRF soil screening process is generally coordinated by soil scientists in the Soil and Plant Sciences Division or by the state soil scientist. Screening with pXRF is not currently available for NRCS in all areas of the U.S. Planners are advised to coordinate with the state soil scientist or regional Major Land Resource Area soil survey office regarding pXRF screening.

Laboratory Analysis of Urban Soils

Laboratory analysis of soil properties is necessary for understanding soil conditions and management of urban sites (Surls et al. 2016). Laboratory soil tests for urban agriculture fall under two broad objectives: (1) investigating the presence and concentration of heavy metals and other contaminants and (2) measuring soil properties that are important for agronomic management, such as nutrients and soil health indicators. Generally, urban agriculture projects benefit from conducting both types of soil testing.

For soil testing at urban sites, it is important to differentiate between samples that are composed of mineral material and samples that are composed primarily of soilless media (such as potting mix or compost), which may be used to create raised beds in urban gardens. Laboratories often have different protocols and testing methods for soilless media.

Laboratory Analysis of Heavy Metals and Contaminants in Urban Soils

Soil Sampling Strategies

A key step in evaluating urban sites is to define objectives for soil sampling and develop a sampling strategy. Depending on the intended land use and potential for contamination, different soil sampling strategies may be necessary. If the goal of the sampling is to understand the average level of soil properties at a site, then the strategy should be a composite sampling based on collecting and mixing several individual samples. If a site has specific areas with unique conditions and particular concerns (e.g., in the drip line of a building or areas close to a road), then it may be beneficial to collect individual soil samples from those areas. For larger, more complex sites with a diversity of soil conditions, it is advisable to collect representative samples from different areas with distinct management, soil conditions, or land use history (Photo 2).

The depth of sample collection may also change depending on objectives at urban sites. For urban agriculture and garden sites, a sampling depth of 0–6 inches is recommended for all types of soil analysis. NRCS soil scientists conducting urban soil assessments have often collected and analyzed soil samples from both a 0–6 inch depth and a 6–12 inch depth to characterize soil properties further down in the root zone.

Photo 2. A community garden in Bronx, NY. Despite the relatively small size of the site, the diversity and intensity of management zones, as well as proximity to adjacent urban land uses, necessitate attention to soil sampling strategies to accurately characterize soil chemical properties at the site. Photo credit USDA.

Identifying Appropriate Laboratories and Methods

Laboratories offering analysis of heavy metals and organic compounds are available in many regions of the U.S. However, these analyses are less available than agricultural tests, and finding an appropriate laboratory may require research. It is recommended to ask laboratories which methodologies they use for analysis.

The EPA sets the standards for measurement of heavy metals, as well as makes recommendations for land use based on the concentration of heavy metals, depending on whether the total extraction of soil elements is done with acid digestion (U.S. EPA method 3050B) or with microwave-assisted acid digestion (U.S. EPA method 3051A). The Mehlich 3 extraction, which is commonly used in soil nutrient tests, has shown a high degree of correlation with the EPA total extraction methods for measuring lead and may be a useful alternative to the total extractions where it is available (Minca et al. 2013; Hamel et al. 2010).

Interpretation of Results for Laboratory Analysis of Heavy Metals and Contaminants

Currently, there is no single standard for measuring the risk of growing crops based on analysis of heavy metal and contaminant levels in soils. Similarly, there is no single set of recommendations for land use and management based on these soil levels. A primary reason for this is that different agencies have used different methods to estimate the health risks of soil contaminants. For estimates of health risks based on heavy metal concentrations, the most widely referenced guidelines are the EPA soil screening levels (SSLs) on the suitability of soils as green space in residential areas. More recently, an EPA working group provided guidance specifically related to soil suitability for gardening based on lead levels (U.S. EPA 2014).

Land use guidance based on soil testing of contaminants can vary considerably across states and municipalities; any work being done should follow local guidance. EPA provides a regularly updated list of SSLs for hundreds of chemical compounds and elements of concern at their "Regional Screening Levels" webpage. Additional discussion and interpretation of SSLs for lead are provided in Surls et al. (2016) and Shayler et al. (2009), and for multiple elements and compounds of concern in Crozier et al. (2020). Differing regulations on SSLs and associated soil management recommendations are reviewed in Basta et al. (2021).

At sites with an established history of industrial land use or where pre-screening and testing procedures indicate highly elevated concentrations of contaminants, it may be advisable to consult professional specialists for a more thorough assessment. This contamination assessment, as well as other types of soil tests, is currently available through the Conservation Evaluation Monitoring Activity (CEMA) for land units enrolled in NRCS conservation programs (Table 3).

Table 3. USDA NRCS Conservation Evaluation and Monitoring Activities (CEMA) that provide financial assistance for soil testing activities.

CEMA number	Name	Purpose	Testing activities
207	Site assessment and soil testing for contamination	An environmental assessment of the site and soil suitability for use in the cultivation of crops in urban and suburban areas.	• Soil testing for contaminants. • Basic Site Assessment or ASTM-E1527 "Environmental Site Assessments: Phase I Environmental Site Assessment Process • ASTM-E1903 "Environmental Site Assessments: Phase II Environmental Site Assessment Process
216	Soil health testing	Quantitative testing for physical, biological, or chemical characteristics of soil and constraints of soil using approved laboratory methods	• Soil health testing using multiple laboratory indicators. • Soil health testing for a single laboratory indicator.
217	Soil and source testing for nutrient management	A sampling strategy for nutrient management measuring nutrient levels in soil and or nutrient source	• Laboratory analysis of soil nutrients. • Laboratory analysis of nutrients in compost.

Soil Nutrient Analysis of Urban Soils

Laboratory soil nutrient tests are a recommended practice, and good investment, for urban gardens and farms. The EPA recommends that urban agriculture sites obtain a nutrient test that analyzes: pH, organic matter, macronutrients, micronutrients, and metals (including lead) (U.S. EPA 2011). These soil properties are known to be highly variable in urban soils and may need to be amended for optimal crop growing conditions.

Macronutrient levels can be a key limitation to crop production at newer urban agriculture sites (especially those that have not previously been managed for gardens) or sites where topsoil has been removed (Beniston et al. 2014). On the other hand, more established urban gardens with intensive management may have an excess of soil nutrients due to repeated applications of compost and other nutrient-rich materials (Nelson et al. 2022). Applying large quantities of such materials can quickly raise phosphorous levels to a point that may be concerning for runoff to surface water. Overapplication of nutrients can be avoided through soil nutrient testing and application of nutrients in precise quantities to achieve recommended levels (Ugarte and Taylor 2020; Nelson et al. 2022).

Soil nutrient samples are generally taken by collecting a composite sample for a site or distinct crop and management areas. Nutrient recommendations for crops are widely available from university extension programs and provide useful guidance for urban agriculture. Generally, crop nutrient recommendations generated by universities or private labs within the region are considered best, as there can be differences in methods in regions. The Oregon State University Extension provides a useful overview of interpreting soil nutrient tests (Hornbeck et al. 2011), which can be used in combination with other university extensions that have recommendations specific to their regions.

Laboratory Soil Health Indicators and Urban Soil

The goal of laboratory soil health testing is to measure indicators related to the ecological function of the soil. These measurements can provide information about microbial activity, availability of carbon sources for microbes, and the relative degree of aggregation in a soil, as well as other functions. This information can then be used to identify aspects of a soil that may be constraining productivity and guide specific management practices to improve those aspects (Moebius-Clune et al. 2016).

Laboratory assessments of soil health indicators are vital when managing urban soils, as urban soils are sensitive to different management practices. Several studies have found that soil properties of urban sites (both urban gardens and unmanaged lots) change depending on many factors, including the use raised beds (Nelson et al. 2022), compost application (Beniston et al. 2014), cover cropping (Beniston et al. 2014), intensity of garden management (Reeves et al. 2014; Tresch et al. 2018; Ugarte and Taylor 2020), and whether the site is a vacant urban lot (Schindelbeck et al. 2008; Knight et al. 2013). Therefore, it is important to conduct multiple laboratory assessments of soil health indicators on a site over time to monitor changes in soil properties and compare the effects of different management practices.

Many laboratories offer assessments of soil health indicators and may also score the indicators based on the results by comparing them against a larger set of results from similar sites. However, scoring of soil health indicators is not well developed for urban sites, as little to no research has been done on the use of these indicators in soilless media common to urban areas. Therefore, as with other analyses, it is important to differentiate sites using soilless media.

Laboratory methods for assessing soil health indicators can be found in Kellogg Soil Survey Laboratory Methods Manual, Version 6.0, Part 1: Current Methods (usda.gov) (Soil Survey Staff 2022) and in the CEMA 216 Soil Health Test document.

Summary

Urban soils have great potential for agriculture and ecosystem services; however, soil health in urban sites is highly variable, ranging from robust conditions to highly degraded. Urban soils are also subject to several resource concerns depending on their site history. The potential for elevated concentrations of heavy metals and organic compounds in urban soils is a particular concern and makes soil testing or screening essential.

Methods for evaluating soil health at urban sites include a review of background information on site history and conditions; field assessment of soil conditions and producer knowledge; soil screening with pXRF; and laboratory testing of soil properties. Taken together, these activities can provide a wealth of information. Planners and land managers can then use this information to move forward with appropriate site-specific plans for managing soil health and minimizing risk, allowing them to use urban sites to their full potential.

Additional Resources

USDA NRCS – Natural Resources Conservation Service. 2017. Soil Quality Urban Technical Note No. 4. Urban Soils in Agriculture.

USDA NRCS Fact Sheet – Soil Screening Procedure Using pXRF (2023)

USDA NRCS - EQIP CPAs, DIAs, and CEMAs (2023)

U.S. Environmental Protection Agency – Technical Review Workgroup Recommendations Regarding Gardening and Reducing Exposure to Lead-Contaminated Soils (2014)

University of California, Agriculture and Natural Resources – Soils in Urban Agriculture: Testing, Remediation, and Best Management Practices (2016)

Cornell Waste Management Institute – Guide to Soil Testing and Interpreting Results (2009)

References

Basta, N. T., Zearley, A. M., Hattey, J. A., and Karlen, D. L. 2021. "A Risk-Based Soil Health Approach to Management of Soil Lead." *Soil Health Series: Volume 1 Approaches to Soil Health Analysis*: 139–168.

Beniston, J. W., Lal, R., and Mercer, K. L. 2014. "Assessing and Managing Soil Quality for Urban Agriculture in a Degraded Vacant Lot Soil." *Land Degradation & Development* 27, no. 4: 996–1006.

Crozier, C., Polizzotto, M. and Bradley, L. 2020. "Minimizing Risks of Soil Contaminants in Urban Gardens." *SoilFacts.* NC State Extension Publications.

Hamel, S., Heckman, J., & Murphy, S. 2010. "Lead Contaminated Soil: Minimizing Health Risks." New Jersey Agricultural Experiment Station. https://njaes.rutgers.edu/fs336/.

Horta, A., Azevedo, L., Neves, J., Soares, A., and Pozza, L. 2021. "Integrating Portable X-Ray Fluorescence (pXRF) Measurement Uncertainty for Accurate Soil Contamination Mapping." *Geoderma* 382: 114712. https://doi.org/10.1016/j.geoderma.2020.114712.

Hornbeck, D. A., Sullivan, D. M., Owen, J. S., and Hart, J. M. 2011. *Soil Test Interpretation Guide.* Oregon State University Extension Service.

Knight, A., Cheng, Z., Grewal, S. S., Islam, K. R., Kleinhenz, M. D., and Grewal, P. S. 2013. "Soil Health as a Predictor of Lettuce Productivity and Quality: A Case Study of Urban Vacant Lots." *Urban Ecosystems* 16: 637–656.

Minca, K. K., Basta, N. T., and Scheckel, K. G. 2013. "Using the Mehlich-3 Soil Test as an Inexpensive Screening Tool to Estimate Total and Bioaccessible Lead in Urban Soils." *Journal of Environmental Quality* 42, 5: 1518–1526.

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M Kurtz, D.W. Wolfe, and G.S. Abawi. 2016. *Comprehensive Assessment of Soil Health – The Cornell Framework, Edition 3.2*. Geneva: Cornell University.

Nelson, M., Mhuireach, G., and Langellotto, G. A. (2022). "Excess Fertility in Residential-Scale Urban Agriculture Soils in Two Western Oregon Cities, USA." *Urban Agriculture & Regional Food Systems* 7, 1: e20027. https://doi.org/10.1002/uar2.20027.

Pouyat, R. V., Day, S. D., Brown, S., Schwarz, K., Shaw, R. E., Szlavecz, K., Trammell, T.L.E., and Yesilonis, I. D. 2020. "Urban soils." In *Forest and Rangeland Soils of the United States under Changing Conditions,* edited by Richard V. Pouyat, Deborah S. Page-Dumroese, Toral Patel-Weynand, and Linda H. Geiser, 127–144. Springer Cham.

Reeves, J., Cheng, Z., Kovach, J., Kleinhenz, M. D., and Grewal, P. S. 2014. "Quantifying Soil Health and Tomato Crop Productivity in Urban Community and Market Gardens." *Urban ecosystems* 17: 221–238.

Schindelbeck, R. R., van Es, H. M., Abawi, G. S., Wolfe, D. W., Whitlow, T. L., Gugino, B. K., Omololu, J. I., and Moebius-Clune, B. N. 2008. "Comprehensive Assessment of Soil Quality for Landscape and Urban Management." *Landscape and Urban Planning* 88, 2–4: 73–80.

Shayler, H., McBride, M., and Harrison, E. 2009. "Guide to Soil Testing and Interpreting Results." Cornell Waste Management Institute. https://cwmi.css.cornell.edu/guidetosoil.pdf.

Soil Survey Staff. 2022. "Kellogg Soil Survey Laboratory Methods Manual." *Soil Survey Investigations Report No. 42, Version 6.0.* U.S. Department of Agriculture, Natural Resources Conservation Service. https://www.nrcs.usda.gov/sites/default/files/2022-10/SSIR42-v6-pt1.pdf.

Surls, R., Borel, V., and Biscaro, A. 2016. "Soils in Urban Agriculture: Testing, Remediation, and Best Management Practices." *ANRCatalog*. University of California, Agriculture and Natural Resources. https://www.doi.org/10.3733/ucanr.8552.

Tresch, S., Moretti, M., Le Bayon, R. C., Mäder, P., Zanetta, A., Frey, D., and Fliessbach, A. 2018. “A Gardener's Influence on Urban Soil Quality.” *Frontiers in Environmental Science* 6. https://doi.org/10.3389/fenvs.2018.00025.

Ugarte, C. M., and Taylor, J. R. 2020. “Chemical and Biological Indicators of Soil Health in Chicago Urban Gardens and Farms.” *Urban Agriculture & Regional Food Systems* 5, 1: e20004. https://doi.org/10.1002/uar2.20004.

Natural Resources Conservation Service. 2019a. Title 450, Resource Concerns and Planning Criteria, Part 309. National Resource Concern List and Planning Criteria.

Natural Resources Conservation Service. 2019b. Soil Health Technical Note 450-06. Cropland In-Field Soil Health Assessment.

U.S. Environmental Protection Agency. 2007. “Method 6200: Field Portable X-ray Fluorescence Spectrometry for the Determination of Elemental Concentrations in Soil and Sediment.” https://www.epa.gov/sites/default/files/2015-12/documents/6200.pdf.

U.S. Environmental Protection Agency. 2011. “Evaluation of Urban Soils: Suitability for Green Infrastructure or Urban Agriculture.” https://nepis.epa.gov/Exe/ZyPDF.cgi/P100GOTW.PDF?Dockey=P100GOTW.pdf.

U.S. Environmental Protection Agency. 2014. “Technical Review Workgroup Recommendations Regarding Gardening and Reducing Exposure to Lead-Contaminated Soils.” https://semspub.epa.gov/work/HQ/174577.pdf.