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Conservation Practices for Soil Health in Urban and Small-Scale Agriculture

Acknowledgments

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Introduction

Soils are the foundation of urban ecosystems and management of soil health is a critical component of conserving natural resources and resilience in urban areas. Urban soils provide a multitude of services to the communities where they exist. Urban soils support climate resilience in cities in several ways, including safe soil interactions, urban ecosystems, stormwater management, cooler cities, and climate change mitigation.[1] Similarly, urban agriculture, along with small-scale agriculture in rural areas, provide many benefits to surrounding communities, including human health benefits, social space, green infrastructure, habitat for biodiversity, and multiple ecological services (such as water cycling).[2] Because a large percentage of the U.S. population live in cities, managing the health and functioning of urban soils can potentially support significant positive ecological outcomes for many people.

Soil degradation and resource concerns, such as compaction, elevated concentrations of salts and other chemicals, organic matter depletion, unsuitable materials or soil sealing, contamination by heavy metals and other compounds, and the removal of topsoil, are frequently found in urban soils. While not all urban soils are impaired by resource concerns, the potential and function of soils can be significantly impaired at sites that do have them. In a survey of urban community gardeners, participants reported that soil quality was their most common limitation to garden productivity.[3] To date, very little research has tested the impact of management practices on soil health and crop production in urban gardens[4] and additional technical assistance and information are needed to serve the needs of urban farmers and gardeners.[5]

Urban sites are also impacted by several alterations in the biophysical environment beyond soil health, including atmospheric pollutants, increased surface temperatures, reduced light and wind speed due to adjacent buildings, stormwater contamination, and unpredictable access to irrigation water.[6] The small scale of urban agriculture, and urban green spaces more broadly, provides an opportunity to implement conservation practices that are intensive in nature and may improve soils and environmental conditions over relatively short timeframes, if producers and managers have the resources and information required to be successful with these methods.

The USDA Natural Resources Conservation Service (NRCS) has distilled the results of extensive scientific research on soil health into four principles of management to conserve the soil ecosystem: (1) minimize disturbance, (2) maximize soil cover, (3) maximize biodiversity, and (4) maximize continuous living roots. These principles offer strategies to manage the soil as a living habitat by protecting the soil surface and structure and providing food sources to soil organisms. The soil health principles can be

[1] Dustin L. Herrmann, Mary Hillemeier, Richard V. Pouyat, Susan D. Day, Yujuan Chen & Lia Soorenian, Urban Soil Management for Climate Resilience (2023).
[2] Prajal Pradham, Max Callaghan, Yuanchao Hu, Kshitij Dahal, Claudia Hunecke, Fritz Reusswig, Hermann Lotze-Campen & Jürgen P. Kropp, *A systematic review highlights that there are multiple benefits of urban agriculture besides food,* 38 Glob. Food Sec. 100700 (2023).
[3] Megan M. Gregory, Timothy W. Leslie & Laurie E. Drinkwater, *Agroecological and Social Characteristics of New York City Community Gardens: Contributions to Urban Food Security, Ecosystem Services, and Environmental Education,* 19 Urb. Ecosystems 763 (2016).
[4] John R. Taylor, *Modeling the Potential Productivity of Urban Agriculture and its Impacts on Soil Quality through Experimental Research on Scale-Appropriate Systems,* 4 Frontiers in Sustainable Food Systems 89 (2020).
[5] Gregory et al., *supra* note 3.
[6] Sam E. Wortman & Sarah Taylor Lovell, *Environmental Challenges Threatening the Growth of Urban Agriculture in the United States,* 42 J. Env't Quality 1283 (2013).

applied at any scale of land management and used to address soil resource concerns and improve the ecological function of urban soils. Several NRCS conservation practices can be used to address resource concerns in small-scale and urban settings and apply the soil health principles (Table 1).

A robust strategy for improving soils is to plan and manage a soil health management system (SHMS). An SHMS uses multiple management practices in synergistic ways to apply the soil health principles in managed landscapes. Developing and implementing SHMSs on small farms, urban gardens, and green spaces in urban areas will improve soil conditions and support ecosystem services in these areas.

This document focuses on how existing NRCS conservation practices can be applied in small-scale farms and gardens in both urban and rural areas to support soil health and implement SHMSs. This is the third technical note in a series of three from the NRCS Soil Health Division focused on urban soil health. The first technical note covers the basics of urban soil health, including properties of urban soils and soil health resource concerns in urban areas. The second addresses site evaluation for urban soil health and applies existing NRCS tools to the testing and evaluation of soils at urban sites.

Table 1. USDA NRCS conservation practices for improving soil health and addressing resource concerns in urban soils

		Resource Concerns						
Practice	**CPS code**	***Concentration of Salts or other Chemicals***	***Compaction***	***Soil Organic Matter Depletion***	***Soil Organism Habitat Degradation***	***Aggregate Stability***	***Unsuitable Material/Soil Sealing***	**Soil Health Principles***
Raised Beds	**812**	**X**					**X**	**1, 3**
Mulching	**484**			**X**				**1,2, 3**
Soil Carbon Amendment	**336**			**X**	**X**	**X**		**2, 3**
Cover Crops	**340**		**X**	**X**	**X**	**X**		**2, 3, 4**
Conservation Crop Rotation	**328**			**X**	**X**	**X**		**2, 3, 4**
Reduced Tillage	**345**			**X**	**X**	**X**		**1, 2, 3**
No Till	**329**			**X**	**X**	**X**		**1, 2, 3**
Conservation Cover	**327**		**X**	**X**	**X**	**X**		**1, 2, 3, 4**
Hedgerows	**422**			**X**				**1, 2, 3, 4**
Nutrient Management	**590**			**X**				**1, 3**
Low Tunnels	**821**				**X**			**2, 3, 4**
Irrigation	**441 & 442**			**X**	**X**			**2, 3**

*Soil Health Principles referenced in table are (1) minimize disturbance, (2) maximize cover, (3) maximize biodiversity, and (4) maximize continuous living roots. Xs mark the resource concerns that are directly addressed in the conservation practice standard (CPS) documents.

Conservation Practices for Improving Soil Health in Urban and Small-Scale Agriculture

Raised Beds (Interim CPS 812)

Constructed raised beds are a widely used soil management practice for urban agriculture (Figure 1). They offer many benefits to urban and small-scale growers, including facilitating good rooting conditions, improved drainage, and intensive soil management at small scales. The raised beds interim conservation practice standard (interim CPS 812) applies specifically to sites where the existing soil is not suitable for in-ground cultivation of crops.

The practice is often used on sites where soils are composed of poor material or high concentrations of coarse fragments or have documented or potential contamination issues. Raised beds overcome these resource concerns by allowing managers to construct a new rooting zone and import improved growing media.

Figure 1. Constructed raised beds. Constructed raised beds were used at the People's Garden in Compton, CA, to create a community garden on a site where the soil conditions were previously not suitable for gardening. (Photo: USDA)

Constructed raised beds generally consist of a box or frame made with wood or similar materials. The box is then filled with a mixture of potting soil, manufactured topsoil, compost, and occasionally the native soil material. Beds can be 6 to 24 inches deep depending on the rooting depth of the planned crops. For further protection, raised beds can include barriers such as non-woven fabric to reduce direct exposure to soil and help prevent crops from taking up contaminants. Drainage is an important consideration for implementing constructed raised beds and must be accounted for in both the design of the boxes themselves and the overall site plan.

Constructed raised beds may be helpful in gardens for groups with specialized needs, such as school gardens or gardens where improved accessibility is needed. The contained nature of constructed beds can simplify many maintenance activities.

Little research has been conducted on long-term management of soil health in constructed raised beds. However, it is likely that soil organism habitat and plant health in these systems will be supported by the application of other conservation practices, including cover cropping, nutrient management, soil carbon amendment, and mulching. A study focused on raised beds for urban agriculture found that sites with raised bed systems consistently had larger vegetable crop yields compared to sites growing crops directly in the ground and recommended that raised beds be filled with a mixture of compost and soil.[7] Raised beds filled with materials that are primarily soilless, such as compost or potting soil, may require frequent irrigation as well as nutrient tests specific to soilless media.

NRCS interim practice standards (such as 812 and 821) are not final standards. They are considered assessments of technology. They may be approved as final standards, become part of existing practice standards, or not be finalized at all.

<u>Key uses for raised beds in urban and small-scale soil management include:</u>

- Providing space for crop growing at sites where the existing substrate or soil material is not suitable for growing crops.

Mulching (CPS 484)

Mulching is an important practice for urban and small-scale soil management. In urban gardens, heavy applications of mulch are often used to cover the ground in open spaces outside of growing areas. Keeping the soil covered decreases the risk of soil and dust inhalation, greatly reducing health risks at sites with potential soil contamination. Mulch is also a key material for covering and feeding soils in urban and small-scale gardens. Mulch can be used to achieve multiple management objectives, such as reducing erosion, reducing airborne particulate matter, covering the soil, providing a carbon source for soil, reducing weed growth and pest pressure, reducing evaporation, and increasing water conservation and irrigation efficiency in covered areas. Mulching is also very beneficial for improving soil health for perennial landscaping and tree plantings in urban areas. A range of studies focused on urban tree management found that surface-applied mulches improved root growth and soil biological responses.[8]

Applying mulch supports at least three of the soil health principles by covering the soil, providing improved habitat and a food source for soil organisms, and likely decreasing disturbances of the soil. A soil health needs assessment from Los Angeles observed that 44 percent of the city's soil was in a bare condition.[9] Mulching bare soils in urban areas is an excellent, cost-effective practice for improving their health and ecological function.

Matching the appropriate mulching material for the situation is key to achieving an optimal outcome in small-scale agriculture. Figure 2 demonstrates diverse organic mulch materials used to achieve different

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[7] Elizabeth A. Miernicki, Sarah Taylor Lovell & Sam E. Wortman, *Raised Beds for Vegetable Production in Urban Agriculture,* 3 Urb. Agric. Reg'l Food Sys. 1 (2018).
[8] Bryant C. Scharenbroch, *A Meta-analysis of Studies Published in* Arboriculture & Urban Forestry *Relating to Organic Materials and Impacts on Soil, Tree, and Environmental Properties,* 35 Arboriculture and Urb. Forestry 221 (2009).
[9] Yujuan Chen, Richard V. Pouyat, Susan D. Day, Erica L. Wohldmann, Kirsten Schwarz, Gordon L. Rees, Manny Gonez, Edith B. de Guzman & Selena Mao, Healthy Soils for Healthy Communities Phase 1: Needs Assessment (2021).

management goals. In general, mulches composed of natural materials, such as those in Figure 2, are preferrable to synthetic mulches.

One aspect of mulch management is matching the C:N ratio to cropping system goals for residue and cover, as lower C:N ratio materials such as compost will decompose more rapidly while higher C:N ratios such as straw and wood chips will provide a more persistent cover. Care must be taken in sourcing mulch materials that are free from potential pests and contaminants such as weed seeds, diseased plant material, herbicide or pesticide residues, and industrial contaminants.

<u>Key uses for mulch in urban and small-scale soil management include:</u>

- Covering bare ground in pathways and open areas at sites (wood chips)
- Mulching of soil around perennial plants (wood chips, compost)
- Covering soil in annual vegetable crop production (straw)
- Compost mulching of growing beds in annual vegetable production systems

Figure 2. Methods for using mulch in urban and small-scale agriculture. Mulch materials can be applied to support several conservation goals in urban and small-scale agriculture. Wood chip mulch can be applied in thick layers onto paths and unused garden spaces in urban gardens to reduce direct soil contact, dust, and weed pressure (left). Straw mulch can be applied to vigorous vegetable crops, such as tomatoes, while wood chips are used to mulch foot paths (center). Compost is used as a surface mulch in some vegetable gardening systems, while wood chips are useful for mulching soil around perennials such as fruit trees and flowers (right). (Photos: Left photo from Youngstown Neighborhood Development Corporation, Ohio; center and right photos by Joshua Beniston USDA NRCS.)

Soil Carbon Amendment (CPS 336)

Soil carbon (i.e., organic matter) is a cornerstone of soil health; most soils benefit from carbon amendments. Increasing soil carbon can lead to increased microbial abundance and activity, improved soil structure and water infiltration, and increased nutrient cycling. The NRCS soil carbon amendment practice provides financial assistance for the use of compost and biochar to increase soil organic matter. Carbon amendments can rapidly improve soil health in small scale systems, and materials such as compost are readily available in most urban areas. Management of soil properties by applying amendments is also a well-documented strategy for reducing risk of heavy metal contamination in urban soils.[10] The mobility of some metals such as lead (Pb) in soils is reduced by having high soil phosphorous (P) and high organic matter levels, which soils can often get from applying compost.

Compost application

Applying significant amounts of compost is generally cost effective for small sites. Many successful small-scale farms use repeated compost applications for soil fertility and high productivity.[11] Compost application can be a key practice for increasing soil organic matter and improving the benefits of other soil health management practices, such as cover cropping, in market farming systems.[12] Compost application generally results in an immediate increase in crop yields in agricultural systems.[13]

At urban sites that lack topsoil or have lower quality soils, large one-time applications of compost are an excellent method of rapidly improving soil conditions. An urban garden experiment in Ohio saw immediate improvements in crop growth and soil properties when a large amount of compost was applied to vacant lots where topsoil had been removed.[14] A review article on using compost recommended adding a 2- to 4-inch layer of compost, or up to 25 percent by volume, for landscape plantings in degraded urban soils.[15] Heavy or repeated compost applications will generally lead to high P levels in urban and small-scale gardens.[16] P levels need to be monitored and managed at sites using compost where there is a risk of generating runoff and exporting P into drainage systems and surface waters.

The composition and quality of composts can vary widely and in some cases be problematic.[17] NRCS requires that compost used in the soil carbon amendment practice be tested for a suite of physical, chemical, and biological parameters. When purchasing large quantities of compost, work with vendors that supply these test results for their products.

<u>Key uses for compost in urban and small-scale soil management include:</u>

- Applying to annual crop land, perennial crops, and tree plantings to increase soil organic matter or use as a nutrient source.
- Applying as surface mulch in small-scale, reduced tillage vegetable production.

[10] Sally L. Brown, Rufus L. Chaney & Ganga M. Hettiarachchi, *Lead in Urban Soils: A Real or Perceived Concern for Urban Agriculture?*, 45 J. Env't Quality 26 (2016).
[11] Jean-Martin Fortier, The Market Gardener: A Successful Grower's Handbook for Small-Scale Organic Farming (2014).
[12] Nicole E. Tautges, Jessica L. Chiartas, Amélie C.M. Gaudin, Anthony T. O'Geen, Israel Herrera & Kate M. Scow, *Deep Soil Inventories Reveal that Impacts of Cover Crops and Compost on Soil Carbon Sequestration Differ in Surface and Subsurface Soils,* 25 Glob. Change Biology 3753 (2019).
[13] Sam E. Wortman, Ashley A. Holmes, Elizabeth Miernicki, Kaelyn Knoche & Cameron M. Pittelkow, *First-Season Crop Yield Response to Organic Soil Amendments: A Meta-Analysis,* 109 Agronomy J. 1210 (2017).
[14] Joshua W. Beniston, Rattan Lal & Kristin L. Mercer, *Assessing and Managing Soil Quality for Urban Agriculture in a Degraded Vacant Lot Soil,* 27 Land Degradation and Development 996 (2016).
[15] Craig G. Cogger, *Potential Compost Benefits for Restoration Of Soils Disturbed by Urban Development,* 13 Compost Sci. & Utilization 243 (2005).
[16] Gaston Small, Paliza Shrestha, Geneviève Suzanne Metson, Katherine Polsky, Ivan Jimenez & Adam Kay, *Excess Phosphorus from Compost Applications in Urban Gardens Creates Potential Pollution Hotspots,* 1 Env't Rsch. Commc'n 091007 (2019); Myki Nelson, Gwynne Mhuireach & Gail A. Langellotto, *Excess fertility in residential-scale urban agriculture soils in two western Oregon cities, USA,* 7 Urb. Agric. Reg'l Food Sys. e20027 (2022).
[17] Weston Miller & Jeremiah Mann, How to Use Compost in Gardens and Landscapes (2021).

- Applying at large rates to rapidly increase soil organic matter in degraded soils.

Biochar application

Biochar has generated intense interest in recent years. Biochar materials are diverse in the physical and chemical composition, depending on the feedstock material and the process that was used to produce a given biochar. Similarly, documented effects of biochar on soil health vary depending on soil type.[18] Applying biochar may support rapid improvements to soil health in soils that are at the sandy or clay ends of the soil texture spectrum, are acidic, or are low in organic matter.[19] A study that compared the use of organic materials as mulch for urban trees found that biochar made from pine improved tree growth and soil properties.[20] Additional field testing of biochar is needed to determine specific application rates and appropriate materials for optimal results in urban and small-scale agriculture.

Cover Cropping (CPS 340)

Cover cropping (i.e., growing specific plant species for the purpose of covering, feeding, and improving the soil) translates well to urban and small-scale farming settings. Cover cropping is a key practice in applying the soil health principles as it facilitates maximizing continuous living roots, soil cover, and biodiversity. Many cover crop species can be managed with small scale tools and techniques (Figure 3).

Cover crops can be used to reach many soil health and agronomic goals, including increasing soil organic matter, improving soil structure or aggregate stability, improving soil organism habitat, providing biomass for soil cover and mulch, reducing weeds, increasing soil nitrogen, increasing nutrient retention and availability, and improving water infiltration and holding capacity. A research project on the restoration of urban soils for crop production following the demolition of vacant houses observed that a year of intensive cover cropping resulted in measurable increases in soil aggregation compared with other experimental treatments.[21] Planting of cover crop mixtures reduced both the density and diversity of weed species in another experiment focused on improving urban soils.[22] In many urban gardens, cover cropping remains an underused practice, and more training and technical assistance are needed to encourage cover cropping in urban agriculture.[23]

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[18] Hardeep Singh, Brian K. Northup, Charles W. Rice & P.V. Vara Prasad, *Biochar Applications Influence Soil Physical and Chemical Properties, Microbial Diversity, and Crop Productivity: A Meta-Analysis,* 4 Biochar 8 (2022).
[19] See *id.*
[20] Bryant C. Scharenbroch, Elsa N. Meza, Michelle Catania & Kelby Fite, *Biochar and Biosolids Increase Tree Growth and Improve Soil Quality for Urban Landscapes,* 42 J. Env't Quality 1372 (2013).
[21] Beniston et al., *supra* note 14.
[22] Naim Edwards, Nicholas Medina & Elizabeth Asker, *Mixing Cover Crops Suppresses Weeds and Roto-till Reduces Urban Soil Penetration Resistance and Improves Infiltration,* 231 Soil and Tillage Rsch. 105708 (2023).
[23] Gregory et al., *supra* note 3.

Figure 3. Cover crop management in small-scale raised beds. Cover cropping in raised beds is possible with small-scale tools and techniques. In this raised bed, a cover crop (CC) of oats and bell beans was established by planting the seed in furrowed rows (top left). At maturity, the CC was chopped down with a hedge trimmer (top center) and then covered with a piece of black landscape fabric to act as a tarp (top right). The fabric was removed after 3 to 4 weeks and had fully terminated the CC (bottom left). Residues were then pushed aside from the soil surface for transplanting of vegetable crops (bottom center). After transplanting, the CC residue was used to mulch the growing plants (bottom right). Using CCs and tarps together facilitate no-till conservation planting at small scales, such as in constructed raised beds. (Photos: Joshua Beniston, USDA NRCS.)

There are many plant species used for cover cropping that are optimized for specific soil management goals. The Managing Cover Crops Profitably manual from USDA SARE is an excellent and comprehensive reference for using cover crops in the United States.[24] There are also four regional cover cropping councils in the United States covering the West, Midwest, Northeast, and Southeast, each of which maintains an online cover crop selection and information tool. Keys to successfully implementing cover crops include finding the appropriate seasonal niche in the cropping system and identifying cover crops that match management goals and can be managed with the tools available.

<u>Key uses for cover crops in urban and small-scale soil management include:</u>

- Keeping soil covered and living roots in the ground during periods when crop plants are not being grown.
- Improving soil health and nutrient availability for crop plants.

[24] Sustainable Agriculture Research and Education, Managing Cover Crops Profitably (Andy Clark ed., 3rd ed. 2008).

- Improving soil structure in sites with compaction or other physical degradation.
- Reducing weed pressure in annual crop production systems.

Conservation Crop Rotation (CPS 328)

Urban and small-scale growers can advance their soil health and productivity by rotating crops throughout the year. Designing a detailed crop rotation helps to explore opportunities for incorporating soil building practices such as cover crops in different seasons and can also identify windows when additional market crops can be grown at the site. Key goals for a soil-building conservation crop rotation include keeping plants growing throughout the year, identifying ways to increase plant and crop diversity in the system, and finding appropriate niches and opportunities to incorporate cover crops.

There are several principles that experienced producers use to develop robust crop rotations. These principles are described in detail in Crop Rotation on Organic Farms.[25] Some of the most used principles include rotating crops according to plant family, rotating vegetable crops between high nutrient and low nutrient feeding crop families, and rotating cash crops and cover crops. One major benefit of crop rotations is that they can reduce pest pressure on crops, which is important for vegetable crop production because many vegetable crops are susceptible to pests when grown in the same location repeatedly. Rotations are required for certified organic farming where pesticide use is limited. A survey of urban gardeners reported that while many were familiar with the concept of a crop rotation, only a minority were implementing the practice correctly in their gardens.[26]

Planners and producers who are new to developing crop rotations will benefit from studying the methods of crop planning. Crop plans are farm production plans that organize tasks such as seeding, transplanting, and soil management into a detailed work calendar and will generally include a crop rotation. The skills of crop planning are beneficial to those who are working towards goals such as maximizing continuous living roots and crop production in small spaces. Several useful references on crop planning for small-scale production exist including a fact sheet by Bachmann[27] and the Crop Planning for Organic Vegetable Growers manual.[28]

<u>Key uses for conservation crop rotations in urban and small-scale soil management include:</u>

- Reducing pest pressure on crops.
- Developing detailed plans for pursuing soil management goals such as maximizing continuous living roots, incorporating cover crops, and maximizing production in small spaces.

Residue and Tillage Management – Reduced Till (CPS 345) and No Till (CPS 329)

Reducing or eliminating tillage is a key strategy for minimizing soil disturbance. Reduced and no till approaches in small-scale and urban systems may look significantly different from those used in larger

[25] Charles L. Mohler & Sue Ellen Johnson, Crop Rotation on Organic Farms: A Planning Manual (Jill Mason ed., 2009).
[26] Gregory et al., *supra* note 3.
[27] Janet Bachmann, Scheduling Vegetable Plantings for Continuous Harvest (2008).
[28] Frédéric Thérilaut & Daniel Brisebois, Crop Planning for Organic Vegetable Growers (2010).

scale agriculture but their effect of conserving and improving soil health is similar. However, completely eliminating tillage may not be a realistic goal for many small-scale producers of specialty crops.

The NRCS reduced till and no till practices are differentiated by the soil tillage intensity rating (STIR) of practices for cultivating and preparing soil. STIR ratings are used in erosion modeling of sites when developing conservation plans. Several methods of reducing tillage in small-scale systems have been developed and refined in recent decades; however, many of the tools that small-scale producers use to reduce tillage do not have well documented STIR ratings. Many producers describe their tillage systems without precisely differentiating levels of soil disturbance and it is not uncommon to hear systems with some level of disturbance be called no till.

Permanent beds

Implementing a permanent bed system can also reduce tillage on small-scale farms. Crops being grown in the ground can get the same benefits of raised beds by using permanent beds of soil alongside permanent pathways for foot traffic (Figure 4).[29] The advantage of permanent beds is that disturbance can be greatly reduced in the growing spaces, allowing the soil structure to fully develop. The pathways limit the compaction that foot traffic can cause. Permanent beds work well in combination with other soil health management practices described in this technical note, including adding carbon amendments, using reduced tillage tools, mulching, and cover cropping.

Figure 4. Permanent raised beds and tarping. The garden in the photo demonstrates the use of permanent raised beds and tarping (occultation) as small-scale methods to reduce tillage. The garden beds are 30 inches wide (a common width for many tools and products) and pathways are 18 inches wide to allow for working between the beds. The permanent beds allow soil-building activities to be focused on the growing area while traffic is concentrated in the pathways. In the background, a silage tarp is being used to terminate a winter cover crop that was mowed. The tarp was recently removed from the beds in the foreground and they are ready to be prepared for transplanting of spring vegetable crops. (Photo: Joshua Beniston, USDA NRCS.)

[29] Fortier, *supra* note 11.

Tools for reducing tillage intensity at small scales

Strategies to reduce disturbance in small-scale agriculture often focus on the tools used for tillage in the system and their frequency of use, depth of disturbance, and tillage intensity. Rototillers, which are commonly used in small-scale agriculture, are considered an intense form of tillage and can lead to degradation of soil health with frequent use. Other soil cultivation implements have less impact on soil in comparison. For example, power harrows provide a shallow, intensive tillage that does not invert soil layers. Spaders can also prepare soil and incorporate amendments with a lower level of disturbance intensity.

At the garden scale, broadforks are hand tools that are used in soil preparation to loosen soil and incorporate amendments. Broadforks provide very little disturbance to the soil structure and have become popular with small-scale growers. Many producers also use cultivation or weeding hand tools for shallow, low intensity cultivation at their sites.

No till growing at small scales

Growing crops without tillage has been a topic of great interest among small-scale growers and gardeners in recent years. Several management practices and systems have demonstrated success for eliminating tillage from small-scale systems. Tarping, or occultation, uses tarp materials to prepare soil. Silage tarps or landscaping fabric are used to cover garden areas for several weeks. The cover cuts off sunlight and kills plants growing on the ground. Soil organisms then consume the dead plant biomass, leaving behind a relatively clean soil surface when the tarps are removed (Figure 4). Tarping can be used for both no till bed preparation and weed management in small-scale systems. Tarps can also be used to kill sod for creating new garden areas without tillage. Recent research has documented some details of using tarps for different soil management goals.[30]

Other small-scale no till methods use various types of mulching for soil management. This can include either deep mulching systems or compost mulch systems (Figure 2). Sheet mulching, or lasagna gardening, is a popular method for establishing new gardens or mulching existing perennials that uses a thick mulch with multiple layers of different materials. Sheet mulching generally includes a layer of carboard or newspaper close to the soil surface that acts as a weed barrier. Numerous cooperative extension publications on sheet mulching are available, such as "Sheet mulching—aka lasagna composting—builds soil, saves time," from Oregon State University.

Conservation Cover (CPS 327) and Hedgerow Planting (CPS 422)

NRCS has a number of conservation practices that involve planting perennial vegetation at sites to address resource concerns. The discussion here will focus on conservation cover (CPS 327), which establishes permanent vegetation cover through planting herbaceous perennials and annuals, and hedgerows (CPS 422), which establishes dense perennial vegetation with woody plants and perennial bunch grasses, because these practices have explicit soil health purposes in their practice standards (Figure 5). Other conservation practices that may be useful for establishing perennial vegetation at urban sites and small-scale farms include field border (CPS 386), wildlife habitat plantings (CPS 420),

[30] Roger Kubalek, David Granatstein, Doug Collins & Carol Miles, *Review of Tarping and a Case Study on Small-scale Organic Farms,* 32 HortTechnology 119 (2022).

and tree/shrub establishment (CPS 612). These practices can potentially support all four of the soil health principles by establishing permanent vegetation and root cover at sites. Research on using native perennial plantings in urban landscapes has documented benefits to soil physical properties such as saturated hydraulic conductivity and bulk density,[31] as well as greater microbial diversity and increases in beneficial microbial populations.[32] In addition to improving soil health, conservation practices that establish perennial vegetation supports habitat for pollinator species.[33]

Conservation Cover

The conservation cover practice is often used to establish perennial vegetation, such as grasses and ground covers, between rows of perennial crops such as in vineyards or orchards. Conservation cover can establish a living cover between raised beds in urban gardens, which can improve soil health in those areas. Perennial vegetation in noncultivated areas is an excellent strategy for reducing runoff and soil erosion and increasing water infiltration. Perennial vegetation can also improve habitat conditions for ground-nesting beneficial insects in gardens. Urban gardens bordered by perennial vegetation contained significantly more species of ants that predate crop pests than gardens next to other garden plots.[34]

<u>Key uses for conservation cover in urban and small-scale soil management include:</u>

- Providing living cover between raised beds or crop production areas in gardens.
- Establishing pollinator and beneficial insect habitat plantings.
- Improving soil physical properties and water infiltration.

[31] Marie R. Johnston, Nick J. Balster & Jun Zhu, *Impact of Residential Prairie Gardens on the Physical Properties of Urban Soil in Madison, Wisconsin,* 45 J. Env't Quality 45 (2016).
[32] Danielle S. Baldi, Christine E. Humphrey, John A. Kyndt & Tyler C. Moore, *Native Plant Gardens Support More Microbial Diversity and Higher Relative Abundance of Potentially Beneficial Taxa Compared To Adjacent Turf Grass Lawns,* 26 Urb. Ecosystems 807 (2023).
[33] Hillary S. Sardiñas, Rebecca Ryals & Neal M. Williams, *Carbon Farming Can Enhance Pollinator Resources,* 76 California Agric. 104 (2023).
[34] Naim Edwards, *Effects of Garden Attributes on Ant (Formicidae) Species Richness and Potential for Pest Control,* 1 Urb. Agric. Reg'l Food Sys. 1 (2016).

Figure 5. Perennial plantings for small-scale agricultural systems. The left photo documents a wildlife habitat planting of herbaceous perennial plants on the edge of cropped areas. The right photo contains an established hedgerow planting of young trees and herbaceous perennial plants. Both plantings use space on the edge of cropped areas to enhance biodiversity, soil organism habitat, and water infiltration. (Photos: Urban Soil Health program, Indiana.)

Hedgerows

Hedgerows are dense, linear plantings of perennial vegetation that address multiple resource concerns. Hedgerows are generally composed of shrubs and smaller trees and may also include herbaceous perennials and perennial grasses. Hedgerow plantings have a long history of being used on the edges of farm fields. In agricultural landscapes, hedgerows can improve soil health and potentially increase soil carbon stocks across soil types to 1 meter in depth.[35] In urban areas, multifunctional hedgerows can potentially improve water infiltration, protect crops from wind and aerosols, improve privacy and aesthetics at the sites, and generate additional marketable products from perennial.[36] Hedgerow plantings based on food forests or multilayered plantings of mostly perennial edible plants, such as fruit trees, have great potential to provide multifunctional landscapes on urban and small-scale farms.[37]

Key uses for hedgerows in urban and small-scale soil management include:

- Establishing multifunctional buffers at the edges of sites that can increase soil carbon, increase water infiltration, provide habitat, moderate climatic conditions, and provide privacy screening.
- Creating food forest landscapes.

Nutrient Management (CPS 590)

[35] Jessica L. Chiartas, Louise E. Jackson, Rachael F. Long, Andrew J. Margenot & Anthony T. O'Geen, *Hedgerows on Crop Field Edges Increase Soil Carbon to a Depth of 1 Meter,* 14 Sustainability 12901 (2022).
[36] Wortman and Lovell, *supra* note 6; see also James A. Allen & Andrew C. Mason, *Urban Food Forests in the American Southwest,* 6 Urb. Agric. Reg'l Food Sys. e20018 (2021).
[37] Allen & Mason, *supra* note 36.

Nutrient management can be key to successful urban and small-scale agriculture. Soil nutrient testing remains an underused practice by urban gardeners[38] and many urban gardens contain nutrient concentrations well above recommended levels.[39] Meanwhile, at urban sites where soil has been degraded, low macronutrient concentrations may be a major limitation to crop growth.[40] Soil tests can help producers identify the quantities and sources of nutrients that are appropriate for their site. Developing a plan for optimized nutrient applications based on soil test results can support successful crop productions and improve soil health while minimizing the risk of nutrient runoff to the environment.

Key uses for nutrient management in urban and small-scale soil management include:

- Using soil tests to determine existing nutrient stocks and soil chemical properties.
- Planning the correct sources, rates, and timing for nutrient applications.

Low tunnels (Interim CPS 821)

Low tunnels are temporary structures in crop growing areas that are placed over vegetables and low growing fruit crops to support a variety of cover materials. Covers used on low tunnels include spun-bonded fabrics (commonly called "row covers"), which protect against pests and cold temperatures and extend the growing season, and fine mesh netting materials, used to exclude insect and bird pests from susceptible crops (Figure 6). Low tunnels have documented impacts of improving crop growth and yield, reducing pest damage, and improving water use efficiency in covered crops.[41] Low tunnels can improve soil organism habitat by extending the duration of both plant growth and cover. Systems using low tunnels also reduce impacts of pesticides on soil organism habitats and biodiversity. Low tunnels can help facilitate more complex conservation crop rotations aimed at improving soil health and increasing productivity. Low tunnels are a low-cost method for extending the growing season and excluding pests and are becoming more widely used by many small-scale growers.[42]

Key uses for low tunnels in urban and small-scale soil management include:

- Extending the growing season and increase plant growth for vegetable crops.
- Preventing pest damage to vegetable crops.

[38] Gregory et al., *supra* note 3; Small et al., *supra* note 16.
[39] Small et al., *supra* note 16; Nelson et al., *supra* note 16.
[40] Beniston et al., *supra* note 14.
[41] Ramón A. Arancibia, Low Tunnels in Vegetable Crops: Beyond Season Extension (2018).
[42] Fortier, *supra* note 11.

Figure 6. Low tunnels in small-scale agriculture systems. Low tunnel systems use simple metal frames to hold protective fabrics over crops. Low tunnels using row covers (or spun-bonded fabric) protect vegetable crops against both cold temperatures and pests (left). Low tunnels using a fine mesh netting material protect recently transplanted vegetable crops from damage by birds and insects (right). (Photos: Left photo from Urban Soil Health program, Indiana; right photo by Joshua Beniston, USDA NRCS.)

Irrigation – Irrigation system, Microirrigation (CPS 441) & Sprinkler system (CPS 442)

Irrigation is necessary for optimal growth of fruit and vegetable crops in most areas and is a key component of many small-scale specialty crop production systems.[43] Irrigation may also be important for soil health management systems in regions and sites where precipitation is limited. Plants and soil organisms require water to maintain growth, and irrigation of dry sites can result in improved soil organism habitat. Research on irrigated soils around the world has demonstrated that irrigation often leads to increased soil organic matter, though these increases are influenced by soil type and the type of irrigation system.[44]

Irrigation systems are also commonly used to support the establishment of many of the soil health practices described in this document, including cover crops, conservation cover, and hedgerows. Sprinklers are generally used to irrigate plantings done by seed (e.g., cover crops) in small-scale systems. The uniform wetting of the planting area facilitates good germination and growth. Hedgerows and other plantings of woody plants can be established using microirrigation systems. Microirrigaiton systems have a high efficiency of delivering water to the root zone and are commonly used in specialty crop systems where water is limited or in cases where water has higher costs, such as in some urban areas.

<u>Key uses for low tunnels in urban and small-scale soil management include:</u>

- Facilitating robust plant growth and improved soil organism habitat at sites without adequate precipitation.

[43] See *id.*
[44] David Emde, Kirsten D. Hannam, Ilka Most, Louise M. Nelson & Melanie D. Jones, *Soil Organic Carbon in Irrigated Agricultural Systems: A Meta-analysis,* 27 Glob. Change Biology 3898 (2021).

- Establishing plantings aimed at improving soil health such as cover crops, conservation cover, and hedgerows.

Applying soil health conservation practices to unique scenarios in urban and small-scale agriculture

Intensive soil health management can be applied across small-scale agriculture settings in both urban and rural environments to improve soils and enhance outcomes. The practices outlined in this document can be used in combination to address resource concerns in scenarios that are both widespread and challenging to manage, including high tunnel production and sites with documented or potential soil contamination.

Recommended conservation practices for soil health in high tunnel production

High tunnels are often very intensively managed environments. A well-managed tunnel can produce significantly greater fruit and vegetable crop yields than uncovered areas. They are also unique in that the plastic cover of the tunnel prevents precipitation from hitting the ground and limits the intrusion of both air movement and pollinators into the tunnel. All these factors create unique challenges for soil health and conservation management. Many of the conservation practices in this document are well suited for improving soil health in high tunnel environments.

- Soil carbon amendment. Supports soil organism habitat, soil organic matter, water use efficiency, and soil nutrients in crop growing spaces.
- Mulch. Supports soil organism habitat, reduced evaporation, and reduced weed pressure around crop plants. Mulch can also support soil health and reduce management of pathways.
- Cover crops. Supports soil health when market crops are not being grown.
- Conservation crop rotation. Optimizes planting times and growing seasons, manages soil health, and reduces plant pathogens.
- Conservation cover. Provides cover, supports soil organism habitat, and improves water infiltration in areas surrounding the high tunnel.
- Reduced tillage. Supports soil health in crop growing areas.
- Nutrient management. Maintains adequate soil nutrients, identifies appropriate nutrient sources, and monitors chemical properties of soil (such as salinity levels and pH).

Recommended conservation practices for soil health at urban sites with documented or potential soil contamination

Soil contamination by heavy metals and organic compounds is common at urban sites with a history of industrial uses or disposal of industrial products such as lead paint and petrochemicals. Urban sites should be evaluated for historical risk and urban soils should be evaluated for elevated levels of contaminants using field screening tools and laboratory testing (see Technical Note Title 470 SH No. 3, "Site Evaluation for Urban Soil Health"). At sites where screening and testing have observed low to moderate levels of contamination or sites with historical uses consistent with contamination, conservation practices can be applied to reduce the risk of human exposure to soilborne contaminants by reducing direct contact with soil, reducing ingestion of soil particles, and adjusting soil chemical properties to reduce the mobility of contaminants.

- Raised beds. Reduces direct contact with soil for crops and producers.
- Mulching. Reduces direct contact with soil and reduces dust and airborne particulates in bare soil areas.
- Soil carbon amendment. Reduces the mobility and availability of some heavy metals in soils. Soil organic matter and enhanced soil microbial activity also help degrade some petrochemical contaminants.
- Conservation cover and hedgerows. Reduces direct contact with soil, reduces airborne particulates and transport of particulates into the site, and stimulates soil microbial activity.
- Nutrient management. Facilitates management of soil chemical properties to optimize soil health and reduce availability of some contaminants.
- Microirrigation. Drip irrigation can reduce splashing of soil particles onto crop plants.

Additional Resources

Books and resources from USDA, Sustainable Agriculture Research and Education (SARE). Digital files of all books are open access.

- Building Soils for Better Crops: Ecological Management for Healthy Soils
- Crop Rotation on Organic Farms: A Planning Manual
- Managing Cover Crops Profitably

Urban soil management reports from TreePeople and ARLA.

- Mulch, Protect, and Grow: Tuning Los Angeles's Soil Engine

Urban Soil Management for Climate Resilience: A Guide for Adopting Best Practices from TreePeople and ARLA

References

Bryant C. Scharenbroch, A Meta-analysis of Studies Published in Arboriculture & Urban Forestry Relating to Organic Materials and Impacts on Soil, Tree, and Environmental Properties, 35 Arboriculture and Urb. Forestry 221 (2009).

Bryant C. Scharenbroch, Elsa N. Meza, Michelle Catania & Kelby Fite, Biochar and Biosolids Increase Tree Growth and Improve Soil Quality for Urban Landscapes, 42 J. Env't Quality 1372 (2013).

Charles L. Mohler & Sue Ellen Johnson, Crop Rotation on Organic Farms: A Planning Manual (Jill Mason ed., 2009).

Craig G. Cogger, Potential Compost Benefits for Restoration Of Soils Disturbed by Urban Development, 13 Compost Sci. & Utilization 243 (2005).

Danielle S. Baldi, Christine E. Humphrey, John A. Kyndt & Tyler C. Moore, Native Plant Gardens Support More Microbial Diversity and Higher Relative Abundance of Potentially Beneficial Taxa Compared To Adjacent Turf Grass Lawns, 26 Urb. Ecosystems 807 (2023).

David Emde, Kirsten D. Hannam, Ilka Most, Louise M. Nelson & Melanie D. Jones, Soil Organic Carbon in Irrigated Agricultural Systems: A Meta-analysis, 27 Glob. Change Biology 3898 (2021).

Dustin L. Herrmann, Mary Hillemeier, Richard V. Pouyat, Susan D. Day, Yujuan Chen & Lia Soorenian, Urban Soil Management for Climate Resilience (2023).

Elizabeth A. Miernicki, Sarah Taylor Lovell & Sam E. Wortman, Raised Beds for Vegetable Production in Urban Agriculture, 3 Urb. Agric. Reg'l Food Sys. 1 (2018).

Frédéric Thérilaut & Daniel Brisebois, Crop Planning for Organic Vegetable Growers (2010).

Gaston Small, Paliza Shrestha, Geneviève Suzanne Metson, Katherine Polsky, Ivan Jimenez & Adam Kay, Excess Phosphorus from Compost Applications in Urban Gardens Creates Potential Pollution Hotspots, 1 Env't Rsch. Commc'n 091007 (2019).

Hardeep Singh, Brian K. Northup, Charles W. Rice & P.V. Vara Prasad, Biochar Applications Influence Soil Physical and Chemical Properties, Microbial Diversity, and Crop Productivity: A Meta-Analysis, 4 Biochar 8 (2022).

Hillary S. Sardiñas, Rebecca Ryals & Neal M. Williams, Carbon Farming Can Enhance Pollinator Resources, 76 California Agric. 104 (2023).

James A. Allen & Andrew C. Mason, Urban Food Forests in the American Southwest, 6 Urb. Agric. Reg'l Food Sys. e20018 (2021).

Janet Bachmann, Scheduling Vegetable Plantings for Continuous Harvest (2008).

Jean-Martin Fortier, The Market Gardener: A Successful Grower's Handbook for Small-Scale Organic Farming (2014).

Jessica L. Chiartas, Louise E. Jackson, Rachael F. Long, Andrew J. Margenot & Anthony T. O'Geen, Hedgerows on Crop Field Edges Increase Soil Carbon to a Depth of 1 Meter, 14 Sustainability 12901 (2022).

John R. Taylor, Modeling the Potential Productivity of Urban Agriculture and its Impacts on Soil Quality through Experimental Research on Scale-Appropriate Systems, 4 Frontiers in Sustainable Food Systems 89 (2020).

Joshua W. Beniston, Rattan Lal & Kristin L. Mercer, Assessing and Managing Soil Quality for Urban Agriculture in a Degraded Vacant Lot Soil, 27 Land Degradation and Development 996 (2016).

Marie R. Johnston, Nick J. Balster & Jun Zhu, Impact of Residential Prairie Gardens on the Physical Properties of Urban Soil in Madison, Wisconsin, 45 J. Env't Quality 45 (2016).

Megan M. Gregory, Timothy W. Leslie & Laurie E. Drinkwater, Agroecological and Social Characteristics of New York City Community Gardens: Contributions to Urban Food Security, Ecosystem Services, and Environmental Education, 19 Urb. Ecosystems 763 (2016).

Myki Nelson, Gwynne Mhuireach & Gail A. Langellotto, Excess fertility in residential-scale urban agriculture soils in two western Oregon cities, USA, 7 Urb. Agric. Reg'l Food Sys. e20027 (2022).

Naim Edwards, Effects of Garden Attributes on Ant (Formicidae) Species Richness and Potential for Pest Control, 1 Urb. Agric. Reg'l Food Sys. 1 (2016).

Naim Edwards, Nicholas Medina & Elizabeth Asker, Mixing Cover Crops Suppresses Weeds and Roto-till Reduces Urban Soil Penetration Resistance and Improves Infiltration, 231 Soil and Tillage Rsch. 105708 (2023).

Nicole E. Tautges, Jessica L. Chiartas, Amélie C.M. Gaudin, Anthony T. O'Geen, Israel Herrera & Kate M. Scow, Deep Soil Inventories Reveal that Impacts of Cover Crops and Compost on Soil Carbon Sequestration Differ in Surface and Subsurface Soils, 25 Glob. Change Biology 3753 (2019).

Prajal Pradham, Max Callaghan, Yuanchao Hu, Kshitij Dahal, Claudia Hunecke, Fritz Reusswig, Hermann Lotze-Campen & Jürgen P. Kropp, A systematic review highlights that there are multiple benefits of urban agriculture besides food, 38 Glob. Food Sec. 100700 (2023).

Ramón A. Arancibia, Low Tunnels in Vegetable Crops: Beyond Season Extension (2018).

Roger Kubalek, David Granatstein, Doug Collins & Carol Miles, Review of Tarping and a Case Study on Small-scale Organic Farms, 32 HortTechnology 119 (2022).

Sally L. Brown, Rufus L. Chaney & Ganga M. Hettiarachchi, Lead in Urban Soils: A Real or Perceived Concern for Urban Agriculture?, 45 J. Env't Quality 26 (2016).

Sam E. Wortman & Sarah Taylor Lovell, Environmental Challenges Threatening the Growth of Urban Agriculture in the United States, 42 J. Env't Quality 1283 (2013).

Sam E. Wortman, Ashley A. Holmes, Elizabeth Miernicki, Kaelyn Knoche & Cameron M. Pittelkow, First-Season Crop Yield Response to Organic Soil Amendments: A Meta-Analysis, 109 Agronomy J. 1210 (2017).

Weston Miller & Jeremiah Mann, How to Use Compost in Gardens and Landscapes (2021).

Yujuan Chen, Richard V. Pouyat, Susan D. Day, Erica L. Wohldmann, Kirsten Schwarz, Gordon L. Rees, Manny Gonez, Edith B. de Guzman & Selena Mao, Healthy Soils for Healthy Communities Phase 1: Needs Assessment (2021).