Principles and Practices to Build Soil Health

Workshop Curriculum

Introduction

Who is this curriculum for?

This curriculum outline is geared toward agricultural extension professionals to lead workshops for agricultural producers for assessing and developing healthy soils on their farms. It presumes a moderate to strong knowledge basis in soils and farm management practices on the part of the workshop leaders.

What is the focus of the curriculum?

This curriculum focuses on soil biology and the role of living organisms in providing the basis for successful long-term functioning and resilience of soil in an agricultural context. It does not address other important aspects of soil, such as soil chemistry including pH and salinity issues, or nutrient, water, and disease management as stand-alone topics, apart from the connection of these topics to the activity of soil organisms.

What you need to know about the activities in this workshop.

Activities in this outline are appropriate for a workshop length of 3-6 hours. The list of activities in this curriculum is not an exhaustive list of possible exercises or all tests needed to comprehensively assess all aspects of soil quality. Rather, these activities were selected for their particular demonstration value with respect to the functioning of soil organisms, and, with a few exceptions, many of them can be done using easily available materials and without specialized equipment. For a more complete list and description of soil quality tests, see the NRCS Soil Quality Test Kit, at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/health/assessment.

Some of the activities would benefit greatly from participant access to fields where soil can be directly observed and handled. However, in most cases, exercises can also be done in a classroom setting with soil samples collected in advance. Comparison of soil from very different management regimes would greatly aid in the instructive value of several of the hands-on exercises. For example, soils from systems with high organic matter input could be compared with soils from systems with low organic-matter input, or soils from an intensively managed site could be compared with soil from a natural, relatively undisturbed area.

Part 1. Soil Microbes: An Introduction

Key Concepts

- Dependence of soil health on **organisms** in the soil
- Importance of **dead microbes** as composing a large fraction of **soil organic matter**
- Importance of **soil organic matter** for soil structure and as a source of plant nutrients
- **Soil food web**: the network of connections between different types of organisms that live in the soil, as described by transfers of energy and nutrients as one organism eats another

- **Soil aggregate:** a "clump" of soil in which many small soil particles are held together in a stable mass, varying in size from less than the width of a human hair to several inches

Activities

Underwear Experiment

Cotton clothing is comprised mainly of cellulose, which can be used by soil decomposers as a food source. By taking a sample of 100% cotton clothing (as exemplified by men's underwear) and burying it in two different soils, the difference in microbial activity can be visualized by looking at the state of the underwear. Ideally, the difference in microbial activity would be large (e.g. burying clothing in a plot treated with high organic matter and few pesticides, versus burying it in a plot with low organic matter and many pesticides). The clothing in the more biologically-active soil will be more degraded. This process may take up to 4-6 weeks, but can be speeded up by dipping both sets of clothing in glucose solution prior to burying. This may reduce the time needed by up to 2 weeks.

Resources

Soil Microbes: An Introduction. A downloadable slide presentation by Daniel Rath, Univ. of California, Davis

Example photo – The underwear on the left was buried in soil from a conventionally-managed annual crop plot, while the underwear on the right was buried in soil from a nearby, organically-managed plot.

Part 2. How to determine the health of your soil

Key Concepts

- **Soil health measurements depend on your location –** Due to the heterogenous nature of soil, climate, and crop types, what constitutes a "healthy soil" may differ from field to field. It is important to understand what range of results for specific soil health indicators is considered "good" for your specific soil type and climate.
- **Soil texture** and **soil classification: Texture:** the percent of sand, silt, and clay in a soil. Knowledge of the soil type that any given soil from a particular location is classified into helps to determine the texture, parent material, and other agriculturally-relevant properties of that soil.

- **Aggregate stability**: the ability of soil aggregates to resist degradation under external forces caused by rain, wind, or compaction
- **Water infiltration rate**: the rate at which water enters the soil
- **Cation exchange capacity**: the capacity of soil to hold nutrients for plants to use, based on the number of negative charges on soil particles available to hold positively-charged ions (nutrients)
- **Organic matter/organic carbon:** Materials in the soil made from molecules that originate in living organisms. They are often closely associated with soil minerals and serve as a food source for microbes and nutrient source for plants.
- **Soil respiration**: the process in which a living organism gives off carbon dioxide as a result of metabolism. In soil analyses, used to refer to the total amount of carbon dioxide given off by living organisms and roots in the soil.

Activities

- **Discussion of soil characteristics**: Discuss characteristics that cannot be changed by farmers (*mineral composition, texture (proportions of sand, silt, clay), depth, slope*), versus those that can be changed (*tilth, organic matter content, biological diversity and activity*)

- **Determine soil classification** of an example field by accessing SoilWeb Apps (https://casoilresource.lawr.ucdavis.edu/soilweb-apps)

- **Qualitative soil observations**: Farmers can use their power of observation to determine a healthy soil based on easily visible markers. With expert guidance, examine soil from differently managed fields – look for dark color for organic matter, ease or difficulty of crumbling soil in the hand, ease or difficulty of digging, smell of organic matter, ability to see distinct aggregates after digging out a slice of soil.

NOTE: Each of the activities listed below is most instructive in a workshop setting when comparing soil from the same classification (and preferably from close proximity to each other) but different management practices, e.g. a) soil managed with organic amendments and mulch to promote microbial health, b) soil managed with synthetic inputs and no organic amendments, and c) uncultivated grassland or woodland soil. The exercises can also compare soil from no-till versus conventionally-tilled fields.

- **Aggregate slake test**: a test in which soil clods are placed in water and observed for rapidity and degree to which they disintegrate (a demonstration of structural stability of soil, a function of soil microbes and organic matter when comparing like soils under different management).

  Materials:
  - *glass or clear plastic jars filled with water*
  - *mesh netting to hold soil fragments, timer or clock or watch*
  - *intact, air-dried, similarly-sized soil fragments from different fields*

  Procedure:

Drop one soil fragment into the mesh in each jar simultaneously, ensuring that each soil fragment is completely submerged in the water. Start timer, if available, or note time, and observe and record the rate at which soil fragments disintegrate.
Alternative materials: commercially available soil stability kits. See NRCS slake test resource below.

- **Water infiltration test:** a test to measure capacity of soil to absorb water (a demonstration of structural stability, when comparing like soils under different management)
  Materials:
  - *Metal ring (about 6 in. diameter, over 4 inches in length), with a mark on the inside to indicate 4 inches from bottom*
  - *Hand sledge or other tool to drive ring into soil*
  - *Plastic wrap*
  - *Distilled water*
  - *Timer or watch*

  Procedure:
  Gently remove any surface residue or weeds from an area of soil. Drive the ring into the soil to a depth of 3 inches. Line the surface of the soil inside the ring with a piece of plastic wrap large enough to cover the soil and extend up and over the sides of the ring. Add water to the ring, on top of the plastic wrap, to a depth of 1 inch (using the mark made in advance). Gently and smoothly pull out the plastic wrap to one side, leaving the water in the ring, and note time. Record the time it takes for the water to enter the soil, until the soil surface is just glistening. NOTE: soil moisture content will affect infiltration rate. If soil is very dry to begin with, a repeat procedure will provide a better estimate of infiltration rate than the initial procedure. If the soil is already saturated, infiltration will not occur. When comparing sites under different management, make sure the starting soil moisture content is the same for both sites. For a more detailed procedure guide, please refer to the NRCS Infiltration Test document referenced below.

- **Rainfall simulator**: requires equipment with sprinkler device and soil trays that allow capture of both surface runoff and infiltrated water that has passed through the soil. Trays should be filled with soil collected from differently managed plots (including, ideally, one unmanaged natural grassland or woodland area). Soil can be left bare in the trays, or have plant residue placed on top. Amount and cleanliness of water collected after infiltration or runoff can then be compared between soil trays to show potential for erosion and/or the capacity of different soils to absorb and hold water.

o  Z.

Kabir, NRCS Regional Soil Health Specialist, demonstrating how the rainfall simulator works.

- **Soil respiration measurement** – Requires Solvita® kits and 24 hours advance soil sampling. Refer to NRCS Soil Respiration Guide for Educators, below.

Resources

- Healthy Soils Are: well-structured. NRCS article describing the value of the slake test.
- Iowa NRCS training video: demonstrates how to conduct a simple slake test with homemade materials
- NRCS slake test procedure: NRCS detailed description of how to perform a slake test using a soil stability kit
- Water infiltration test: NRCS detailed description of how to perform water infiltration test with metal ring
- NRCS Soil Respiration Guide for Educators: a guide for observing soil respiration rates using Solvita® kits
- NRCS Soil Quality Test Kit: NRCS guide on numerous tests and their procedures for determining soil quality

Part 3. Farm Management Practices to Build Soil Health

Key Concepts: The Four Principles of Managing Soil Health

- **Feed the soil**
  - **C:N ratio:** the ratio of carbon content to nitrogen content in an organic material. This ratio affects the rate of decomposition of a material in the soil, the types of organisms that are promoted in the soil, and the availability of nitrogen to plants.
- **Keep it covered**
- **Disturb less**
- **Increase plant diversity**

Activities

- Brief presentation to introduce one or more specific practices for each of the four principles.
- Provide an example from scientific research on how each practice contributes to indicators of soil health.
- Farmer panel discussions with farmers experienced in implementing specific practices for soil health.

Specific farming practices and selected training activities for each key concept:

Feed the soil: Use of **compost** and **cover crops** to provide carbon for microbes and build soil organic matter

Activities:

- Consider carbon/nitrogen ratios in different cover crop species and crop residues, using tables (see for example Carbon to Nitrogen Ratios in Cropping Systems https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1166766.pdf).
- Conduct an exercise to harvest a small area of cover crop and calculate N content. (see https://apps1.cdfa.ca.gov/FertilizerResearch/docs/Adjustments.html#top4)

Keep it covered: Use of **mulch** and **cover crops** to conserve soil moisture, modulate surface temperatures, reduce surface crusting

Activities:

- Consider carbon/nitrogen ratio – see activity under "Feed the soil"
- Use a rainfall simulator to compare water infiltration on mulched and bare soil
- Use a field site to measure surface temperatures of mulched versus bare soil and examine the surface for degree of crusting, if conditions are suitable

Disturb less: **Reduced tillage** (strip tillage, zone tillage, combining multiple functions per tractor pass) to preserve soil aggregate structure and avoid disturbance of fungi mycelia and macro-organisms.

Activities:

- Use a rainfall simulator to compare infiltration and runoff on tilled versus untilled soils

Increase plant diversity: **Crop rotation** to diversify root structure and root exudates and diversify soil microbial community

Activity:

- Examine and compare root structures of excavated plants with very different structures (taproot systems like carrots, radishes, clover versus fibrous root systems like grasses).
- Compare soil conditions in fields with different plant types/rotations – conduct hands-on examination of soil in fields that have had a single crop grown for several years, compared to a field that has had more than one crop rotated through.

Resources

Soil Health Principles and Practices in Organic Farms. A downloadable slide presentation by Z. Kabir, Regional Soil Health Specialist, USDA-NRCS

Bossio, DA, Scow, KM, Gunapala, N, & Graham, KJ. 1998. Determinants of soil microbial communities: effects of agricultural management, season, and soil type on phospholipid fatty acid profiles. Microbial ecology, 36(1): 1-12.

Mitchell, JP, Shrestha, A, Horwath, WR, Southard RJ, Madden, N, Veenstra, J, Munk, DS. 2015. Tillage and Cover Cropping Affect Crop Yields and Soil Carbon in the San Joaquin Valley, California. Agronomy Journal 107(2): 588-596.

Tiemann, LK, Grandy, AS, Atkinson, EE, Marin-Spiotta, E, and McDaniel, MD. 2015. Crop rotational diversity enhances belowground communities and functions in an agroecosystem. Ecology letters 18(8): 761-771.

Soil Health Information Resources

Practical Resources for Farmers

Soil Health, Soil Quality

1. ***UC Agriculture and Natural Resources Publications***:
    a. Soil Management and Soil Quality for Organic Crops (free download)
    b. Alive and Well: Sustainable Soil Management DVD ($20.00)
    c. Diagnosing Soil Physical Problems (free download of 1976 B&W publication)
2. ***ATTRA Soils and Compost website*** – large range of free or almost free downloadable pdf guides and factsheets on everything from soil testing to cover crops, soil amendments, and tillage for a range of crop and livestock systems.
3. ***ATTRA Online Tutorial on Soil Health***
4. ***Natural Resources Conservation Service (NRCS) Online Soil Biology Primer*** - an introduction to the living component of soil and how it contributes to agricultural productivity and air and water quality.
5. ***Soil Health and Organic Farming: An Ecological Approach***, Organic Farming Research Foundation. Series of educational guides to help organic farmers and ranchers enhance soil health and overall resilience of their operations.
6. ***Building Soils for Better Crops, 3rd ed.*** 2010. Fred Magdoff and Harold Van Es. Sustainable Agriculture Research and Education Program. (online version free).

Cover Crops

1. ***UC Sustainable Agriculture Research and Education Program (UC SAREP)* Cover Crops Database.** In-depth information on common cover crop species.
2. ***UC Agriculture and Natural Resources Publications***:
    a. Cover Crops for Walnut Orchards (free download)
    b. Cover Cropping in Vineyards: A Grower's Handbook ($20.00)
    a. Cover Cropping and Conservation Tillage in California Processing Tomatoes (free download)
    b. Cover Cropping for Vegetable Production ($25.00)
3. ***Cover Crop in Organic Systems: California Implementation Guide***. This document provide an overview of how the USDA Natural Resources Conservation Service (NRCS) Cover Crop 340 conservation practice can be implemented on organic operations in California.
4. ***Economic Analysis of Cover Crops*** – NRCS tool (Excel file) to calculate on-farm costs and benefits of planting cover crops.
5. ***Cover Crop Chart*****,** USDA Agricultural Research Service
6. ***Managing Cover Crops Profitably*** ***(3rd edition) 2012.*** Handbook series Book 9 published by the Sustainable Agriculture Research and Education Program.

Compost

1. ***Composting for Soil Borne Disease Control,*** The Gordon Lab, UC Davis

Reduced tillage/Conservation Tillage

1. Conservation Agriculture Systems Innovation
   http://casi.ucanr.edu

2. ***To Till or Not to Till: That is the Question***. Youtube presentation by Dr. Eric Brennan, USDA-Agricultural Research Service, Organic Research Program, Salinas, Ca.
Eric Brennan discusses the complexity of no-till and conservation tillage systems with colorful examples & images, cutting-edge science, and research efforts to develop cover crop-based reduced-tillage methods for vegetable production in California's tillage-intensive Salinas Valley.
3. ***Organic No-Till Weed Management***, Youtube presentation by Rodale Institute.

Crop Rotation

1. ***Crop Rotation on Organic Farms: A Planning Manual.*** 2009. Charles L. Mohler and Sue Ellen Johnson, eds. Sustainable Agriculture Research and Education Program. (online version free).

Nutrient Management and Soil Health

1. ***Solution Center for Nutrient Management*** – This UC ANR website was created by UC SAREP to increase access to sustainable nutrient management information resources for California agriculture and to serve as a platform for conversations on important nutrient management issues. It also includes resource pages specifically devoted to soil health.