Conservation and Soil Health Practices for Organic Production Systems

Building Soil Organic Matter

Based on "Building Organic Matter for Healthy Soils: An Overview" by Mark Schonbeck, Diana Jerkins, Joanna Ory and Organic Farming Research Foundation. Available at https://ofrf.org/soil-health-and-organic-farming-reports/

Introduction: What is Soil Organic Matter?

Soil organic matter (SOM) consists of carbon-based substances formed through biological processes such as plant photosynthesis and the digestion of plant and animal residues by soil microbes. SOM generally accounts for 1 to 10% of the dry weight of the topsoil (A horizon) and decreasing proportions of subsoil (B and C) horizons. SOM is about 50% carbon (C).

History: SOM and Organic Agriculture

When soil degradation and erosion culminated in the Dust Bowl of the 1930s, the newly established Soil Conservation Service under the leadership of Hugh Hammond Bennet promoted soil-saving practices such as crop rotation, green manures, and contour farming. While a few farmers at that time began to use soluble fertilizers to sustain crop yields, forward-thinking agriculturists such as Sir Albert Howard, Ehrenfried Pfeiffer, and J. I. Rodale warned that we must also replenish soil organic matter and soil life in order to reverse soil degradation, stop erosion, and restore fertility.

They urged farmers to "feed the soil" by:

- Returning all organic residues such as manure and grain straw to the soil.
- Composting these materials before use to form humus and stabilize nutrients.
- Diversifying the crop rotations and growing green manures.
- Integrating livestock and crop production for a balanced farm ecosystem.

This focus on organic matter became a founding principle of the organic agriculture movement. While today's organic industry is most widely known for exclusion of synthetic agrochemical inputs as codified in the USDA Organic Standards, agricultural scientists and

This publication was produced in partnership with the Organic Farming Research Foundation www.ofrf.org

ORGANIC FARMING RESEARCH FOUNDATION

conservationists have widely embraced organic agriculture's emphasis on SOM as vital to soil health, resource conservation, and long-term farm productivity, resilience, and profitability.

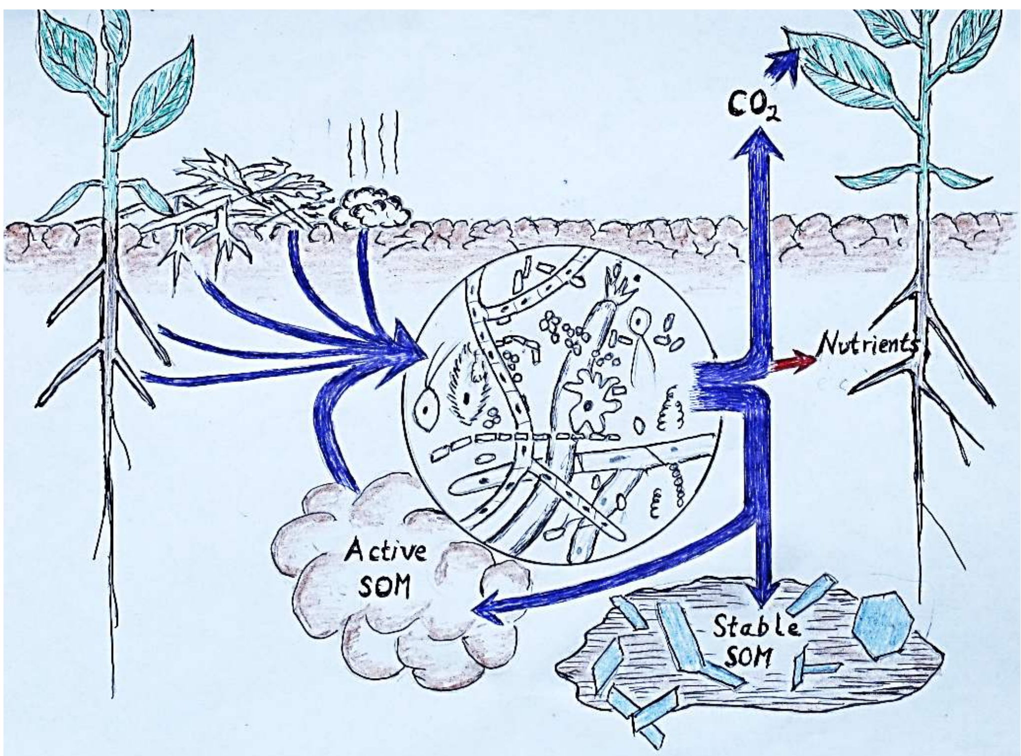
Components of SOM

Organic materials in the soil include:

- Plant litter, animal manure, and other organic residues recently added to the soil.
- The soil life itself.
- Active soil organic matter – "food" for soil organisms, including:
  1. Partially decomposed residues.
  2. Plant root exudates.
  3. Recently-dead soil organisms.
- Stable soil organic matter – shielded from further decomposition by:
  1. Physical protection within soil aggregates.
  2. Adsorption to soil minerals, especially clay and silt.
  3. Deposition deep in the soil where microbial activity is low.

Soil test labs generally remove visible fresh residues before analysis, so the % SOM in a soil test report estimates the sum of living organisms, active SOM, and stable SOM.

Note that "stable" is a relative term; the turnover time for stable SOM ranges from decades to millennia. Tillage can degrade "stable" SOM by pulverizing aggregates, while fungicides or soluble NPK fertilizers can alter the soil food web in ways that accelerate SOM decomposition.



Soil organic matter is as much a process as it is a substance. As soil organisms continually utilize fresh residues and active SOM to grow and multiply, part of the organic matter is mineralized – converted to carbon dioxide (CO2) through respiration – and part is stabilized in aggregates or mineral complexes. Both processes are vital, as mineralization releases plant-available nutrients, while stabilization sequesters carbon and sustains long term soil health.

Functions of a Healthy Soil and the Role of SOM

NRCS defines soil health as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans." SOM plays a central role in each of the functions required to meet this definition of soil health **(Table 1)**.

Table 1. The role of SOM in contributing to soil function and health.

Soil Function	Soil Organic Matter Components and Roles
Sufficient but not excess nutrients: • Optimizes crop nutrition • Protects water quality	Active SOM – slow-release N, P, S, micronutrients Stable SOM – cation exchange – K, Ca, Mg Soil life – unlock and cycle nutrients, help crops take up nutrients, immobilize surplus N and P
Soil structure and porosity: • Absorbs rainfall • Stores plant-available moisture • Drains and aerates well • Promotes deep, healthy roots • Resists erosion and compaction	Soil life – bacterial byproducts and fungal mycelia bind soil particles into aggregates Active and stable SOM – maintain aggregation, enhance moisture holding capacity
Food and habitat for abundant and diverse beneficial organisms that: • Enhance crop resilience and vigor • Suppress disease	Active SOM – microbial food Stable SOM – microbial habitat Soil life – maintain micro- and macro pores – "housing" for microbes and larger organisms
Climate stabilization: • Sequester carbon (C) • Reduce greenhouse gases	Soil life – stabilize organic C, maintain aerobic conditions that limit CH4 and N2O emissions Stable SOM – long-term C sequestration
Waste management: • Convert organic residues into SOM • Neutralize toxic chemicals	Stable SOM – bind and inactivate toxins Soil life – process fresh residues to build SOM; degrade toxins

Opportunities & Challenges in Building SOM in Organic Agricultural Systems

Through its emphasis on SOM and reliance on biological sources of nutrients in lieu of soluble fertilizers, the organic method can build SOM and thereby improve soil function (see Sidebar on the next page). Non-use of synthetic inputs protects the community of soil life and thereby sustains its capacity to process organic residues and continually regenerate active and stable SOM.

Organic producers also face several challenges in building SOM:

- Reliance on tillage to manage weeds and cover crop can speed SOM oxidation.
- Organic nutrient sources such as compost, poultry litter, and manure provide excess P relative to plant-available N and K. Excess soil P can inhibit mycorrhizal fungi and run off to surface waters.

SOM can be difficult to assess precisely, and total SOM on the soil test responds slowly to improved management.

Research-Based Best Practices for Building SOM in Organic Production Systems

Because plant photosynthesis is the primary source of soil organic matter, living plants comprise the farmer's #1 tool for building SOM and soil health. Thus, the National Organic Standards emphasize cover crops and crop rotations, and three of the four NRCS soil health principles – cover soil, living roots, and crop diversity – focus on living plants.

Plants deliver 10 – 40% of their photosynthetic product to the soil life via root exudates and fine root sloughing. This "liquid carbon pipeline" plays a major role in building SOM throughout the soil profile.

Organic amendments like compost and biochar play a vital supplemental role, working with living plants to enhance and maintain soil health. Organic producers conserve and build active and stable SOM in cropland through the following practices:

- Tight, diverse crop rotations with minimal bare soil periods.
- High biomass cover crops.
- Adding a perennial sod crop to annual crop rotations.
- Integration of livestock into cropping systems.
- Finished compost at rates consistent with good nutrient management.
- A diverse mix of organic inputs with a balanced C:N ratio (~20:1).
- Reduced tillage frequency and intensity when practical.
- Integrated weed management to reduce need for cultivation.
- Use of crop cultivars bred for organic systems (when available).
- Field assessments of soil: tilth, color, earthworms, rain infiltration, crop vigor, etc.

Soil Organic Matter in the National Organic Standards

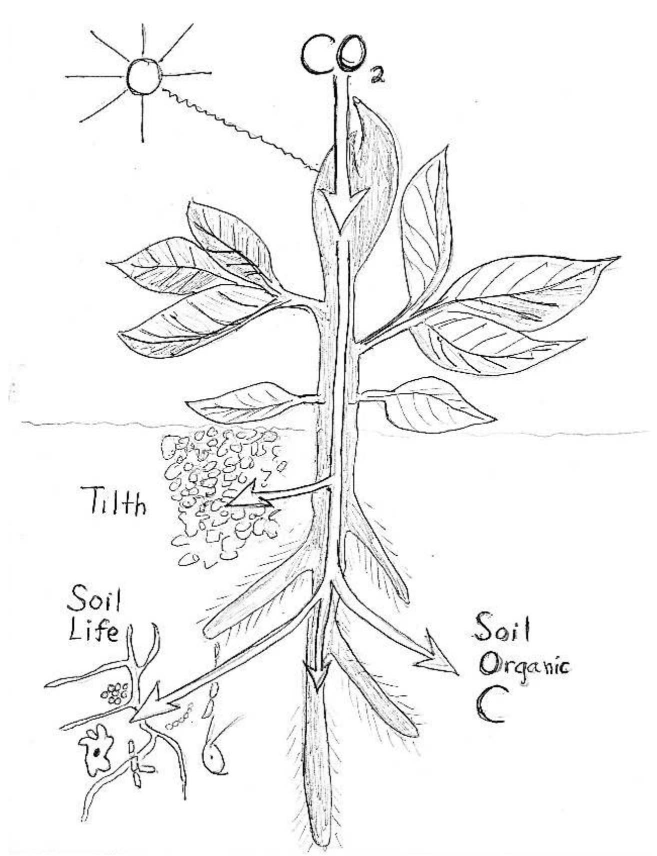
From § 205.203 Soil fertility and crop nutrient management practice standard:

"Manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials."

"Manage plant and animal materials, crop nutrients, and soil fertility to maintain or improve soil organic matter."

From § 205.205 Crop rotation practice standard:

"Implement a crop rotation including … sod, cover crops, green manure crops, and catch crops that … maintain or improve soil"



Farm Story: Building SOM and Fertility in a Sandy Soil

Mattawoman Creek Farms *Eastern Shore, Virginia*

Rick and Janice Felker produce 11 acres of organic vegetables for their Mattawoman Creek Farms Community Supported Agriculture (CSA) membership, in the Eastern Shore of Virginia. Their soil is a Bojac sandy loam (order Ultisols) with initially low SOM and fertility. They have managed it organically for more than 20 years.

Practices:

- Tight, diverse rotation, no unplanted fallow.
- High biomass cover crops: winter rye + hairy vetch, buckwheat in summer.
- All crop residues returned to the soil.
- Poultry litter and mushroom compost at low to moderate rates.
- Rototiller geared-down with higher tractor forward speed for low-intensity tillage.
- Subsurface drip irrigation to encourage deeper root development.

Outcomes:

- SOM has increased to 2.0 – 2.2% (excellent for this soil type).
- In-row drip fertigation (fish emulsion) no longer needed.

"The soil gets better every year, and we have excellent growth."

-Rick Felker,
Mattawoman Creek Farms

Some Key Research Findings on Building SOM in Organic Systems

- Total SOM responds slowly to management, but is well correlated with active SOM, microbial activity, soil structure, moisture infiltration, and capacity to provide N to crops yet reduce N leaching (Carpenter-Boggs et all, 2016; Delate et al., 2015b; Fortuna et al., 2014).
- SOM mineralization and stabilization increase together, except when excessive tillage or nutrients, lack of soil cover, or agrochemicals stress soil life and stimulate respiration at the expense of microbial growth (Grandy and Kallenbach, 2015; Hurisso et al., 2016; Lori et al., 2017).

- Cover crops and compost work together in a complementary and synergistic manner to build active and total SOM, organic N, and microbial biomass, activity, and diversity (Delate et al., 2015a; Hurisso et al., 2016; Hooks et al., 2015).
- In long term farming trials, organic rotations with cover crops, perennial sod, compost, and routine tillage accrue as much or more SOM than no-till corn-soy rotations with conventional inputs (Cavigelli et al., 2013; Delate et al., 2015b).
- Organic field crop rotations with winter cover crops can build SOM and reduce fertilizer needs in sandy soils of the southeastern US coastal plain (Kloot, 2018).
- Orchard floor SOM under living cover is twice that under tilled fallow (Lorenz and Lal, 2016).
- A single 22 ton/ac compost application doubled topsoil SOM and boosted dryland organic wheat yields for 15 years in Utah (Reeve and Creech, 2015).
- A one-time compost application to California grassland boosted plant production, which, in turn, built SOM over a three year period (Ryals and Silver, 2013).
- Reliance on N-rich organic fertilizers can reduce SOM and increase N leaching and denitrification to N2O (Baas et al.,2015; Bhowmik et al., 2017; Bowles et all, 2015).
- Compost (C:N 15-20) builds more SOM and microbial activity than poultry litter (C:N 7) (Bhowmik et al., 2017).

Informational Resources on Building SOM in Organic Systems

Cornell Comprehensive Assessment of Soil Health (CASH)
https://soilhealth.cals.cornell.edu/

National Sustainable Agriculture Information Service: resources on organic soil & nutrient management
https://attra.ncat.org/topics/organic-soils-fertilizers-issues/

Soil and Fertility Management in Organic Farming Systems, eOrganic
https://eorganic.org/menu/867

Building Soils for Better Crops (Fred Magdoff and Harold Van Es, 2009, 294 pp)
http://www.sare.org/Learning-Center/Books

This publication was produced in partnership with the Organic Farming Research Foundation www.ofrf.org

ORGANIC FARMING RESEARCH FOUNDATION

References

Baas, D. G., G. P. Robertson, S. R. Miller, N. and Millar, N. 2015. Effects of Cover Crops on Nitrous Oxide Emissions, Nitrogen Availability, and Carbon Accumulation in Organic versus Conventionally Managed Systems. Final report for ORG project 2011-04952. CRIS Abstracts.*

Bhowmik, A. A-M. Fortuna, L. J. Cihacek, A. Bary, P. M. Carr, and C. G. Cogger. 2017. Potential carbon sequestration and nitrogen cycling in long-term organic management systems. Renewable Agriculture and Food Systems, 32 (6): 498-510.

Bowles, T. M., A. D. Hollander, K. Steenwerth, and L. E. Jackson. 2015. Tightly-Coupled Plant-Soil Nitrogen Cycling: Comparison of Organic Farms across an Agricultural Landscape. PLOS ONE http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0131888.

Carpenter-Boggs, L., D. Granatstein, and D. Huggins. 2016. Greenhouse Gases and Agriculture: Where does Organic Farming Fit (Webinar). https://eorganic.org/node/5617.

Cavigelli, M. A., J. R. Teasdale, and J. T. Spargo. 2013. Increasing Crop Rotation Diversity Improves Agronomic,Economic, and Environmental Performance of Organic Grain Cropping Systems at the USDA-ARS Beltsville Farming Systems Project. Crop Management 12(1) Symposium Proceedings: USDA Organic Farming Systems Research Conference. https://dl.sciencesocieties.org/publications/cm/tocs/12/1.

Delate, K., C. Cambardella, and C. Chase. 2015a. Effects of cover crops, soil amendments, and reduced tillage on carbon sequestration and soil health in a long term vegetable system. Final report for ORG project 2010-03956. CRIS Abstracts*

Delate, K., C. Cambardella, C. Chase, and R. Turnbull. 2015b. A review of long term organic comparison trials in the US. Sustainable Agricultural Research 4(3): 5-14.

Edgell, J., D. L. Osmond, D. E. Line, G. D. Hoyt, J. M. Grossman, and E. M. Larsen. 2015. Comparison of Surface Water Quality and Yields from Organically and Conventionally Produced Sweet Corn Plots with Conservation and Conventional Tillage. J. Environ. Qual. 44 (6): 1861-1870.

Fortuna, A., D. Collins, and C. Cogger. 2014. Management to Reduce N2O Emissions in Organic Vegetable Production Systems. https://eorganic.org/node/10433.

Grandy, S., and C. Kallenbach. 2015. Microbes drive soil organic matter accumulation in organic cropping systems. Recording from the Organic Agriculture Research Symposium, LaCrosse, WI February 25-26, 2015. http://eorganic.info/node/12972.

Hooks, C. R., K. H. Wang, G. Brust, and S. Mathew. 2015. Using Winter Cover Crops to Enhance the Organic Vegetable Industry in the Mid-Atlantic Region. Final report for OREI project 2010-01954. CRIS Abstracts.*

Howard, Sir Albert. 1947. The Soil and Health: a Study of Organic Agriculture. University Press of Kentucky (2006), 307 pp.

Hu, S., C. Reberg-Horton, M. Schroeder-Moreno, Y. Cardoza, J. Grossman, W. Robarge, and W. Eveman. 2015. Assessing the Greenhouse Gas Mitigation Potential of Organic Systems in the Southeast. Progress report for ORG project 2012-02978. CRIS Abstracts.*

Hurisso, T. T., S. W. Culman, W. R. Horwath, J. Wade, D. Cass, J. W. Beniston, t. M. Bowles, A. S. Grandy, A. J. Franzluebbers, M. E. Schipanski, S. T. Lucas, and C. M. Ugarte. 2016. Comparison of

Permanganate-Oxidizable Carbon and Mineralizable Carbon for Assessment of Organic Matter Stabilization and Mineralization. Soil Sci. Soc. Am. J. 80 (5): 1352-1364.

Kallenbach, Cynthia M., Frey, Serita D., & Grandy, A. Stuart. 2016. Direct evidence for microbial-derived soil organic matter formation and its ecophysiological controls. Nature Communications 7, Article number: 3630 https://www.osti.gov/pages/servlets/purl/1363941.

Kloot, Robin. 2018. Using adaptive nutrient management to answer "how much fertilizer do you actually need?" NRCS webinar May 8, 2018. Science and Technology Training Library. http://www.conservationwebinars.net/listArchivedWebinars.

Lorenz, K., and R. Lal. 2016. Environmental Impact of Organic Agriculture. Advances in Agronomy 139: 99-152.

Lori, M., S. Symnaczik, P. MaEder, G. De Deyn, A. Gattinger. 2017. Organic farming enhances soil microbial abundance and activity – A meta-analysis and meta-regression. PLOS ONE | https://doi.org/10.1371/journal.pone.0180442. July 12, 2017, 25 pp.

Pfeiffer, E. E. 1943. Biodynamic Farming and Gardening: Soil fertility renewal and preservation, 3rd Edition. Anthroposophic Press, New York, 240 pp.

Reeve, J., and E. Creech. 2015. Compost Carryover Effects on Soil Quality and Productivity in Organic Dryland Wheat. https://eorganic.org/node/14629.

Rillig, M.C. 2004. Arbuscular mycorrhizae, glomalin, and soil aggregation. Can. J. Soil Sci. 84(4): 355–363.

Ryals, R., and W.L. Silver. 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands. Ecol. Appl. 23(1): 46–59.

USDA National Organic Program (NOP). Organic Regulations. https://www.ams.usda.gov/rules-regulations/organic.

USDA NRCS, undated. Soil Health https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/.

Weil, R. R., and N. C. Brady 2017. The Nature and Properties of Soils, 15th Edition.

* For project proposal summaries, progress and final reports for USDA funded Organic Research and Extension Initiative (OREI) and Organic Transitions (ORG) projects, enter proposal number under "Grant No" and click "Search" on the CRIS Assisted Search Page at: http://cris.nifa.usda.gov/cgi-bin/starfinder/0?path=crisasw\sist.txt&id=anon&pass=&OK=OK.