Why “Organic” Matters

Soil Organic Matter, Soil Health, and USDA-Certified Organic Farming

Mark Schonbeck, PhD

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Mark Schonbeck

Mark Schonbeck has worked for 35 years as a researcher, consultant, educator, and advocate for sustainable and organic agriculture. He works one-on-one with farmers and homesteaders, taking a site-specific approach to soil test interpretation and organic soil, nutrient, and weed management for vegetables and other crops. In his capacity as Research Associate with Organic Farming Research Foundation (OFRF), he develops research-based education materials including a series of practical guides on *Soil Health and Organic Farming*, available at http://ofrf.org/.

In the past, Mark has led or participated in several on-farm research projects conducted by Virginia Association for Biological Farming (VABF) and collaborated with VABF and National Center for Appropriate Technology (NCAT) to help USDA Natural Resources Conservation Service (NRCS) programs better serve organic producers.

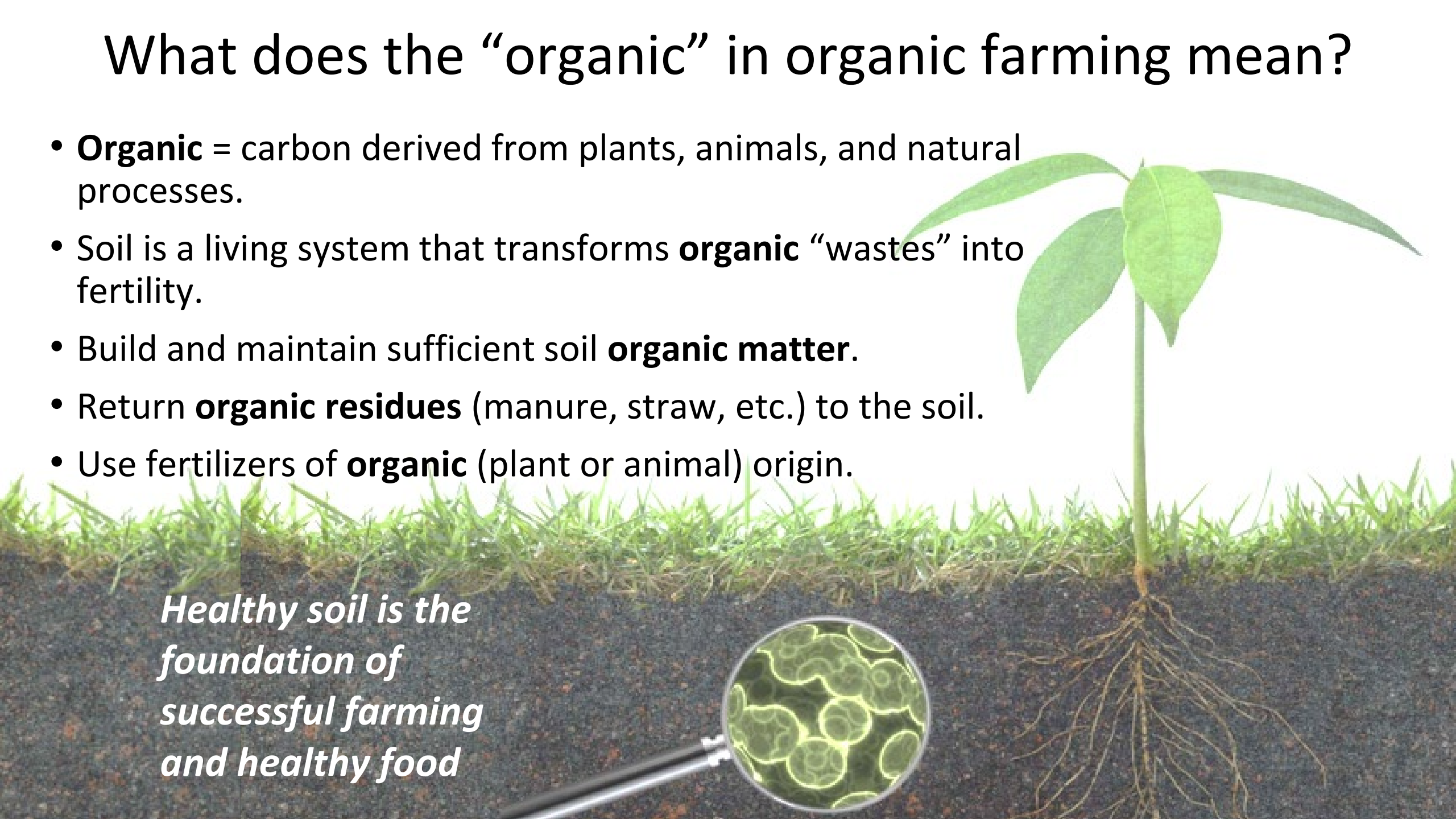
Mark also serves as VABF policy liaison with National Sustainable Agriculture Coalition (NSAC) of which VABF is a member group and writes the policy update column for the monthly VABF e-newsletter. He also works with OFRF to develop policy recommendations to help organic producers mitigate the impacts of climate change on their operations and the communities they serve.

Soil Organic Matter and the Organic Farming Method

A brief history

What does the “organic” in organic farming mean?

- **Organic** = carbon derived from plants, animals, and natural processes.
- Soil is a living system that transforms **organic** “wastes” into fertility.
- Build and maintain sufficient soil **organic matter**.
- Return **organic residues** (manure, straw, etc.) to the soil.
- Use fertilizers of **organic** (plant or animal) origin.



Healthy soil is the foundation of successful farming and healthy food

History of Organic Farming
1896 – early 1900s

George Washington Carver of Tuskegee University helped Black sharecroppers to better feed their families and restore Alabama's worn-out soils through organic practices, including:

- Use of compost, manure, and swamp muck to restore soil fertility
- Crop rotation
- Crop diversification
- Legume cover crops and food crops
- Farming systems that mimic natural processes (permaculture)

Soil Conservation and the 1930s Dust Bowl

Hugh Hammond Bennett – Soil Conservation Service, established 1935

Soil Erosion: a National Menace (USDA bulletin, 1928)

"The supply of available plant food is markedly reduced by the removal of the surface soil, as well as the population of beneficial microorganisms. The **humus supply** is usually exhausted."

"The **humus-charged surface layer** [is] the farmer's principal capital."

"Hugh Hammond Bennett, Address at Ohio State University, January 31, 1933"

"Summer and winter cover crops … have made terraces more effective."

"By terracing, strip cropping, plowing **humus into the soil** and practicing good rotations it is practical to slow down … erosion."

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History of Organic Farming – 1930s – 1940s

<u>Ehrenfried Pfeiffer</u> ***Biodynamic Farming and Gardening*** **(2nd ed, 1943)**

"The quality and amount of the **humus** determine the fertility of the soil. Soil bacteria as well as the earthworms … are the chief participants in the formation of humus."

<u>Sir Albert Howard</u> ***The Soil and Health*** **(1947, pp 26-32)**

"**Humus** is the most significant of all Nature's reserves … the beginning of vegetable life and therefore of animal life and of our own being."

<u>Lady Eve Balfour</u>

- Haughley Experiment (1939-1980s) organic vs conventional systems
- Book *The Living Soil* (1943)
- The Soil Association, founded 1946.

*Early leaders of the organic farming movement understood that, to sustain fertility, farmers must replenish **soil organic matter** and **soil life** as well as plant nutrients. They recommended feeding the soil with:*

Compost

Cover crops

Diverse crop rotations

Crop-livestock integration

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Soil Organic Matter and Soil Health in the National Organic Standards

§ 205.203 Soil fertility and crop nutrient management practice standard:

(a) The producer must select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion.

(b) The producer must manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials.

(c) The producer must manage plant and animal materials, crop nutrients, and soil fertility to maintain or improve soil organic matter content.

National Organic Program INOP) Regulations, https://www.ams.usda.gov/rules-regulations/organic.

Soil Organic Matter and Soil Health in the National Organic Standards

§ 205.205 Crop rotation practice standard.

The producer must implement a crop rotation including but not limited to sod, cover crops, green manure crops, and catch crops that provide the following functions that are applicable to the operation:

(a) Maintain or improve soil organic matter content;

(b) Provide for pest management in annual and perennial crops;

(c) Manage deficient or excess plant nutrients; and

(d) Provide erosion control.

NOP Regulations, https://www.ams.usda.gov/rulesregulations/organic.

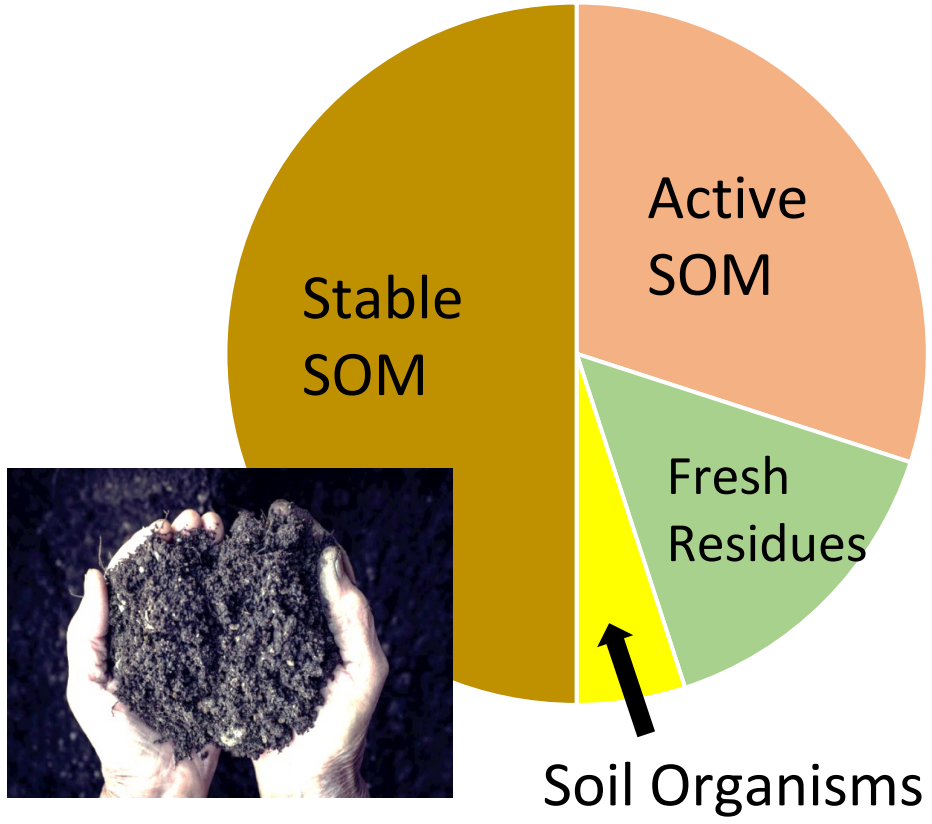
The Nature of Soil Organic Matter

SOM is a process as well as a substance

What is Soil Organic Matter?

- *Soil organic matter* (SOM) consists of carbon-based substances formed through plant photosynthesis followed by the digestion of root exudates and plant and animal residues by soil organisms.

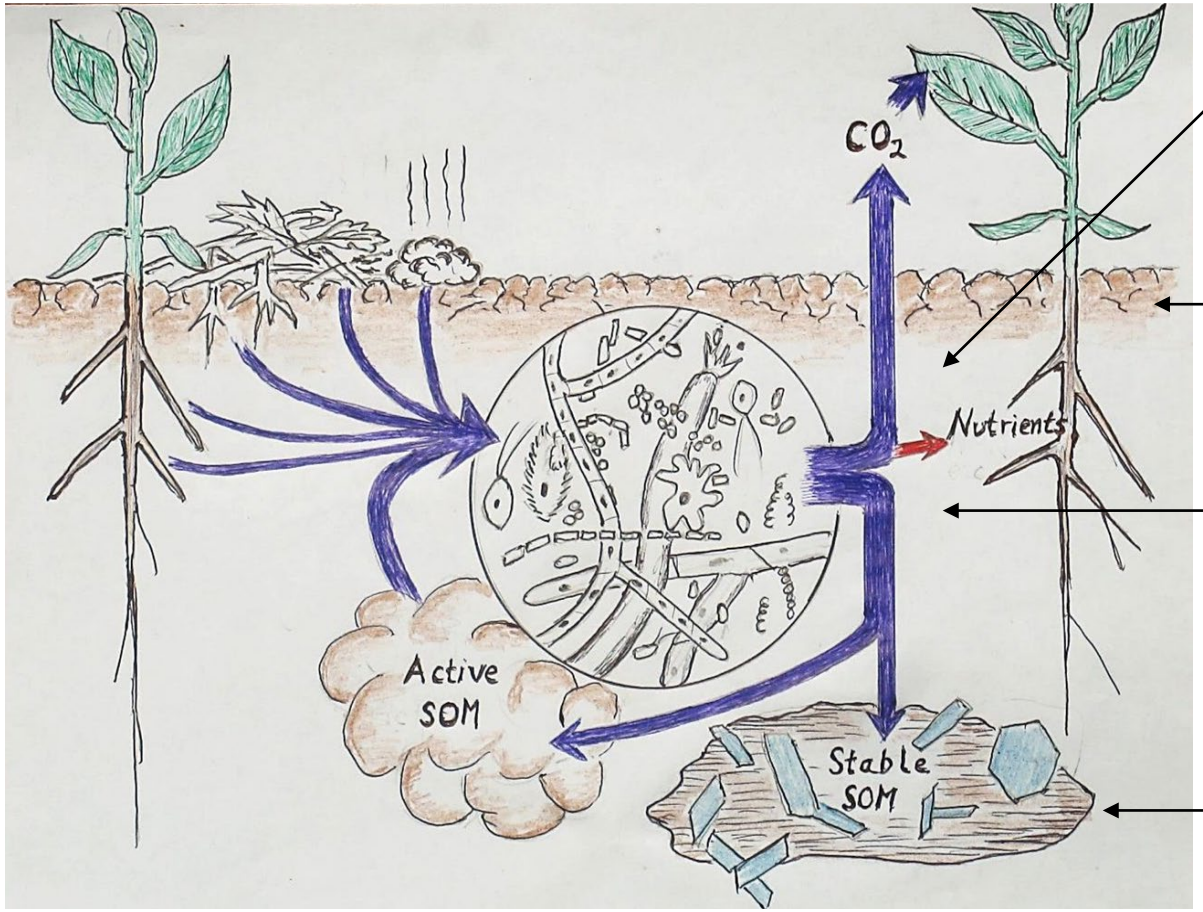
- SOM comprises 1 – 10% of the topsoil (A horizon) and decreasing proportions of subsoil (B and C) horizons. SOM is about 50% *soil organic carbon* (SOC).



Does “Stable” Soil Organic Matter = Humus?

- Humic substances – humic and fulvic acids – occur in soil only in trace amounts.
- *Active* SOM = decomposing residues, plant root exudates, microbial metabolites, and recently dead microbes (half life months to years).
- Soil organic matter can become *stabilized* by:
  - Protection within soil aggregates (half life years to decades).
  - Adsorption to soil clays and silts to form ***mineral-associated organic matter*** (**MAOM**, half life centuries to millennia).
  - Leaching into or formation within subsurface soil horizons where lower oxygen levels limit microbial activity (MAOM, long half life).

Soil Microbes Convert Organic Inputs into SOM



Mineralization (respiration) releases nutrients and supports plant growth

Active SOM protected in soil aggregates

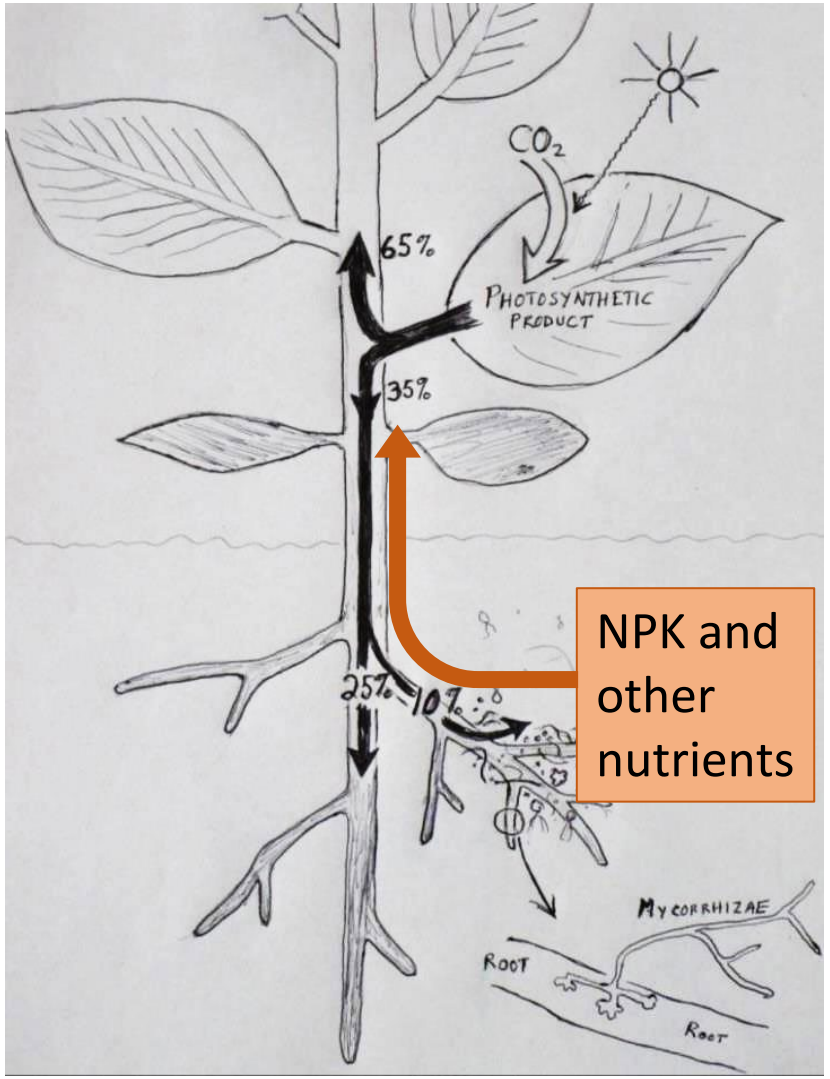
Microbial metabolites and dead microbes form both active SOM and MAOM

Deep roots and leached SOM form subsoil MAOM

Stabilization adds structure, builds water holding and cation exchange capacity, and sequesters C

An Ancient Partnership

- Plants donate 10 – 30% of their photosynthetic product to the soil life.
- In return, soil microbes help plants obtain nutrients.
- The Earth's first land plants co-evolved with their fungal symbionts.

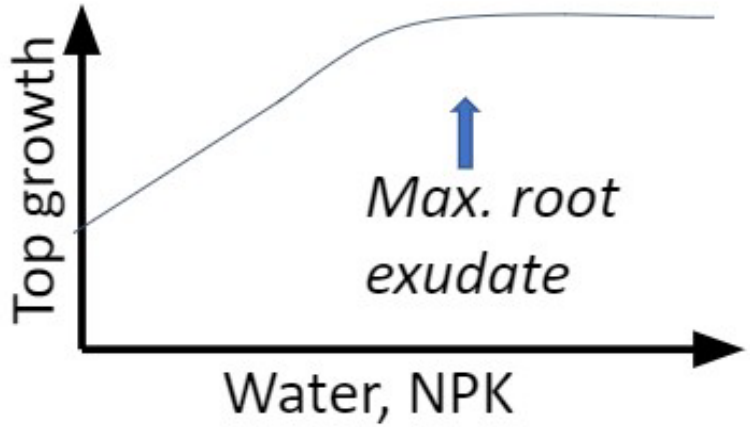


How to Feed the Soil

Diverse, vegetative cover and living roots are the "tried and true way" to feed soil life and build SOM. It has a 450-million-year track record.

How to Enhance Root Exudation and Build MAOM

- Provide plant-available N, P, and water at slightly below the optimum for aboveground growth.
  - ➢ *This can reduce fertilizer and irrigation input needs*
- Include legumes in crop rotations and pasture mixes.
- Schedule rotational grazing late in the rapid growth stage of forage when root exudation is greatest.



NCAT-ATTRA

Organic Farming Practices and Soil Organic Matter

Do organic production systems build SOM?

Does Organic Farming Build Soil organic Matter?

Study and Parameter Measured	Conventional	Organic
SOM in >1300 fields across US [1]		
Total SOM %	7.37	8.33 (*13% higher*)
"Humic substances" %	3.10	4.76 (*53% higher*)
Meta-analysis, 56 studies, global [2]		
Total soil organic carbon (SOC ~ SOM X 0.5)		*19% higher*
Microbial biomass carbon		*41% higher*
Soil microbial enzyme activity		*32 – 84 % higher*
Meta-analysis, 20 studies, global [3]		
SOC accrued, lb/ac-yr	80	490 (*6-fold higher* [4])

1 Ghabbour et al., 2017. 2 Lori et al., 2017. 3 Gattinger et al., 2012

4 About 40% of new SOC from imported amendments; 60% sequestered *in situ*.

Long-Term Farming Systems Trials

In six trials in CA, IA, MD, MN, PA, and WI, organic systems have accrued:

- 400 – 600 lb/ac-yr more SOC than conventional systems.

In the Beltsville, MD trial, organic systems with tillage accrued:

- 380 lb more SOC/ac-yr than conventional no-till.
- 600 lb more SOC/ac-yr than tilled conventional.

The organic systems include:

- Cover crops and organic amendments.
- Diverse rotation.
- Perennial sod phase in the rotation – deep roots and long duration.
- Moderate frequency and intensity of tillage.

Four NRCS Principles of Soil Health

Keep the soil covered

Diversify the farming system

Maintain living roots

Minimize soil disturbance

How does organic farming stack up?

Organic Farmers Use More Cover Crops

% of Farmers who Plant Cover Crops

Crop type	Organic	Non-organic
Specialty	92%	61%
Field	76%	10%

"Complex, multispecies cover cropping [on organic farms] suggests that cover crops have become an essential part of organic cropping systems"

Schoolman & Arbuckle, 2022.

National Organic Standards Limit Chemical Disturbance

§ 205.202 Land requirements.

Any field … from which harvested crops are … labeled “organic,” must:

(b) Have had no prohibited substances … for 3 years [prior to] harvest.

§ 205.206 Crop pest, weed, and disease management practice standard.

(e) When [cultural] practices … are insufficient … a biological or botanical substance or a substance included on the National List of synthetic substances allowed for use in organic crop production may be applied.

§ 205.105 Allowed and prohibited substances …

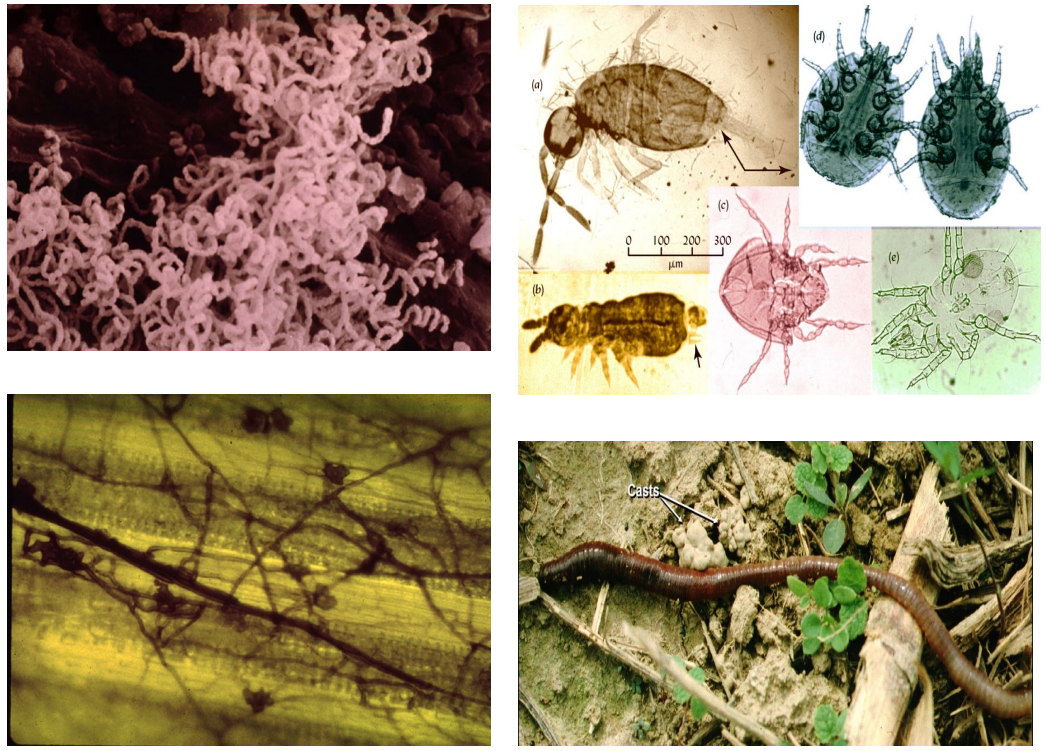
[Organic products] … must be produced and handled without the use of:

(a) Synthetic substances … except as provided in [the National List]

Synthetic Inputs Can Hurt Soil Life and Reduce SOM

- Pesticides harm earthworms, micro-arthropods, and other soil invertebrates (Gunstone et al., 2021).
- Pesticides and herbicides can alter soil microbial communities and reduce mycorrhizal activity (Klein, 2019).
- Earthworms are more abundant in tilled organic soils than in conventional soils with pesticide use (Pelosi et al., 2014).
- Synthetic NPK can hinder stable SOM formation (Khan et al., 2007).

E. Ingham et al., 2011. Soil Biology Primer



Ray R. Weil, U. Maryland

These soil organisms work together to convert residues into SOM. Organic farming protects them from harmful chemicals.

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Organic Farming Soil Health Challenges

Practice	Concern	Remedies
Tillage and cultivation for weed control	Tillage oxidizes SOM, hurts soil life, can promote erosion	Reduced or shallow tillage, ecological weed IPM, tight rotations
Manure and compost for fertility	Excess soil P inhibits mycorrhizal fungi (which stabilize SOM)	Legume cover crops, low P organic N sources, soil tests, nutrient budgeting
NOP-allowed N at “agronomic rates”	Excess soluble N burns up SOM and weakens biological N cycling	Healthy soils need much less N to sustain crops – *research ongoing*.

Organic Practices, Microbial Biomass, and SOM

Practice	Microbial Biomass[1]	Total SOM[2]
Reduced till[3]	+99%	"Conservation till" +14%
No-till	-4%	
Organic fertilizer[4]	+127%	
Organic amendment		+24%
Crop rotation	+21%	
Cover crop		Gradual increase[5]

Justin Rich

The high-speed disk provides shallow (~3 in) non-inversion tillage to terminate cover crops and prepare fields for planting.

[1] Morugan-Coronado et al., 2022. [2] Crystal-Ornelas et al., 2021. [3] Non-inversion full field tillage (4-6 in) vs moldboard plow (8+ in). [4] Organic nutrient sources vs conventional NPK. [5] Significant after 5 yr cover cropping, +22% at 15 yr.

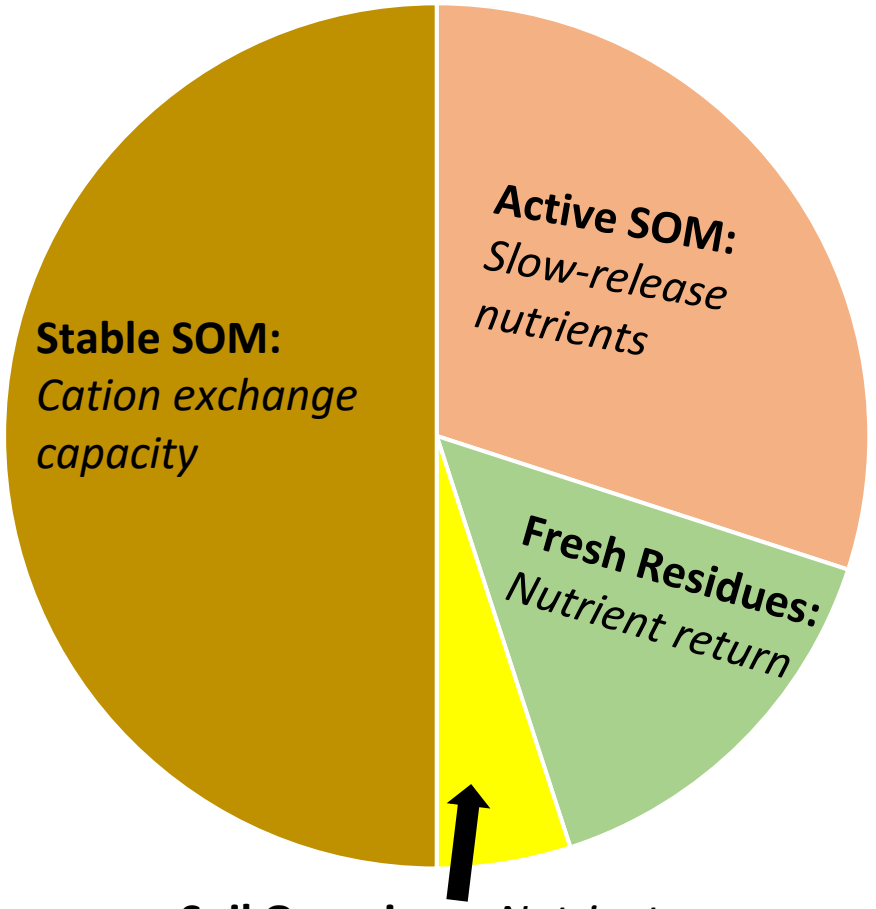
Functions of Soil Organic Matter

How the different components of SOM support vital functions of a healthy agricultural soil.

SOM Function: *Crop Nutrition*

Provide sufficient yet not surplus crop nutrients.

- Active SOM provides a slow release reserve of N, P, S, and micronutrients.
- Stable SOM expands capacity to hold cations K^{+}, Mg^{++}, Ca^{++}, NH_4^{+}
- Soil organisms deliver nutrients to roots, tie up excess soluble N.



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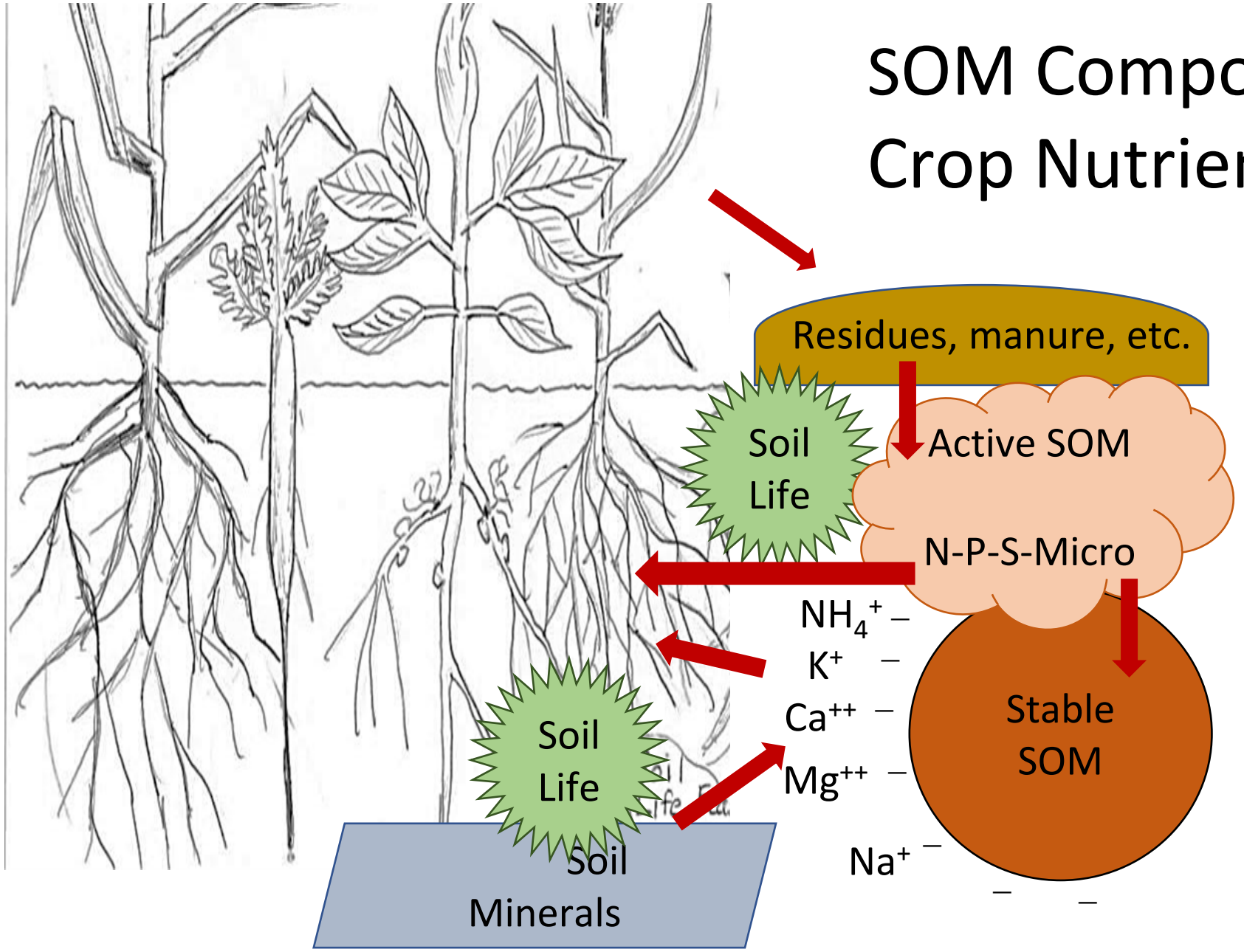
SOM Components and Crop Nutrient Cycling



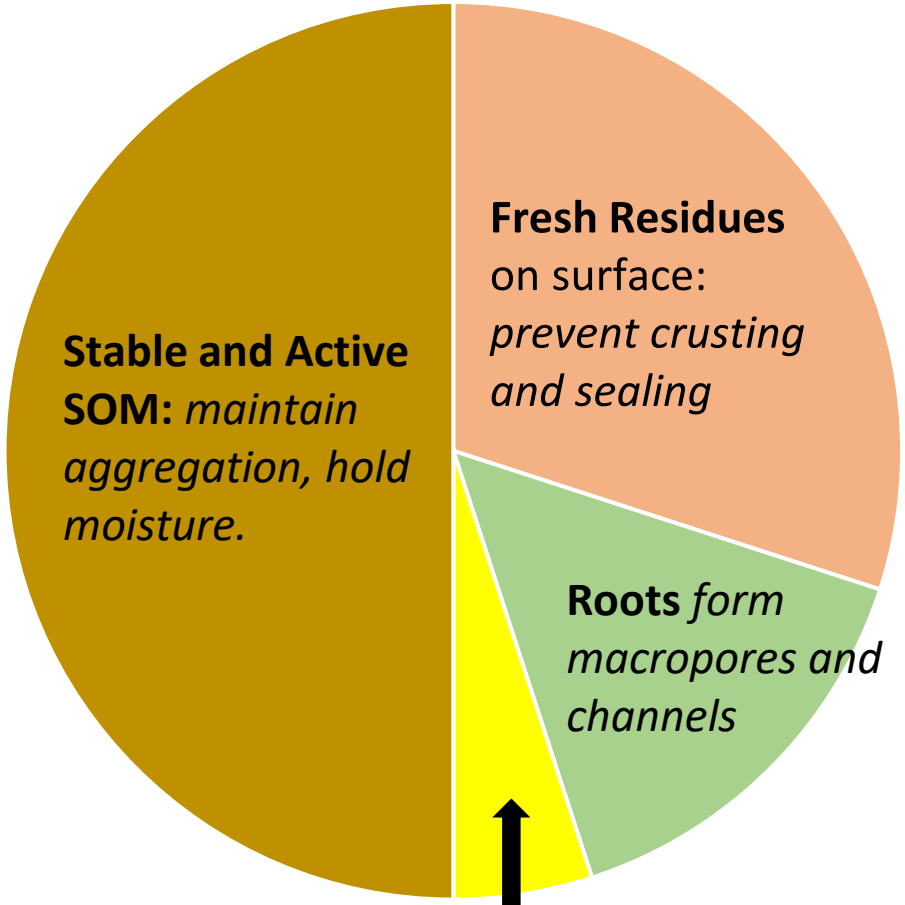
Sufficient SOM improves nutrient cycling and:

- Lowers fertilizer costs
- Protects water quality
- Maintains crop yield and quality

SOM Function: *Structure, Porosity, Water, and Air*

Porous, aggregated soil:

- Absorbs rainfall.
- Stores plant-available moisture.
- Drains and aerates well.
- Promotes deep, healthy roots.
- Resists erosion and compaction.



Soil Organisms: *bind soil into aggregates (bacterial "glues" and fungal mycelia)*

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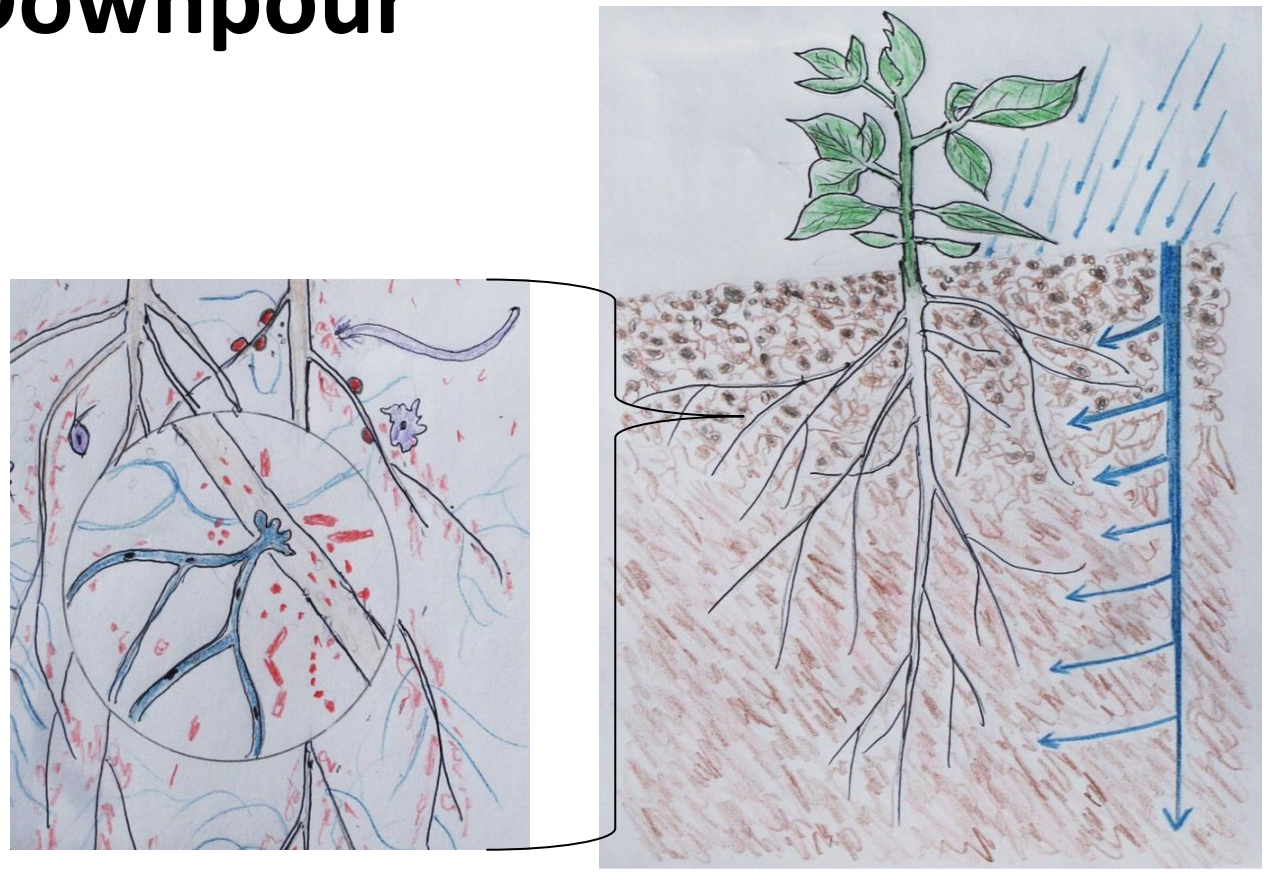
How porous, SOM-rich Soil Absorbs and Retains a Downpour

Plant roots and soil biota aggregate soil and maintain a network of large and small pores

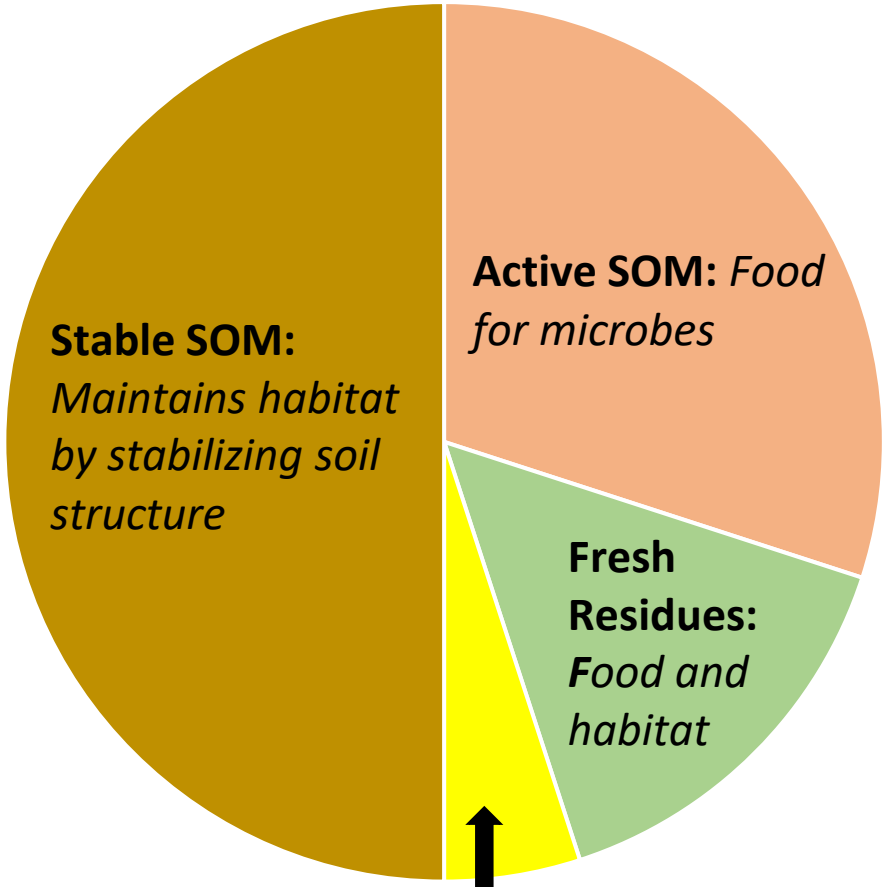


- Rapid infiltration
- Moisture retained
- Unrestricted root growth
- Excess drains out

SOM Function: *Habitat for Soil Organisms*

Sufficient SOM provides habitat for soil organisms that:

- Enhance crop resilience and vigor
- Suppress plant diseases
- Cycle nutrients
- Sequester carbon



Soil Organisms: *Continually form new micro and macro pores*

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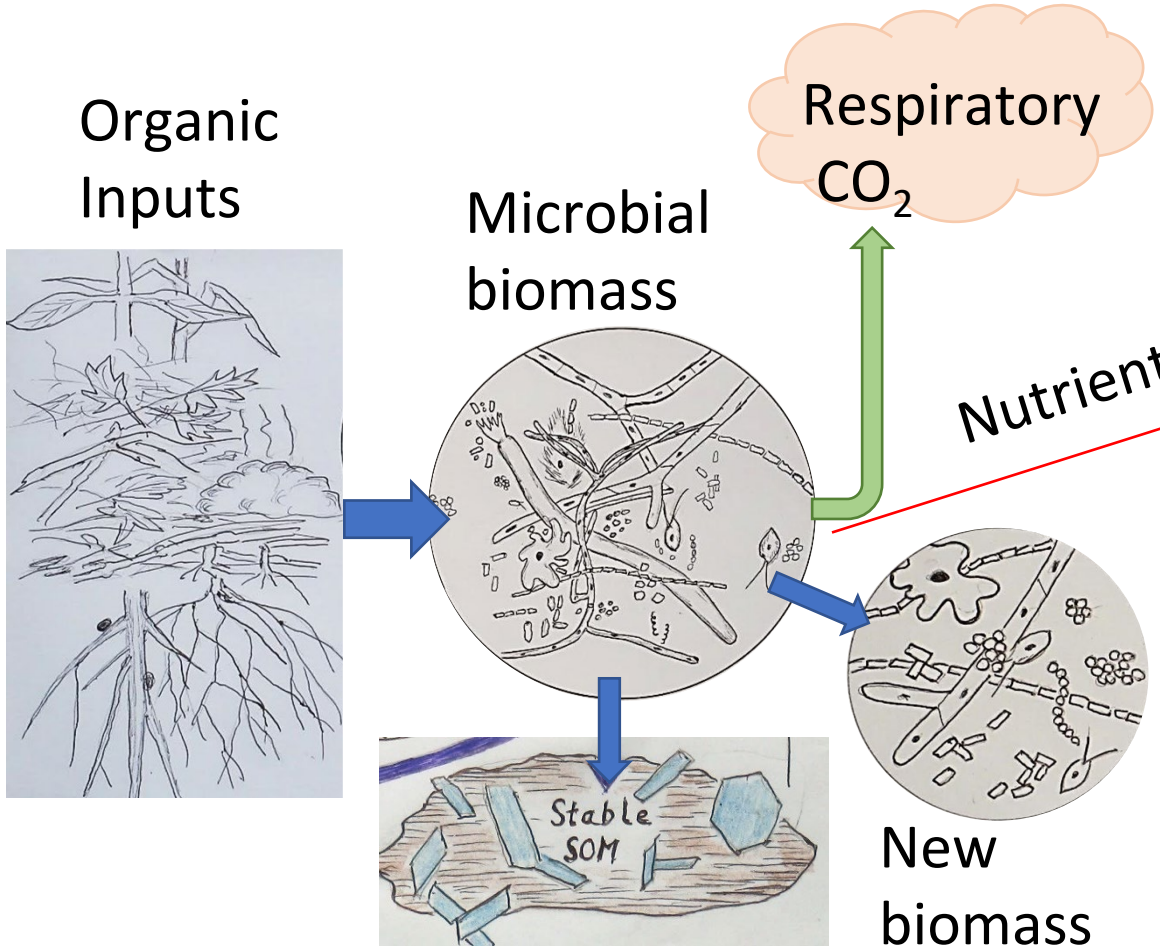
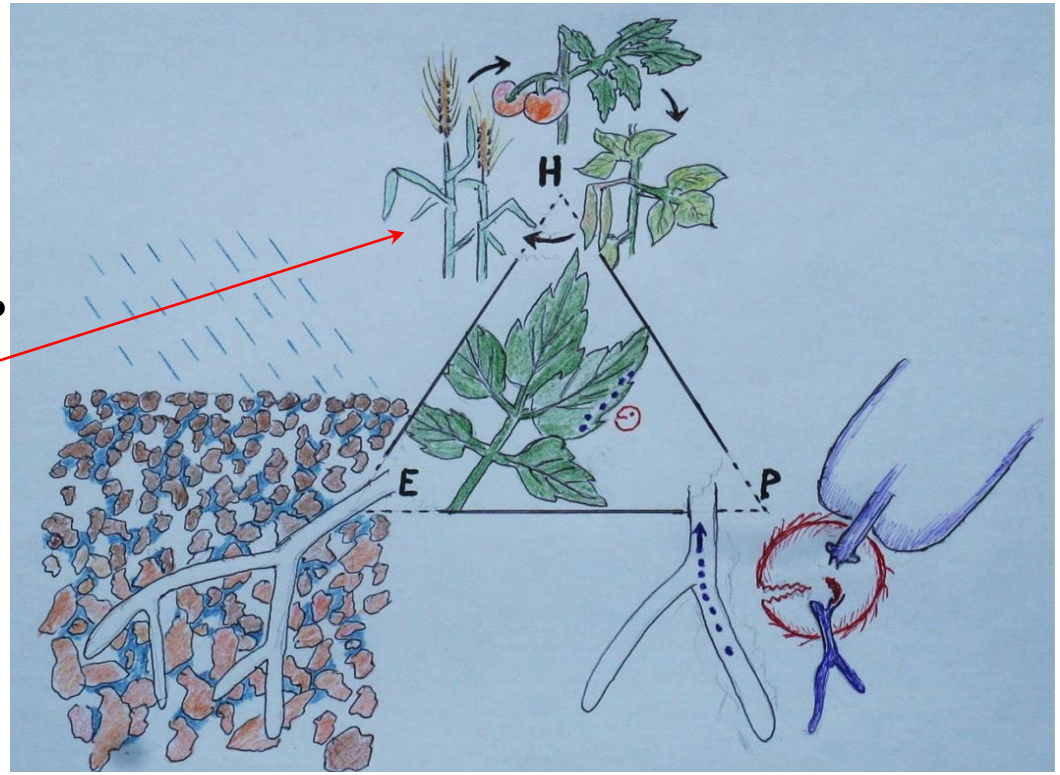
SOM Supports Healthy Plants by Providing Microbial Habitat





SOM and soil life break the “disease triangle” with better drainage (E), natural enemies of pathogens (P) and induced plant resistance (H)

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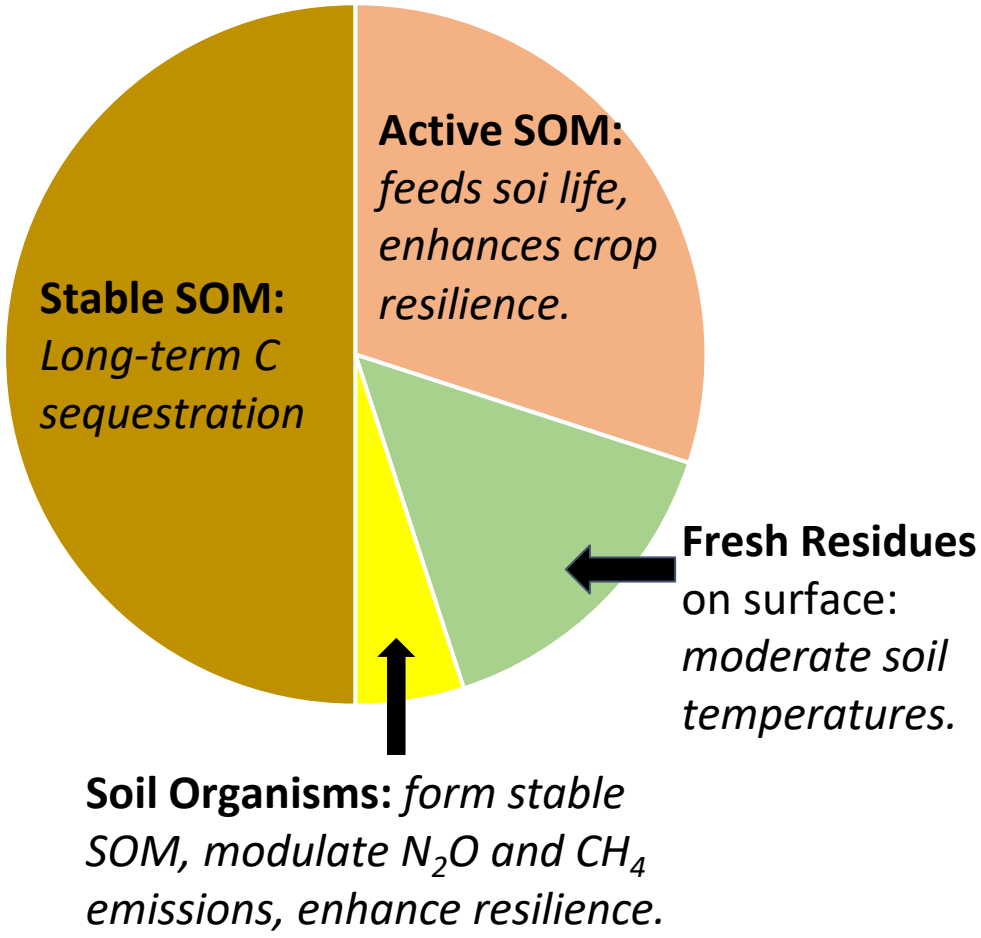
SOM function: *Climate stabilization and resilience*

Global loss of SOM over past 500 years represents 20% of today's atmospheric CO_2 surplus.

- Increases in total SOC – imported C = net C sequestration.
- Stable SOC lasts 100 – 1000+ years.
- Efficient nutrient cycling reduces N_2O emissions.
- Well aerated soils emit no CH_4.



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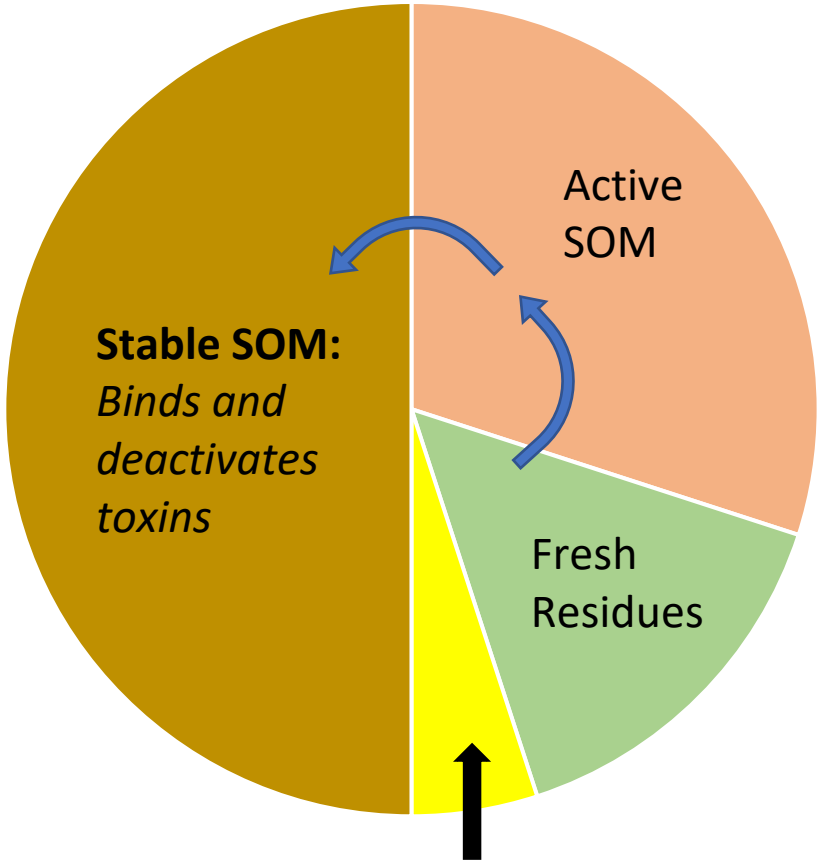
SOM Function: Waste management



Soil Organisms: *convert fresh residues into SOM, decompose toxins into harmless materials*

Building Soil Organic Matter in Agricultural Soils

Best organic management practices to optimize the quantity and quality of soil organic matter.

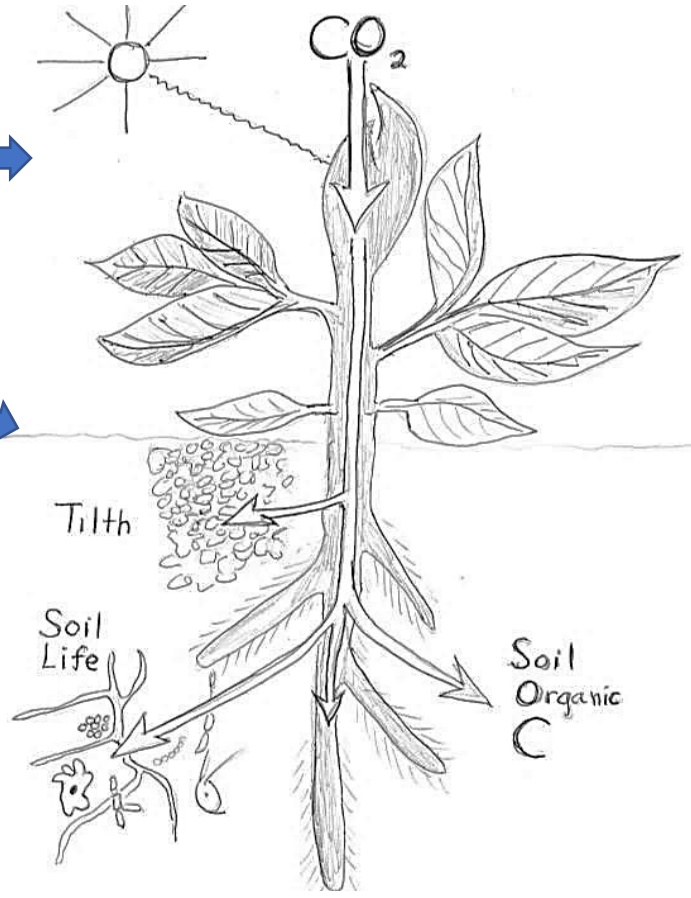
The Living Plant is the Farmer's #1 Tool for Building Soil Organic Matter

Photosynthesis is the source of all SOM.

Plant cover protects near-surface SOM.

Living roots:

- Feed soil organisms
- Maintain soil structure
- Build SOM throughout soil profile



Practices:

- Diverse crop rotation
- High-biomass cover crops
- Perennial sod crops
- Prompt planting after harvest
- Intercropping
- Relay planting
- No bare fallow

Animals Help Build SOM

Practices:

- Advanced rotational grazing management
- Livestock-crop integration
- Grazing cover crops and crop residues
- Silvopasture

Grazing livestock and poultry:

- Improve SOM quantity and quality.
- Provide and cycle crop nutrients.
- Enhance soil microbial diversity.

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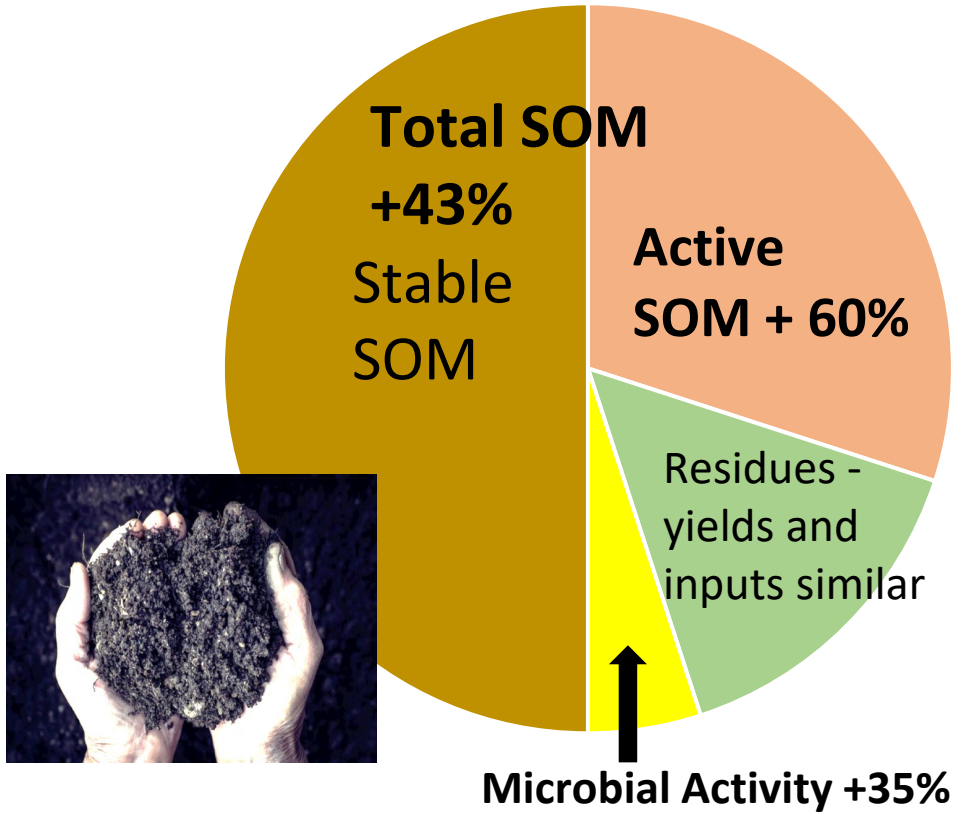
Organic Amendments + Living Plants Build More SOM

- Use compost, manure, biochar, or organic mulching materials.
- Use diversity of materials with moderate overall C:N ratio.
- Avoid over applying nutrients.
- Limit use of concentrated, low-C:N organic nutrient sources.
- Biologically active soils may need little or no added soluble N for top yield (Franzluebbers et al., 2018).



Soil effects of 11 years organic vegetable cropping with finished compost (C:N 20) vs poultry litter (C:N 7) at the same total N rates (Bhowmik et al., 2016)

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Additional Organic Practices to Build SOM

- Reduce tillage when practical.
- Use Integrated Weed Management to lessen need for cultivation.
- Use cultivars and breeds developed for organic when available.
- Use NOP-allowed pesticides and fungicides only when all else fails.
- Monitor SOM and Soil Health
  - Field observations – soil color and tilth, water infiltration and retention, crop resilience
  - Total SOM long term trends (10+ years)
  - Cornell Assessment of Soil Health (CASH) or component tests
  - Sol Test Biological Activity (3-day respiration, Franzluebbers, 2018)

Farm Story: Organic Practices Build SOM and Fertility in a Sandy Soil

Rick and Janice Felker
Mattawoman Creek Farms
Eastern Shore of Virginia

The Starting Point

- Bojac sandy loam (order Ultisols)
- Initially low SOM and low fertility

The Practices

- Diverse rotation, no bare fallow
- Replant promptly after each harvest
- High biomass cover crops
- Return all crop residues to the soil
- Mushroom compost and poultry litter at moderate rates
- Subsurface drip for deeper roots
- Rototiller run at reduced PTO speed

Rick Felker

Aerial View of Mattawoman Creek Farms, Cape Charles, VA. Total 30 acres, 11 acres in organic vegetables.

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The Outcome

After 20 years under organic management:

- SOM has increased to 2.0 – 2.2% (excellent for this soil)
- Visible crumb structure (aggregates)
- Soil test P has not exceeded optimum
- Enhanced N mineralization - no longer need fertigation with fish emulsion
- High yields – can rest some fields in season long cover each year
- “The soil gets better every year, and we have excellent growth” – *Rick Felker*

Rick Felker

Transplanting vegetable starts into mellow, living soil at Mattawoman Creek Farms

Questions?

In-depth Soil Health Guidebooks available at https://ofrf.org/research/reports/.

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