Why “Organic” Matters for Soil Health in Virginia

Soil Organic Matter and Organic Farming

ORGANIC FARMING RESEARCH FOUNDATION

https://ofrf.org

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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** (SOM).
- Return **organic residues** – manure, straw, etc. – to the soil.
- Use fertilizers of **organic** (plant or animal) origin.

George Washington Carver
Tuskegee University, 1896-1943

As Professor and researcher in agriculture at Tuskegee, George Washington Carver taught Black sharecroppers how 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)

Hugh Hammond Bennett
Father of Soil Conservation in the US

- Soil survey in Louisa, VA in 1905, recognized link between soil erosion and soil health.
- *Soil Erosion: a National Menace* (USDA bulletin, 1928).
- Quotes from January 1, 1933 Address at Ohio State University:
  - "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."
  - "By terracing, strip cropping, plowing **humus into the soil** and practicing good rotations it is practical to slow down … erosion."
  - Summer and winter cover crops … have made terraces more effective."
- USDA Soil Conservation Service (SCS, now NRCS) established 1935.

Virginia's "Dust Bowl": Red Clay at the Surface

Tillage and inadequate living cover in a dry region can create a dust bowl.

The 1930s Dust Bowl was the classic erosion disaster that led Congress to launch the SCS, and farmers to begin taking soil conservation seriously.

A similar, though slower disaster overtook the southern Piedmont, where two centuries of continuous cotton and other row crops eroded 5-10" of topsoil.

Red clay naturally occurs in the subsoil or "B" horizon. Its visibility at the surface indicates a history of severe erosion and loss of SOM.

The entire A horizon has been lost from this NC Piedmont field.

Other Early Leaders in Organic Farming

Ehrenfried Pfeiffer *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."

Sir Albert Howard *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."

Jerome Irving Rodale *Pay Dirt* (1945)

> Founded the Rodale Institute in 1947; farming systems trial launched 1981.

Lady Eve Balfour *The Living Soil* (1943)

> Haughley Experiment (1939-1980s) organic vs conventional systems.

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.

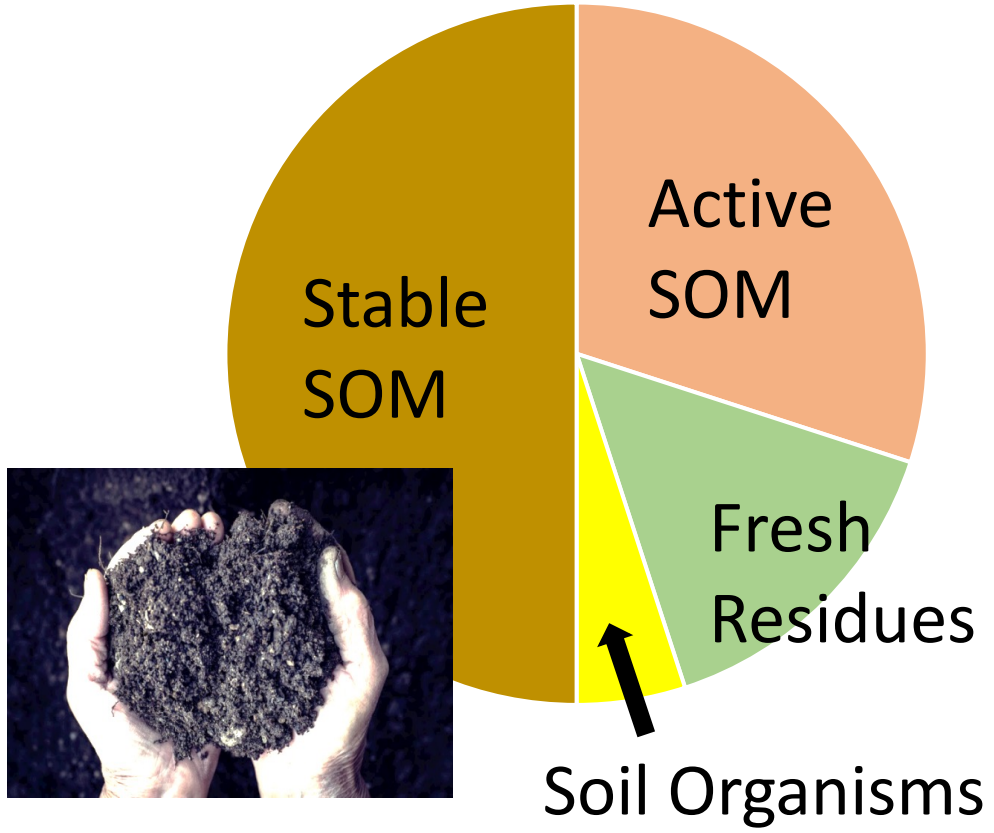
NOP Regulations, https://www.ams.usda.gov/rulesregulations/organic.

The Nature of Soil Organic Matter

SOM is a process as well as a substance

What is Soil Organic Matter?

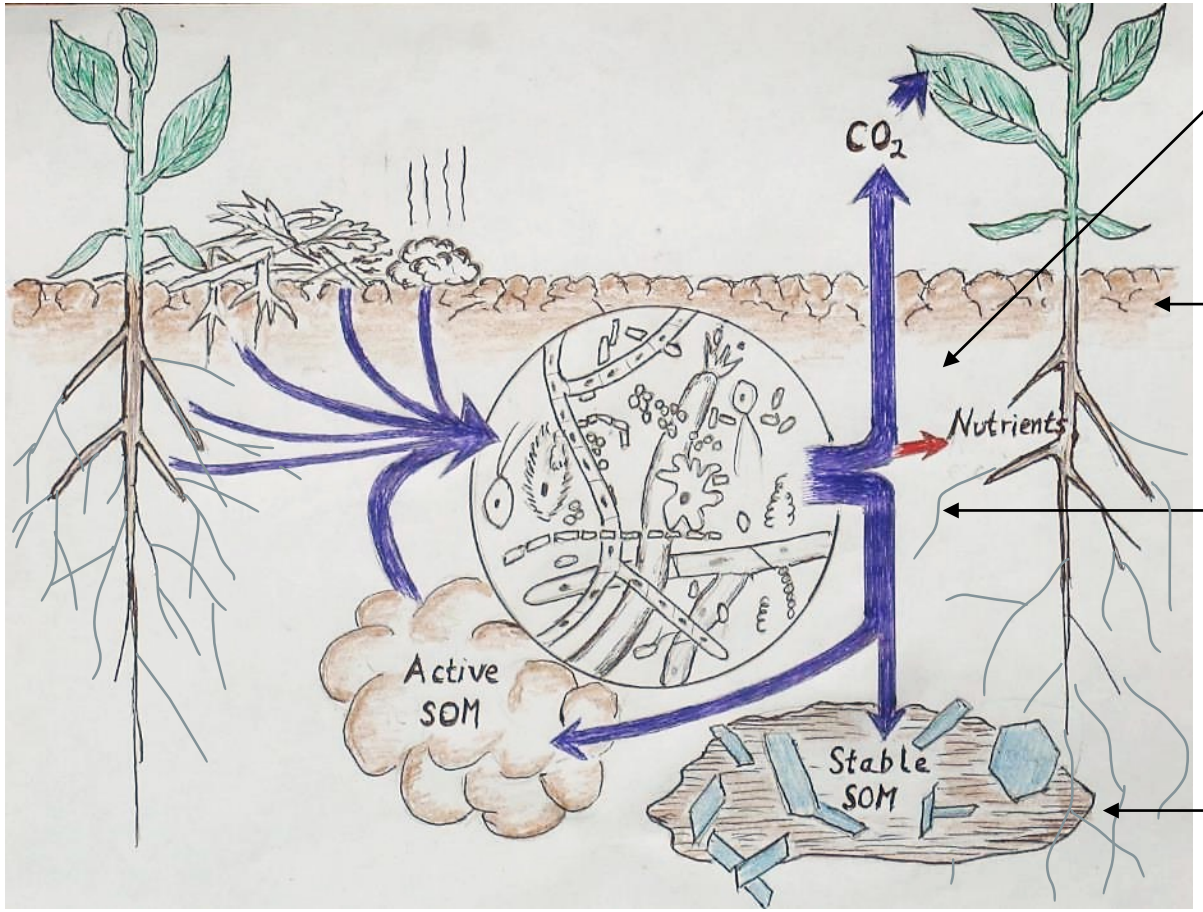
- *Soil organic matter* (SOM) consists of carbon-based substances formed through plant photosynthesis followed by the digestion of root exudates and plant and animal residues by soil organisms.
- SOM comprises 1 – 10% of the topsoil (A horizon) and decreasing proportions of subsoil (B and C) horizons. 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

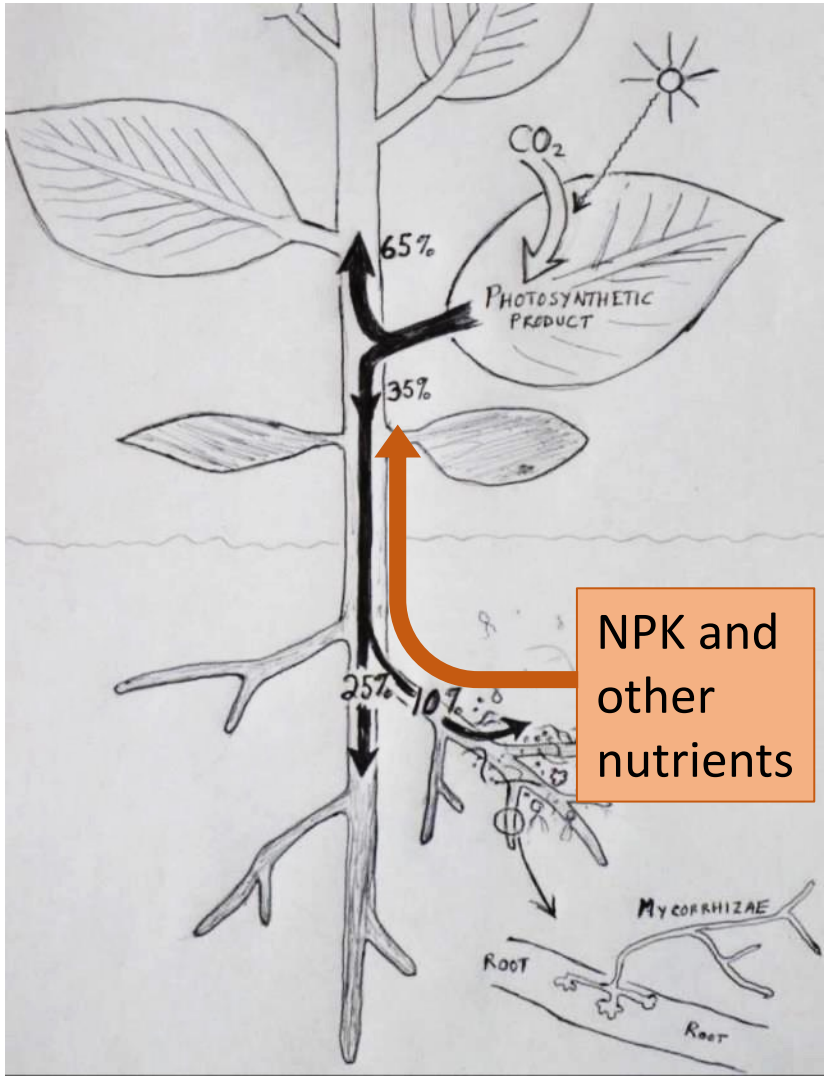
Microbial metabolites and dead microbes form both active SOM and MAOM

Deep roots and leached SOM form subsoil MAOM

Stabilization adds structure, builds water holding capacity 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.

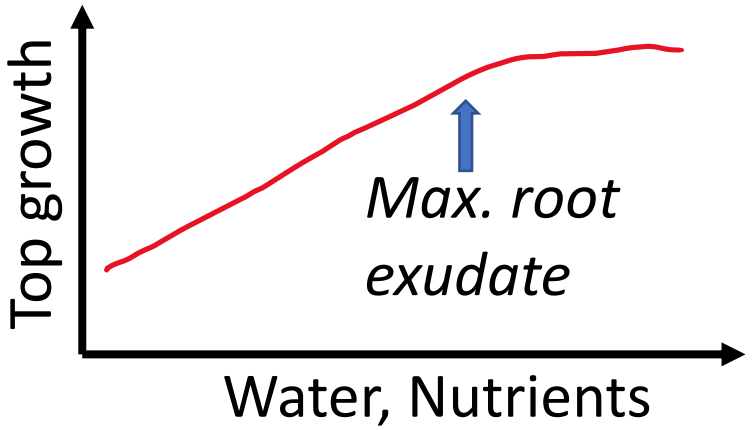


How to Feed the Soil

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	70%	10%

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

Schoolman & Arbuckle, 2022.

Diversified Crop Rotations on Organic Farms

Conventional system: corn-soy with winter fallow

Many organic crop rotations include winter covers and a cereal grain overseeded with perennial legume-grass forage, and thus return more organic matter to the soil.

Organic system: corn-cover-soy-cereal-overseeded perennial pasture (2-3 yr)

Soil Health Challenges in Organic Farming

Practice	Concern	Remedies
Tillage and cultivation for weed control	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.

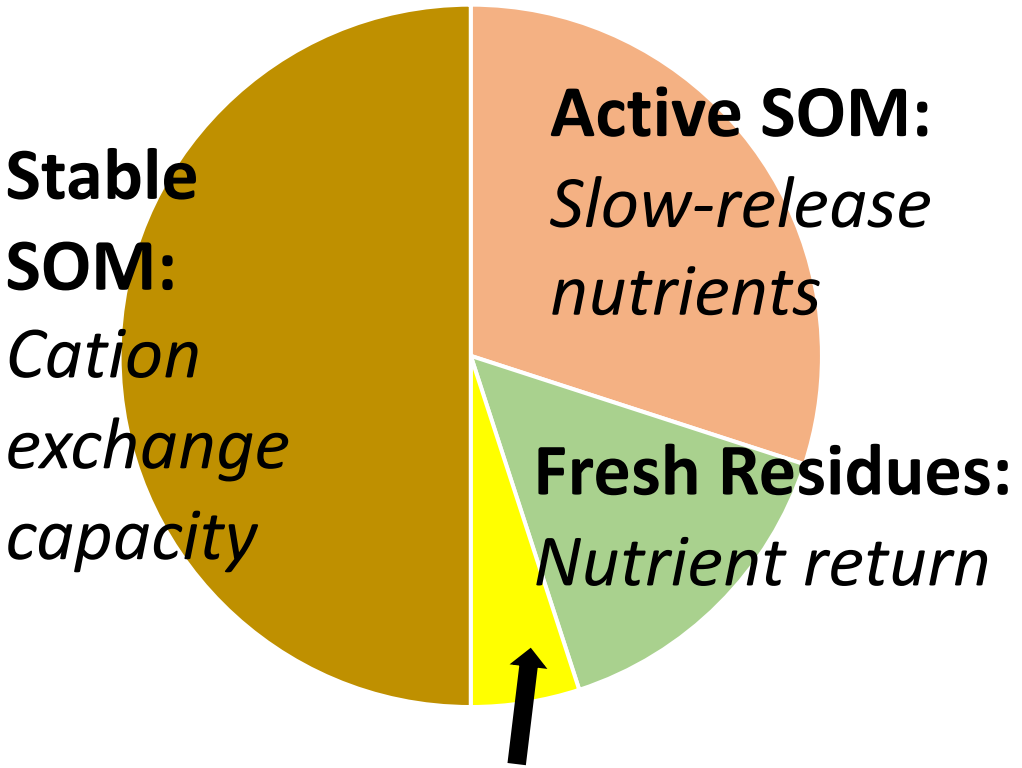
Functions of Soil Organic Matter

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

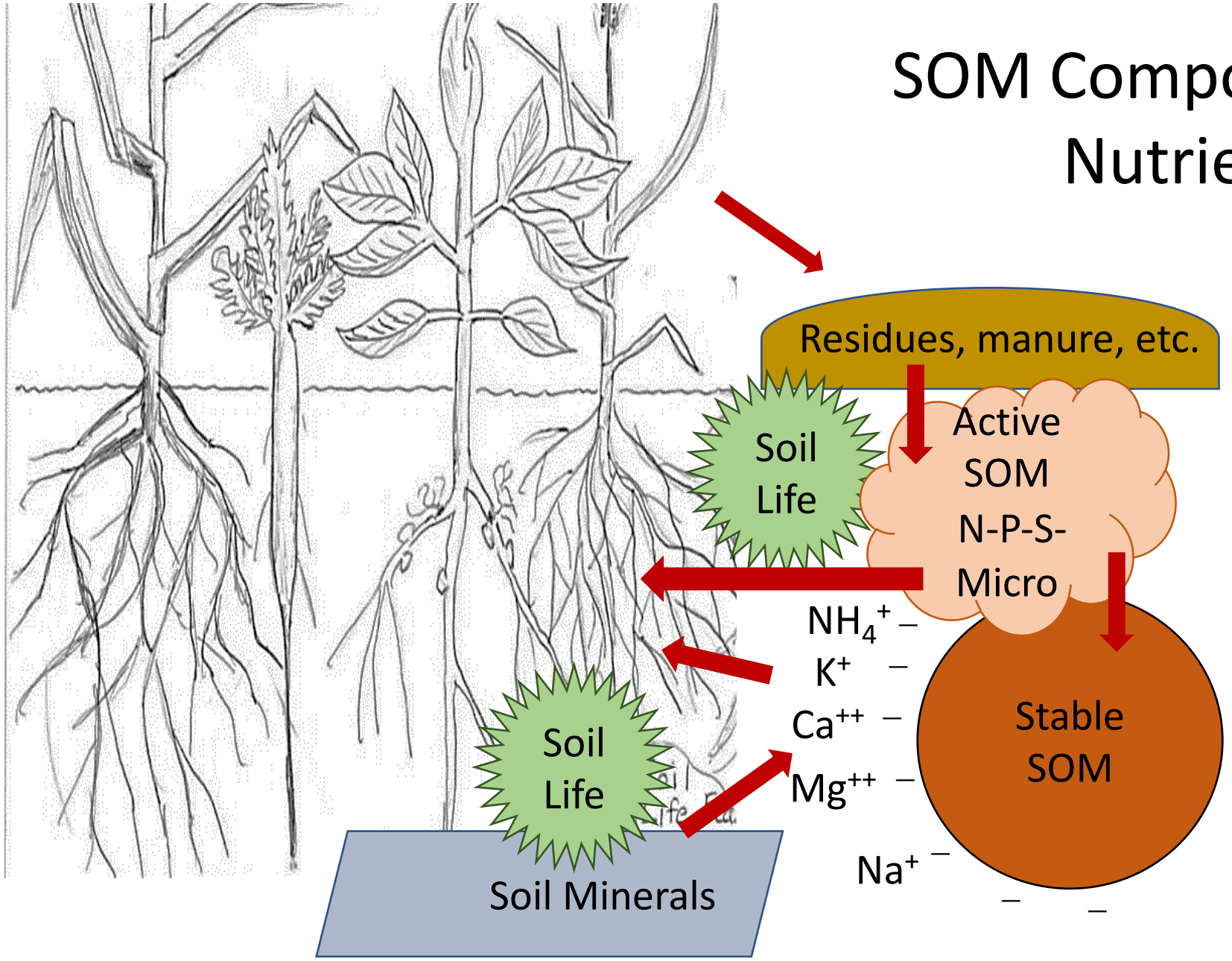
SOM Function: *Crop Nutrition*

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.



SOM Components and Crop Nutrient Cycling



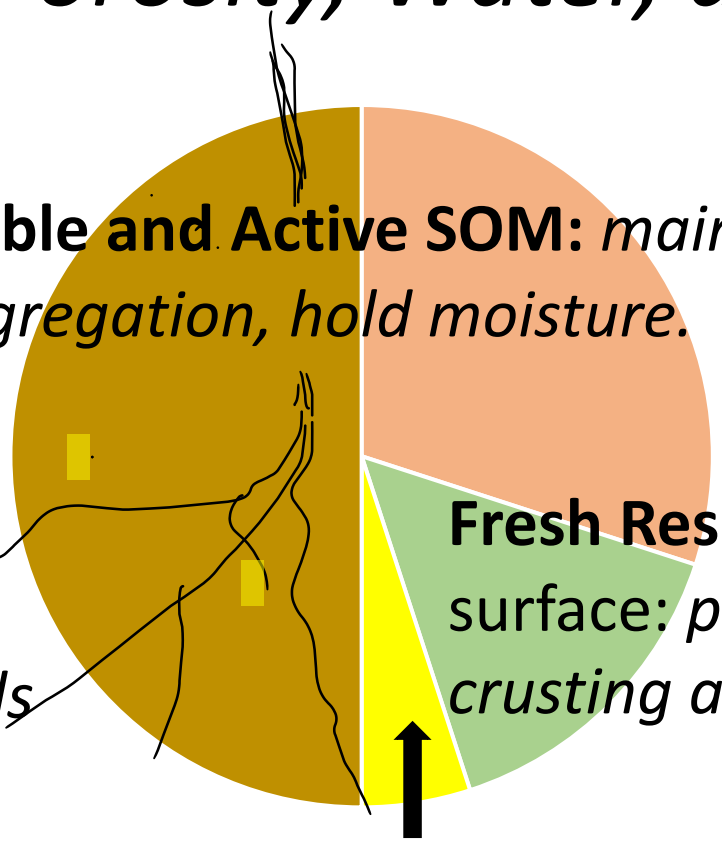
Sufficient SOM improves nutrient cycling and:

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

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.
- Reduces runoff to streams and Chesapeake Bay



Stable and Active SOM: *maintain aggregation, hold moisture.*

Roots *form macropores and channels*

Fresh Residues on surface: *prevent crusting and sealing*

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

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

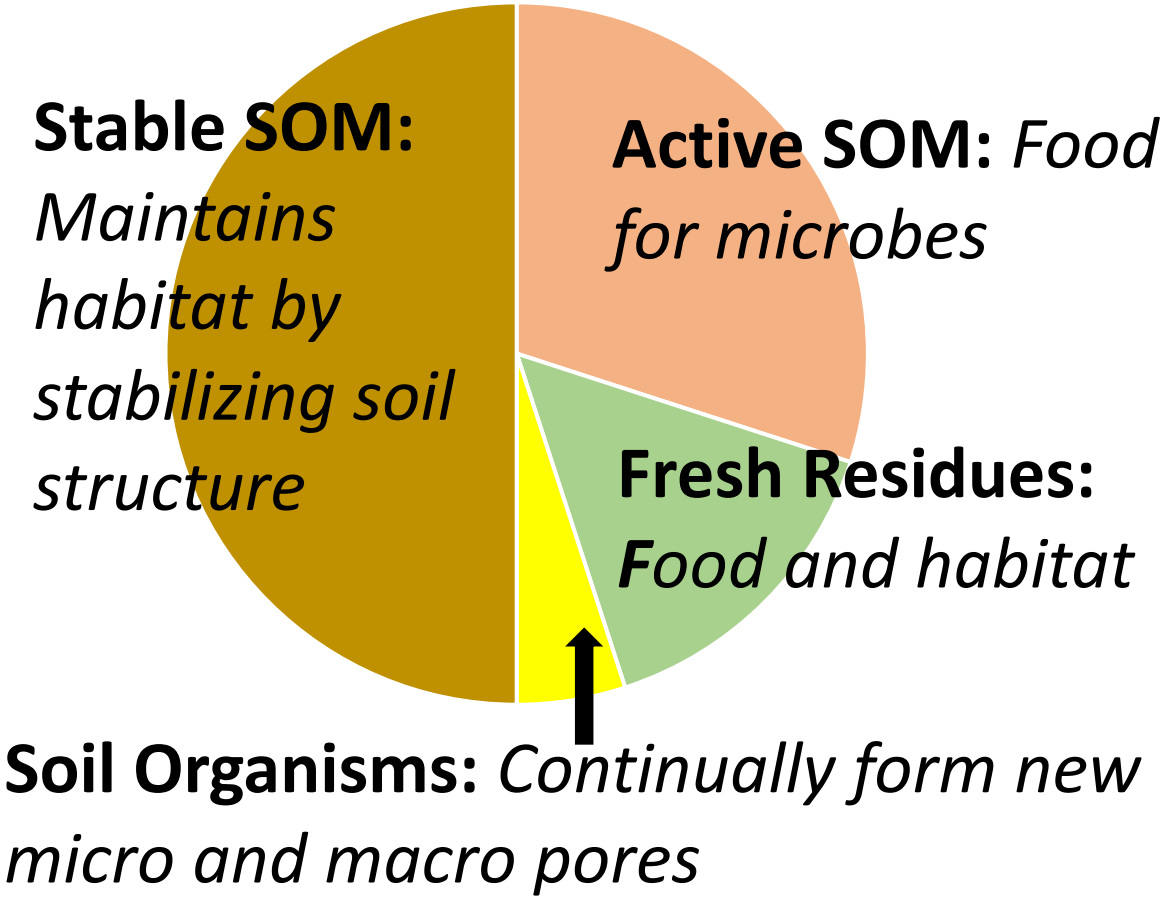
Unrestricted root growth

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



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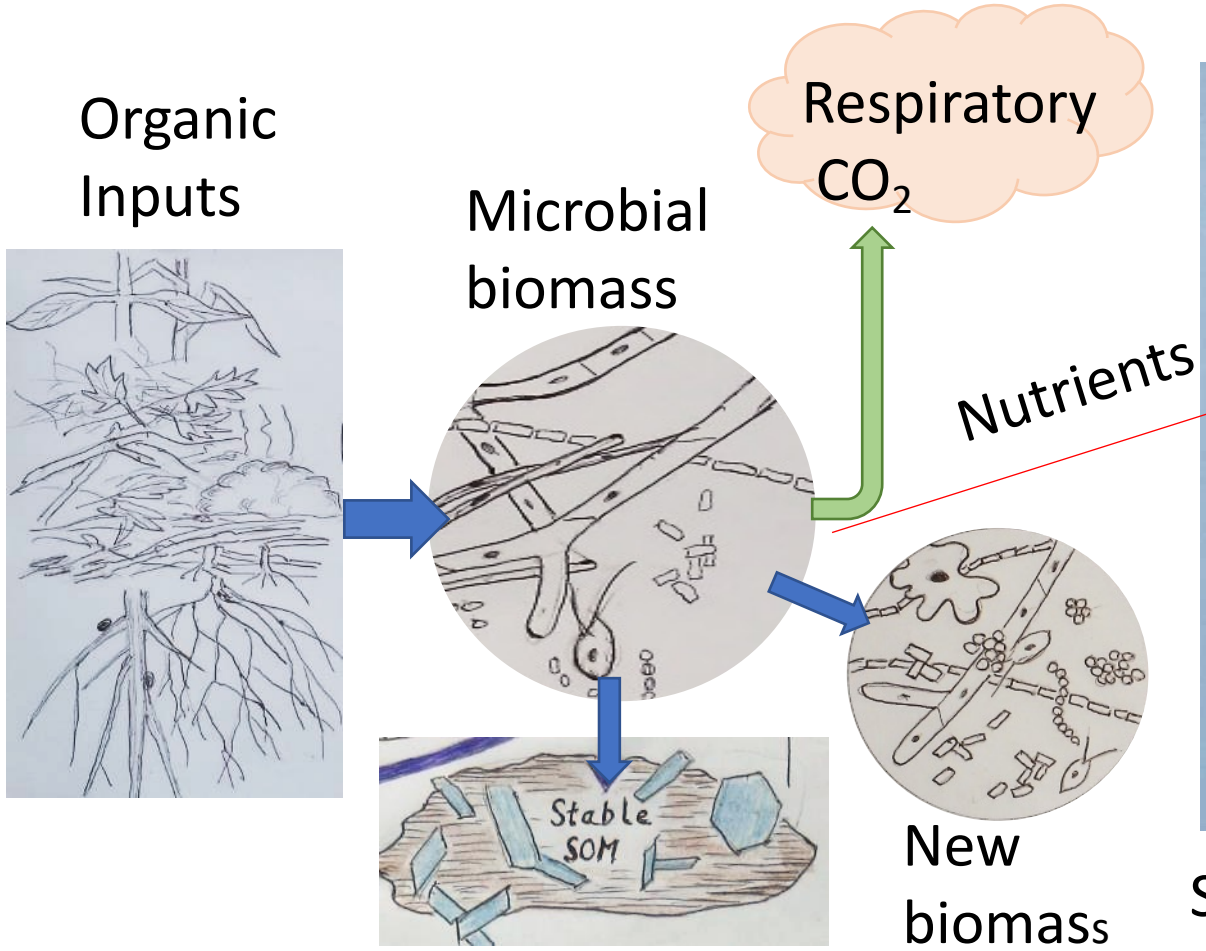
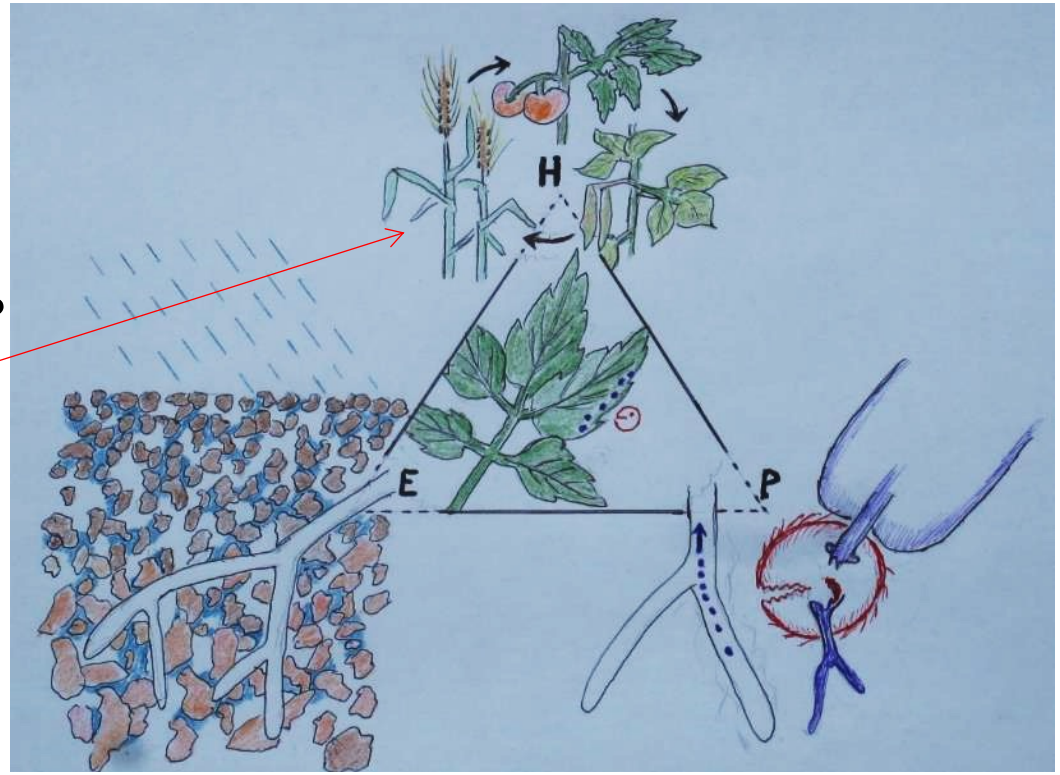
SOM Supports Healthy Plants by Providing Microbial Habitat



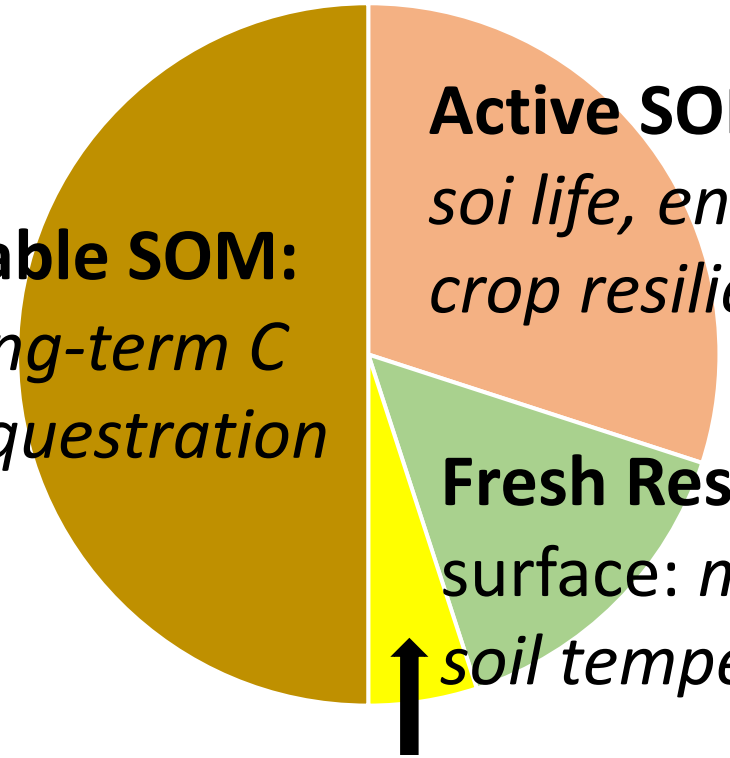


SOM and soil life break the “disease triangle” with better drainage (E), natural enemies of pathogens (P) and induced plant resistance (H)

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.
- Diverting organic "wastes" from landfills for composting reduced GHGs
- Stable SOC lasts 100 – 1000+ years.
- Efficient N cycling reduces N_2O emissions.
- Well aerated soils emit no CH_4.



Soil Organisms: *form stable SOM, modulate N_2O and CH_4 emissions, enhance resilience.*

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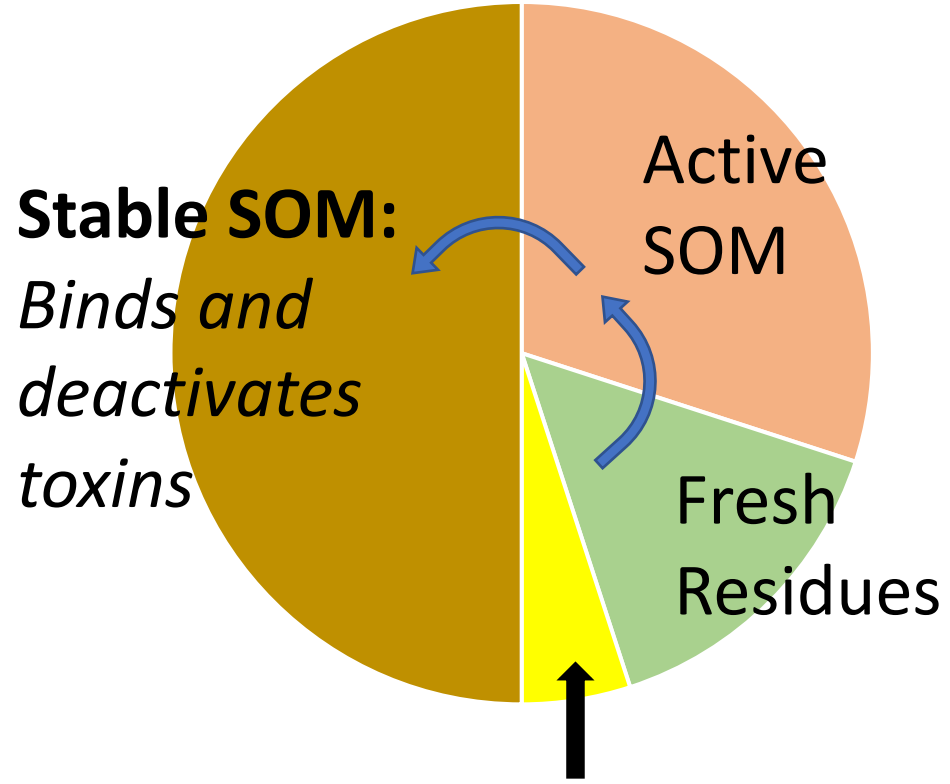
SOM Function: Waste management



Stable SOM: *Binds and deactivates toxins*

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

Building Soil Organic Matter in Agricultural Soils

Best organic management practices.

Farm Stories.

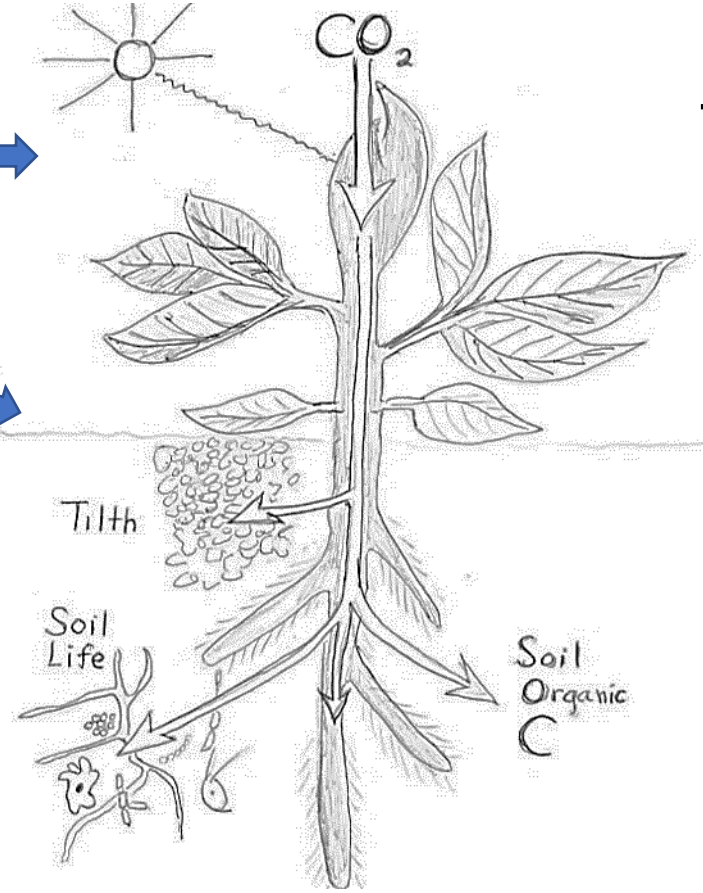
The Living Plant is the Farmer's #1 Tool for Building Soil Organic Matter

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

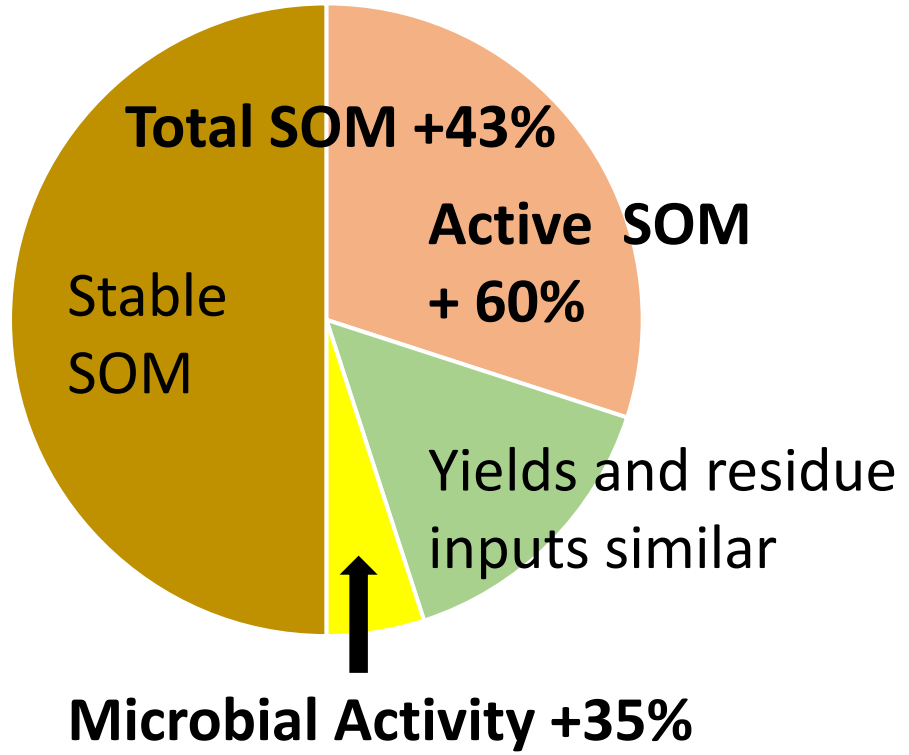
Organic Amendments Play a Complementary Role

Soil carbon amendments “anchor” SOM.

Amending depleted soils with compost enhances plant growth, exudates, residues.

<u>Practices:</u>

- Use compost, biochar, manure, and organic mulches such as straw.
- Use diversity of materials with moderate overall C:N ratio.
- Avoid overapplying nutrients.
- Limit use of concentrated, low-C:N organic nutrient sources.



SOM after 11 years organic vegetables with finished compost (C:N 20) vs *poultry litter (C:N 7) at same total N rates.*

Bhowmik et al., 2016

Stack Practices to Build SOM and Soil Fertility

Cover crops

+

Diverse rotation

+

Compost with sound nutrient budgeting

+

Reduced tillage

→

- Organic amendments, living cover, and conservation tillage work together to build SOM and soil health.
- Meta-analysis of specific “best practices” in 36 organic systems trials:
  - Organic amendment → SOM up 24%.
  - Reduced till → SOM up 14%.
  - Cover crops slowly build SOM over 5-10- year period.
  - All practices → 30% higher microbial biomass.
- Other studies show that multiple practices build more SOM.

Farm Story: Building SOM in a Sandy Coastal-plain Soil

Rick and Janice Felker

Mattawoman Creek Farm, Cape Charles, VA

- Bojac loamy sand (Ultisol), low SOM.
- 11 acres field + 0.35 ac high tunnels, organic vegetables for four-season CSA.

<u>Soil health practices</u>:

- Tight crop rotation (no bare fallow) of diverse vegetables and cover crops.
- Cover crops mowed and incorporated 3-4” with organic amendments at moderate rates.
- Rototiller operated at low PTO speed and 2.5 mph tractor speed to protect soil aggregates.

Rick Felker

Mature rye + vetch was flail-mowed, moved onto bed tops with a bed shaper, then tilled in.

Farm Story: Building SOM in a Sandy Coastal-plain Soil

Soil health practices, continued:

- All residues returned to the soil.
- Subsurface in-row drip to promote deeper roots.

Outcomes:

- Sandy soil has developed visible crumb structure.
- SOM has increased to 2.0-2.2% (excellent for this soil).
- In the farmer's words, *"the soil gets better every year, and we have excellent growth."*

Rick Felker

Mattawoman Creek Farm crew sets vegetable starts into healthy, fertile soil.

Animals Help Build SOM

Practices:

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

Grazing livestock and poultry:

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

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Farm Story: Soil and Watershed Stewardship in a Crop-Livestock Integrated System

C. J. Isbell

Keenbell Farm, Rockville, VA (central Piedmont)

- Located near waters that drain to Chesapeake Bay.
- 340 acres, grass fed beef, pork, poultry, eggs, specialty grains, popcorn, milling corn, and soybeans.
- Ultisols with clayey B horizon and history of erosion; poorly drained soil near river.
- One-time herbicide to “reset” weedy new land; all other practices and inputs are organic.

Pastured hogs at Keenbell Farm

Farm Story: Soil Health and Watershed Stewardship in a Crop-livestock Integrated System

Soil health and watershed practices:

- Winter and summer cover crop mixes for grazing.
- Specialty grains every few years in rotation.
- No tillage. Seeds drilled or broadcast.
- Rotational mixed-species grazing.
- Steeper land in permanent pasture.
- Fencing at 2X minimum buffer for streams.

Outcomes:

- % SOM has doubled. *Crops + livestock build SOM and soil life much faster than crops alone.*
- Reduced runoff and erosion.
- Increased nutrient and water retention.

After intensively grazing the cover crop for 24 hours (foreground), the cattle have been moved to a fresh paddock (background). The annual cover crops can be grazed 3-4 times at 30-45 day intervals.

Additional Organic Practices to Build SOM

- Stop erosion! Perennial systems or terracing for sloping land.
- 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, tilth, water infiltration , crop health
  - Total SOM long term trends
  - Cornell Assessment of Soil Health (CASH) or component tests

Farm Story: Permaculture Terraces for Soil Conservation

David and Lee O'Neill

Radical Roots Farm, Keezletown, VA

- 5 acres in organic vegetables for CSA.
- South facing, 5-10% slopes, erodible.
- Frederick and Lodi silt loams (Ultisols)

<u>Soil health practices</u>:

- Diverse rotation, cover crops, compost tea, organic mulches, reduced tillage
- Berm-and-swale terrace system

The O'Neills installed a berm-and-swale terrace system and this pond to receive and store runoff from swales for irrigation during dry spells.

Farm Story: Permaculture Terraces for Soil Conservation

- Berms planted in trees, shrubs, and perennial herbs that provide fruit, medicinal herbs, windbreak, and beneficial habitat.
- Swales in permanent grass to retain and channel runoff during heavier rain events.
- Eight to ten raised beds per terrace.

<u>Outcomes:</u>

- Fertile soil, prosperous CSA operation.
- Soil stays on the farm through 2018 deluges.
- Water conservation and recovery sustains farm through “flash drought” of 2019.

The farmers and CSA members tending vegetables on near-level terrace beds with trees and shrubs on berm in background.

In Summary: How to Have More SOM

Living plants feed soil at Radical Roots Farm in Keezletown, VA.

- Grow it
- Add it
- Save it

High quality compost made by William Hale in Louisa, VA

Roller-crimping a cover crop at Keenbell Farm in Rockville, VA

Questions?

Soil Health Guidebooks available at: https://ofrf.org/resources/#publications.