Meeting Weather Challenges in the Western U.S.

Organic Practices to Mitigate and Prepare for Climate Change

Mark Schonbeck, PhD
Organic Farming Research Foundation

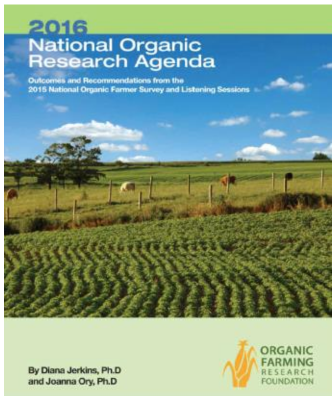
Joined by Maegen Simmonds, PhD
Lawrence Berkeley Lab

ORGANIC FARMING
RESEARCH FOUNDATION

How is Climate Change Impacting Organic Agriculture in the Western Region?

Farmer-identified
Research Needs

Organic Farmer Research Priorities in the Western Region



Available at http://ofrf.org/

<u>Soil health – 71%</u>

- Practices to sequester soil organic carbon (SOC)
- Economic benefits for SOC

<u>Irrigation and drought – 56%</u>

- Irrigation efficiency
- Soil water retention
- Soil salinity
- Drought and pasture health

ORGANIC FARMING
RESEARCH FOUNDATION

Extremes of Drought and Flood

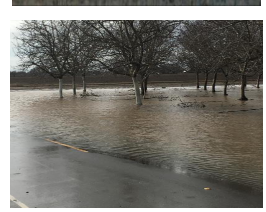
- "Drought…heat waves…costs [of] mitigation have me concerned I can no longer do this."
- "Three years ago…drowning rain and lack of sun…this June was one in 400 year drought"

Farmer quotes, NORA 2016

- "11.7 inches is the average…[with] climate change, last three years [were] 26 – 2.5 – 5.4 inches."

Doug Crabtree, Havre, MT, pers. comm.

Doug Crabtree
Vilicus Farms



Z. Kabir, NRCS,
Davis, CA

ORGANIC FARMING
RESEARCH FOUNDATION

Irrigation in the Era of Climate Change

- "The current drought has dramatically decreased irrigation water allocated to organic tomato growers."
  Amelie Gaudin et al., 2018.
- "Irrigation is not truly sustainable…we need better practices that improve our water capture, retention, and cycling."
  Farmer quote, NORA 2016, p. 25

Restricted access to irrigation water puts pressure on central CA vegetable growers.

ORGANIC FARMING
RESEARCH FOUNDATION

Other Climate Related Concerns

- Impact of altered temperature patterns on chill hours for bud break in tree crops
- Need for new crops and cultivars to adapt
- New weed and insect pest species
- Increased disease pressure

NCAT / ATTRA

Warmer winters may fail to meet chilling requirements for normal development in tree fruit and nut crops.

ORGANIC FARMING
RESEARCH FOUNDATION

How Does Agriculture Affect Climate?

Greenhouse Gas (GHG) Emissions
- Carbon dioxide (CO_2)
- Nitrous oxide (N_2O)
- Methane (CH_4)

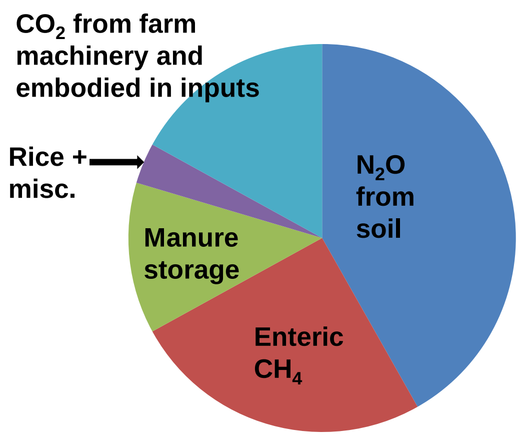
Carbon Cycle: Soil and Plant Cover

Greenhouse Gases in Agriculture

Gas	CO_2eq	CO_2-Ceq	Sources in Agriculture
CO_2	1	1	• Fossil fuel – farm machinery • Embodied energy in inputs • Lime, urea, field burning • Losses of soil organic carbon (SOC) and biomass
CH_4	21	7.6 (CH_4-C)	• Livestock enteric methane • Manure storage • Paddy rice cultivation
N_2O	310	133 (N_2O-N)	• N-fertilized soil • Manure (pasture & storage)

ORGANIC FARMING RESEARCH FOUNDATION

Direct Agricultural GHG Emissions in the U.S. in 2017



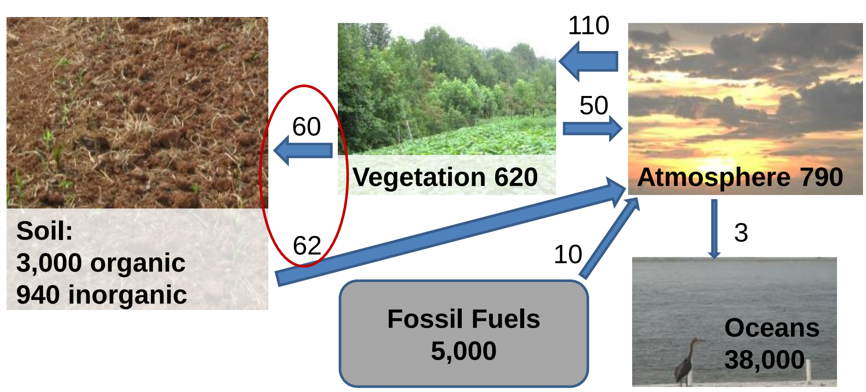
Accounts for ~10% of total U.S. GHG emissions.

Does not include CO_2 emissions from:

- Soil erosion.
- *In-situ* SOC losses.
- Breaking sod or clearing forest for agriculture.

ORGANIC FARMING
RESEARCH FOUNDATION

Soil and the Global Carbon Cycle

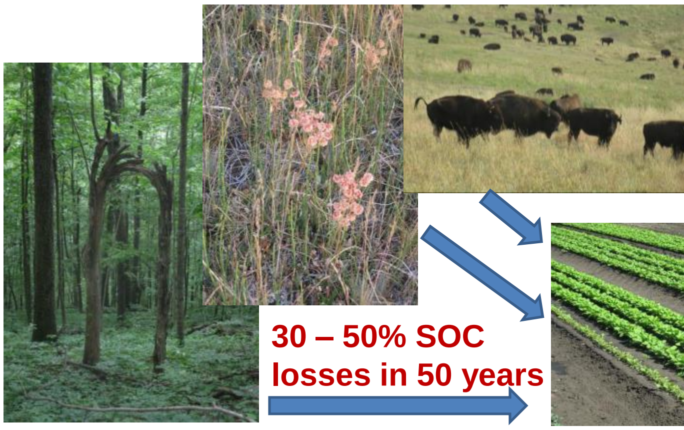


Based on Weil & Brady, 2017. *The Nature and Properties of Soils.*

C pools: billions of tons
Flows: billions of tons per year

ORGANIC FARMING
RESEARCH FOUNDATION

The Carbon Cost of Clearing Land



30 – 50% SOC losses in 50 years

ORGANIC FARMING
RESEARCH FOUNDATION

Sustainable Farming Can Build SOC

Cover crops

+

Diversified rotation

+

Compost

+

Reduced tillage

=

More soil carbon

Long term trials:

- Organic systems add 400 – 600 lb SOC/ac-yr.
- Can offset direct agricultural GHG

ORGANIC FARMING
RESEARCH FOUNDATION

"Agriculture and natural and working lands across rural America are an important part of our climate solution. [Soils] are the largest storage source for terrestrial carbon.

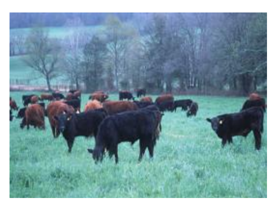
Karen Ross, Secretary
CA Dept. Food and Agriculture
March 12, 2019

Methane (CH_4)

In anaerobic conditions, soil microbes convert organic C into CH_4.

Agriculture emits CH_4 from:

- Livestock (enteric) ~500 lb per animal-year
- Manure lagoons ~ 10% of U.S. agricultural GHG
- Flooded rice paddies ~110 lb per acre-year



NCAT / ATTRA

Cattle emit CH_4, whether pastured or confined.

M. Tarlock

Rice paddy soils convert organic residues to CH_4.

ORGANIC FARMING RESEARCH FOUNDATION

Denitrification and Soil N_2O Emissions

Soluble N + limited O_2 + available organic C + soil microbes → N_2O

- 80% water filled pore space (little at <60%)
- Compacted soil
- Fine-textured soils
- Little N_2O if soil <6 ppm nitrate-N

IPCC Models for N_2O emissions:

- Direct:1% of applied fertilizer N
- Indirect: 0.75% of leached N

N_2O increases as N > crop need

Wet soils, such as this winter-fallow vegetable field in CA, convert soluble N into N_2O.

ORGANIC FARMING
RESEARCH FOUNDATION

N_2O in Organic Systems

N_2O from organic N sources:

- Average 0.57% of applied N.
- 0 – 0.3% for finished compost.
- >1% for manure slurry.

N_2O risk factors in organic:

- Ample active SOM
- Poultry litter + excess rain
- Legume plowdown
- Heavy N feeder, e.g., broccoli

Plowing a legume green manure can lead to a burst of N_2O emissions.

ORGANIC FARMING
RESEARCH FOUNDATION

Organic Farming Practices to Meet Climate Challenges

- Building Resilience through Healthy Soil
- Sequestering Carbon
- Mitigating Greenhouse Gases

Pop Quiz:

What sophisticated biotechnology shows the greatest promise to help humanity slow climate change and protect our food system against its effects?

Hint: It is not a human invention.

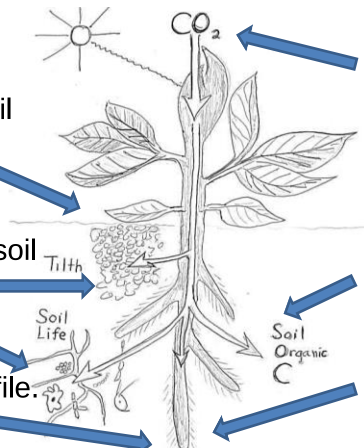
Living Plants:

Build healthy, resilient soils

Foliage protects soil surface.

Living roots:

- Build SOM and soil structure.
- Feed soil life.
- Deepen soil profile.



Sequester C

Photosynthesis converts CO_2 into organic C.

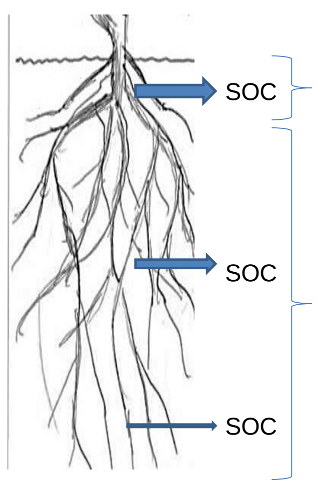
Roots deliver organic C to soil.

Deep roots build stable SOC below tillage depth.

ORGANIC FARMING
RESEARCH FOUNDATION

How Roots Build SOC Throughout the Soil Profile

1 ft.
2 ft.
3 ft.
4 ft.
5 ft.



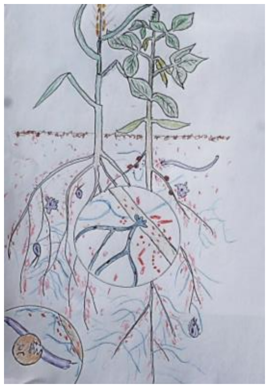
Soil biological activity is concentrated near the surface; SOC turns over quickly.

At least half of SOC occurs deeper than 12 inches, where it has greater stability.

Annual crops root to 3 – 6 ft; perennials 5 – 10 ft or deeper.

ORGANIC FARMING
RESEARCH FOUNDATION

Soil Health and Climate Resilience



Rain soaks in.

Healthy soil holds ample moisture and hosts myriad beneficial organisms.

Crops are resilient to drought, disease, and other stresses.

Healthy soil drains well and stays aerated.

ORGANIC FARMING RESEARCH FOUNDATION

Climate Benefits of Organic Practices

Practices	Mitigation	Resilience
Tight rotation, sod, and cover crops	**SOC** N_2O	Soil and crop health, drought tolerance
Crop diversification	SOC	Soil biodiversity and health, reduced risk
Nutrient management	**N_2O**	Rhizosphere health, nutrient cycling
Rotational grazing	**SOC** CH_4	Drought resilience, forage and livestock health
Compost	SOC, CH_4	Soil and crop health

ORGANIC FARMING RESEARCH FOUNDATION

Combine Practices to Sequester C

Continuous no-till, cash crop residues only: 510 lb C/ac-yr
Not stable

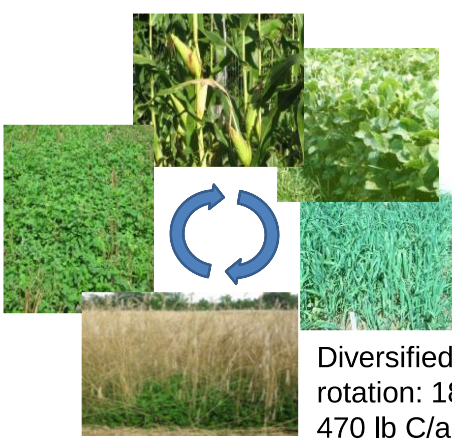
Cover crop: 135 – 195 lb C/ac-yr

Cover crop + no-till, roll-crimping and planting in one pass: 440 – 800 lb C/ac-yr

Cornell University

ORGANIC FARMING RESEARCH FOUNDATION

Diversify the Rotation



Diversified crop rotation: 180 – 470 lb C/ac-yr

ORGANIC FARMING RESEARCH FOUNDATION

Make and Use Compost Wisely

- Stable SOC
- Beneficial microbes
- On-farm nutrient cycling
- Diverts:
  - Leaves, yard waste, food waste from landfill
  - Manure from lagoons

- Composting emits some GHG.
- Importing feedstock can deplete source acreage.
- Can accrue excess soil P, suppress mycorrhizae
  - Calibrate rate to soil test P

ORGANIC FARMING
RESEARCH FOUNDATION

Manage N to Tame the N_2O Beast

- Provide N from SOM and slow-release sources.
- Encourage mycorrhizae, avoid excess P.
- Band concentrated N in crop rows at low rates (<50 lb/ac).
- Avoid spreading manure or tilling-in legumes during wet conditions.
- Sow legumes with grasses in cover crop or sod plantings.
- Grow deep-rooted, N-demanding crops to "mop up" leftover N.

Pearl millet can retrieve nitrate-N to 6 ft depth.

ORGANIC FARMING
RESEARCH FOUNDATION

System of Rice Intensification

The Method:
- Fields not flooded
- Seedlings set 1 foot apart
- Compost for fertility

Results:
- Healthy soil, healthy roots
- Enhanced N use efficiency
- Much higher yields
- Much less CH_4
- 60% less GHG / ton yield

Norman Uphoff, Cornell U

Farmer Moghanraj Yadhav grows excellent SRI rice crop without flooding in Tamil Nadu, India.

ORGANIC FARMING RESEARCH FOUNDATION

Restore Soils with Livestock

Management-intensive rotational grazing (MIG) builds ≥ 2,000 lb C/ac-yr. Silvopasture (top right) can add 3,900 lb C/ac-yr. Multispecies grazing (right) builds soil diversity and resilience.

ORGANIC FARMING RESEARCH FOUNDATION

MIG vs. Continuous Grazing:

- Sequesters > 1 ton SOC/ac-year.
- Improves forage quality, and meat and milk production.
- Reduces enteric CH_4/cow by 30%.
- Distributes manure and reduces N_2O hotspots.

NCAT / ATTRA

Continuous grazing leaves N_2O hotspot.

Multiple paddocks for MIG system

Healthy cows on resilient pasture

ORGANIC FARMING
RESEARCH FOUNDATION

Plant Perennial Crops and Conservation Buffers

Doug Crabtree

Herbaceous perennial conservation buffers, field border, filter strip, etc.: 375 – 800 lb/ac-yr

USDA NRCS

Agroforestry practices, SOC + aboveground biomass C: 2,400 – 3,700 lb/ac-yr (semiarid – humid regions)

ORGANIC FARMING
RESEARCH FOUNDATION

Technical and Financial Assistance in Meeting the Climate Challenge

- Estimating Benefits
- Federal Conservation Programs
- State and Local Programs

Estimating GHG Footprint and Documenting Benefits of Practices

Monitoring soil organic carbon:

- Total SOC (= SOM/2)
- Permanganate oxidizable C (POX-C)
- Soil respiration

Estimating Greenhouse Gas Emissions:

- COMET Farm http://cometfarm.nrel.colostate.edu/ - GHG decision support tool, updated to include MIG, cover crops, and organic amendments
- Organic Farming Footprint https://ofoot.wsu.edu/ - estimates SOC and net GHG for organic systems

ORGANIC FARMING RESEARCH FOUNDATION

NRCS Conservation Programs

CSP and EQIP support:
- Cover cropping
- Improved crop rotation
- Advanced grazing system
- Conservation buffers
- Comprehensive conservation planning

2018 Farm Bill:
- Emphasis on soil health
- Address "increasing weather volatility"

Soil Health Principles


Keep soil covered


Maintain living roots


Minimize disturbance


Diversify crops

ORGANIC FARMING
RESEARCH FOUNDATION

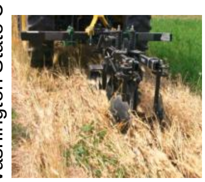
California Healthy Soils Program

Soil health practices to build SOC and reduce GHG
- Incentives for practices
- Demo projects
- Measure/estimate GHG benefits
- $15M for 2019, part from state cap & trade
- https://www.cdfa.ca.gov/oefi/healthysoils/


Cover crop


Compost

Washington State U


Reduced till


Mulching

ORGANIC FARMING
RESEARCH FOUNDATION

Other State Soil Health Programs

- New Mexico Healthy Soils Program
  - Soil Health Act 2019 - $455,000 of funding
  - Research, monitoring, education, tech assistance
- Hawaii Carbon Farming Task Force – report due Dec. 2022
  - Research best practices for Hawaii
  - Carbon farming certificate and carbon credits
- Soil Health Institute listing of additional State agency and University programs, including the land grant universities in CA, CO, MT, and WA: https://soilhealthinstitute.org/resources/catalog/

ORGANIC FARMING
RESEARCH FOUNDATION

Meeting Climate Challenges in the Western Region

Research Findings and
Farmer Experiences

Saving Water through Soil Health and Deficit Irrigation

OFRF-funded project

Can healthy soil improve water use efficiency and resilience in organic tomato?

Scott Park's soil health practices:

- Diverse crop rotation
- Winter cover crops
- Compost, microbial inoculant
- Reduced till, controlled traffic

Renwick et al., UC Davis

Assessing plant moisture status in deficit-irrigated tomato.

ORGANIC FARMING RESEARCH FOUNDATION

2016 Trial: Deficit Irrigation at Park Farm Organics

Irrigation treatments:

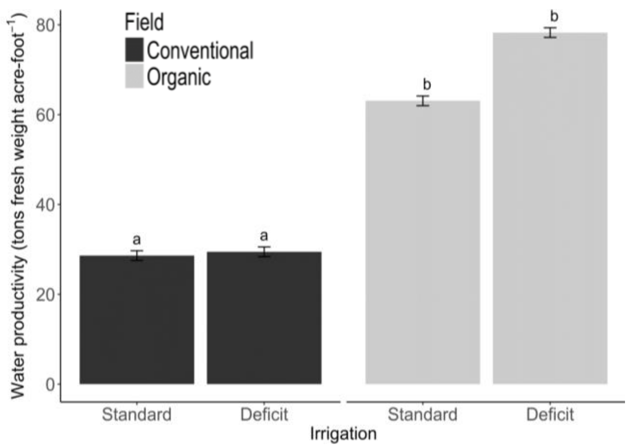
- Standard (stop 30 days before harvest)
- Deficit (stop 45 days before harvest)

Outcomes with deficit irrigation:

- Saved 0.5 acre-ft of water
- Yield and quality unaffected
- End-of-season soil microbial activity doubled
- Nitrate-N significantly less

ORGANIC FARMING RESEARCH FOUNDATION

2017: Organic Enhances Water Efficiency



- Organic used much less water.
- Organic doubled soil moisture reserves.
- Yields were similar across all treatments.

Based on slides
by Dr. Amelie Gaudin

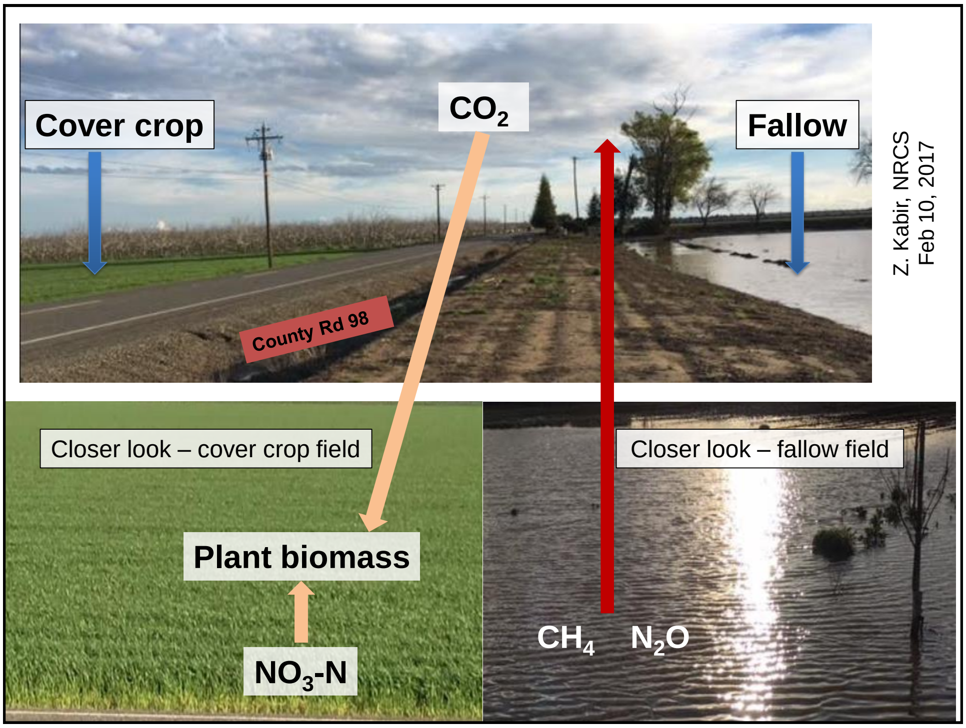
ORGANIC FARMING
RESEARCH FOUNDATION

Vital Role of Winter Cover Crops during California's Rainy Season

Poor Soil Structure &
Poor Soil Health

Healthy Soil with Good
Structure

Photo: Z. Kabir, NRCS, Feb 07, 2017



N_2O Challenge in Organic Broccoli

Organic N rate trials in WA:
- Linear yield response to > 200 lb N/ac
- $4 -34 return per $1 on N.

Organic broccoli in CA, 215 lb N/ac:
- Leached 180 lb N/ac
- Emitted 23 lb N/ac as N_2O
- Net loss of SOM

2/3 of N as compost and cover crops:
- Increased SOM
- Cut N_2O by half, leaching same

N deficiency (top) and N sufficiency (bottom) in organic broccoli

ORGANIC FARMING
RESEARCH FOUNDATION

Winter Cover Crop Recycles N

Spring lettuce

Fall broccoli

Winter cover: rye + legume mix

Sarah Brown, Oregon Tilth

N recovery, SOM, higher lettuce yield

Eric Brennan, USDA ARS, https://www.youtube.com/watch?v=JurC4pJ7Lb4

ORGANIC FARMING RESEARCH FOUNDATION

Tightly Coupled N Cycling in Organic Tomato in California

Study of 13 fields, three patterns*:*

- *N deficient* – Nitrate-N < 6 ppm, low SOC, low yield
- *N saturated* – Nitrate-N > 6 ppm, moderate SOC, high yield, **risk of N_2O emissions**
- *Tight N cycling* – Nitrate-N < 6 ppm, high SOC, **high yield with minimal N_2O risk**

Tomato grown with compost and no concentrated N

Bowles et al., 2015. PLOS ONE.

ORGANIC FARMING RESEARCH FOUNDATION

Balancing C and N in Organic Inputs

Puyallup, WA (maritime) organic vegetable rotations receiving:

Compost, Moderate C:N

or

Fertilizer, Low C:N

← Same total N →

After 11 years, the higher-C compost resulted in:

- Better soil structure and water infiltration.
- 35% higher microbial activity.
- 43% higher total SOC.
- Changes in soil biota that could mitigate N_2O emissions.

ORGANIC FARMING RESEARCH FOUNDATION

More Compost Research Findings

- In Utah dryland, one-time heavy application of compost *doubled* topsoil SOC and organic wheat yields for 15 years.
- In California rangeland, one compost application enhanced plant production and net SOC storage.
- LCA: composting manure and yard waste avoids massive GHG emissions from lagoon and landfill.
- A little compost can enhance SOC accrual from cover crops and other practices.

ORGANIC FARMING RESEARCH FOUNDATION

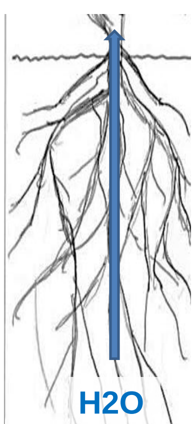
Living Cover Builds Orchard and Vineyard SOC and Resilience

- Bare orchard floor soils can lose half their SOC.
- Living cover improved soil and tree health in Utah orchards.
- Living mulch in Oregon cherry orchard enhanced SOM, N cycling, and microbial activity.
- Bonterra Vineyards found 9 – 12% higher SOC in organic systems.

Living orchard floor cover builds SOC, and soil and tree health without adding to irrigation needs.

ORGANIC FARMING
RESEARCH FOUNDATION

Sequestering SOC in Dry Regions: Can Deep Roots Backfire?



Dryland challenge:

- Wheat-fallow depletes SOC.
- Cover crops can deplete moisture and hurt yields.
- Alfalfa is one of the worst.
- Barley, medic, millet, and cowpea conserve moisture.

Sunflower and pearl millet root deep; sunflower uses a lot of moisture; millet is water-efficient.

ORGANIC FARMING
RESEARCH FOUNDATION

Building SOC on Limited Rainfall

Doug Crabtree
Vilicus Farms, MT

Diverse rotations, covers terminated by blade plow, intercrops (kamut-flax in photo, left), and no fallow enhanced SOC by 27% in 10 years on 11” rain/year at Vilicus Farms in MT. A crop-livestock integrated system with MIG, no till, and high crop diversity tripled SOC in 20 years near Bismarck, ND (16” moisture/year).

ORGANIC FARMING
RESEARCH FOUNDATION

Some Unanswered Questions

Research Needs

Soil Inorganic Carbon

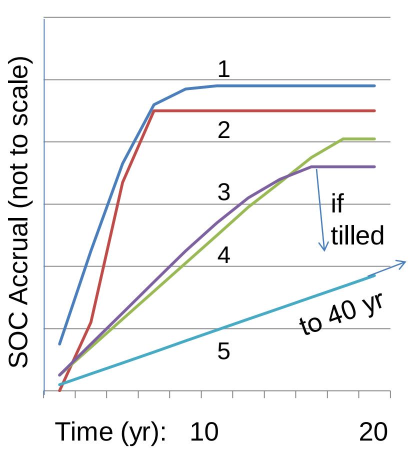
- Many soils of drier regions are rich in carbonates, or soil inorganic carbon (SIC).
- Lowering soil pH could convert it to CO_2.
- Organic systems lost 9 – 14 tons SIC/ac in 3 out of 7 studies.
- Research on SIC conservation is urgently needed.

Ray R. Weil

A semiarid Montana soil with visible calcium carbonate horizon.

ORGANIC FARMING RESEARCH FOUNDATION

SOC Saturation



1. Depleted cropland → permanent pasture
2. Cropland → MIG pasture
3. Continuous no-till crops
4. Organic cropping system
5. Diversified rotation

Steady state SOC:

- Cropland ~55% of native
- Best soil health mgmt. →85%
- Future innovation→100%?

ORGANIC FARMING RESEARCH FOUNDATION

Will Climate Change Itself Make Mitigation More Difficult?

- Warming temperatures will accelerate SOC oxidation, especially in colder climates.
- Thawing of permafrost and rapid oxidation of peat soils may cause large global SOC losses.
- N_2O emissions increase about 20% for each 1˚C (1.8˚F) increase in mean July temperatures.
- One field study suggests that increasing atmospheric CO_2 may accelerate SOC losses.
- Organic practices are especially beneficial to SOC and microbial activity in warm climates.

ORGANIC FARMING
RESEARCH FOUNDATION

Research Needs and Opportunities

- Crop breeding for:
  - Climate resilience
  - Nutrient-efficiency
  - Climate-friendly organic systems
- Deep roots for SOC sequestration
- Tightly coupled N cycling
- Farmer payment for ecosystem services

ORGANIC FARMING
RESEARCH FOUNDATION

Questions?

Download the Soil Health and Organic Farming Guides at
www.ofrf.org

This webinar was made possible by a grant from USDA Western SARE.