Defining Healthy Soil

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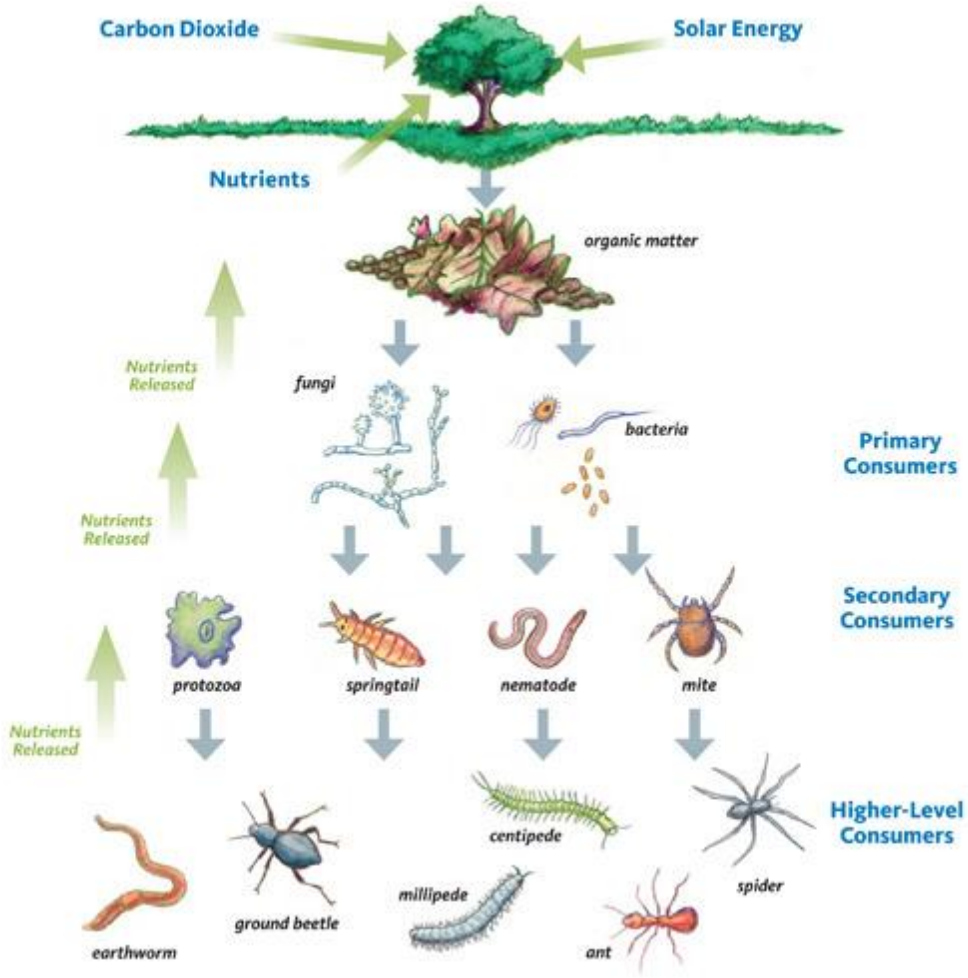
Definitions of soil health: physical and biological aspects

- "Continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans" - Natural Resources Conservation Service (NRCS)
- "Soils that enhance their continuing capacity to function as a biological system, increase soil organic matter, improve soil structure and water-and nutrient-holding capacity, and result in net long-term greenhouse gas benefits." -California Department of Food and Agriculture

- Related to soil quality- productivity, physical and chemical characteristics

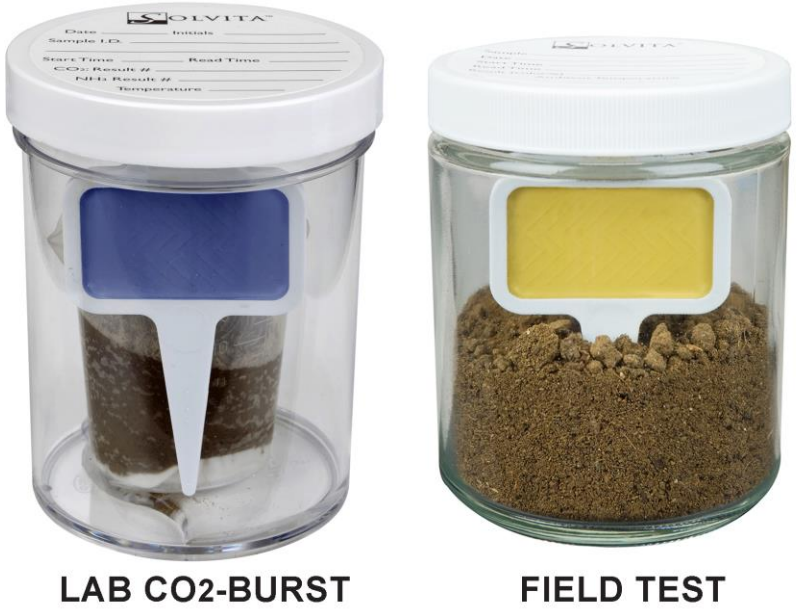
Soil health

- Functions well, both agronomically and ecologically
- Soil biodiversity and crop management work in synergy
- Biodiversity
- food web structure
- ecosystem functioning
- Linked to
  - disease and weed suppression
  - resilience to environmental stress
  - increased plant productivity



Soil Health

- Results of interactions
  - microbial communities
  - management decisions
  - soil physical and chemical factors
- What about “unhealthy” biodiversity?
- How do you measure it?
- Soil health is not static!



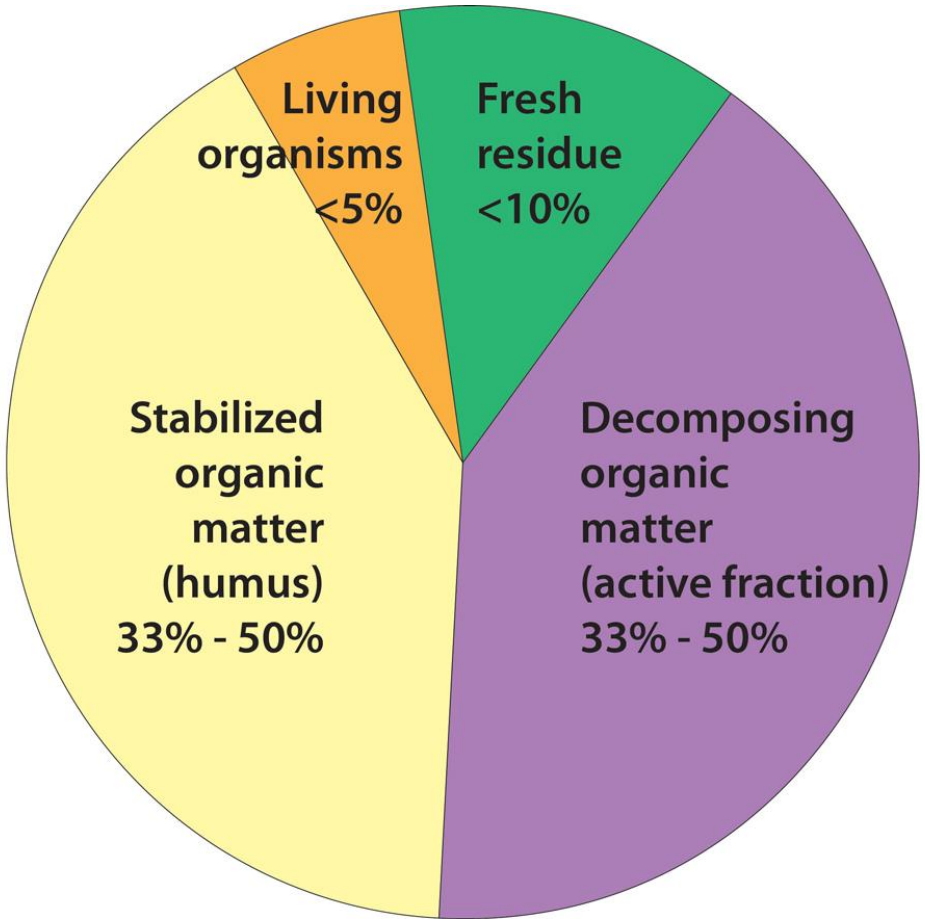
Organic Matter

- Litter: nonliving material shed by plants
- Detritus: all forms of dead organic matter with recognizable origins
- Soil Organic Matter (SOM): In a narrow sense: dead plant, animal or microbial material that is no longer recognizable (by this definition, litter and feces are not SOM).
- Microorganisms (living and dead): important contributor to labile SOM
- Humus: organic matter whose source is unrecognizable and is relatively stable

Soil Organic Matter Pools

Pool	Turnover rate	Examples of materials	Density
Very labile	Very fast	Parts of recently added litter (sugars, amino acids)	Very light
Labile	fast	Cellulose, dead microbes	light
Slow		More resistant litter components and microbial products	
Passive	Very slow	humus	heavy

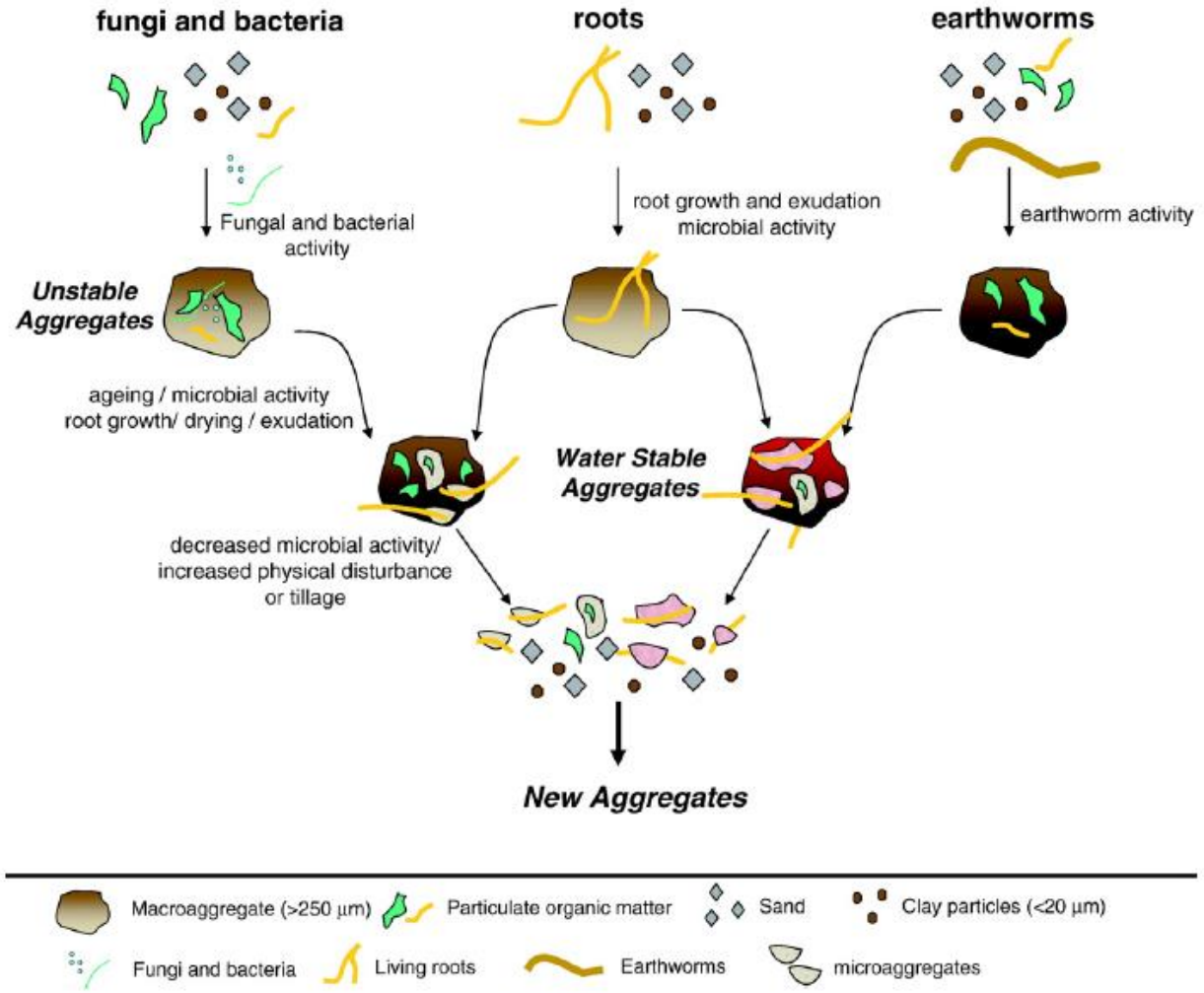
Organic Matter Pools



- Most important to soil quality is the active SOM fraction (10 to 35%) which is composed of partially decomposed plant and animal residues, microbial biomass and metabolites.
- Most of what's left is the passive SOM fraction which is resistant to microbial decomposition.

Biological Microaggregates

Soil biology and Roots stabilize soil by binding particles together



Conventional Tillage

- Growers till soil to prepare seedbeds and kill weeds
- Tillage also disturbs soil microbial communities
- Wetter environment
- Bacteria-dominated
  - Have 20-30% C-use efficiency
  - Prefer Aerobic Conditions

No-till systems

- Fungal dominated
- Fungal hyphae bridge spaces between food
- Fungi has 40-55% C-use efficiency
- Obligate aerobes & Heterotrophs

No-till systems at work

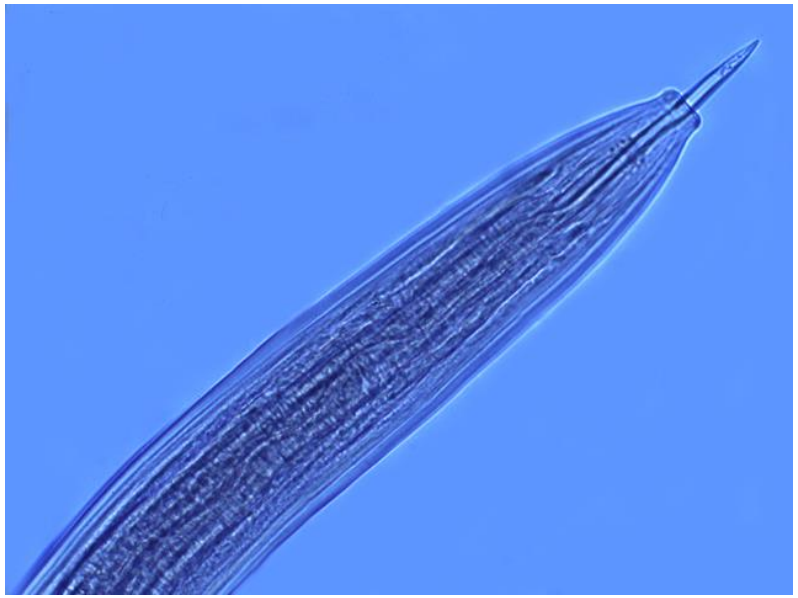
- Cotton and processing tomato
- Yields comparable to standard tillage (Mitchell, Klonsky et al. 2012a; Mitchell et al. 2015b)
- Reduce seed banks of weeds (Shrestha et al. 2008).
- Environmental benefits
  - reduced particulate matter emissions (Baker et al. 2005)
  - Less evaporative water loss (Mitchell, Singh et al. 2012)
  - Increased soil carbon (Veenstra et al. 2007).

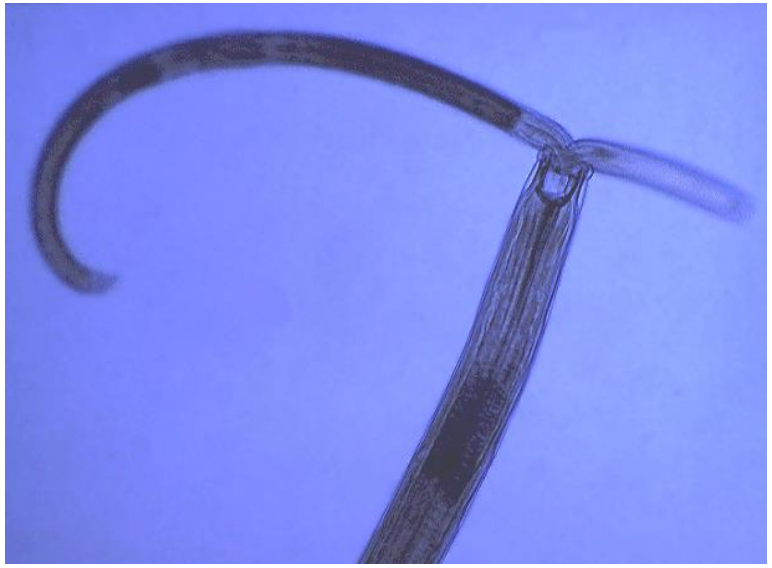
Tillage and earthworms

- “Night crawler,” Lumbricus terrestris
- Surface residue builds up and triggers growth in earthworm population
- Worms incorporate crop residue into soil
- mix organic, improve soil structure and water infiltration.

Tillage and nematodes

- Larger bodied predatory and omnivore nematodes more sensitive to tillage and disturbance in general
- No till systems have more complex nematodes communities that provide natural pest suppression

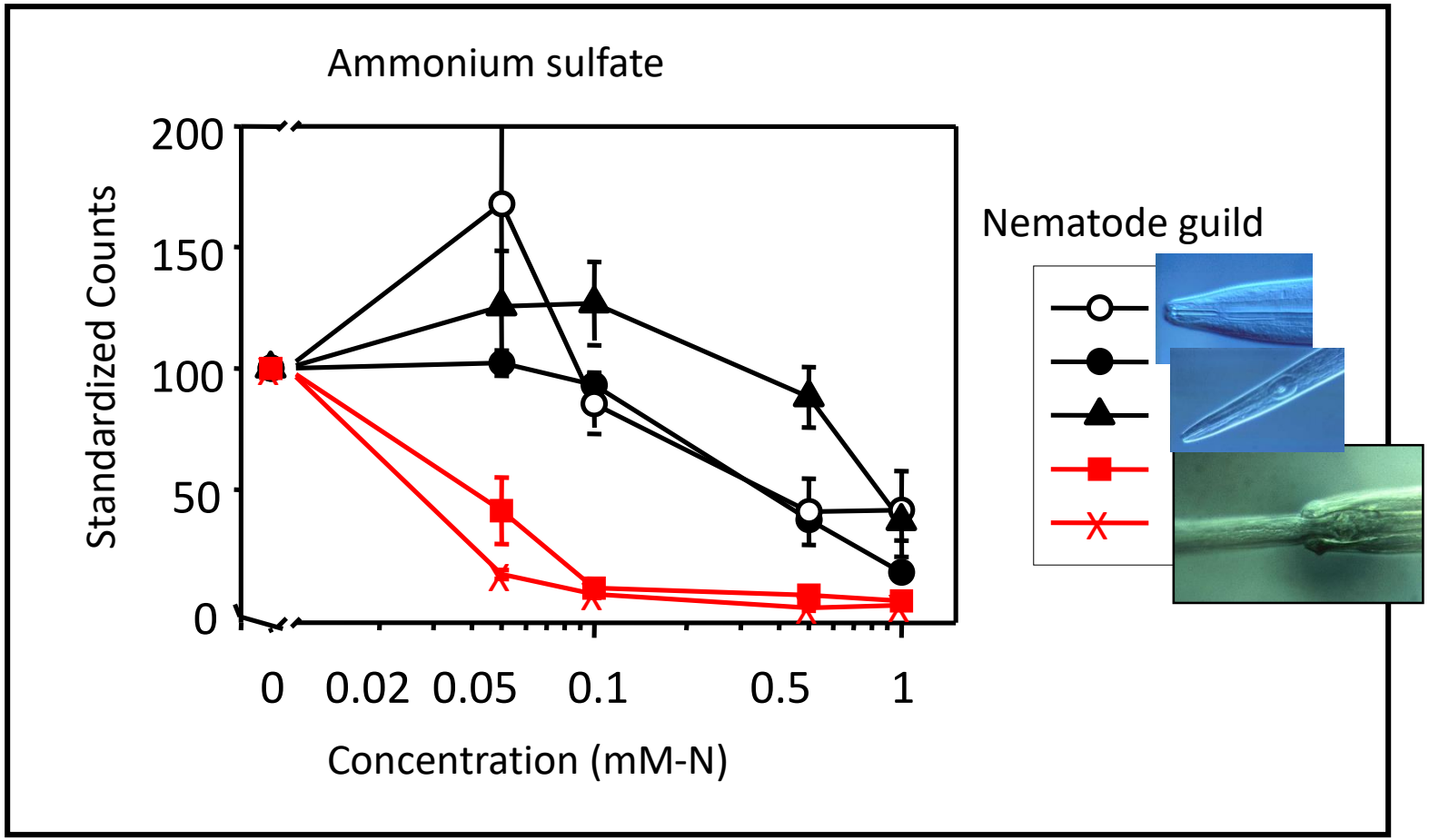




Nematodes and fertilizer

- Omnivorous and predaceous nematodes not common in cultivated soil
- More sensitive to nitrogen solutions
- Use of fertilizer may reduce food web complexity and natural pest suppression

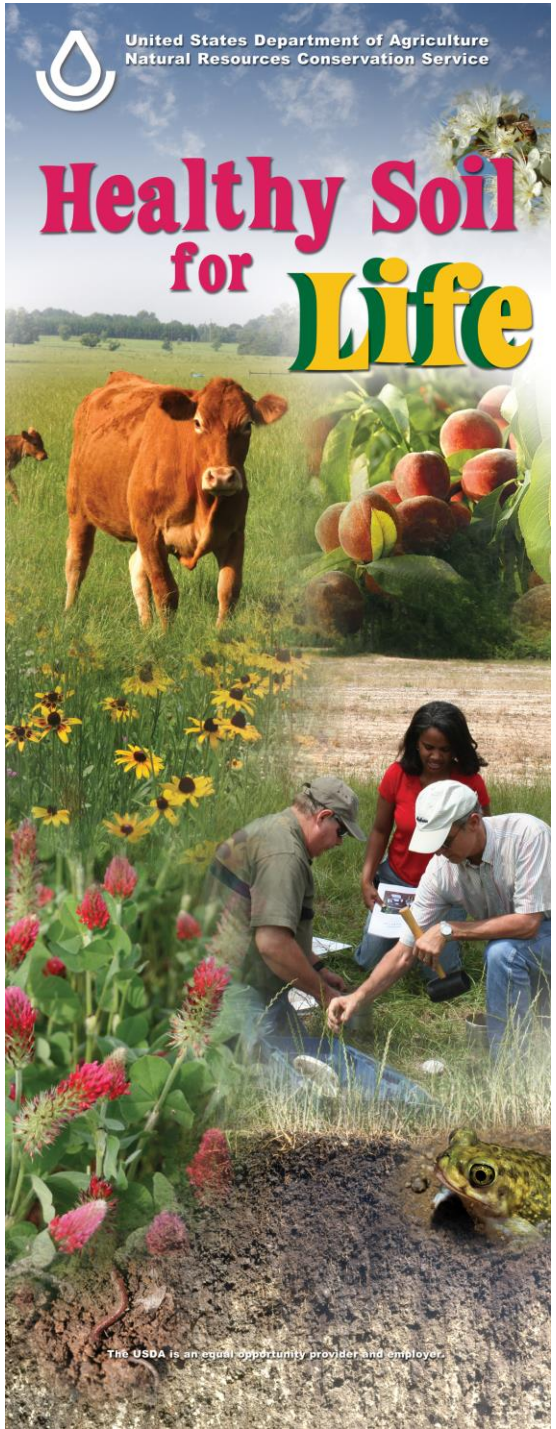
Nematode Sensitivity – Mineral Fertilizers



Tenuta and Ferris (2004)

How to manage for soil health?

- Disturb soil less
- Keep a Living Root Growing Throughout the Year
- Keep the soil covered
- Increase organic matter



Manage More by Disturbing Soil Less

- Physical, chemical or biological disturbance
- Tillage-physically destructive and disruptive to soil microbes
- Fertilizer/Pesticides-disrupt the symbiotic relationships between fungi, other microorganisms, and plant roots.

Keep a Living Root Growing Throughout the Year

- Living roots provide the easiest source of food for soil microbes.
- Growing long-season crops or a cover crop following a short-season crop, feeds the soil food web.

Cover crops and nematodes

- Cover crop quality as well as quantity is important
  - Those with higher N (legume
    more effect on nematodes th
    with lower N (grain).
- Affected soil food web servi
  using nematodes as indicato
- Doubled number of opportu
  bacterial feeding nematodes
  active participants in nitroge
  mineralization.
- Increased productivity with
  increased complexity of the
  community.

Photo: Lisa Stocking

(DuPont et al.,2009- Applied Soil Ecolo

Cover cropping

- Results vary with
  - quality and quantity
  - cultural practices
  - history of crop site
  - time of planting
- Choose wisely!
- Some cover crops/mixes
  - hosts for nematode pests
  - incompatible with other practices
  - can have allelopathic effects

- Check out NRCS technical publications-Cover Crops and Soil Health

Mulching-keeping the soil covered

- Conserves moisture
- Reduces temperature
- Intercepts raindrops (to reduce their destructive impact)
- Suppresses weed growth
- Provides habitat for members of the soil food web that spend at least some of their time above ground.

Compost

- Commercial organic amendments and compost possess widely different characteristics, effects vary even between production batches
- Generally enhance soil microbial activity by providing carbon in forms which that are easy for microbes to digest
- risks of crop contamination with pathogens/weeds

What is compost?

- Fresh manure? – No
- Aged manure – Maybe
- “Fully composted”
  - C:N > 11 - in addition to the nutrient management system on the farm
  - C:N < 11 - part of the nutrient management system

What is Bokashi?

- Japanese term meaning ‘fermented organic matter’
- anaerobic fermentation - different end product than that produced via composting
- Pro: It can be used to deal with ALL kitchen wastes (even meat, dairy etc)
- Con: You have to buy/make Bokashi “mix”- innoculum

Vermiculture Composting?

- using worms to decompose organic food waste
- End result-vermicompost, wormpoop,or worm castings.
- provides nutrients for plants and improves texture and fertility of soil.
- Adds beneficial organisms to the soil.

CDFA compost guidelines and regulations

Crop Type	Compost Type	Moist Compost Application Rate (tons/acre)	Equivalent Dry Compost Application Rate (tons/acre)†	% of total plant required N represented by rate
Annual	Higher N (C:N ≤ 11)	3 – 5	2.2 – 3.6	7.3 – 12.1%
Annual	Lower N (C:N > 11)*	8	5.3	8.1%
Tree	Higher N (C:N ≤ 11)	2 – 4	1.5 – 2.9	6.8 – 13.6%
Tree	Lower N (C:N > 11)*	6 – 8	4.0 – 5.3	8.6 – 11.4%

Healthy Soils Initiative

- Led by CDFA
- Incentives for compost use
- Innovative farm and ranch management practices
  - building soil organic matter
  - carbon sequestration
  - reduce greenhouse gas emissions

Research story: Soil Biodiversity at Bobcat Ranch Nature Reserve

Land Use Comparisons

Prior Agricultural Study vs. Nature Reserve

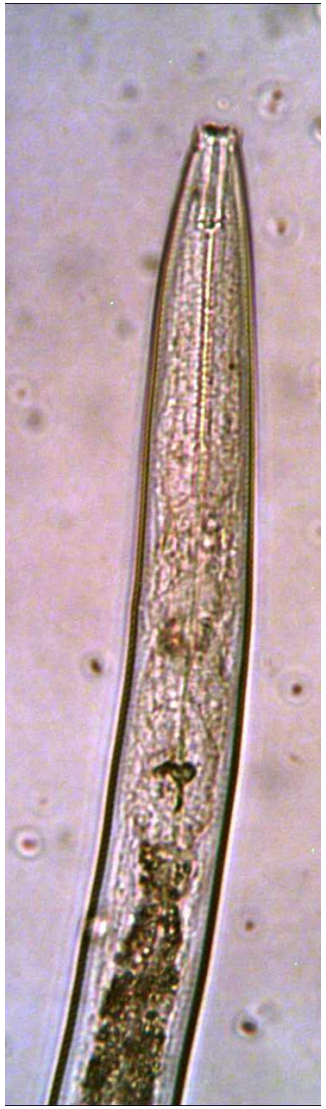
	20 Agricultural Sites		Site 1		Site 2	
	mean	**range**	**mean**	**range**	**mean**	**range**
No. taxa	**16**	7-30	**13**	8-17	**12**	5-15
Bacterivores (100 g^{-1})	**116**	2-426	**129**	22-540	**115**	3-335
Fungivores (100 g^{-1})	**181**	1-786	**32**	4-66	**57**	0-246
Plant feeders (100 g^{-1})	**121**	1-552	**59**	5-188	**227**	11-3281
Omnivores (100 g^{-1})	**26**	0-117	**17**	1-71	**27**	0-124
Predators (100 g^{-1})	**<1**	0-10	**11**	1-40	**10**	0-37

Nematodes and N Cycling

- Many bacterial feeders

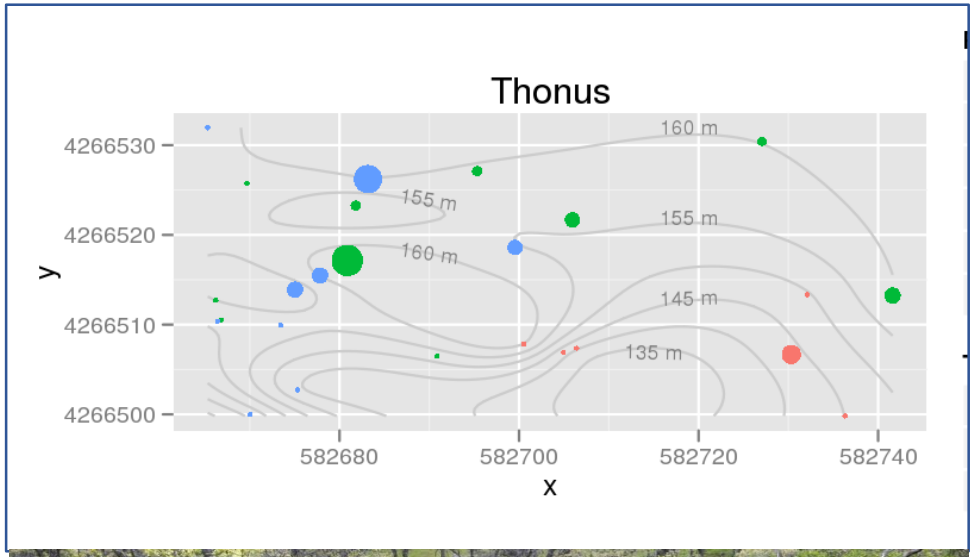
  = high enrichment footprints
- Also many Predators

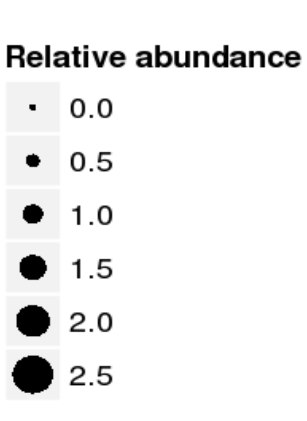
  = high structure footprints
- Low soil NH_4+ and NO_3- concentrations
- Tightly coupled N cycling
- Retention of soil organic N rather than loss to the environment



Site 2: Omnivores Along Stream

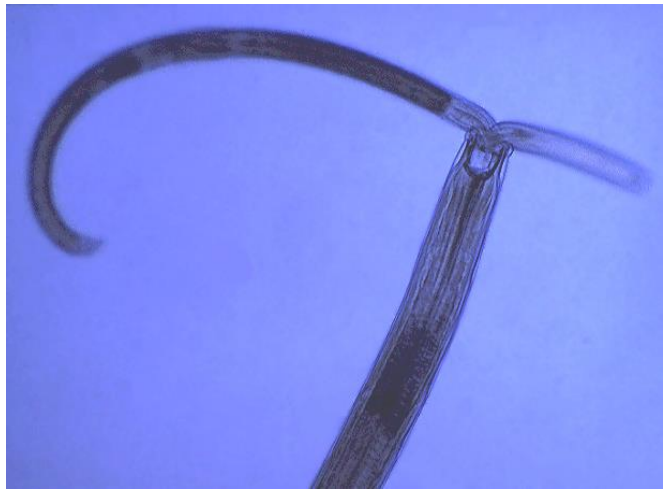
- Omnivore abundance increases with distance from stream (P=0.02)
- Good drainage?
- Tree preference?

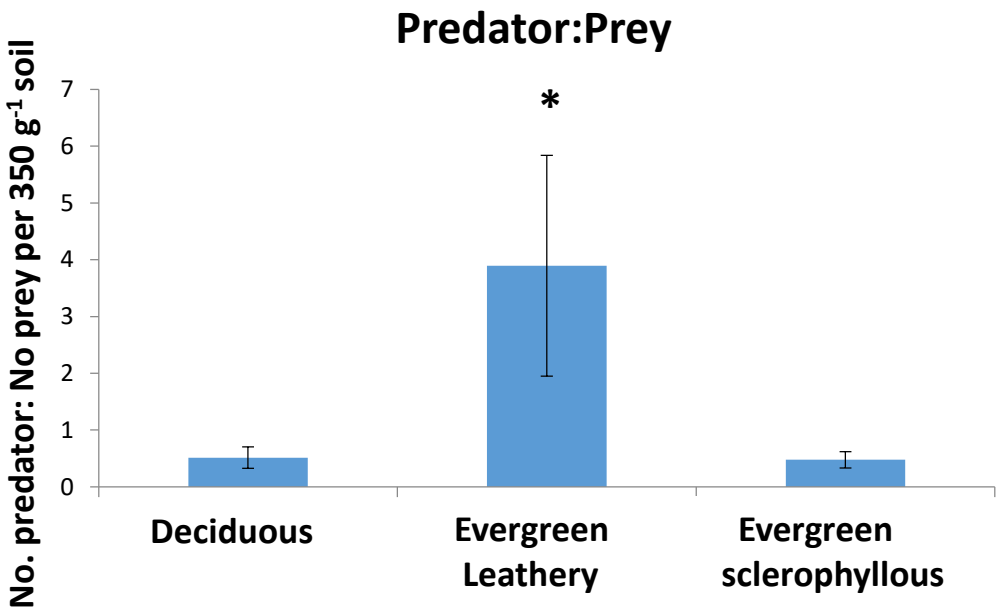




Site 2: Ratios of Predator:Prey

- Food web snapshot
- Can indicate resource and pest regulation
- What is responsible for a high ratio?
- Is litter chemical complexity allowing more dynamic cycling of food web?





Conclusions

- High levels of ecological structure and enrichment in the riparian corridors of the nature reserve
- Higher activity of nutrient cycling and regulation near stream
- More predators and possibly greater regulation of nutrient cycles under evergreen leathery-leaved shrubs

- Remaining relict native ecosystems can help guide the restoration and farmscaping projects in the valley's agroecosystems
- Once biodiversity is gone, it may be gone for good.