Soil Health for Your Farm and How to Achieve It

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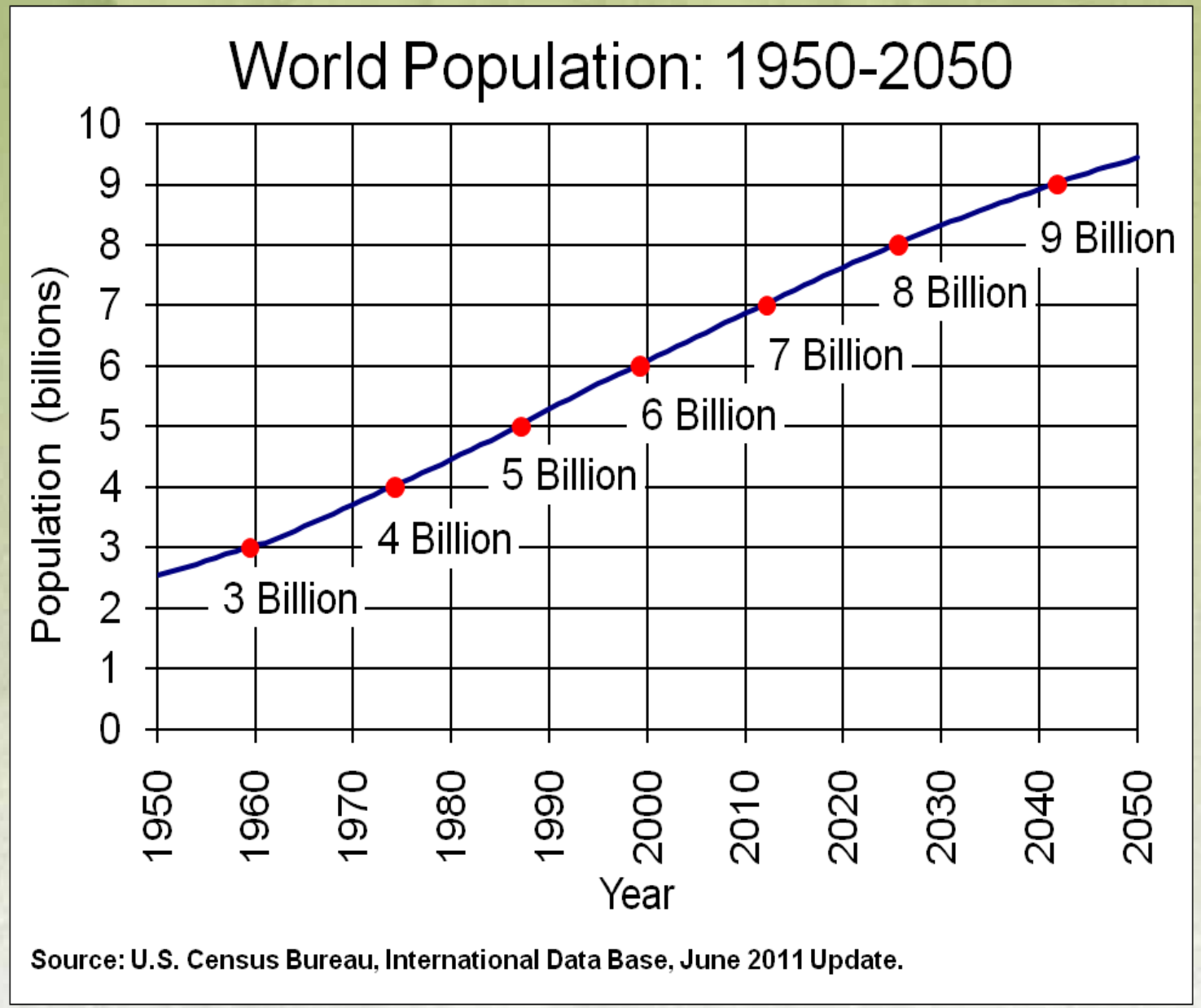
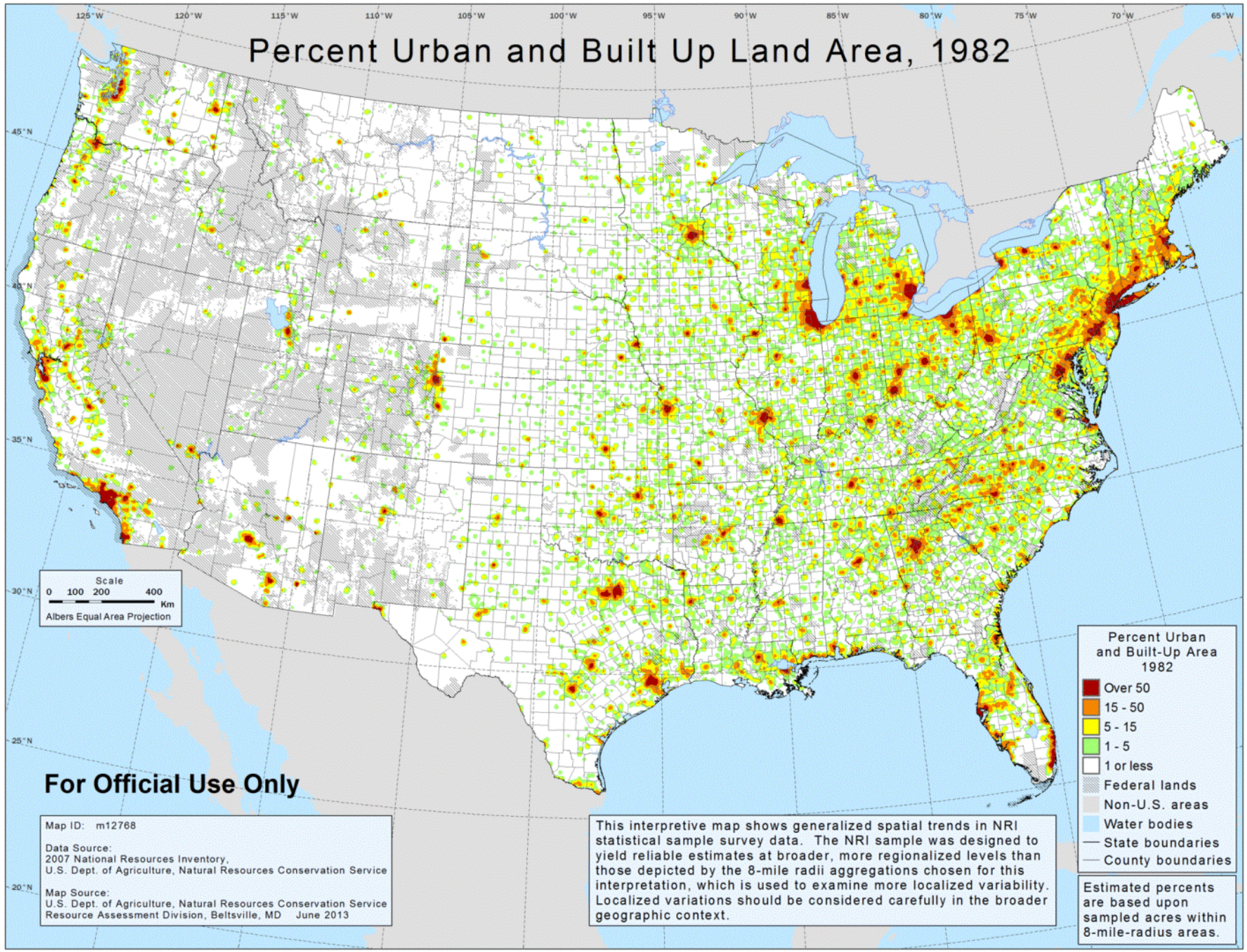
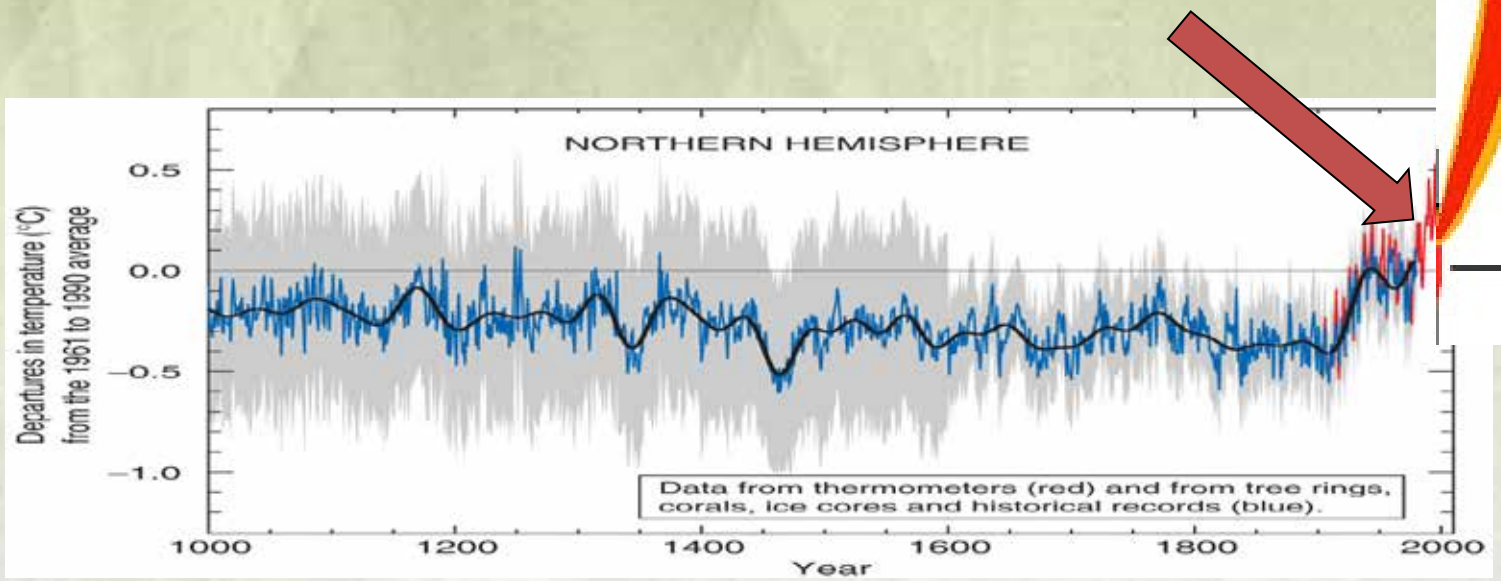
Our Challenges

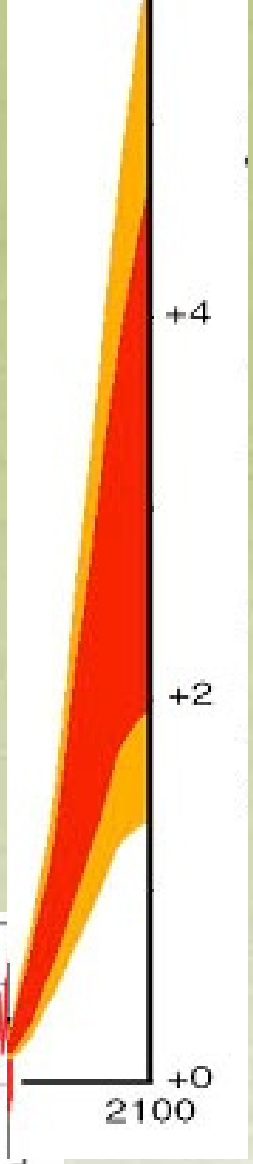
Feeding the population on a shrinking available land base




Percent Urban and Built Up Land Area, 1982
125°W
120°W
115°W
110°W
105°W
100°W
95°W
90°W
85°W
80°W
75°W
70°W
65°W
45°N
40°N
35°N
30°N
25°N
20°N
Scale
0 100 200 400
Km
Albers Equal Area Projection
For Official Use Only
Map ID: m12768
Data Source:
2007 National Resources Inventory,
U.S. Dept. of Agriculture, Natural Resources Conservation Service
Map Source:
U.S. Dept. of Agriculture, Natural Resources Conservation Service
Resource Assessment Division, Beltsville, MD June 2013
This interpretive map shows generalized spatial trends in NRI statistical sample survey data. The NRI sample was designed to yield reliable estimates at broader, more regionalized levels than those depicted by the 8-mile radii aggregations chosen for this interpretation, which is used to examine more localized variability. Localized variations should be considered carefully in the broader geographic context.
Percent Urban and Built-Up Area 1982
Over 50
15 - 50
5 - 15
1 - 5
1 or less
Federal lands
Non-U.S. areas
Water bodies
State boundaries
County boundaries
Estimated percents are based upon sampled acres within 8-mile-radius areas.

Increasing Temperature

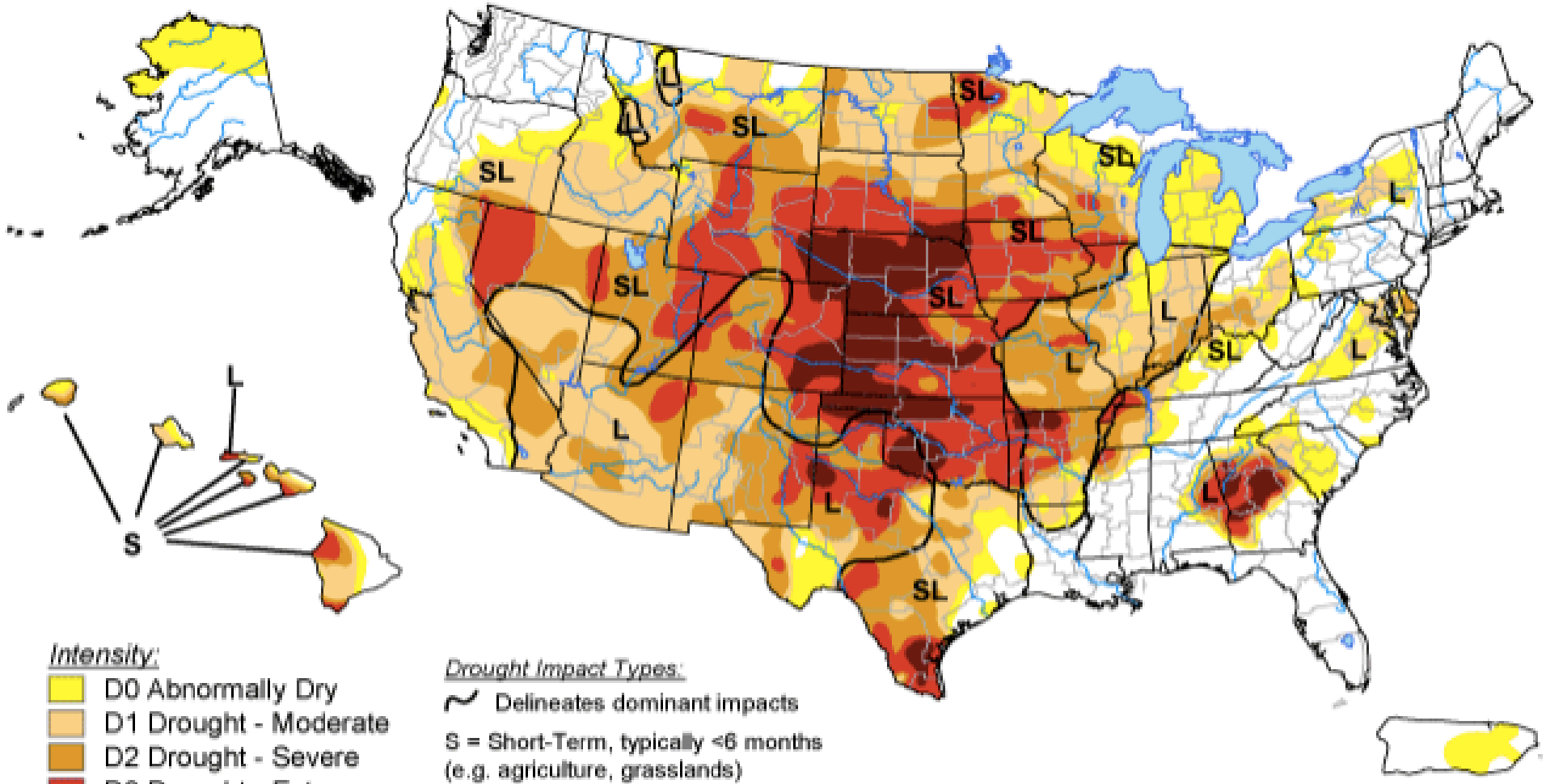




Adapted from Hayhoe 2011

U.S. Drought Monitor

September 25, 2012
Valid 7 a.m. EDT



Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:

Delineates dominant impacts

S = Short-Term, typically <6 months (e.g. agriculture, grasslands)

L = Long-Term, typically >6 months (e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu/

USDA

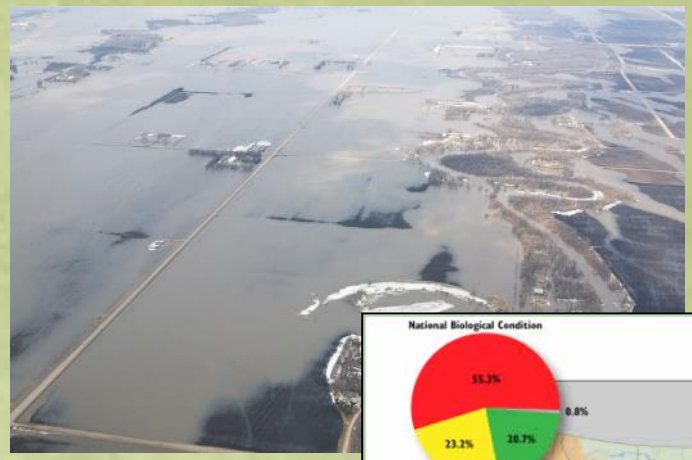
National Drought Mitigation Center

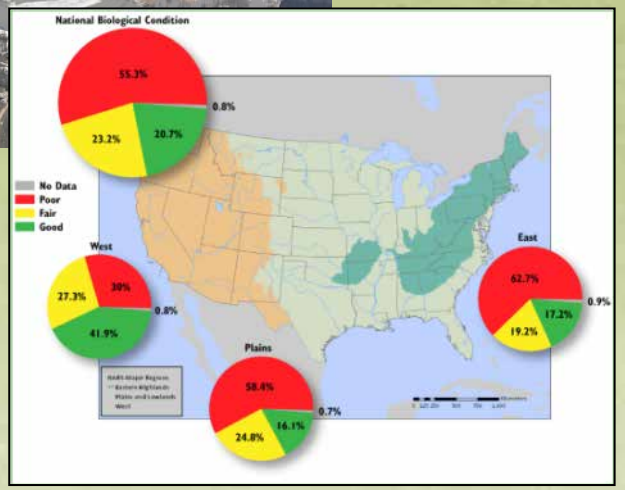
Released Thursday, September 27, 2012

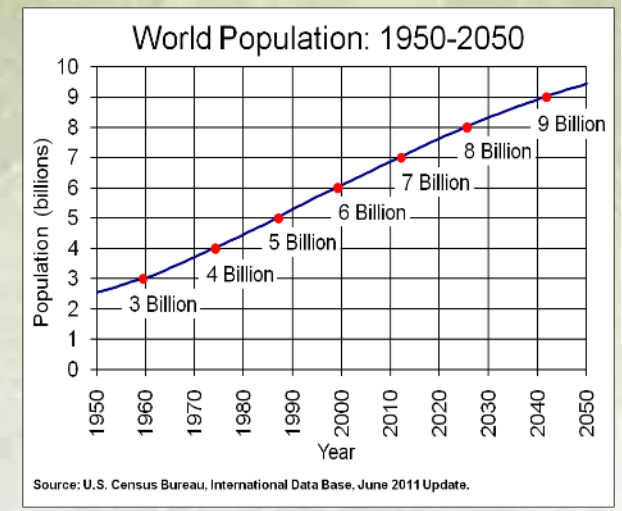
Author: Anthony Artusa, NOAA/NWS/NCEP/CPC

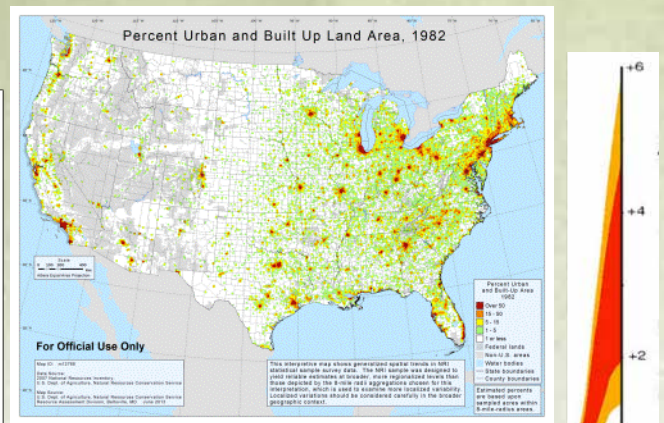
Challenges

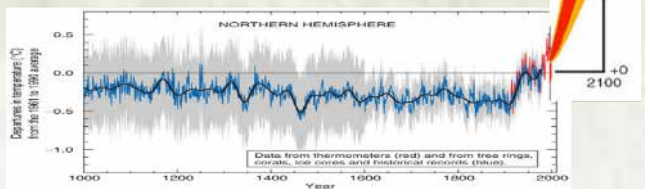
- Population growth
- Loss of ag soils
- Changing climate
- Water quality and quantity

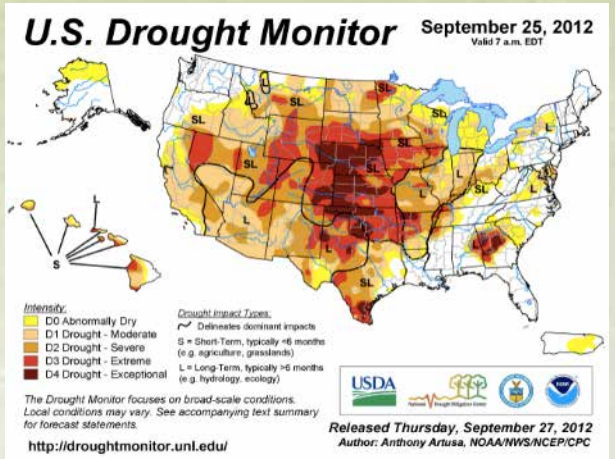













SOIL HEALTH:
The capacity of a soil to function as a vital, living ecosystem that sustains plants, animals, and humans.
Doran et al., 1996
Doran et al., 1998

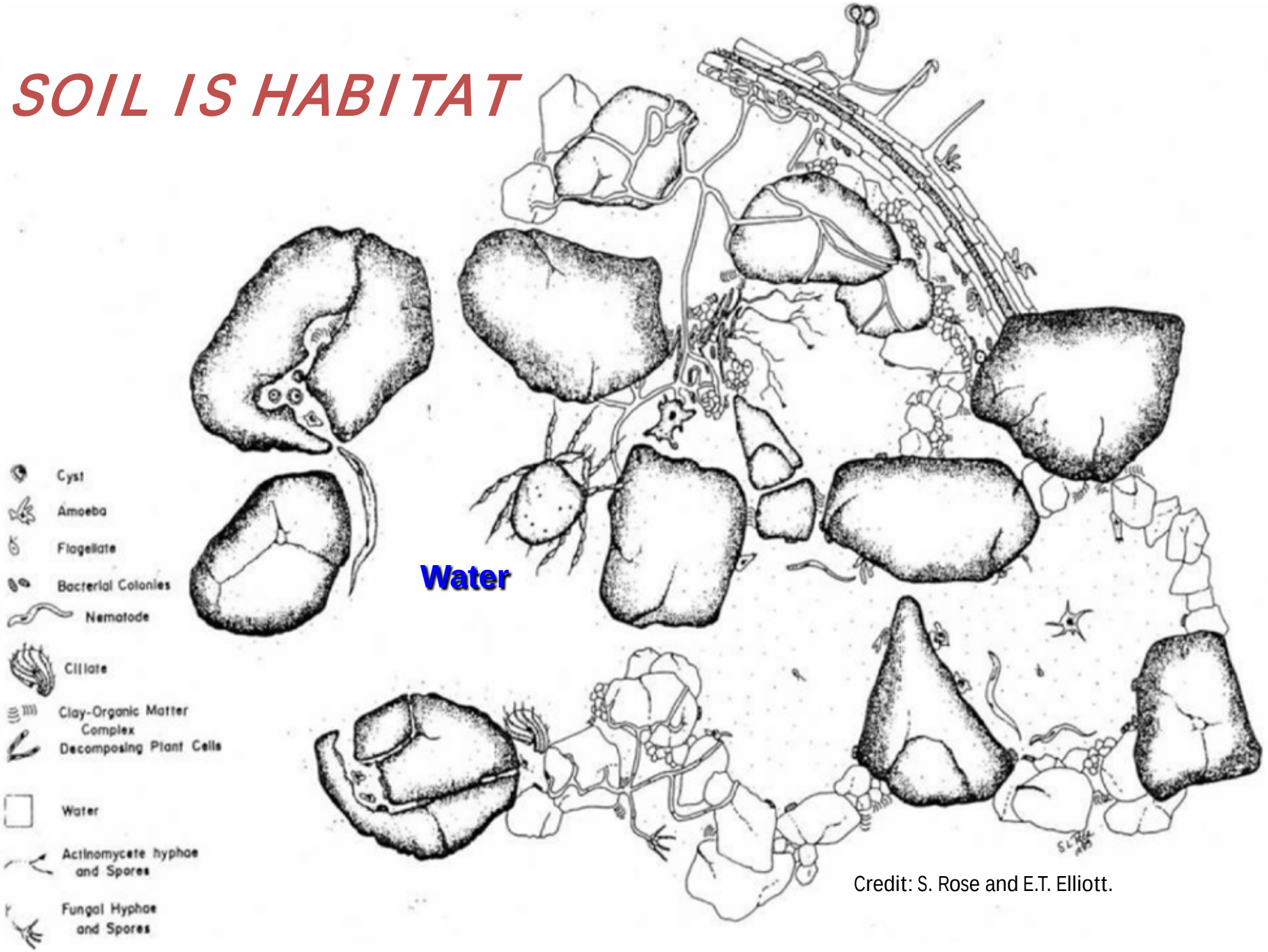
Soil Health Demos

- Slake Test
- Infiltration
- Rainfall Simulator

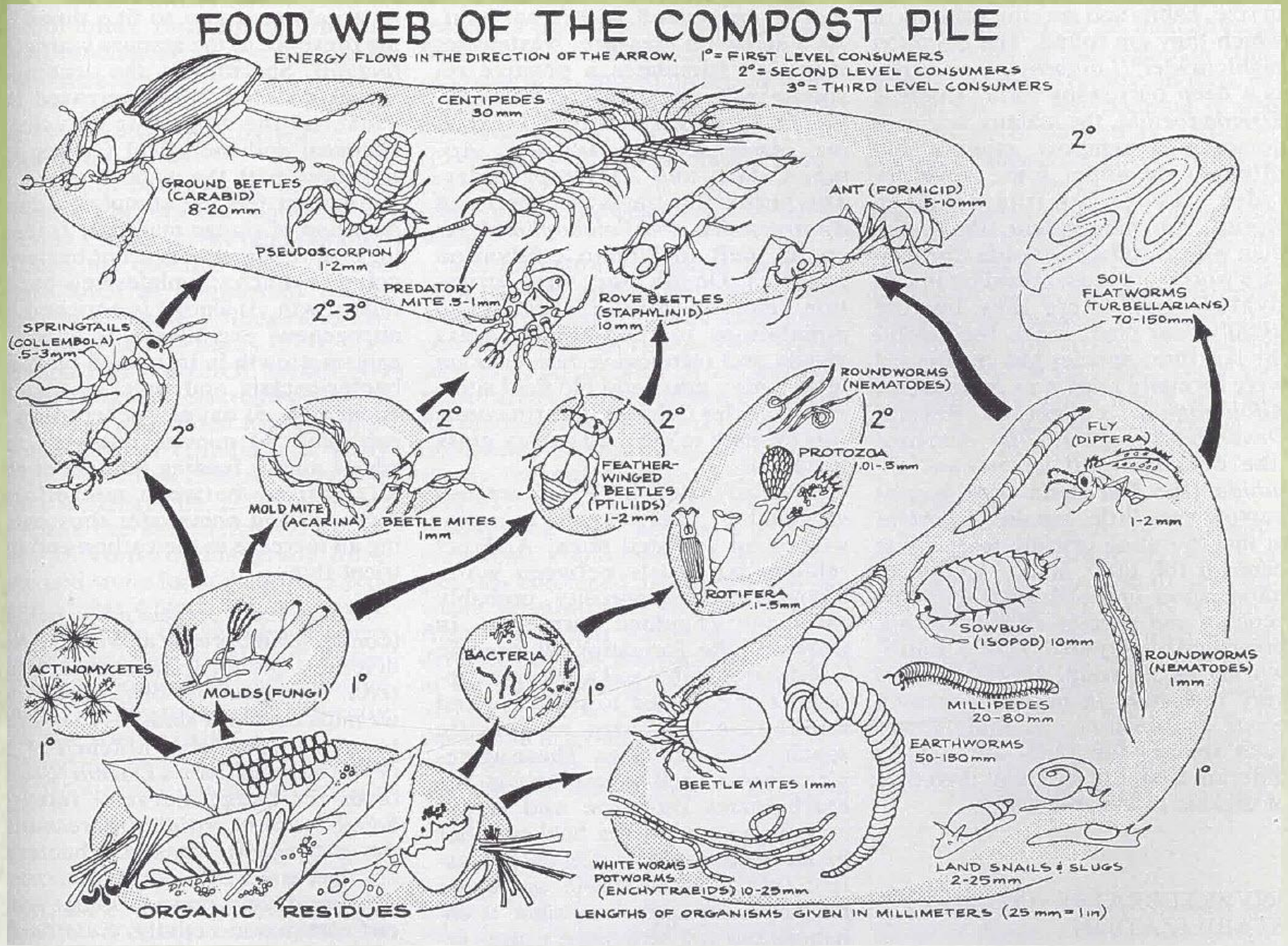
Soil Health Principles

unlock the SECRETS IN THE SOIL

SOIL IS HABITAT



Credit: S. Rose and E.T. Elliott.



Dindal, Dan. 1978. Soil Organisms and Stabilizing Wastes. Compost Science and Land Utilization. JG Press. Emmaus, PA. Vol. 19: 8-11.

Where Do Soil Organisms Live

What Do Soil Organisms Do In Soil?

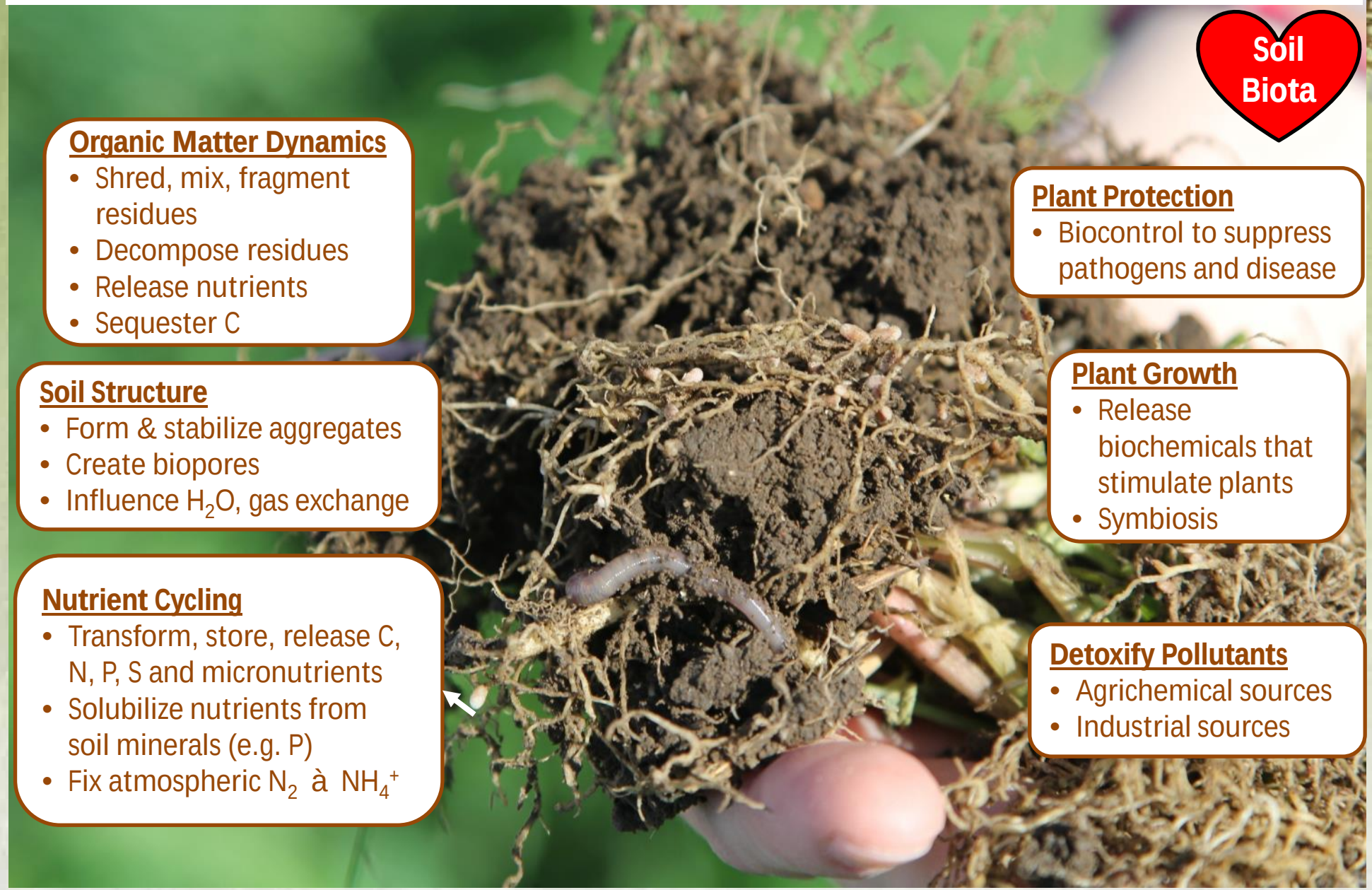
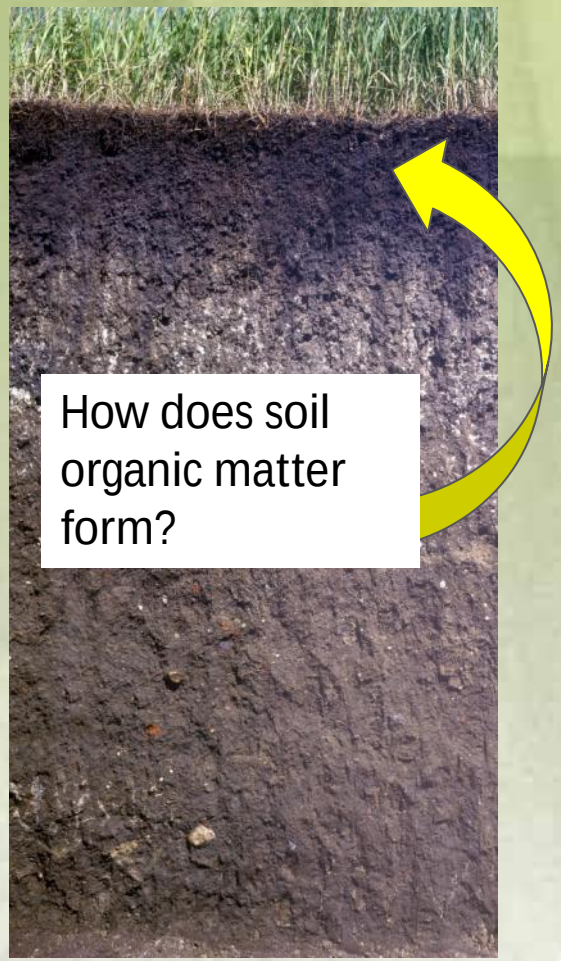


Photo credit: Aaron Roth, NRCS-OR; Slide design: Jen Moore Kucera, NRCS-SHD

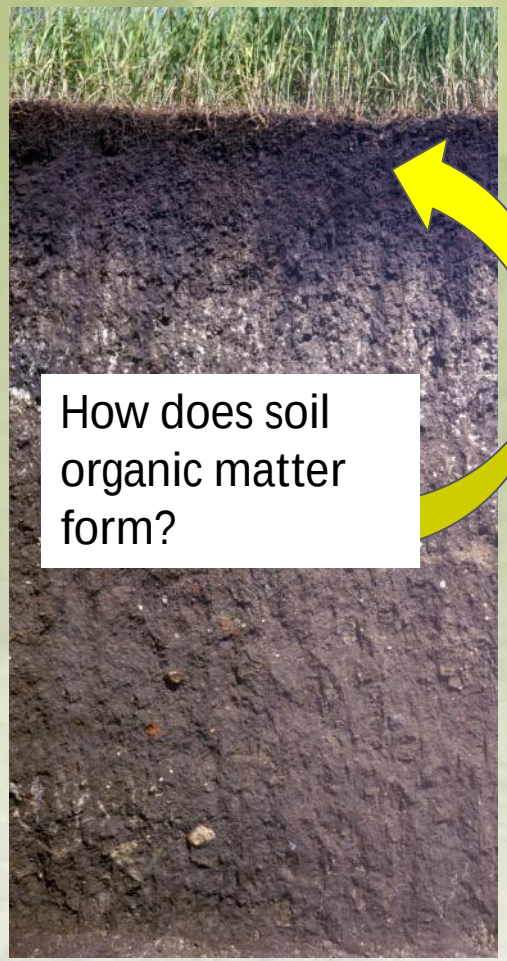
Soil Food Web Benefits: Organic Matter Formation



- Begins with macrofauna (large soil animals) and mesofauna (med sized) that shred, mix, and relocate plant and animal residues
- Some key representatives:
  - Macro: Earthworms, beetles, centipedes, millipedes, ants, termites, etc.
  - Meso: Mites, potworms, springtails, pseudoscorpions, etc.

Mollisol image:
http://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1237739.jpg

Soil Food Web Benefits: Organic Matter Formation



Mollisol image:
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- Soil bacteria and fungi attack the small pieces (greater surface area) and chemically breakdown and transform plant residues into organic matter (and release nutrients)

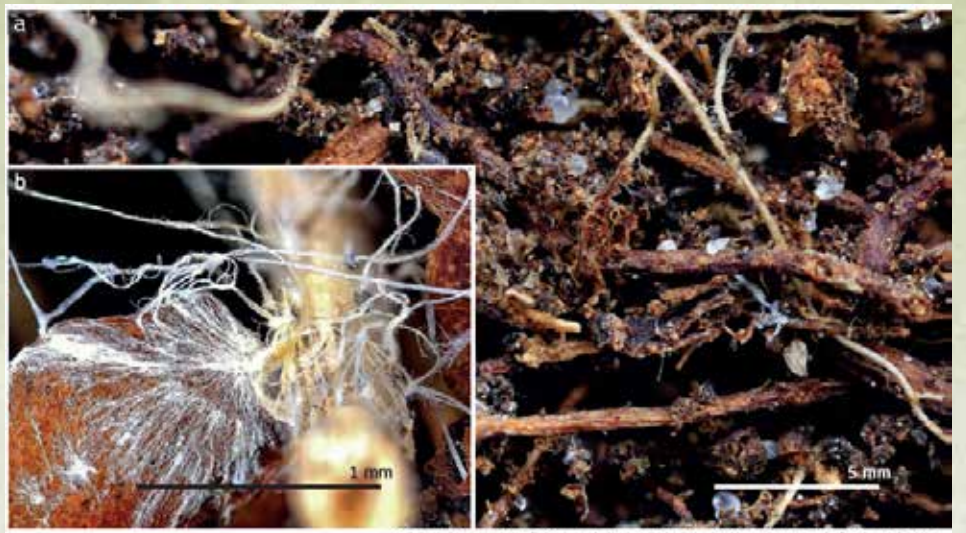
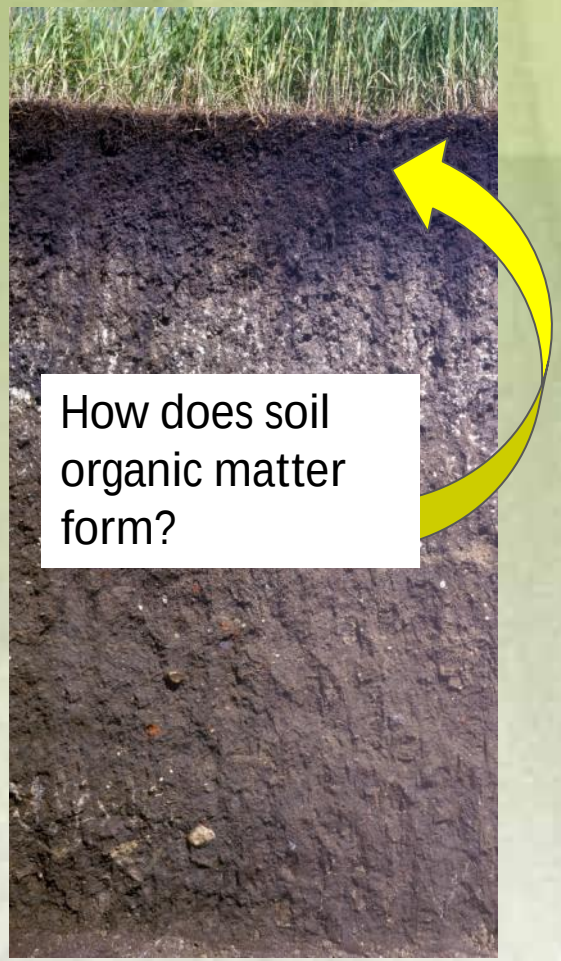


Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union**: 176p.**

Soil Food Web Benefits: Organic Matter Formation



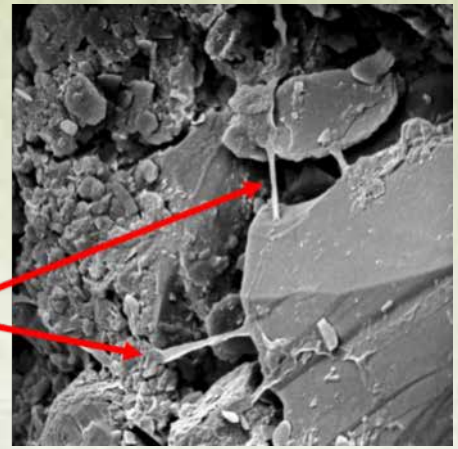
- Soil bacteria and fungi attack the small pieces (greater surface area) and chemically breakdown and transform plant residues into organic matter (and release nutrients)
- Some key fungal representatives:
  - Saprophytic fungi (degrade dead materials)
  - Some are pathogenic

Mollisol image:
http://www.nrcs.usda.gov/Internet/FSE_MEDIA/stelprdb1237739.jpg

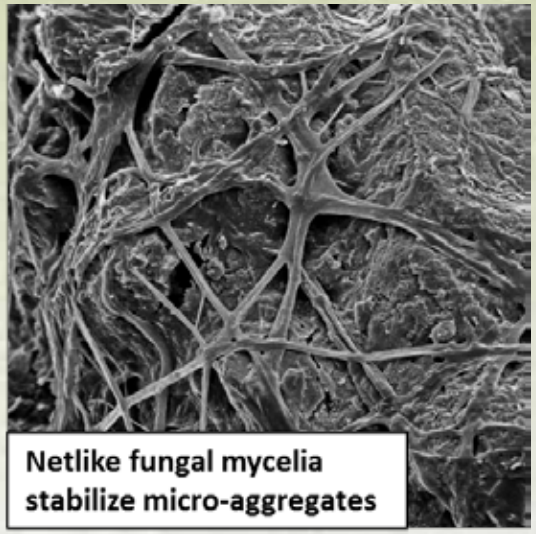
Soil Food Web Benefits: Formation & Stabilization of Aggregates

How do soil aggregates form?

- Physical interactions
  - Plant roots enmesh soil particles
  - Earthworms (casts) and termites (mounds)
  - Soil fungi and some Actinobacteria produce filaments that physically enmesh soil particles together



Stabilization of soil structure by actinomycete (bacterial) filaments



Netlike fungal mycelia stabilize micro-aggregates

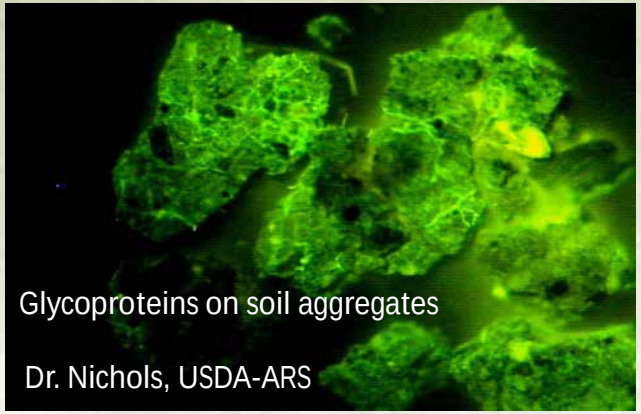
Soil image with worm: Aaron Roth, NRCS-OR

SEM photo source (accessed on 6/2/2016): Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen.de

Soil Food Web Benefits: Formation & Stabilization of Aggregates

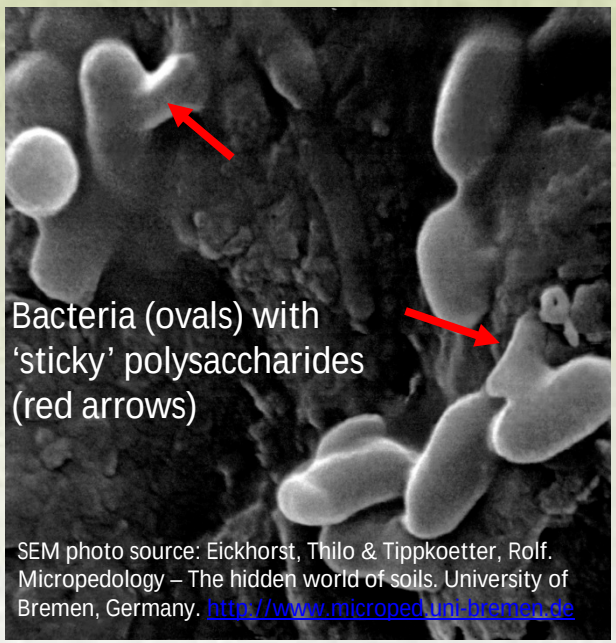
How do soil aggregates form?

- Chemical interactions
  - Polysaccharides (sugars) released by bacteria act like glues to bind particles
  - Glycoproteins (glomalin-related soil proteins and other proteins) act like glues



Glycoproteins on soil aggregates

Dr. Nichols, USDA-ARS

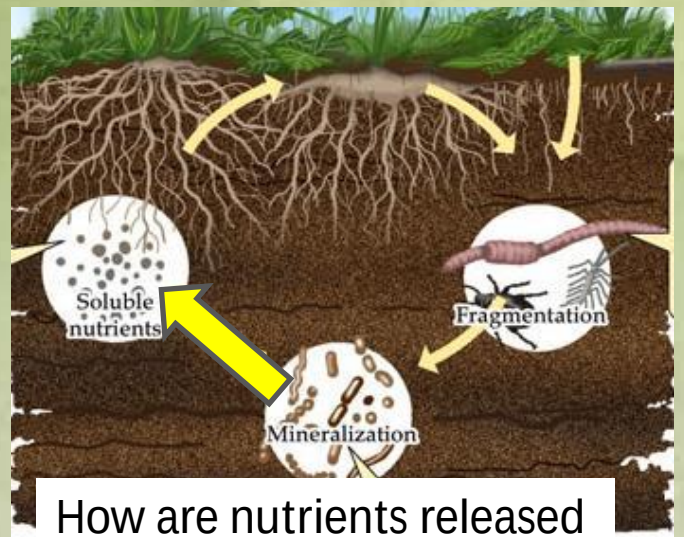


Bacteria (ovals) with 'sticky' polysaccharides (red arrows)

SEM photo source: Eickhorst, Thilo & Tippkoetter, Rolf. Micropedology – The hidden world of soils. University of Bremen, Germany. http://www.microped.uni-bremen.de

Soil image with worm: Aaron Roth, NRCS-OR

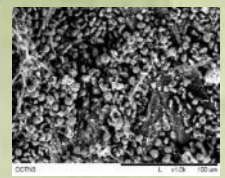
Soil Food Web Benefits: Nutrient Cycling and Release



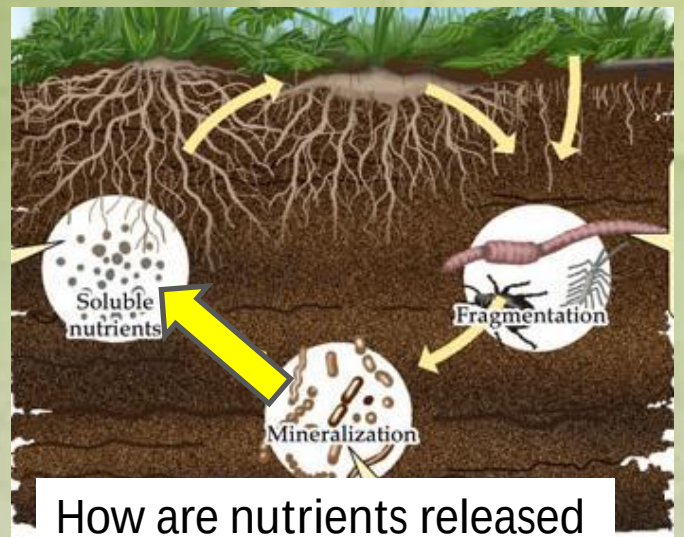
How are nutrients released from SOM?

Mineralization

- Bacteria and fungi release enzymes that act convert organic molecules from residues into soluble nutrients (N, P, S)



Soil Food Web Benefits: Nutrient Cycling and Release



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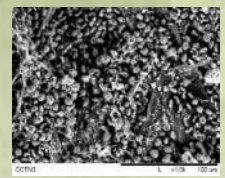
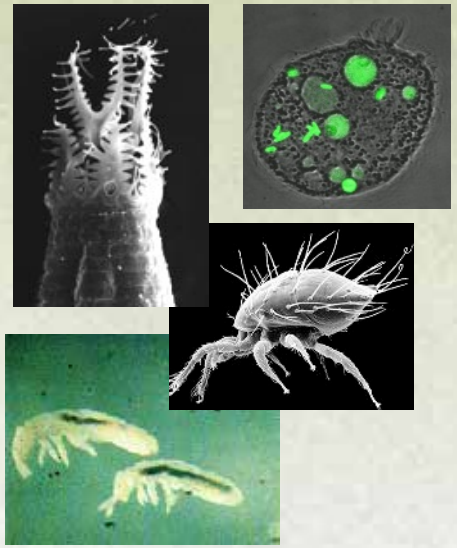
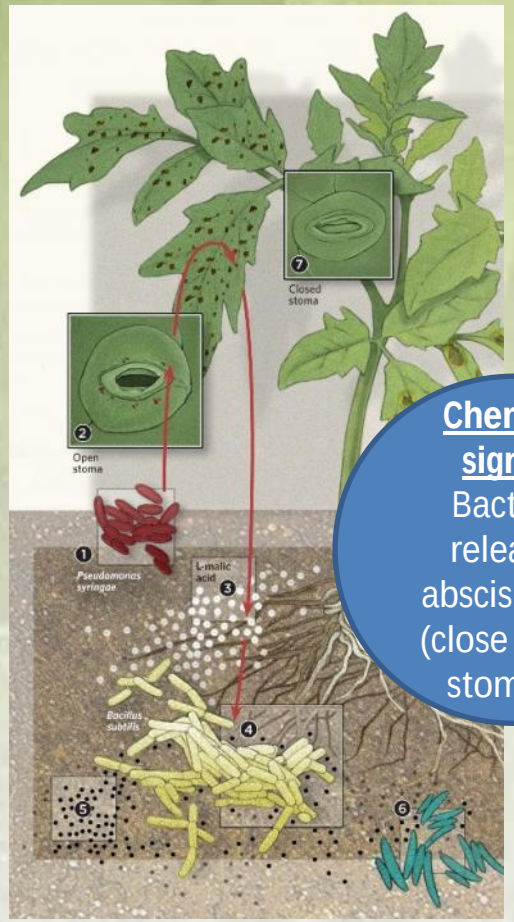



- Microbes become food and are mineralized (eaten) by protozoa, nematodes, springtils, mites, etc.



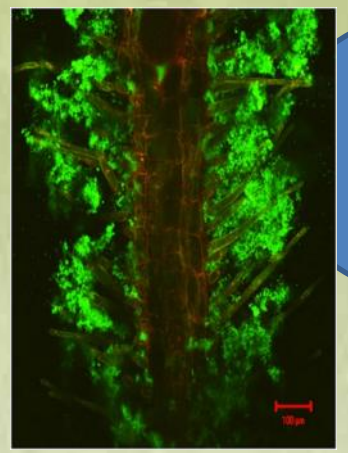
Soil Food Web Benefits: Plant Protection Examples

Antibiotic Production
Fungi
Bacteria



http://www.the-scientist.com/?articles.view/articleNo/34209/title/The-Soil-Microbiome/

Chemical signals
Bacteria released abscisic acid (close plants stomata)



http://www.udel.edu/udaily/2009/oct/bais101708.html

Protection
Biofilm of beneficial bacteria protecting against *P. syringae*

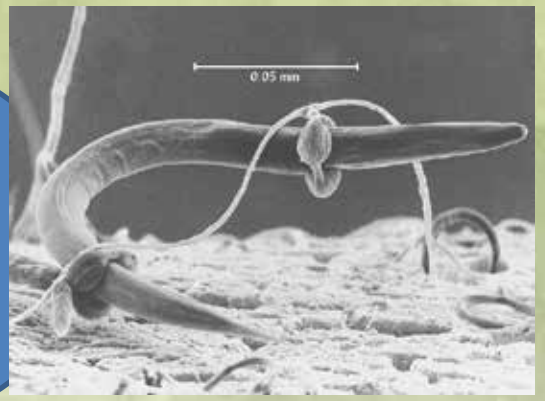
Predation
Soybean cyst nematode parasitized by a fungus

http://www.extension.umn.edu/agriculture/soybean/soybean-cyst-nematode/chemical-biological-potential.html

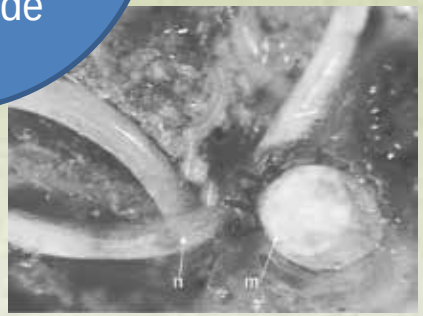
Protection
Roots protected from *Rhizoctonia solania* by springtails (left) and without (right)

Soil Food Web Benefits: Population Control (Predation)

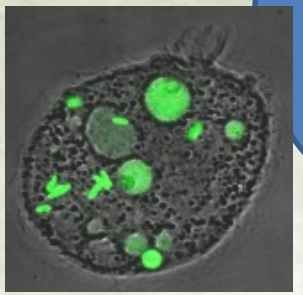
Nematode trapping fungi



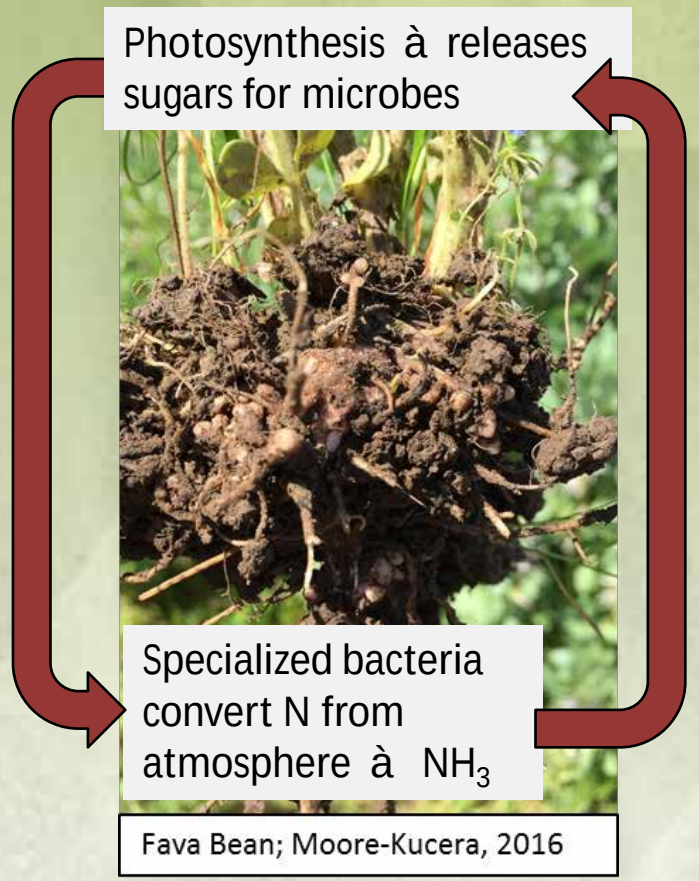
Predation
Mite consuming springtail and a nematode



Predation
Protozoa consume billions of bacteria; some consume fungi



Soil Food Web Benefits: Symbiosis- N fixation



Fava Bean; Moore-Kucera, 2016

Symbiosis between soil bacteria associated with some plant roots supply:

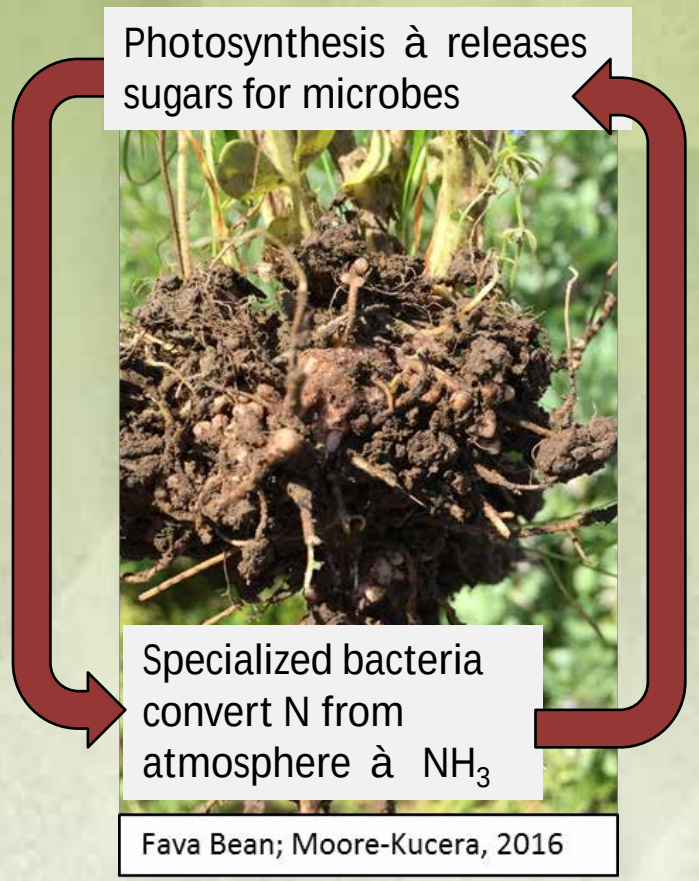
- 20-75 lb/ac in natural systems
- 100-200 lb/ac in cropland

Free-living fixers also important but not inside of plant roots

- Cyanobacteria (bluegreen but not algae (Anabaena, Nostoc)
- Azotobacter, Azospirillum

Photo source: Jen Moore Kucera, NRCS-SHD, 2016

Soil Food Web Benefits: Symbiosis- N fixation



Fava Bean; Moore-Kucera, 2016

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- 20-75 lb/ac in natural systems
- 100-200 lb/ac in cropland

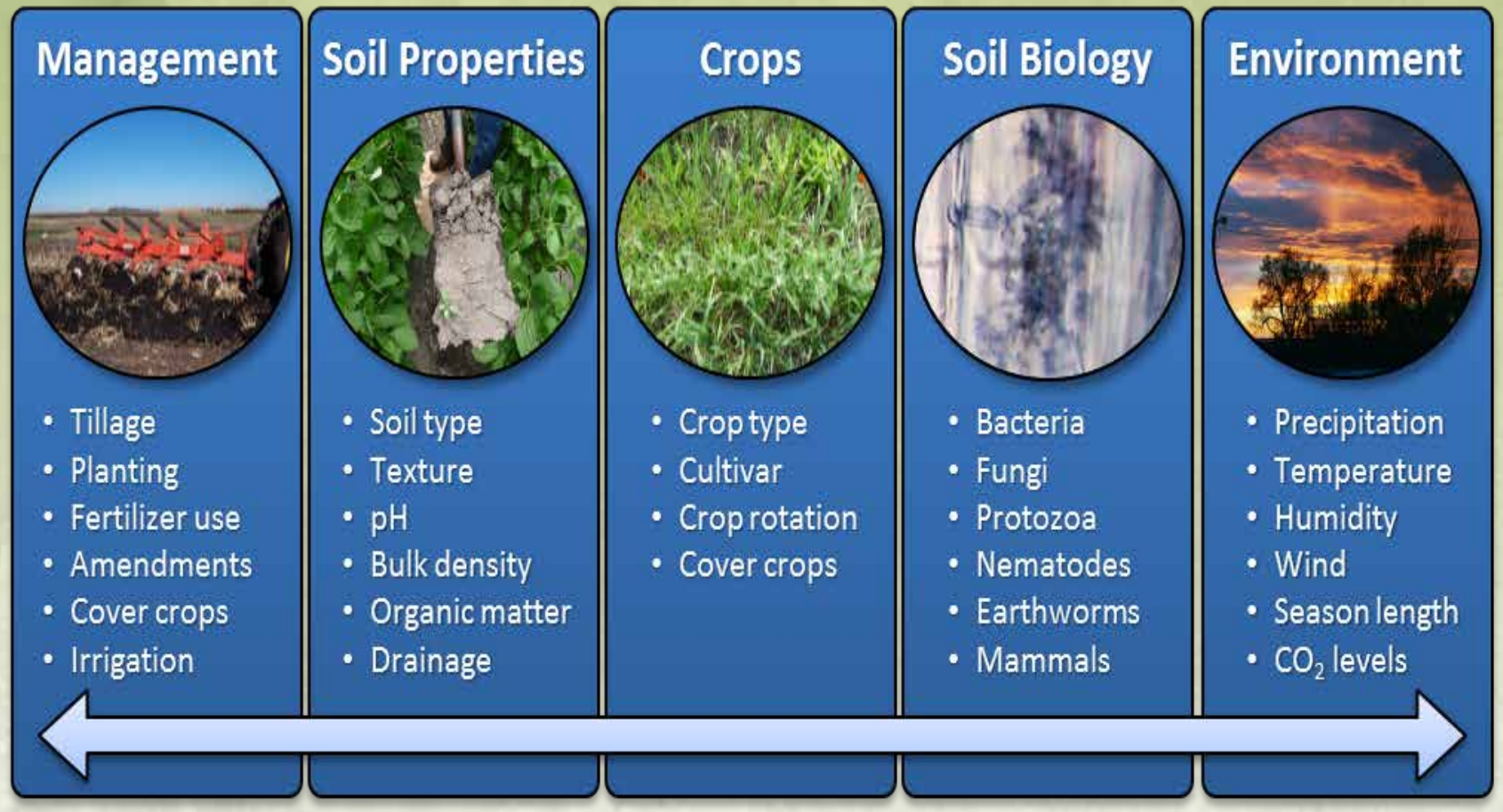
Nitrogen fixing bacteria can contribute 90 million tons or more of usable nitrogen to agricultural lands each year.

Chemical nitrogen fertilizers, lightening, and fire contribute only 10-20 million tons

Hardy, R.W.F., Havelka, U.D. 1975. Nitrogen Fixation Research: A Key to World Food? *Science*, ***188(4188), 633-643.***

Photo source: Jen Moore Kucera, NRCS-SHD, 2016

Interacting Factors Affecting Soil Biology And Soil Function



Lehman, R. M., et al. (2015). "Soil biology for resilient, healthy soil." Journal of Soil and Water Conservation 70(1): 12a-18a.

Management Impacts on The Soil Food Web: Plants Play Key Role

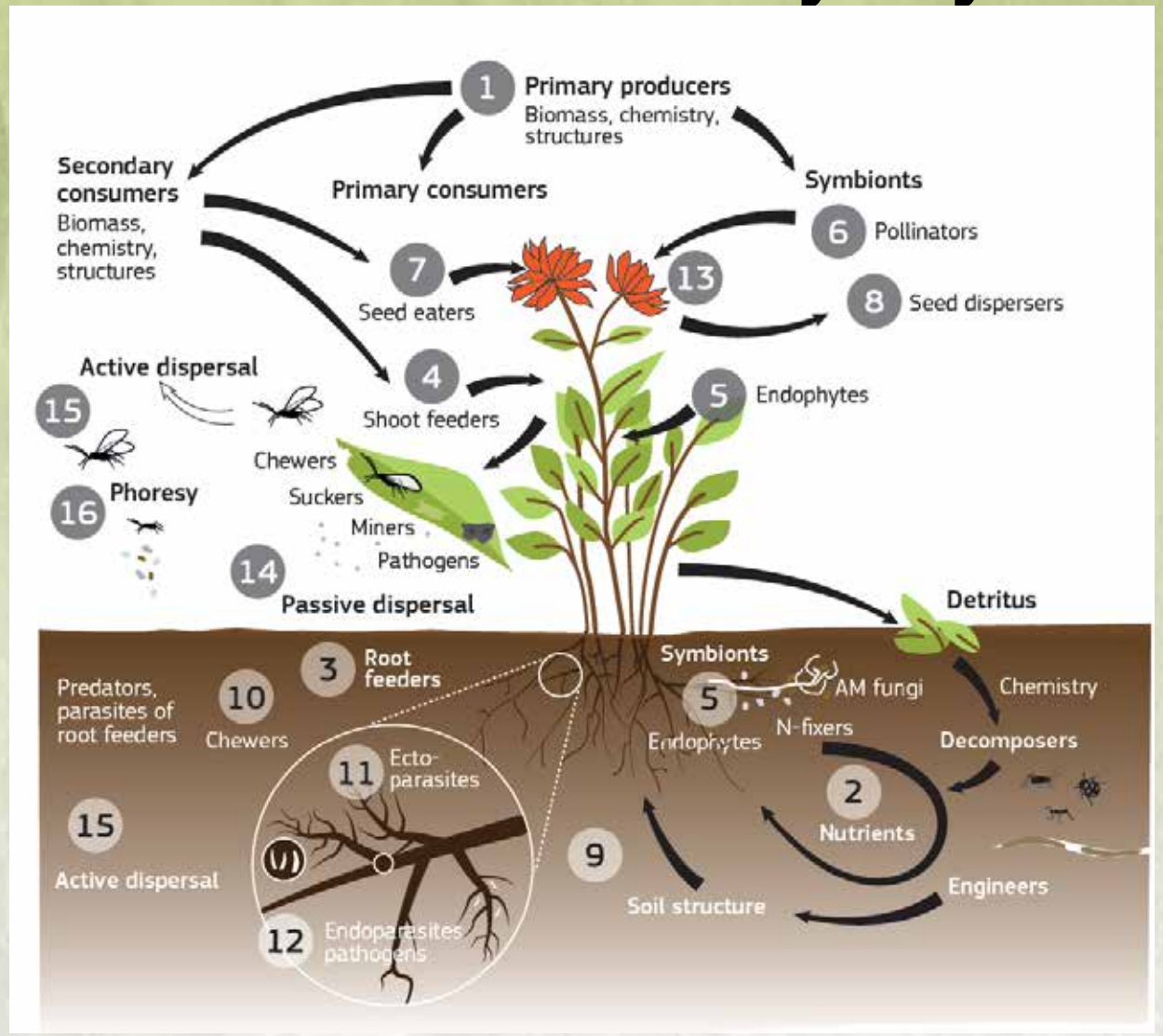
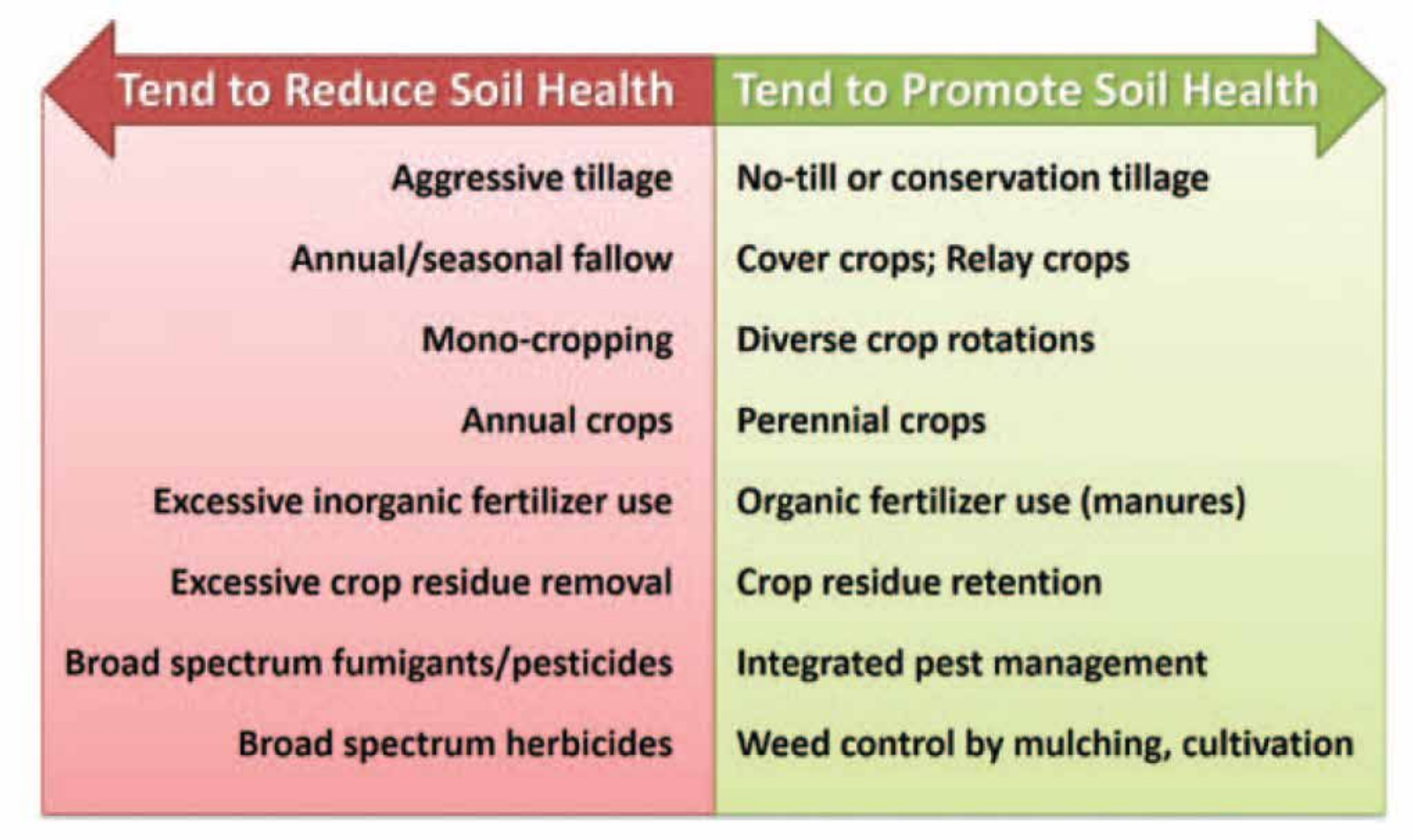


Photo citation: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, et al. Luxembourg, European Commission, Publications Office of the European Union**: 176p.**

Agricultural Management Effects on Soil Health



Lehman, R. M., et al. (2015). "Soil biology for resilient, healthy soil." Journal of Soil and Water Conservation 70(1): 12a-18a.

Management and Microbes

Table 10.7
SOIL-MANAGEMENT PRACTICES AND THE DIVERSITY AND ABUNDANCE OF SOIL ORGANISMS

Note that the practices that tend to enhance biological diversity and activity in soils are also those associated with efforts to make agricultural systems more sustainable.

Decreases biodiversity and populations	Increases biodiversity and populations
Fumigants	Balanced fertilizer use
Nematicides	Lime on acid soils
Some insecticides	Proper irrigation
Compaction	Improved drainage and aeration
Soil erosion	Animal manures and composts
Industrial wastes and heavy metals	Domestic (clean) sewage sludge
Moldboard plow–harrow tillage	Reduced or zero tillage
Monocropping	Crop rotations
Row crops	Grass–legume pastures
Bare fallows	Cover crops or mulch fallows
Residue burning or removal	Residue return to soil surface
Plastic mulches	Organic mulches

Brady, N. C. and R. R. Weil (2000). Elements of the nature and properties of soils, Prentice Hall Upper Saddle River, NJ, USA.

Solutions for Optimal Soil Food Webs

Two simple rules:

1. **Protect the home (water, air, nutrients)**
2. **Feed soil biology a diverse, year-round diet**

Minimize soil disturbance

'Protect the home (aggregate)'

Maximize diversity (plants, animals, amendments, inoculants…)

'Feed soil organisms'

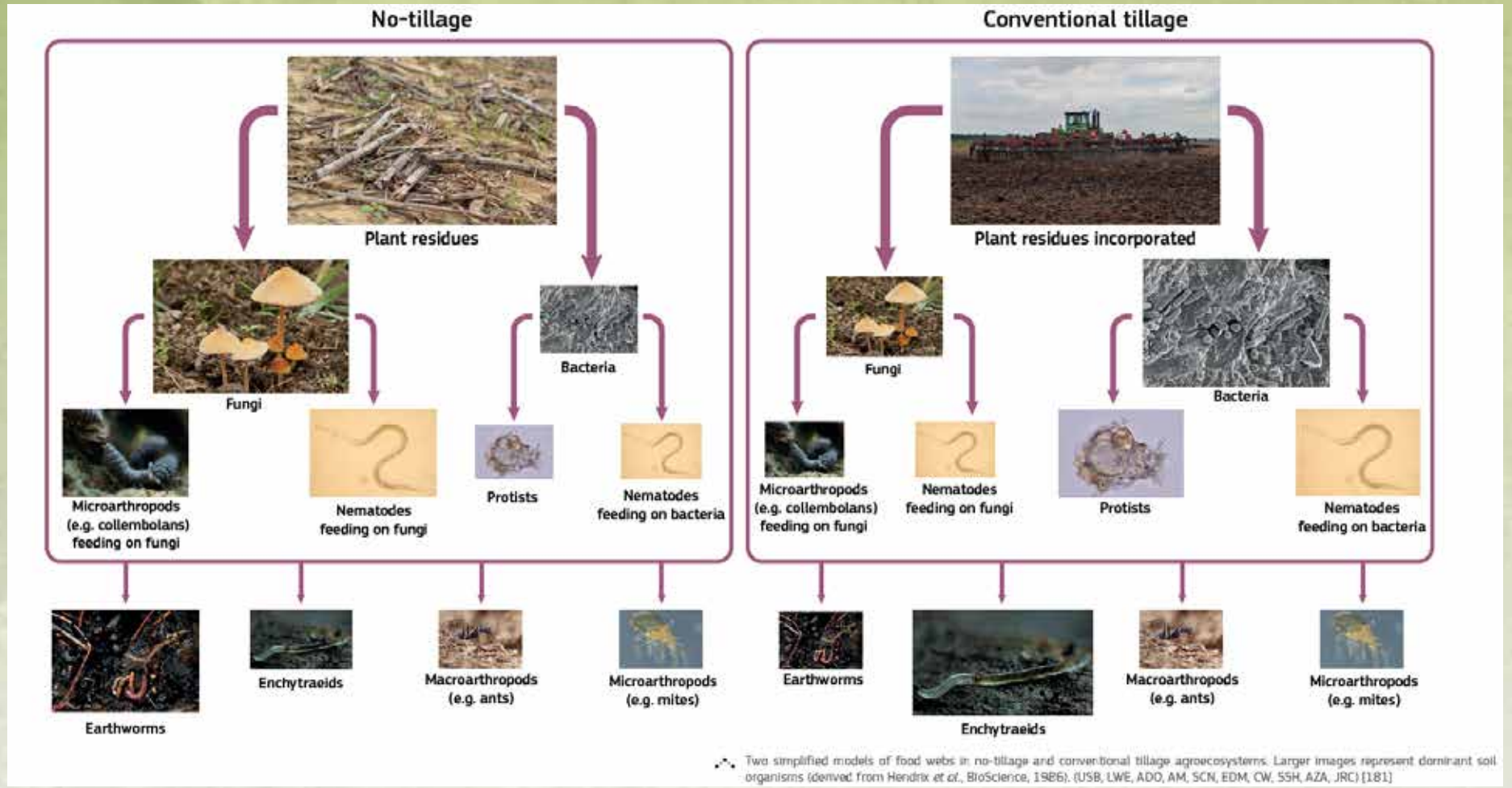
Keep the soil covered

'Protect the aggregate'

Maximize living roots

'Feed soil organisms'

Soil Food Webs in No-till and Conventional Tilled Systems



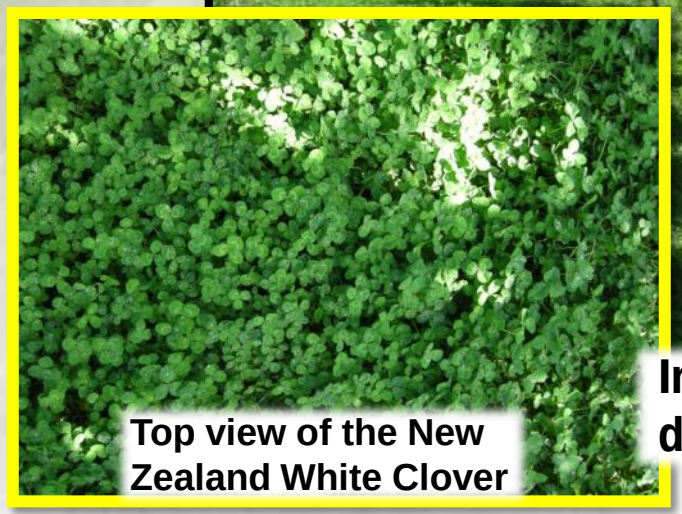
Two simplified models of food webs in no-tillage and conventional tillage agroecosystems. Larger images represent dominant soil organisms (derived from Hendrix *et al.*, BioScience, 1986). (USB, LWE, ADO, AM, SCN, EDM, CW, SSH, AZA, JRC) [181]

Photo source: (2016). Global Soil Biodiversity Atlas. A. Orgiazzi, R. D. Bardgett, E. Barrios et al. Luxembourg, European Commission, Publications Office of the European Union**: 176p.**

How do we integrate the principles on a small scale?

Add Cover Crops

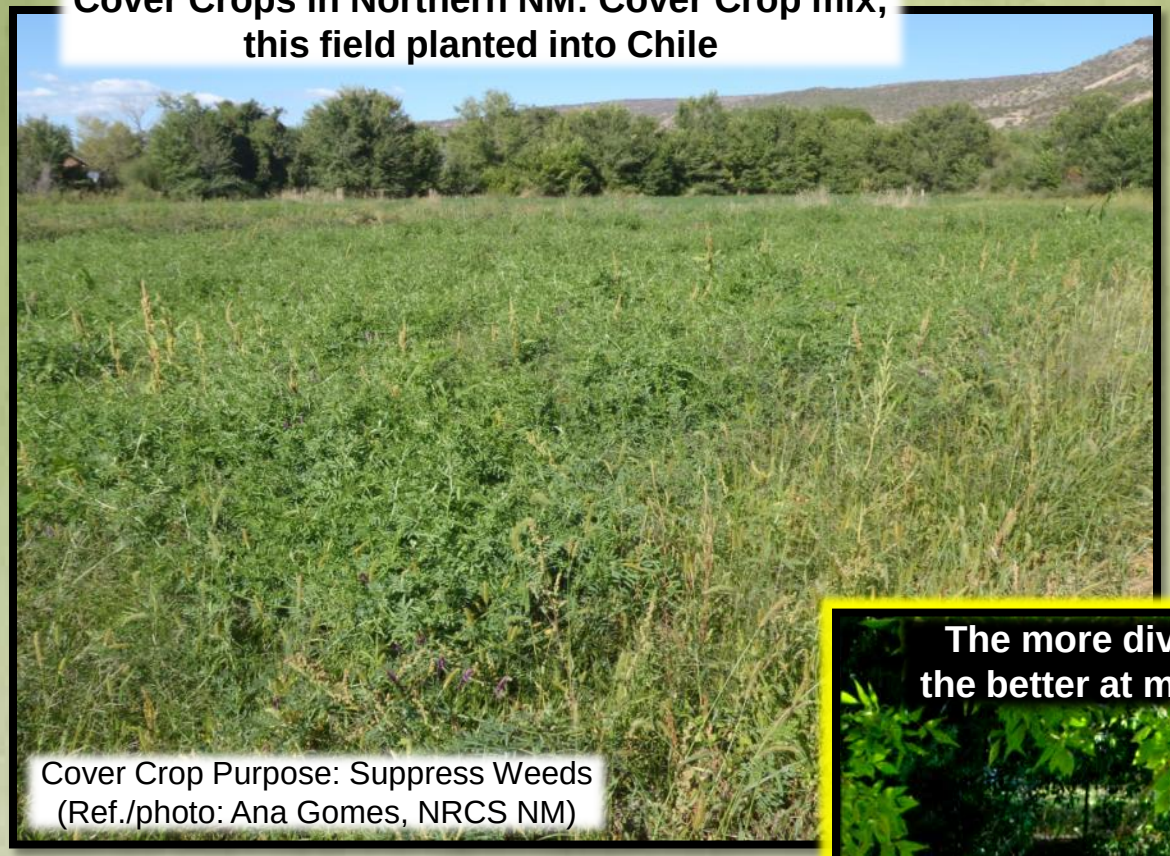
Fruit Orchard with New Zealand White Clover as a permanent ground cover. (Plant Material Center, Los Lunas, NM)



Top view of the New Zealand White Clover

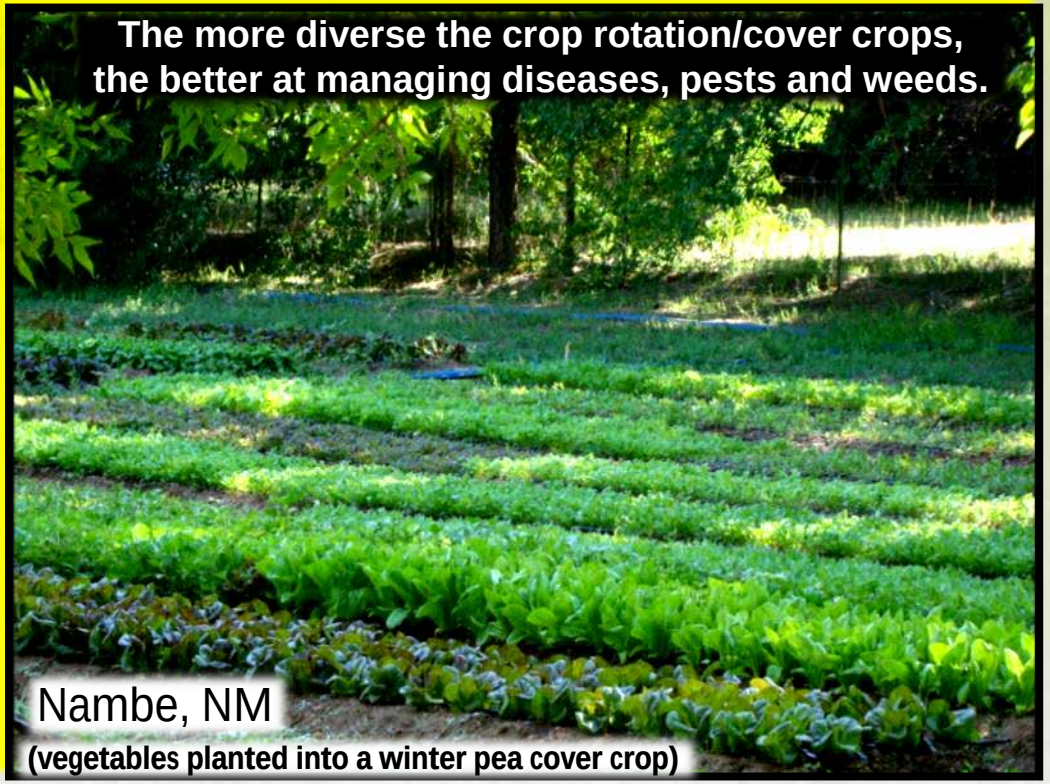
In NM, we have found soil temperature difference of about 20 degrees Fahrenheit (cover crops had lower temp. vs. bare soil)

Add Cover Crops



Cover Crops in Northern NM: Cover Crop mix; this field planted into Chile

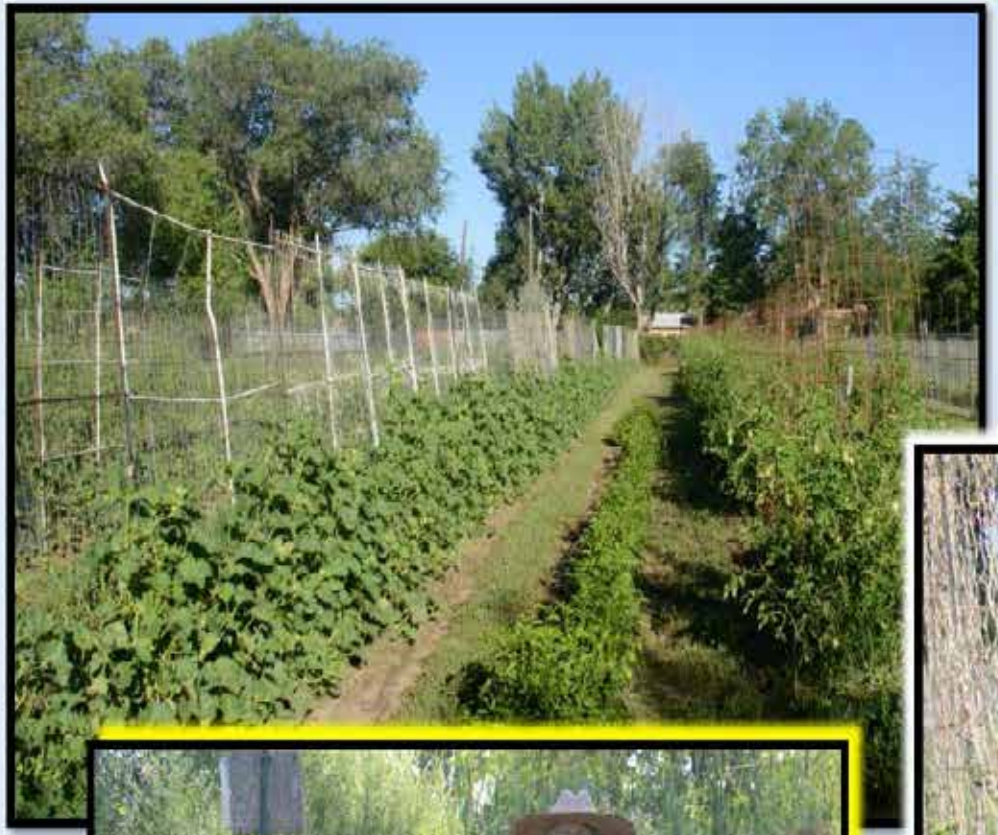
Cover Crop Purpose: Suppress Weeds
(Ref./photo: Ana Gomes, NRCS NM)



The more diverse the crop rotation/cover crops, the better at managing diseases, pests and weeds.

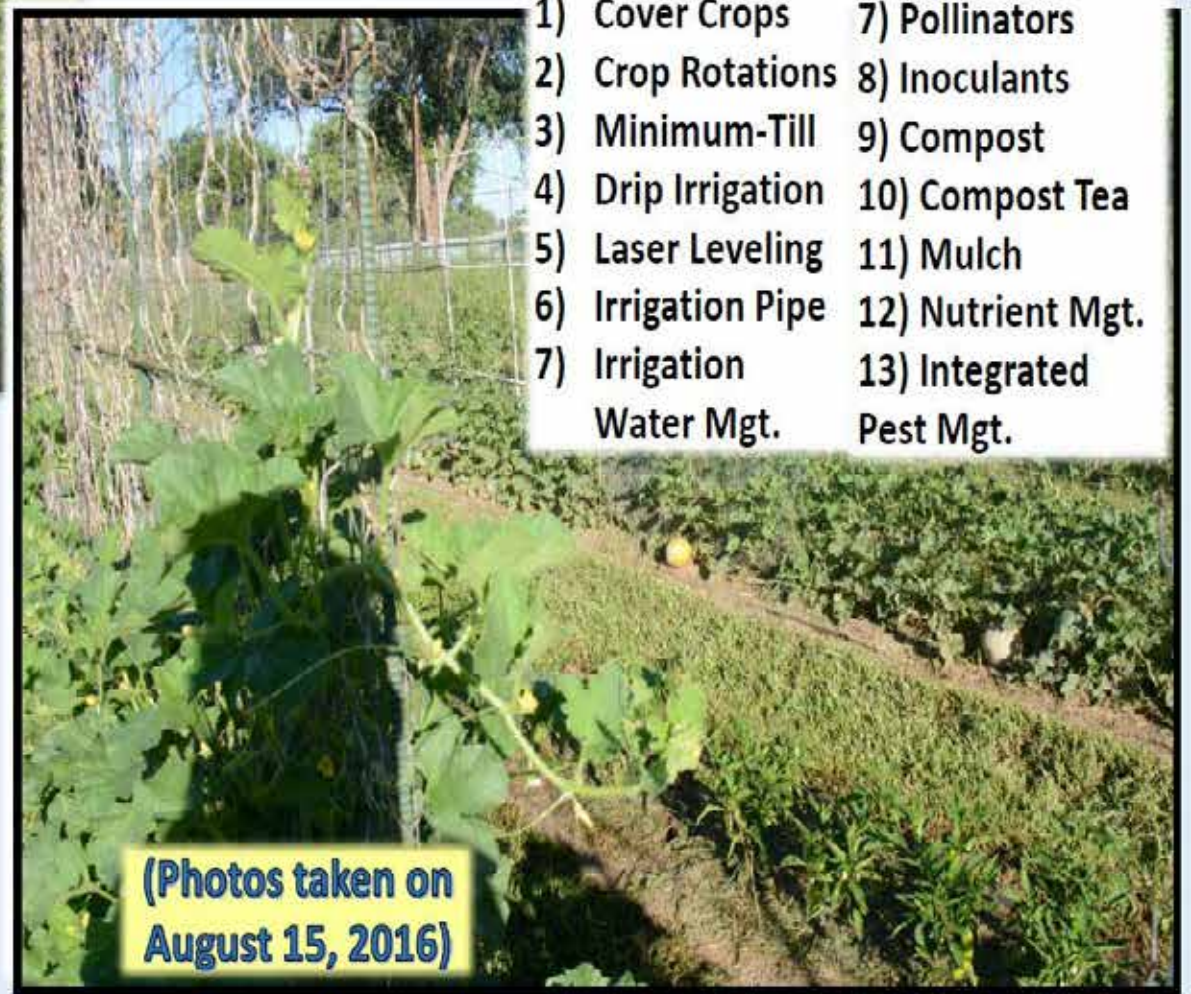
Nambe, NM
(vegetables planted into a winter pea cover crop)

North Valley Organics
(Minor Morgan; Albuquerque, NM)



Using a Soil Health Mgt. System on Organic Vegetable production:

1) Cover Crops
2) Crop Rotations
3) Minimum-Till
4) Drip Irrigation
5) Laser Leveling
6) Irrigation Pipe
7) Irrigation Water Mgt.
7) Pollinators
8) Inoculants
9) Compost
10) Compost Tea
11) Mulch
12) Nutrient Mgt.
13) Integrated Pest Mgt.



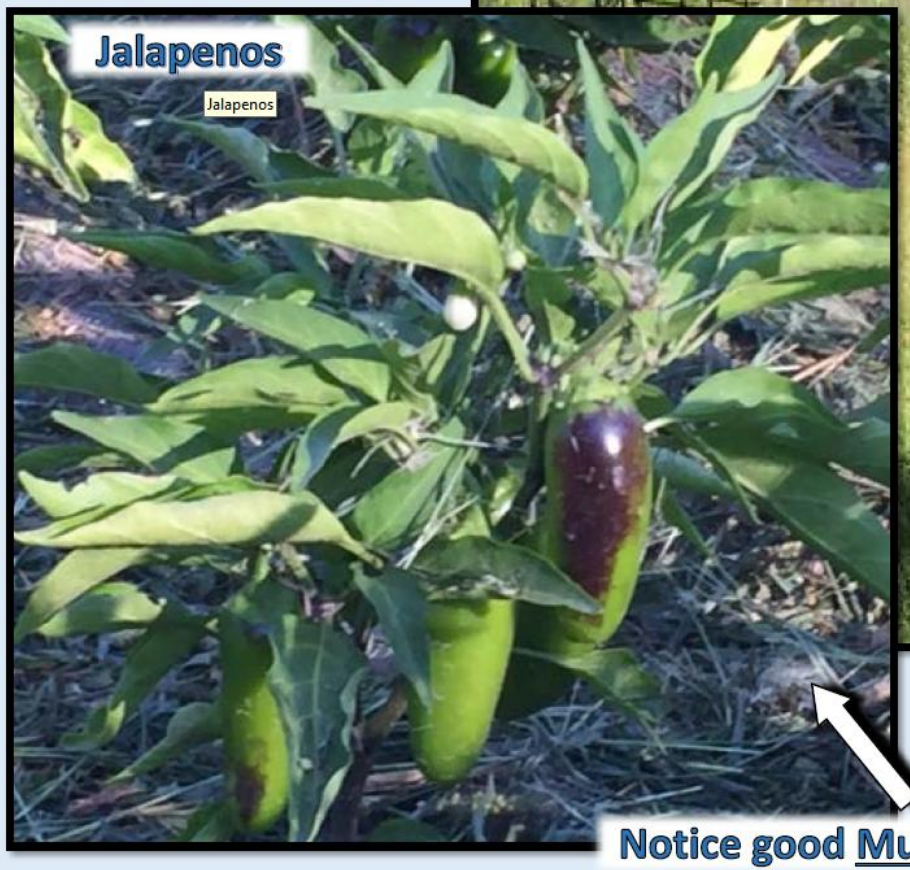
(Photos taken on August 15, 2016)

Photos: Rudy Garcia and N. Valley Organics

Melons growing on trellis. Cover Crops grown between all Cash Crop rows.

Photos: Rudy Garcia and N. Valley Organics

Mulching & Cover Crops: Keep the ground covered!!!



Notice good Mulch Cover on Cash Crop row and Cover Crop between rows.

Photos: Rudy Garcia and N. Valley Organics

Plant diversity is a Major Component of the IPM strategy

Top view of Cover Crop before being mowed

Emphasis on Complete Ground Cover & Organic Matter/Plant Biomass Diversity (this provides habitat for diverse beneficial Soil Organisms)

Photos: Rudy Garcia and N. Valley Organics

unlock the SECRETS in the SOIL

Pollinators (very important!)

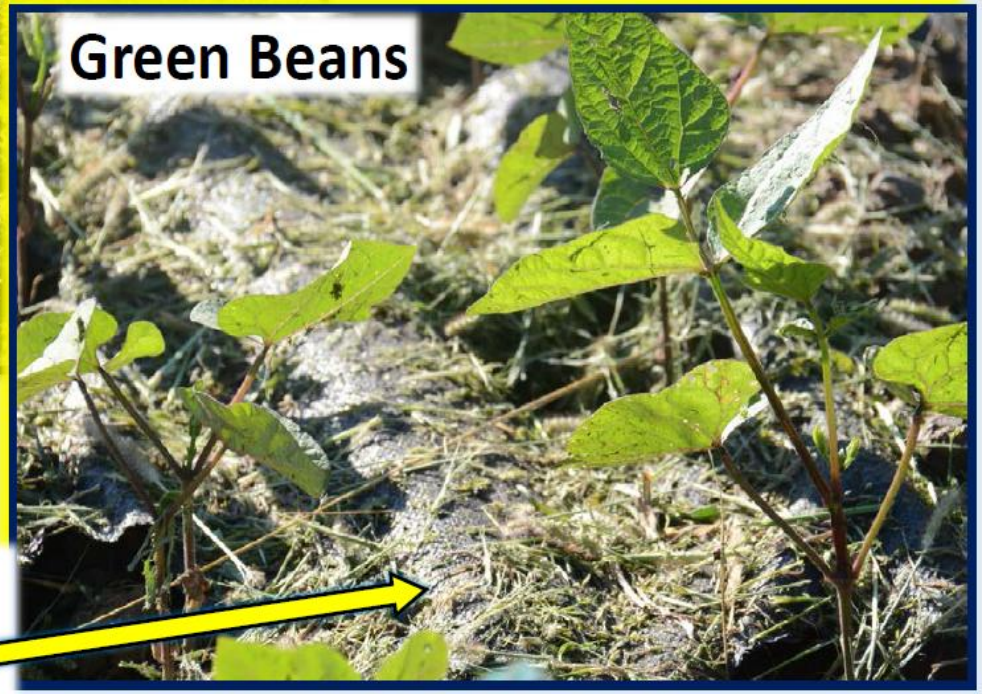
Photos: Rudy Garcia and N. Valley Organics

Tomatoes growing on trellis. Marigolds planted with tomatoes as part of IPM plan.

Notice middle row, which is been prepared for planting another Cash Crop, which will have compost and mulch placed on this row.

Photos: Rudy Garcia and N. Valley Organics

Irrigation Water use is optimized with Fabric Mulch, Straw Mulch, Compost & Surface Drip Irrigation, IWM, and a continual Soil Health Building Program.



Green Beans planted into Fabric Mulch (Straw Mulch will then be applied on top)

Photos: Rudy Garcia and N. Valley Organics

Terminate at an appropriate time

Cover Crop Termination

Terminate the cover crop before or during soil preparation for next main crop.

- At blooming- before seeds
- Wait 1-2 weeks for next crop planting after killing the cover crop.

Connecting Biology & Management

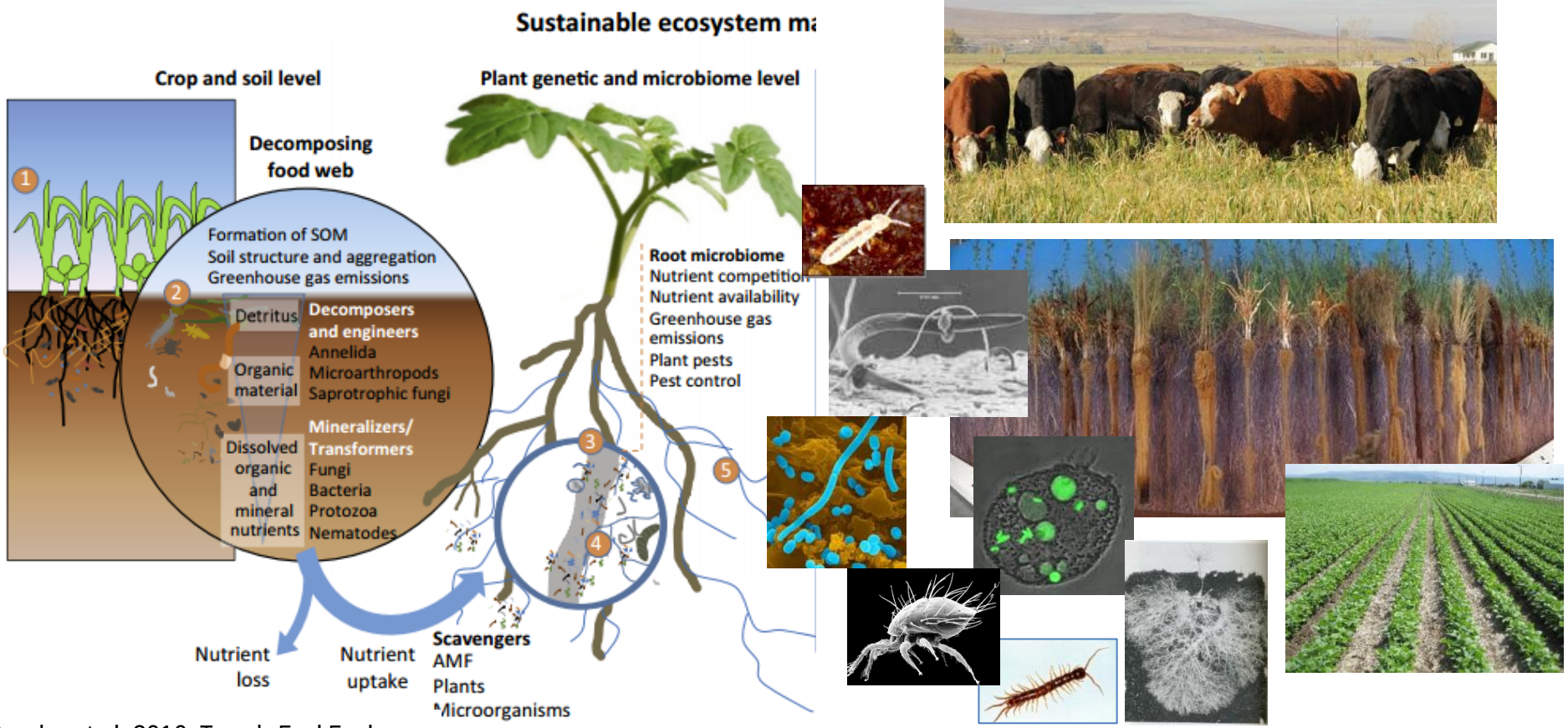
unlock the SECRETS IN THE SOIL

discover THE COVER

do not DISTURB

mix it UP

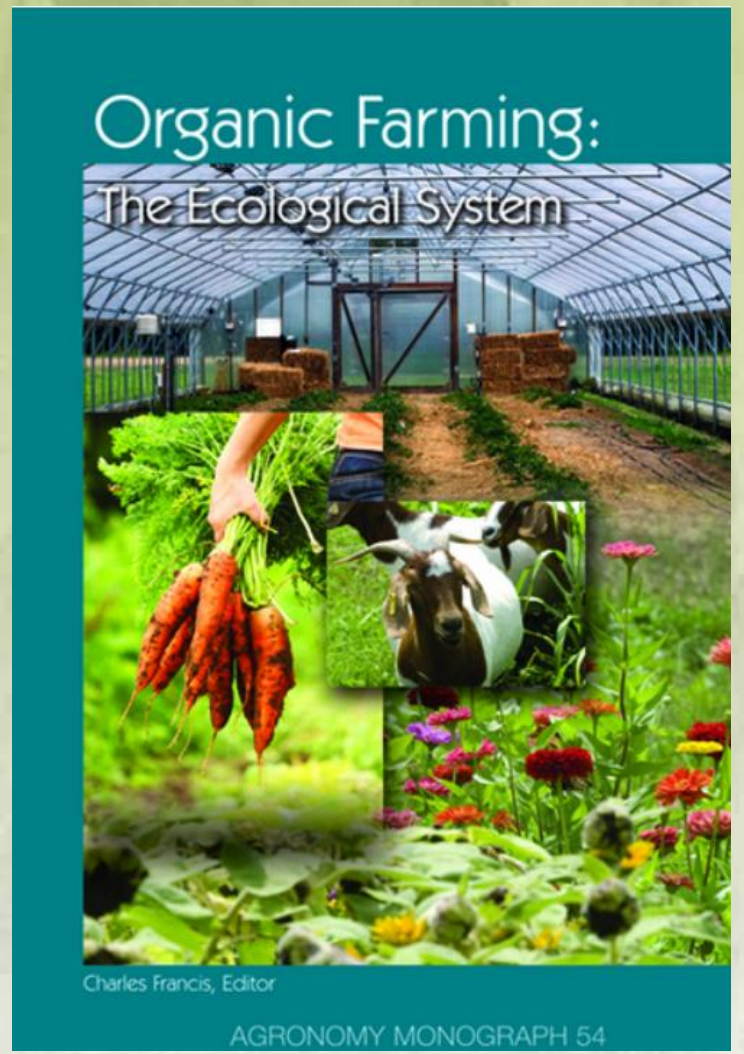
tap into ROOTS

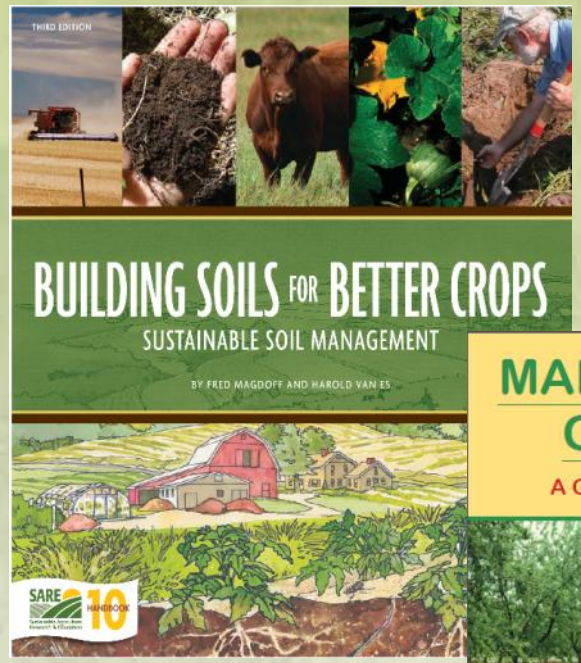


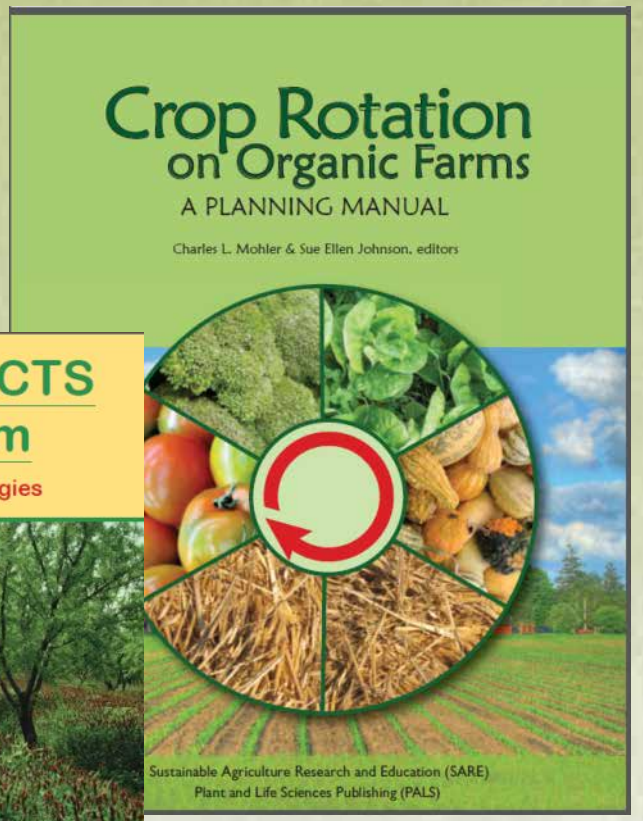
Bender et al. 2016. Trends Ecol Evol.

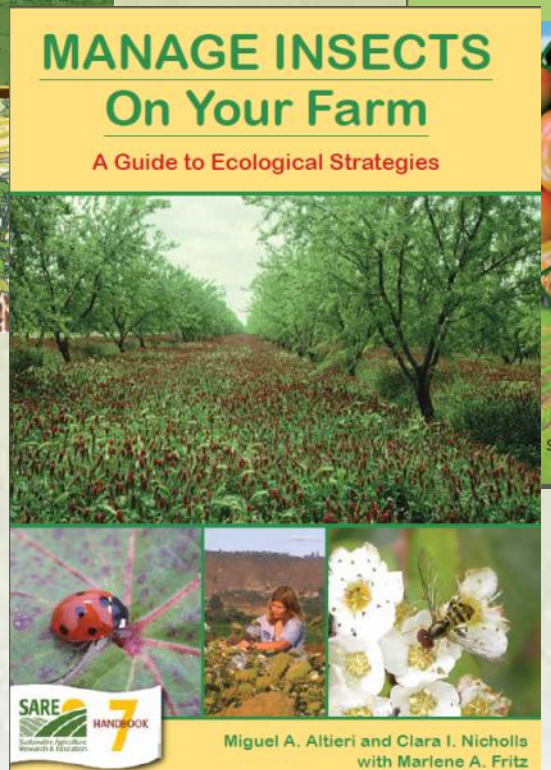
Resources Available

Free e-books from SARE.ORG



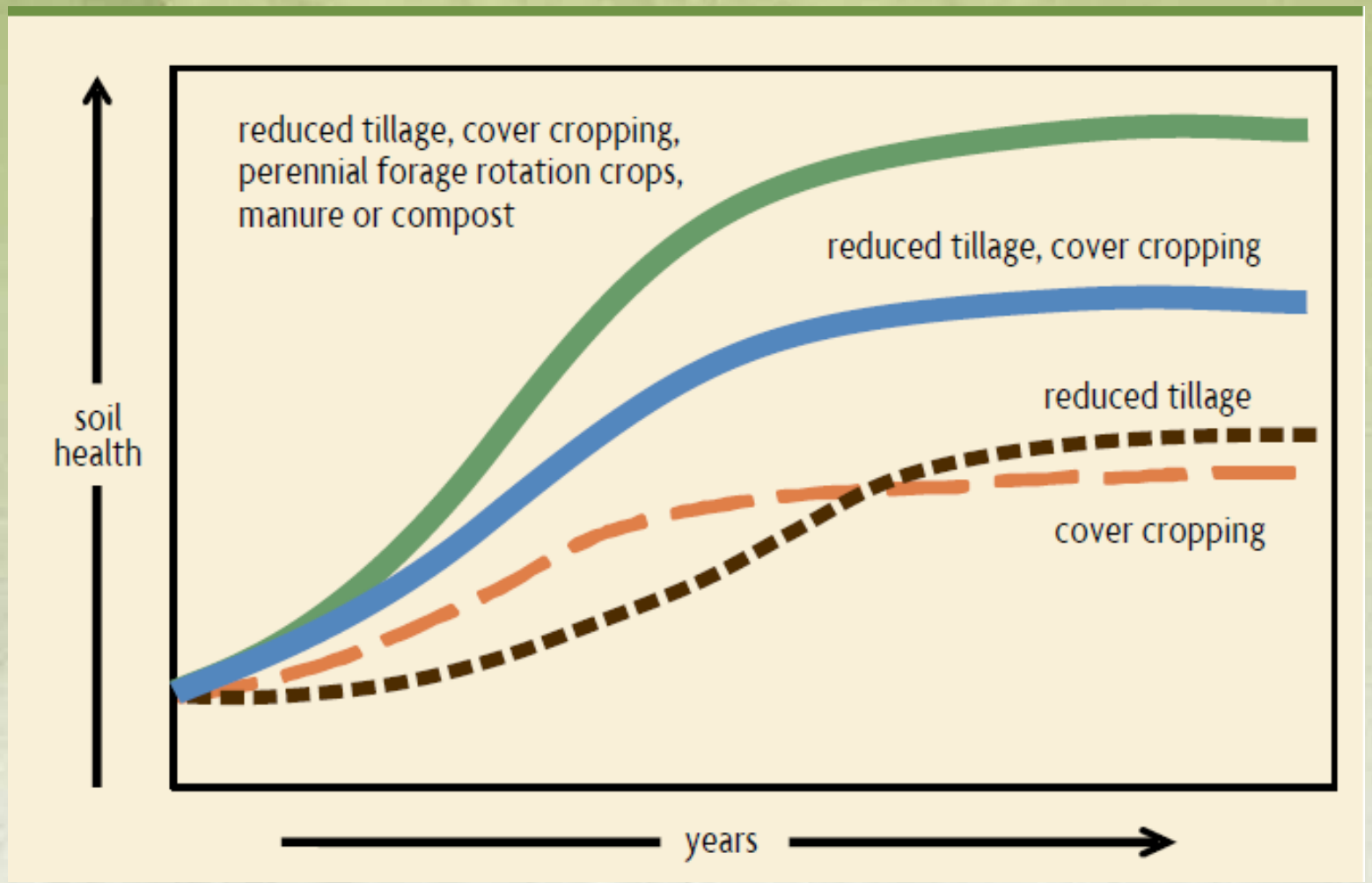






Organic Farming: The Ecological System. (2009). (C. Francis Ed.). Madison, WI: American Society of Agronomy, Crop Science Society of America, Soil Science Society of America

Improvement Over Time



Soil Health Principles

unlock the SECRETS IN THE SOIL