Soil Health & Assessments Training in NM

Part 1: 54 Slides (Total of 108 Slides)

Photo: Rudy discussing Soil Health Assessments with NRCS WEPS Specialist, Rick Fasching (note: Rick does not look too convinced yet). Rick is now retired and was very helpful to NM NRCS.

Rudy Garcia
USDA-NRCS Regional Soil Health Specialist (NM, CO, UT, AZ)

(http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nm/technical/?cid=nrcs144p2_068965)

Goals of the new NRCS Soil Health Division

- **Leverage Partners**

NACD, SARE, TNC, EDF, Soil Renaissance, ARS, NIFA, Hatch, Universities, Nonprofits …

- **Ensure Scientific Basis**
- **Evaluate Economics**
- **Quantify Benefits**

Soil health training
↓
Soil Health Assessment
↓
Soil Health Management Planning
↓
Soil Health Management Systems Implementation
↓
Observation, Adaptation

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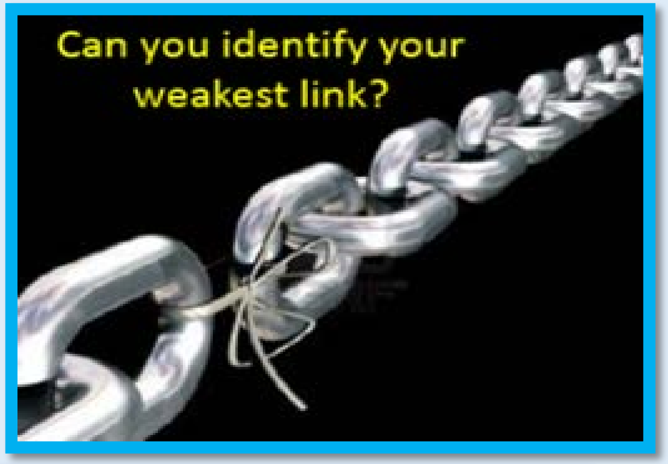
How do we get there?

unlock the SECRETS IN THE SOIL

- Producers and service providers must understand basic processes
- Assess current soil health status
- Develop appropriate plan
- Implement and adjust!
- Need economic info for broader adoption

Photos: NRCS and Dorn Cox, 2012

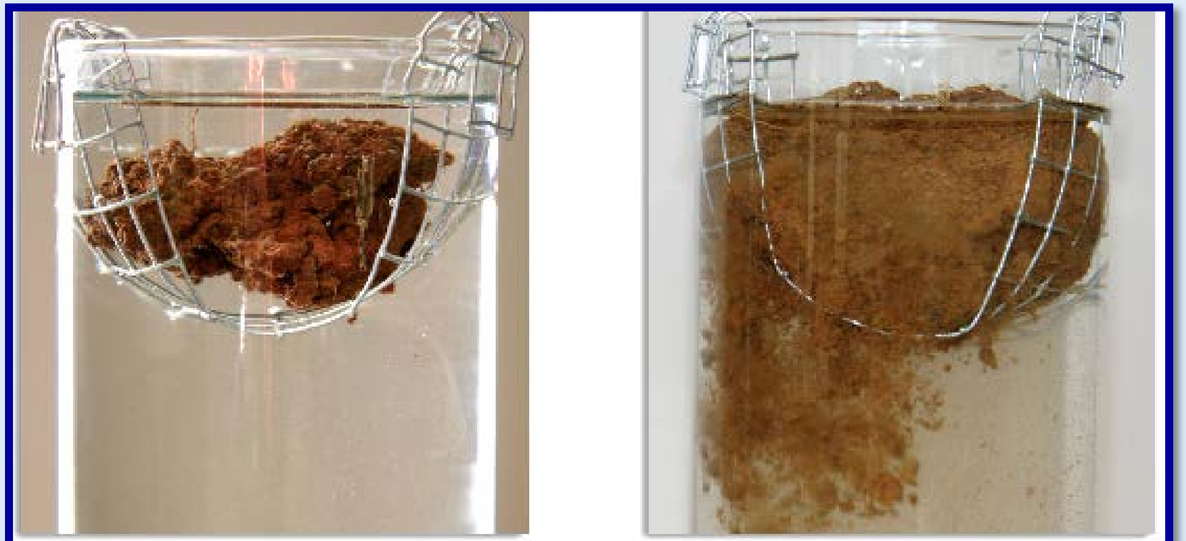
Your System is only as Strong as Your Weakest Link!



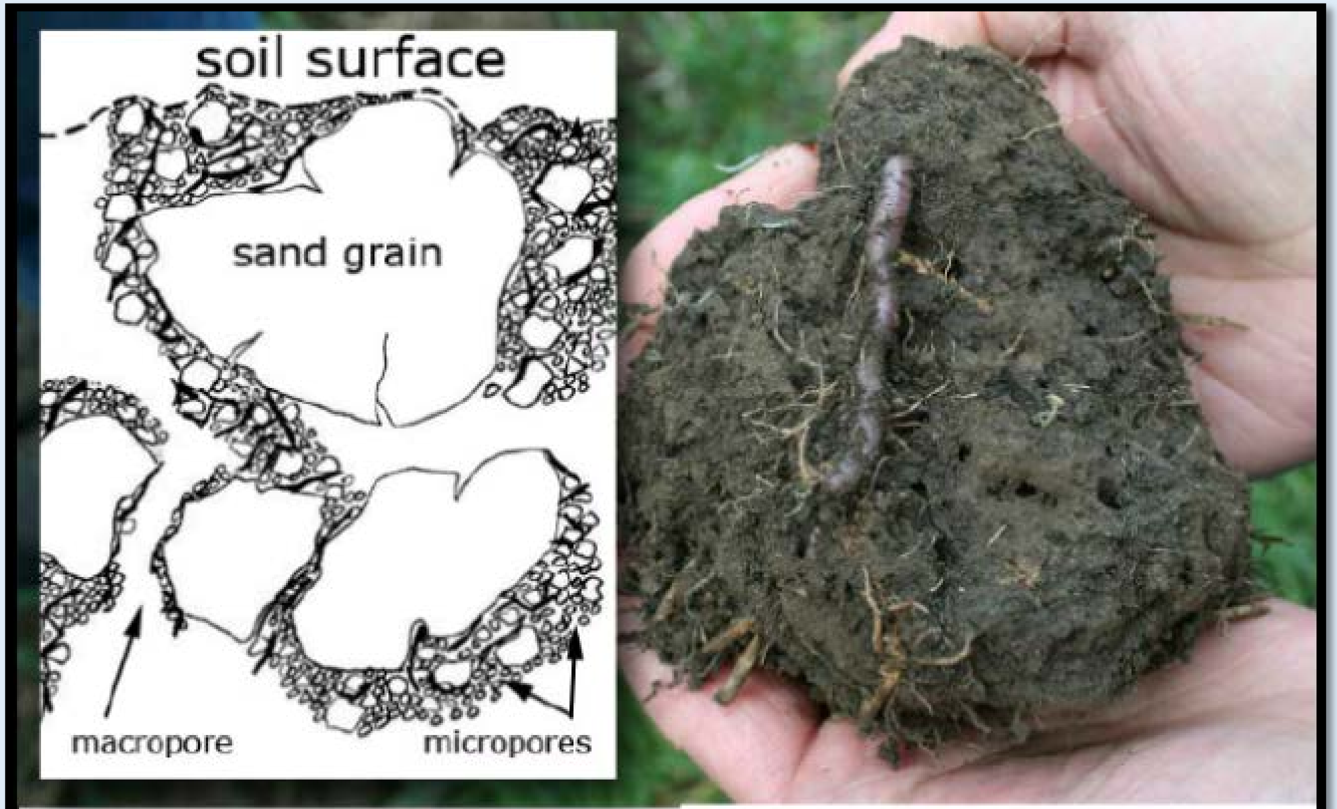
Soil Biology – Plant Interaction

Soil Structure & Macropores

Crumbly structure of surface soil is associated with adequate organic matter content.



Healthy soils are held together by soil glues, or glomalin, that are produced by fungi. Soils rich in soil biota hold together, while soils devoid of soil life fall apart and form a layer of sediment in the bottom of the jar. Pictured above, the soil on the left is from a field that has been managed using no-till for several years. The soil on the right is from a conventionally-tilled field.



High residue and cover crops contribute organic matter to soil, while no-till management helps protect organic matter and allow accumulation. Organic matter provides food for earthworms and other soil biota. All play a role in developing or protecting soil structure and macropores to help soil function at a high level. Inset shows relationship of macro- and micropores to soil aggregates.

Slaking

conventional till corn: low organic matter

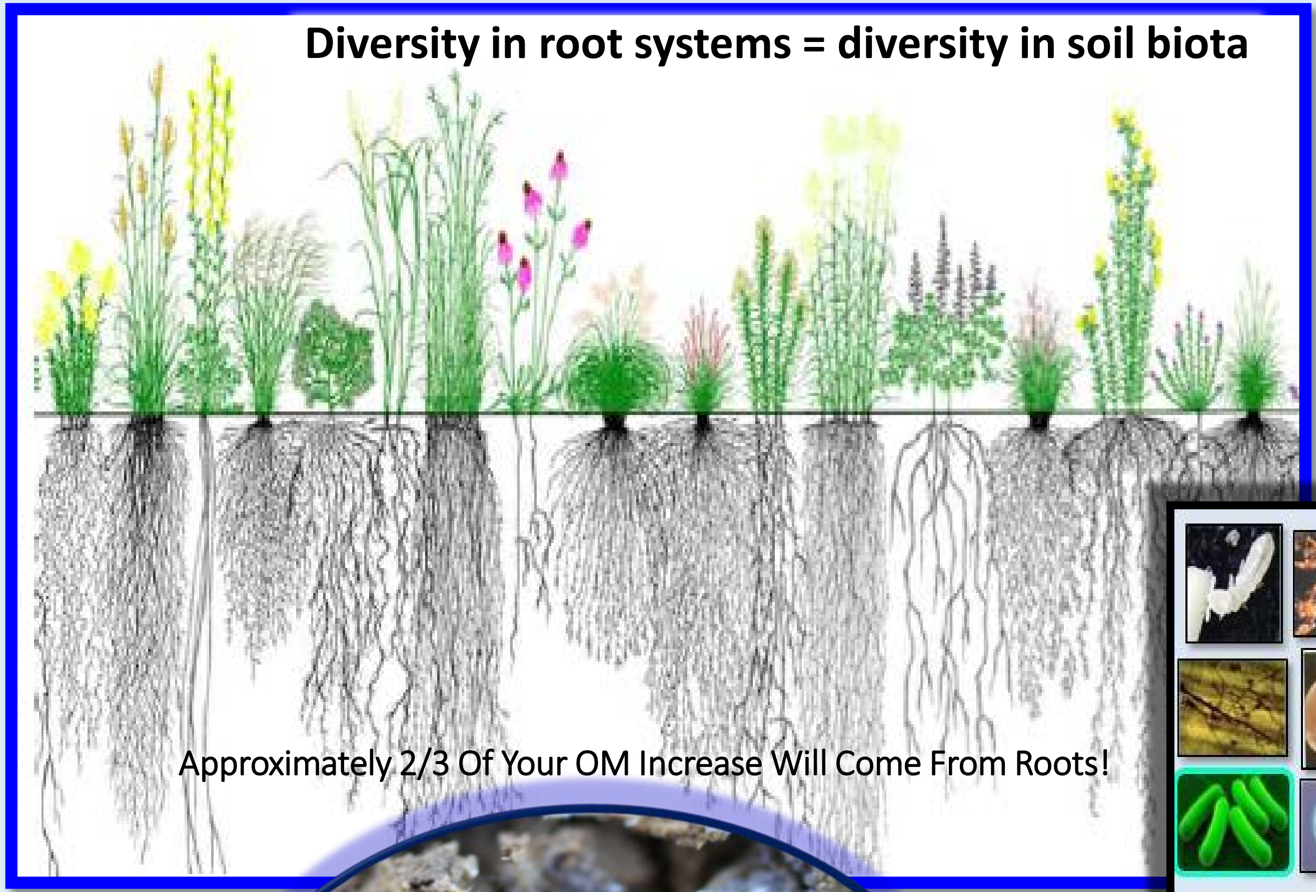
perennial sod: high organic matter

Soil samples collected from 20 year old conventional till corn and perennial bluegrass sod systems were saturated with water and allowed to dry. Note the soil crusting in the low organic matter conventional till sample compared to the abundance of stable aggregates in the high organic matter perennial sod sample. Photo courtesy Ray R. Weil, University of Maryland.

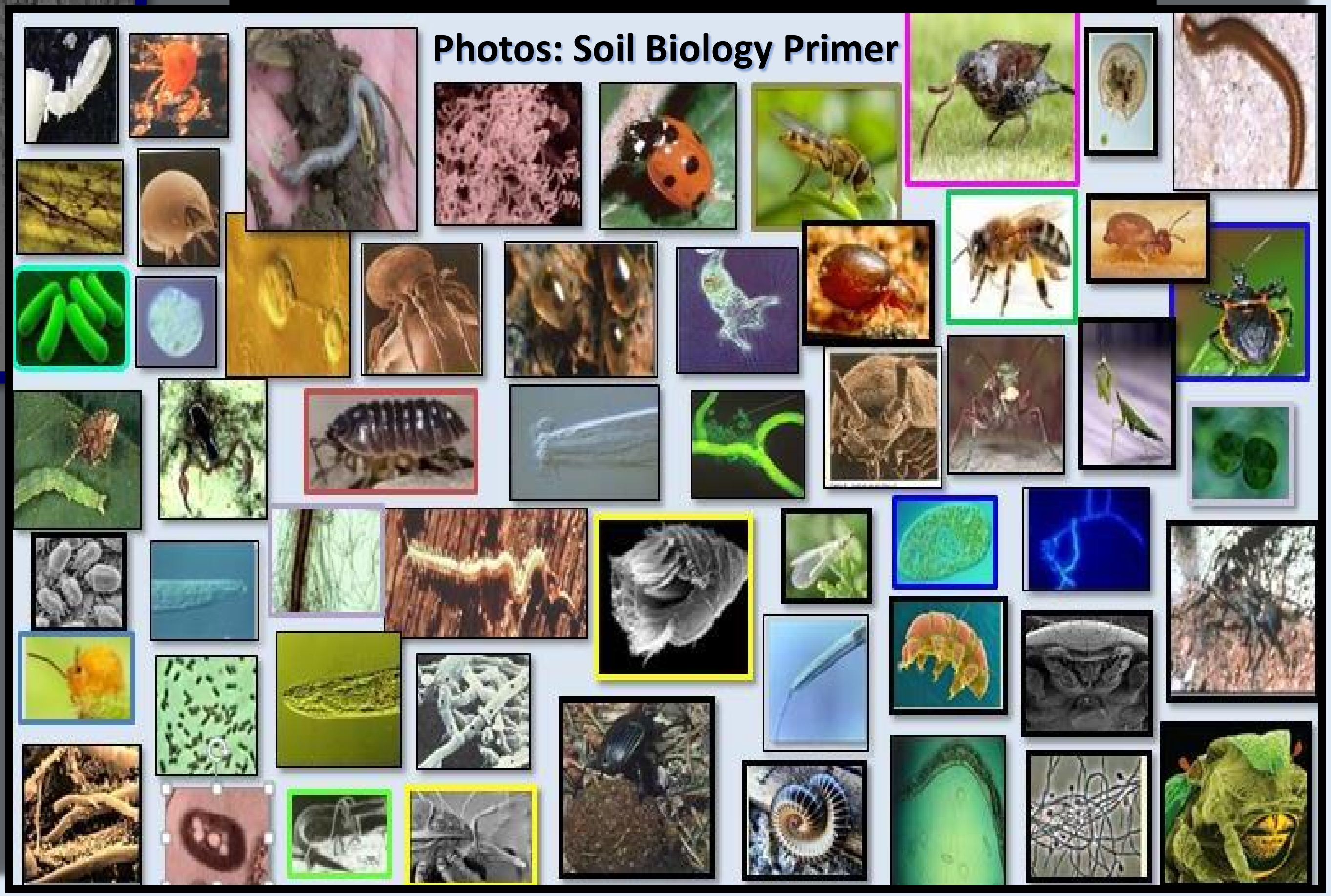
Ref.: NRCS Soil Quality Indicators

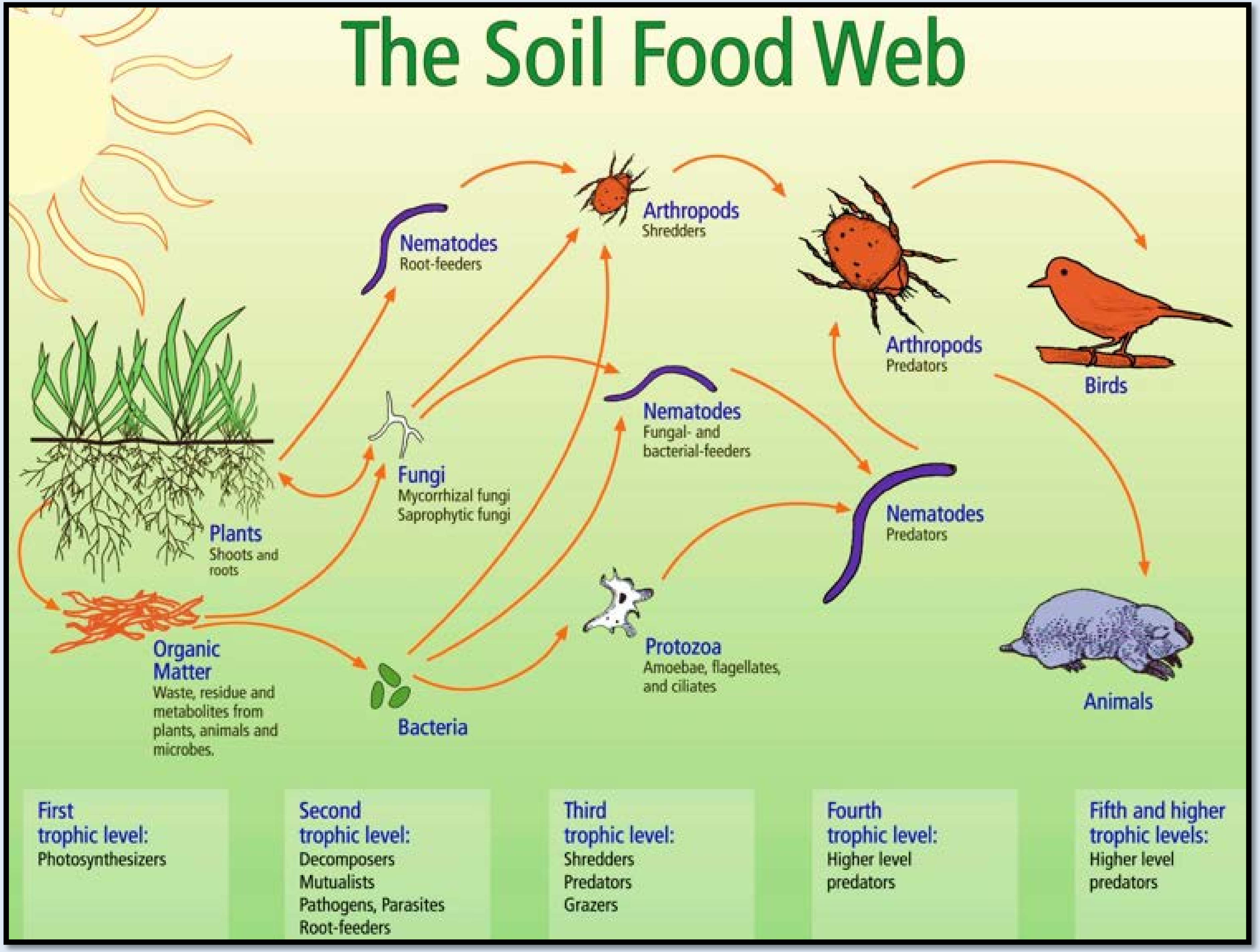
These photos were taken from fields near Davis, California. The soil contains clay with slight to moderate swelling potential. Left: Soil aggregates were collected from a field used to produce dry beans in rotation using organic management. Soil organic matter helps the aggregates resist slaking. Right: Soil aggregates collected from a conventional walnut operation are much less stable and burst apart when rapidly wetted. The walnut orchard is cultivated frequently, which destroys plant residue and prevents accumulation of organic matter.

Diverse Plants = Diverse Soil Food Web = Healthy Soil, when implementing a Soil Health Mgt. System



Diverse Soil Organisms = Healthy Soil
(Are you feeding & caring for your Soil Livestock?)





- All organisms that the plant requires are present and functioning
- Nutrients in the soil are in the proper form for plant up take
- Correct ratio of fungi to bacteria is present

Most people are familiar with the above-ground food web: Plants are eaten by herbivores are eaten by carnivores, and so on. But **most plant matter is not eaten by herbivores; it is decomposed by the underground food web. All plants depend on the soil food web for their nutrition.**

File name: A-3 (145KB). (Also fw.jpg 574K, and fwb.jpg at 422K) Image courtesy of the USDA-NRCS.

Soil Foodweb Inc. 2009

Earthfort
(formally Soil Foodweb)

- Offers a variety of soil biology assessment packages.
    - Each package contains more assays for soil organisms.
- Measure the Biomass of Total Populations in general categories of the functional groups.
- Represent a comprehensive picture of the health and utility of the soil.

Soil
Foodweb Analysis

Report prepared for:
Burleigh Co. Soil Conservation

Report Sent: 07/29/2005
Sample#: 01-100984
Unique ID: GB1
Plant: Corn
Invoice Number: 8357
Sample Received: 07/14/2005

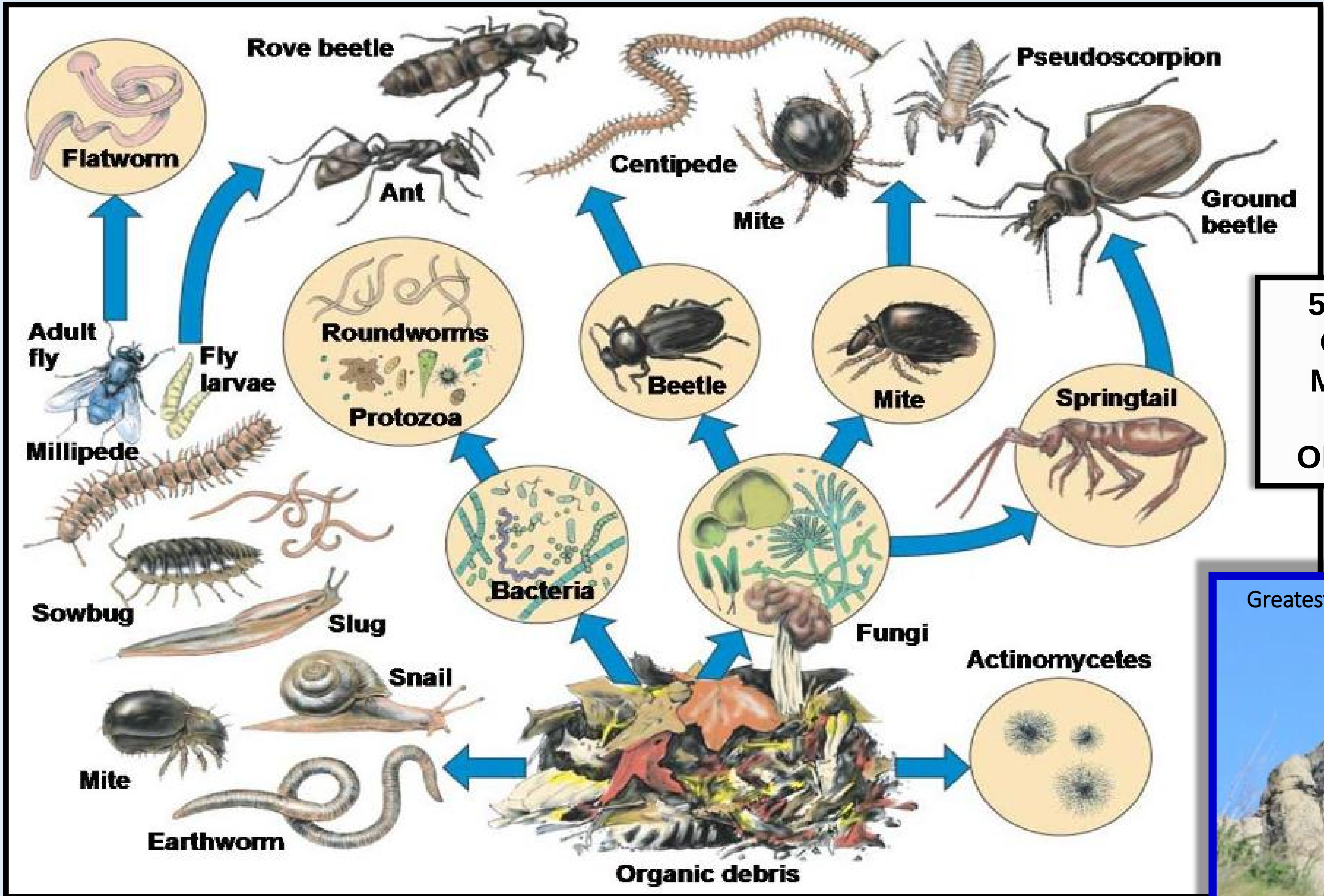
For interpretation of this report please contact:
Local Advisor: or regional lab
Soil Foodweb, Inc
info@soilfoodweb.com
(541) 752-5066
Consulting fees may apply

Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		0.850	46.3	405	5.24	274	2.5
Comments		To Wet	Excellent	Excellent	Low	Good	
Expected Range	Low	0.45	15	100	15	100	
	High	0.85	25	300	25	300	

		Protozoa Numbers/g			Total Nematodes #/g	Percent Mycorrhizal Colonization	
		Flagellates	Amoebae	Ciliates		ENDO	ECTO
Results		178500	9736	331	4.45	31%	0%
Comments		High	Low	High	Low	Low	Low
Expected Range	Low	10000	10000	50	20	40%	40%
	High			100	30	80%	80%

Organism Biomass Ratios		Total Fungal to Total Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Active Bacterial	Plant Available N Supply
Results		0.68	0.02	0.11	0.11	200+
Comments		Low	Low	Low	Low	
Expected Range	Low	0.8	0.25	0.25	0.75	
	High	1.5	0.95	0.95	1.5	

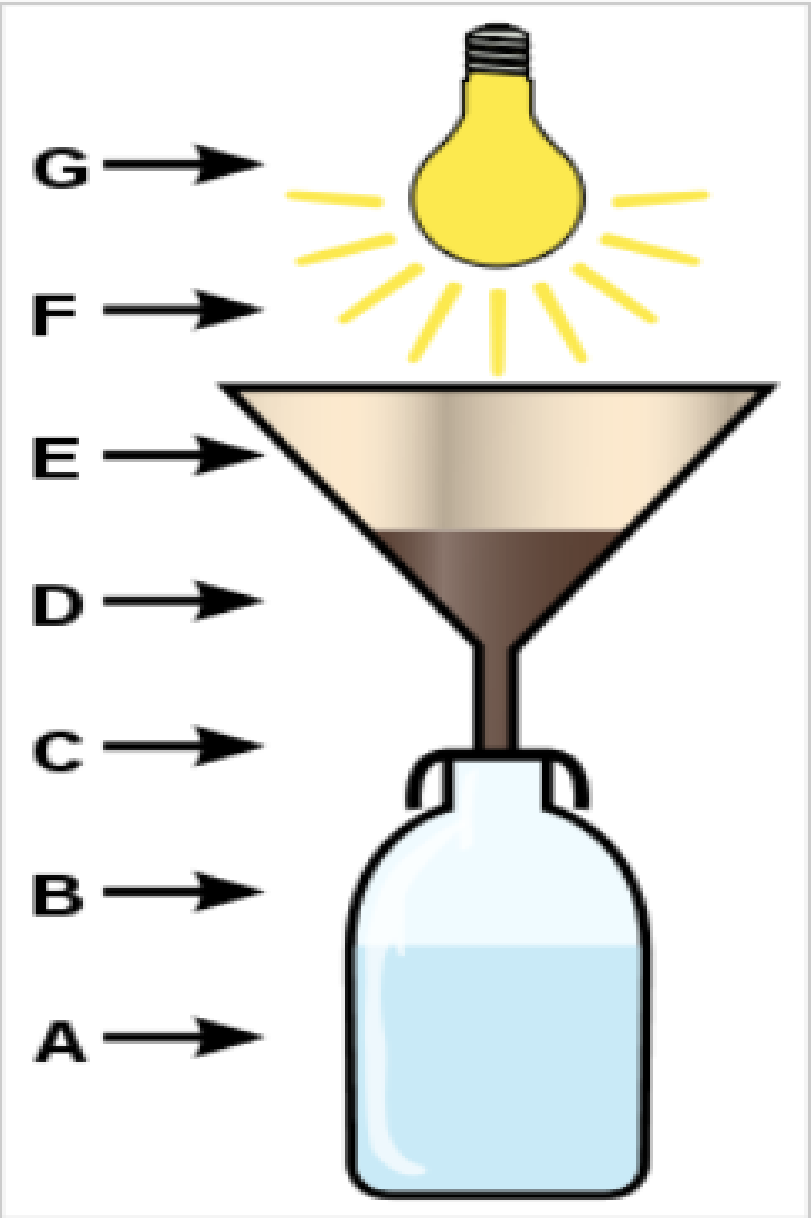
Nematodes per Gram of Soil identification to genus		
Bacterial Feeders		
Acrobeles		0.81
Acrobeloides		0.18
Cephalobus		0.45
Cervidellus		0.18
Rhabditidae		0.45
Fungal Feeders		
Eudorylaimus		0.09
Fungal/Root Feeders		
Aphelenchoides	Foliar nematode	0.54
Aphelenchus		0.45
Ditylenchus	Stem & Bulb nematode	0.54
Filenchus		0.09



5% OF SOIL ORGANIC MATTER IS LIVING ORGANISMS

Greatest Geological Force is “Life” itself!

http://www.rw.ttu.edu/2302_butler/chapter6.htm



The Berlese funnel is used to extract organisms from soil.

A **Tullgren funnel**, also known as **Berlese funnel** or **Berlese trap**, is an apparatus used to extract living organisms, particularly arthropods, from samples of soil. The Tullgren funnel works by creating a temperature gradient over the sample such that mobile organisms will move away from the higher temperatures and fall into a collecting vessel, where they perish and are preserved for examination. The illustration shows how it works: a funnel (E) contains the soil or litter (D), and a heat source (F) such as an electric lamp (G) heats the litter. Animals escaping from the desiccation of the litter descend through a filter (C) into a preservative liquid (A) in a receptacle (B). This illustration is merely a schematic, since usually the soil sample will not be crumbled and poured into the funnel (this would inevitably lead to a high amount of soil particles in the preservation fluid requiring laborious work to sort out the soil organisms). In fact, the soil sample is placed on a mesh sieve that will allow the soil animals to pass but should retain most of the soil particles.

Costa Rica
150 Plants & Animals
24 Hours - Forest

Cape Town, South Africa
100 Plants & Animals
24 Hours - Grassland

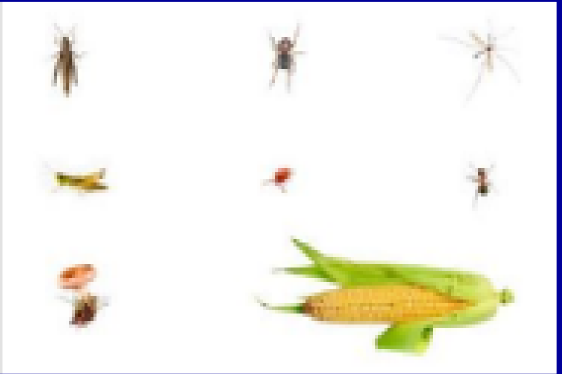
Build it… they will come!

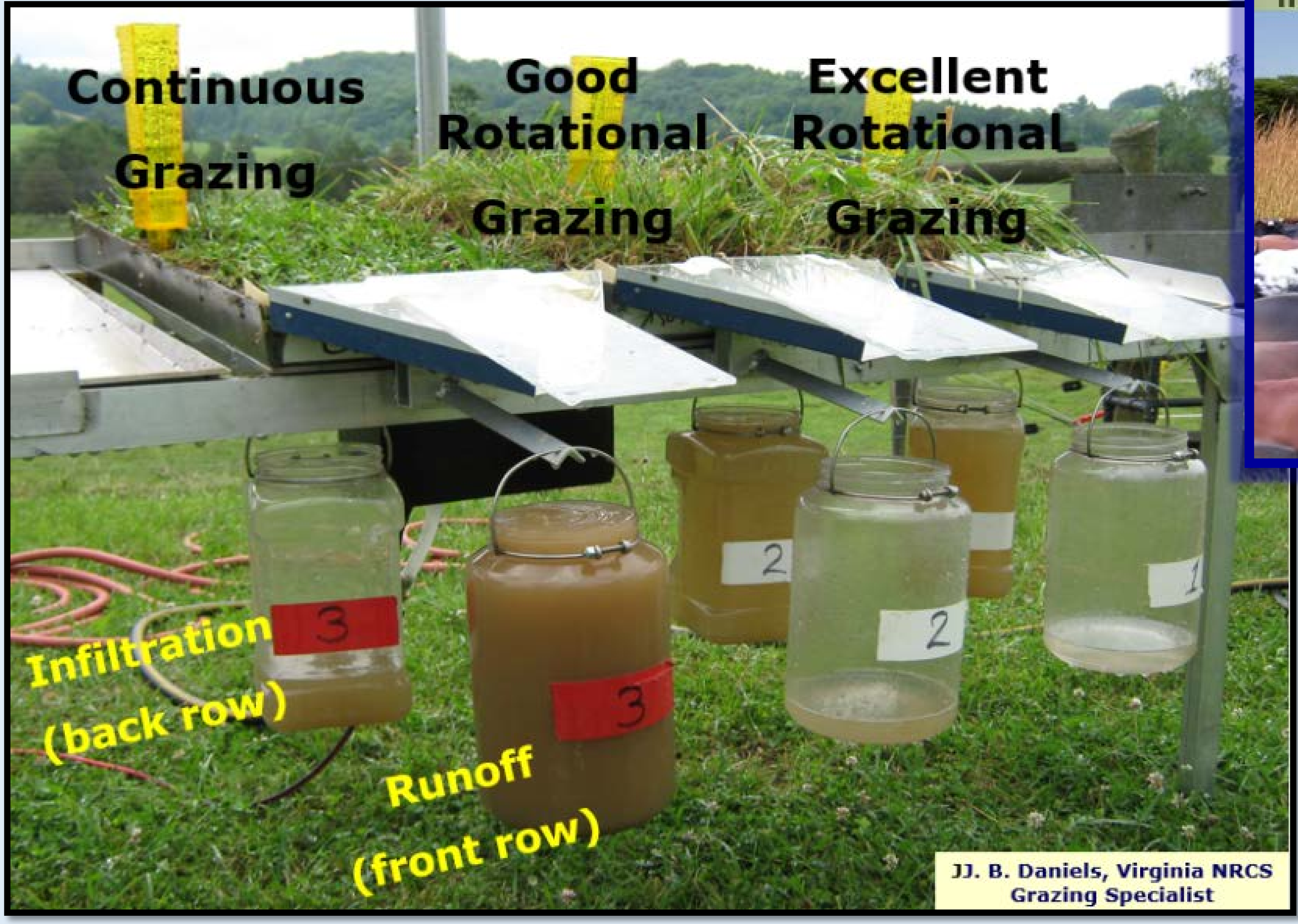
162,000 weed seeds/ 1 sq. meter of a farm field. 137,000 to 161,000 predators per acre of corn canopy.

Approximately 10 percent of weed seeds are eaten per day by Millipedes, Small crickets, Isopods, Field Crickets an Carabid Beetles.

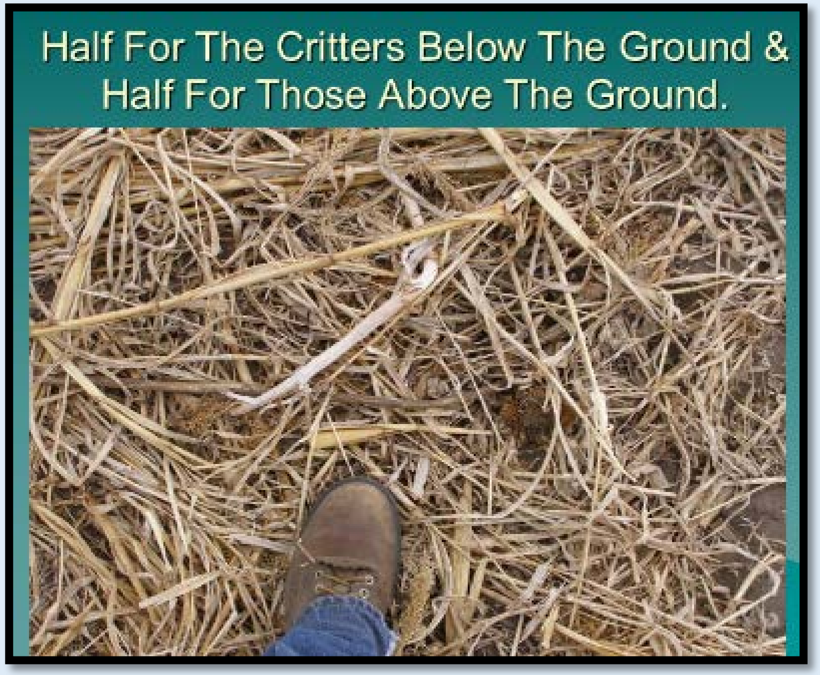
Jan 9, 2015. Dr. Jonathan Lundgren SD ARS/USDA.

Iowa Corn Field
8 Plants & Animals
24 Hours




Continuous
Grazing
Good
Rotational
Grazing
Excellent
Rotational
Grazing
3
3
2
2
1
Infiltration
(back row)
Runoff
(front row)
JJ. B. Daniels, Virginia NRCS
Grazing Specialist


Increase nutrient cycling: Herd Impact
Allan Savory


Half For The Critters Below The Ground &
Half For Those Above The Ground.

Rainfall Simulator Demonstration

Runoff and

Erosion Results

Did You Know?

Soil stability serves as a qualitative indicator of soil biological activity, energy flow, and nutrient cycling. Binding of soil particles must constantly be renewed by biological processes.

Rainfall Simulator Demonstration

Infiltration Results

Ref.: Ray the Soil Guy

Infiltration

Ref.: NRCS Soil Quality Indicators

Table 1. Steady infiltration rates for general soil texture groups in very deeply wetted soil. (Hillel, D. 1982. Introduction to soil physics. Academic Press, San Diego, CA)

Soil Type	Steady Infiltration Rate (in/hr)
Sands	> 0.8
Loams	0.2 - 0.4
Clays	0.04 - 0.2

A one inch layer of water is added to a six inch diameter ring to measure infiltration rate.

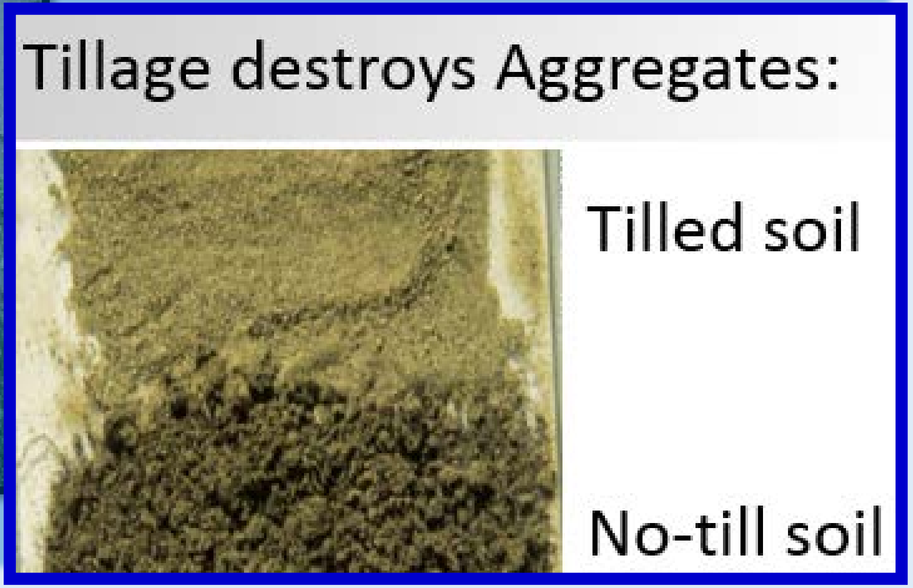
Table 3. Infiltration rates and classes.

Infiltration rate (minutes per inch)	Infiltration rate (inches per hour)	Infiltration class
< 3	> 20	Very rapid
3 to 10	6 to 20	Rapid
10 to 30	2 to 6	Moderately rapid
30 to 100	0.6 to 2	Moderate
100 to 300	0.2 to 0.6	Moderately slow
300 to 1,000	0.06 to 0.2	Slow
1,000 to 40,000	0.0015 to 0.06	Very slow
> 40,000	< 0.0015	Impermeable

This picture shows two fields, one on each side of a fence, in Brookings County, SD. The soil was saturated from a series of rain events.

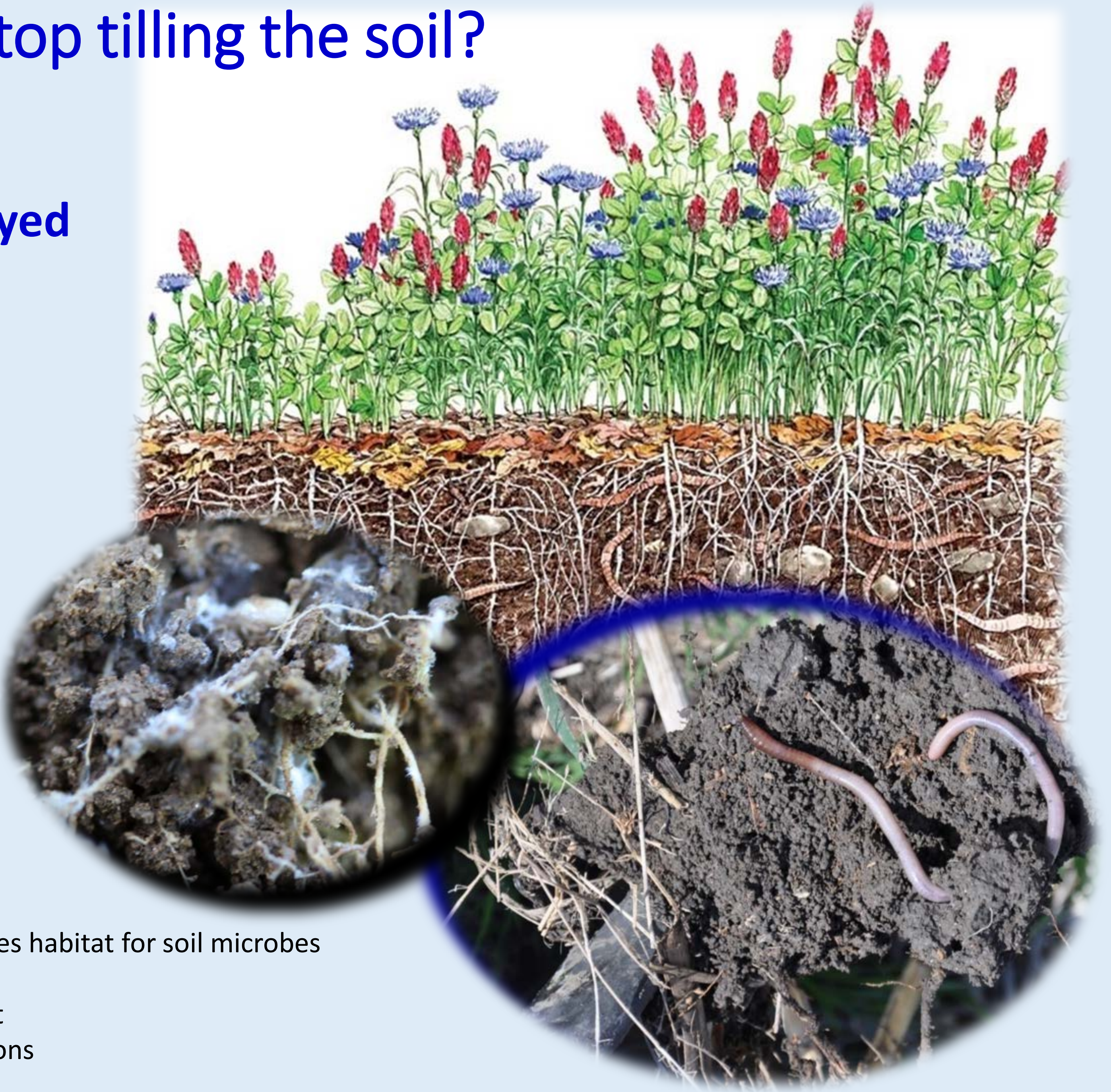
Hours after a storm left almost another inch of rain, water in the no-till field was able to infiltrate into the soil.

By contrast, the adjacent field under conventional tillage was still ponded, and had runoff that moved tons of topsoil off the field.



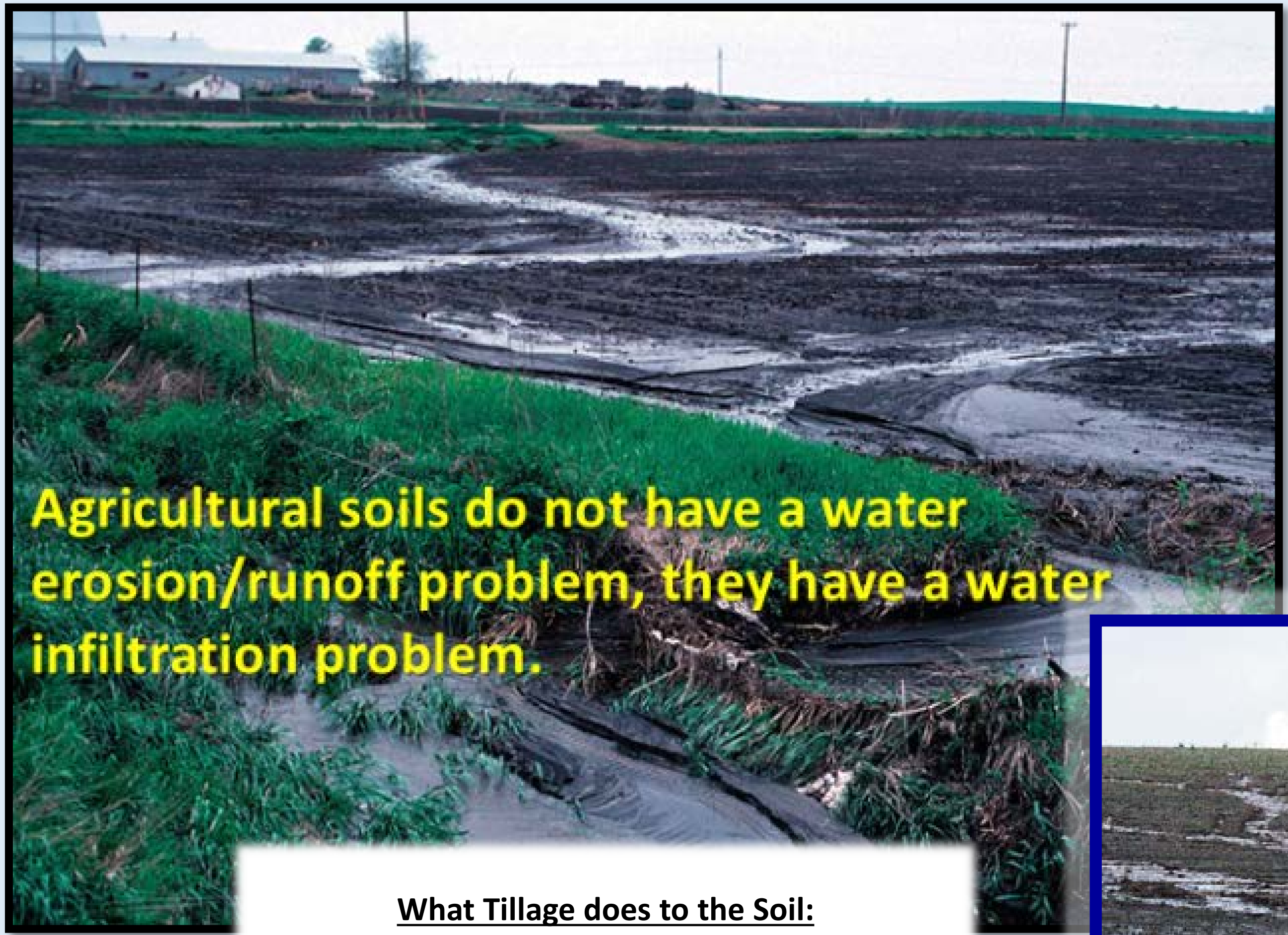
What things change when you stop tilling the soil?

- **Soil pores remain continuous**
- **Soil aggregates form and are not destroyed**
- **Soil Food Web increases and diversifies**
- **Weed seeds are not planted**
- **Water is captured and stored**
- **Bulk density increases slightly; then stabilizes**
- **Soil fungi and earthworms increase**
- **Microarthropods increase (>20% of nutrient cycle)**



Here are positive changes in the soil that occur when you stop tillage:

- **Pores** remain continuous-allows for increased infiltration
- **Aggregates form** – increase soil stability, improves aeration and provides habitat for soil microbes
- **SFW** – adds trophic levels and complexity, increasing functional groups
- **Water** is held in place by increased SOM and held until plants require it
- **Bulk density** decrease over time to levels that approach native conditions
- **Soil organisms** flourish because there habitat is not being destroyed



- NRCS has always tried to deal with the runoff at the field level, accepting the fact that runoff occurs
- NRCS has tried to deal with poor infiltration and excess runoff by designing waterways, terraces, diversions that allow runoff to safely leave a field without causing gully erosion.
- Improving soil health will improve infiltration and reduce surface runoff
- Managing for Soil Health treats the problem of soil dysfunction.
- We must have a soil that will infiltrate water where the rain drop lands not were it leaves the field.

<u>What Tillage does to the Soil:</u>

- **Destroys aggregates**
- **Exposes organic matter to decomposition**
- **Compacts the soil**
- **Damages soil fungi**
- **Reduces habitat for the Soil Food Web**
- **Disrupts soil pore continuity**
- **Increases salinity at the soil surface**
- **Plants weed seeds**

What do Your Roots Say?

Healthy Roots:
- **Uninhibited root growth**
- **Lots of fine roots**
- **White (no root pathogens)**

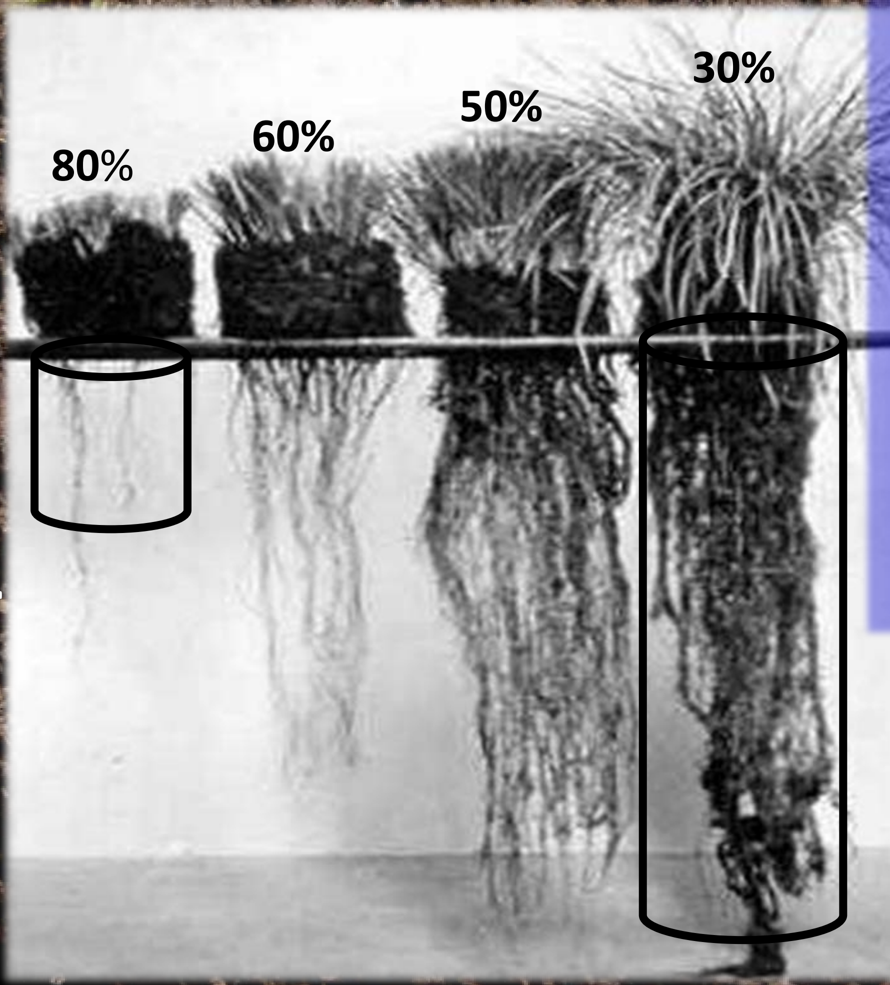
Unhealthy Roots:
- **Restricted root growth**
- **Few fine roots**
- **Short thick roots**
- **Discolored & Lesions (root pathogens present)**

- **Roots are a great indicator of soil conditions**, especially related to compaction.
- Roots should grow uninhibited into the soil profile, generally they hit a compacted layer at varying depths.
- Compacted layers that exceed 300 psi will restrict root growth
- Roots need a pore space greater than 0.1 mm

Improving Plant Health with High Density Grazing

- *Graze fully recovered plants*

- Fully recovered plants have more biomass above- and below-ground
- Plants with more root mass and depth can access water for longer periods of time
- Deeper roots enable plants to allocate minerals from lower in the soil profile

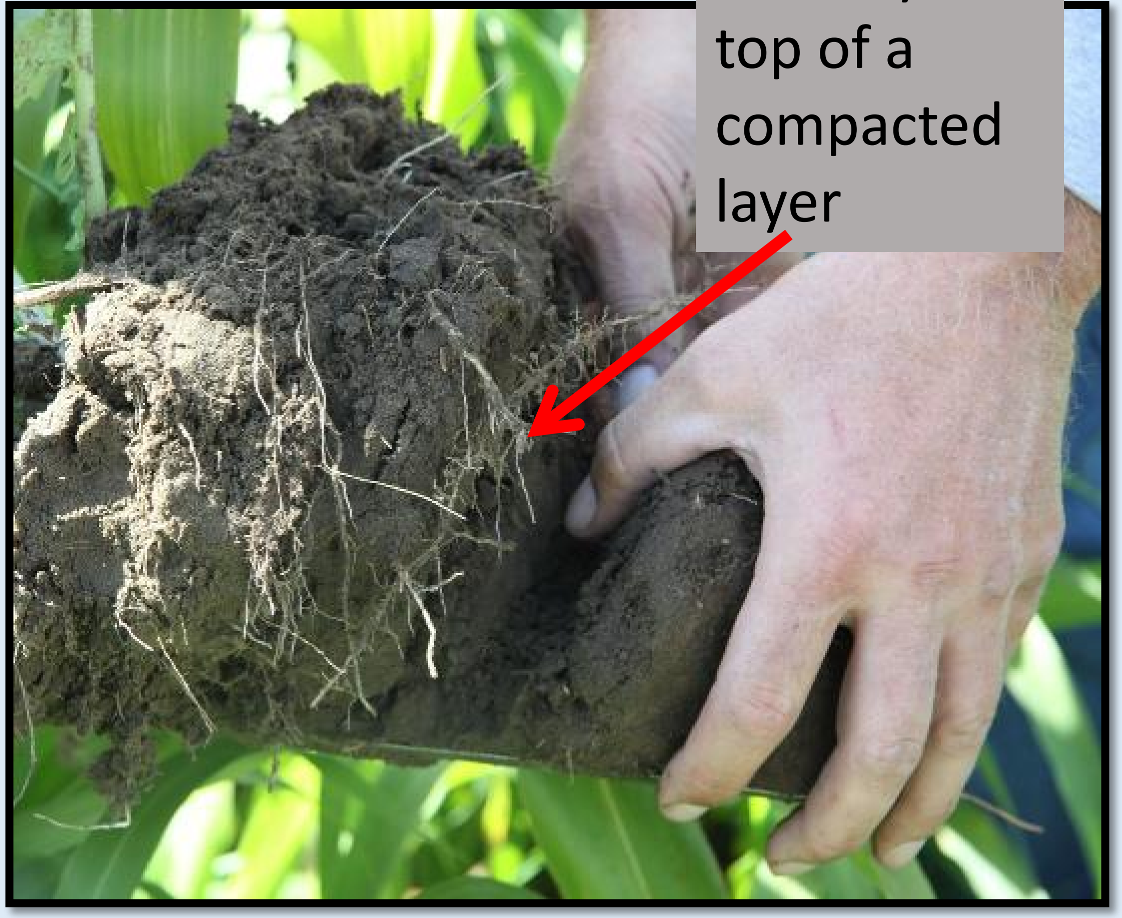


Rhizosphere

- Narrow region of soil directly around roots.
- Living roots release many types of organic materials.
- These compounds attract Bacteria that feed on the proteins & sugars.

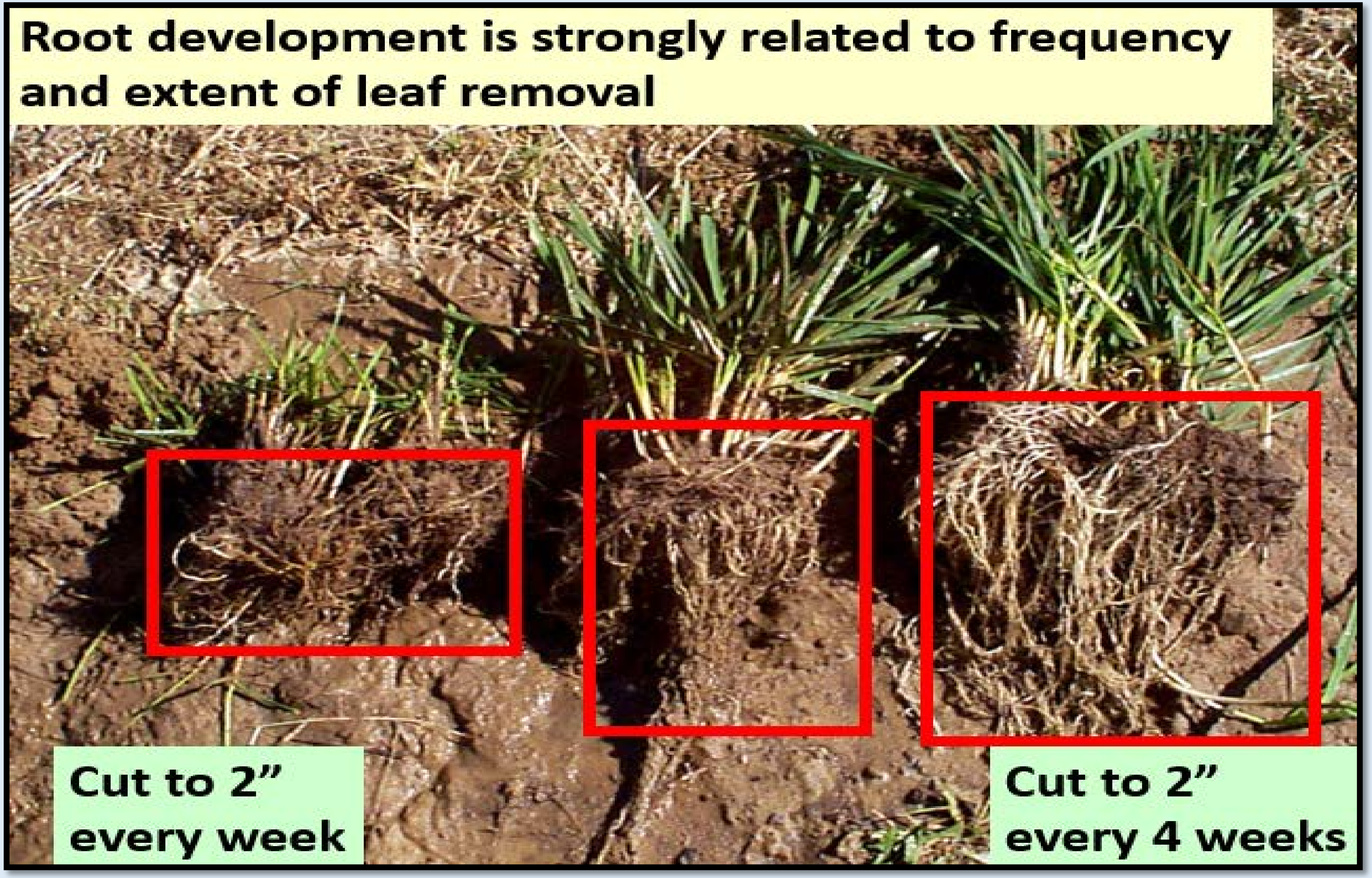
Proper grazing will increase your "bucket". The amount of area/volume the plant can draw from for nutrients and most importantly – water.

Healthy Soil allows for Straight Roots

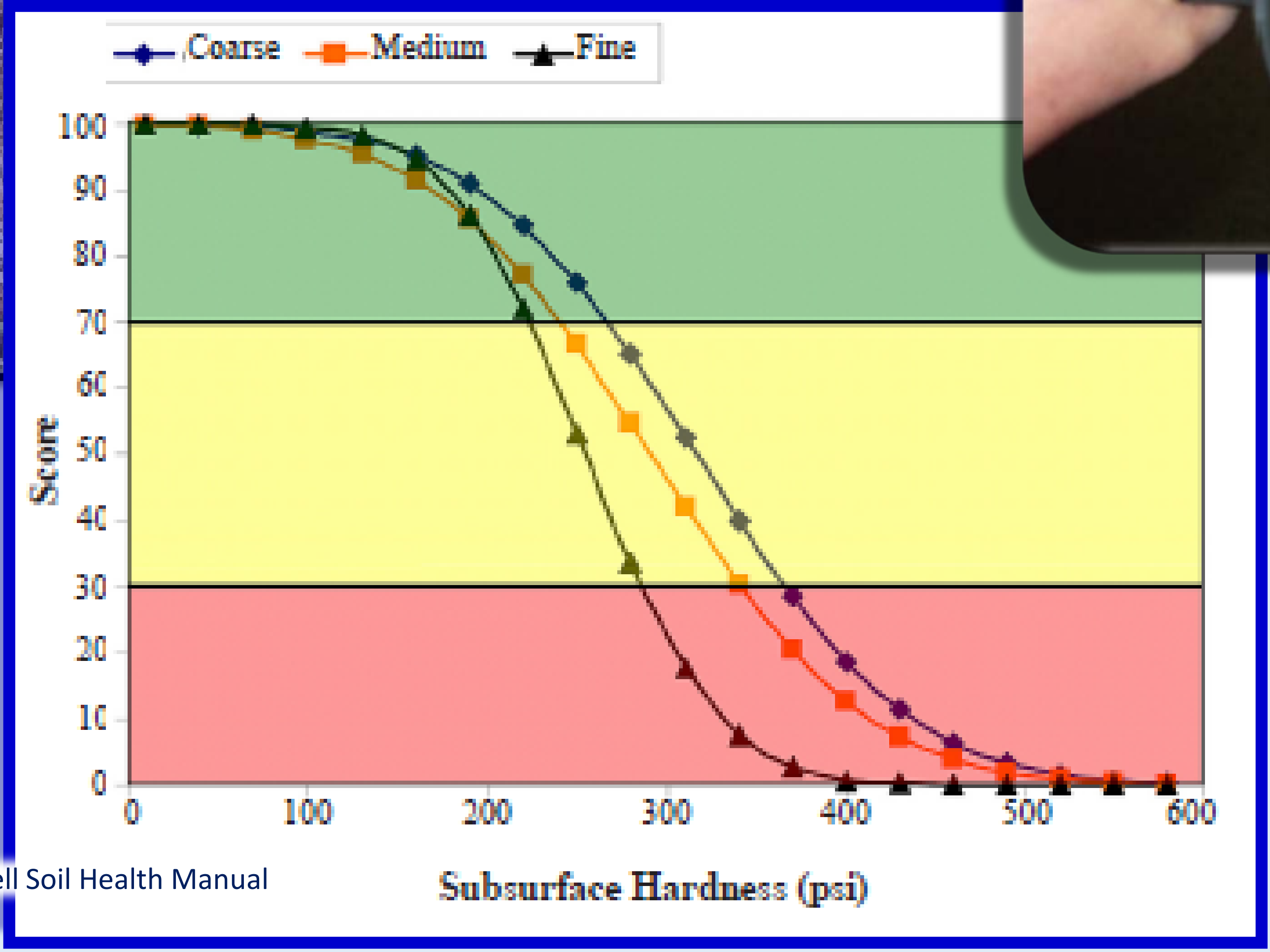


Compacted Layers

Important: use adaptive grazing mgt. with plenty recovery time (don't graze so low; take 50% leave 50% to feed the soil organisms).



How compressed is your soil?



From: Cornell Soil Health Manual

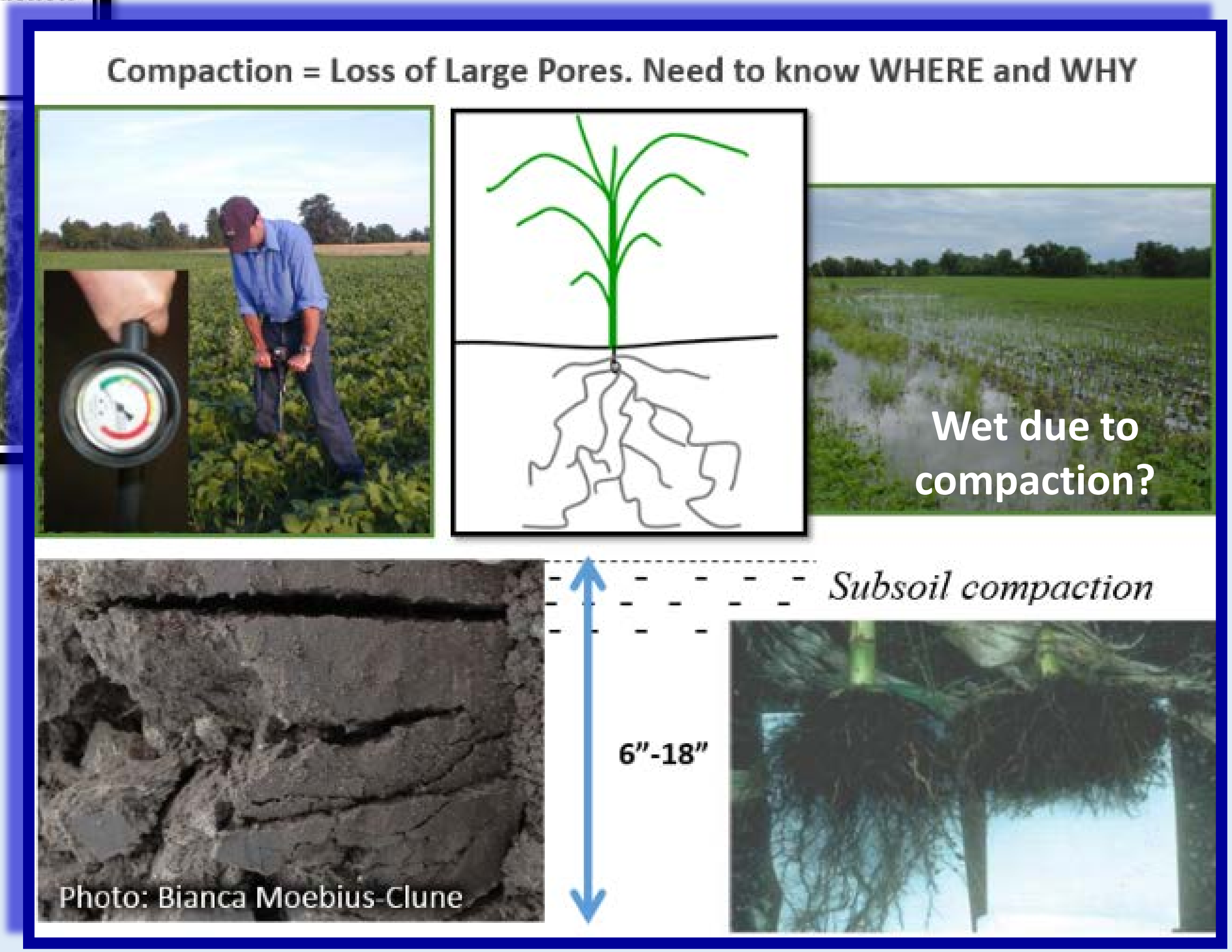
Penetrometer - Measures pressure to penetrate soil

Used to identify:
- **Surface crust**
- **Tightly packed crumbs**
- **Subsoil compacted layers**

Effects of compaction
- **Poor germination**
- **Reduced infiltration**
- **Poor root development**
- **Poor air exchange**

Measuring compaction in the field can be done using:
Penetrometer: measure pressure to penetrate soil on a given day, subject to current soil moisture levels, will vary from day to day.
Could use a survey flag or other type of rod to get a feel for were compacted layer occur, won't give pressure reading but good place to start discussions.
Shovel is another good tool, how hard is it to get into the ground, will stop at compacted layers.


Compaction = Loss of Large Pores. Need to know WHERE and WHY
Plow layer compaction
0-6”


Compaction = Loss of Large Pores. Need to know WHERE and WHY
Wet due to compaction?
Subsoil compaction
6”-18”
Photo: Bianca Moebius-Clune


Which answer to compaction?

Bulk Density

A three inch diameter ring is hammered into the soil to collect bulk density samples. Ref.: NRCS Soil Quality Indicators

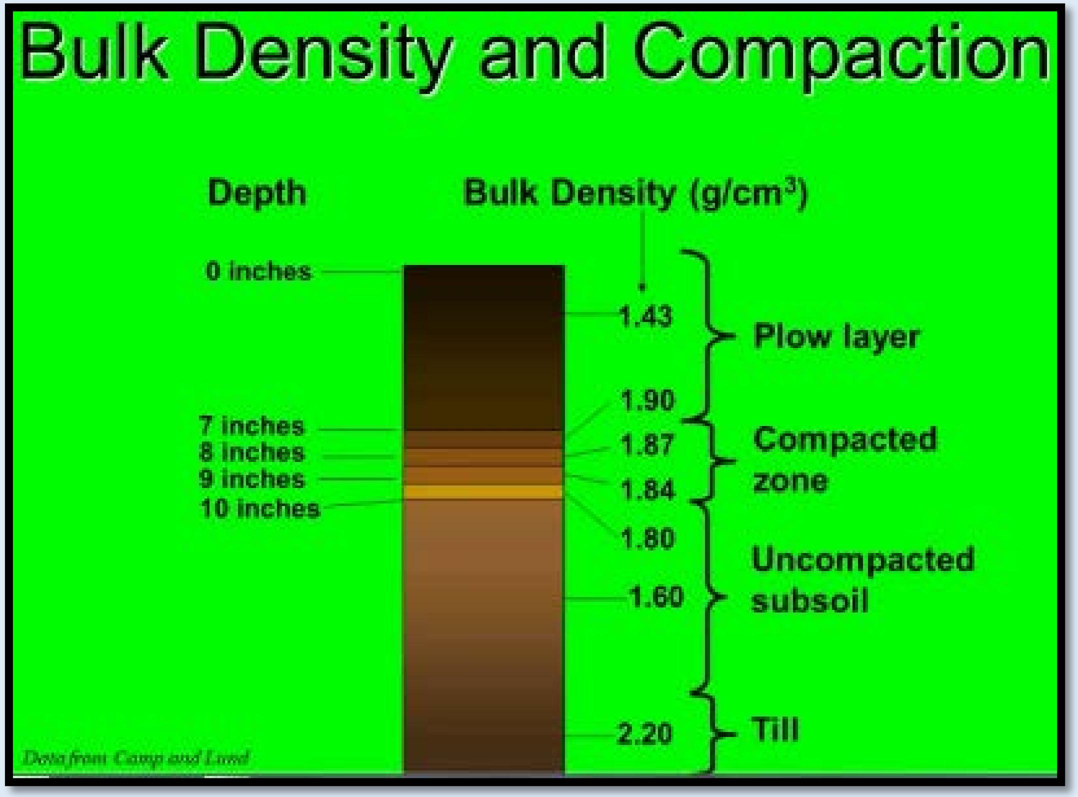
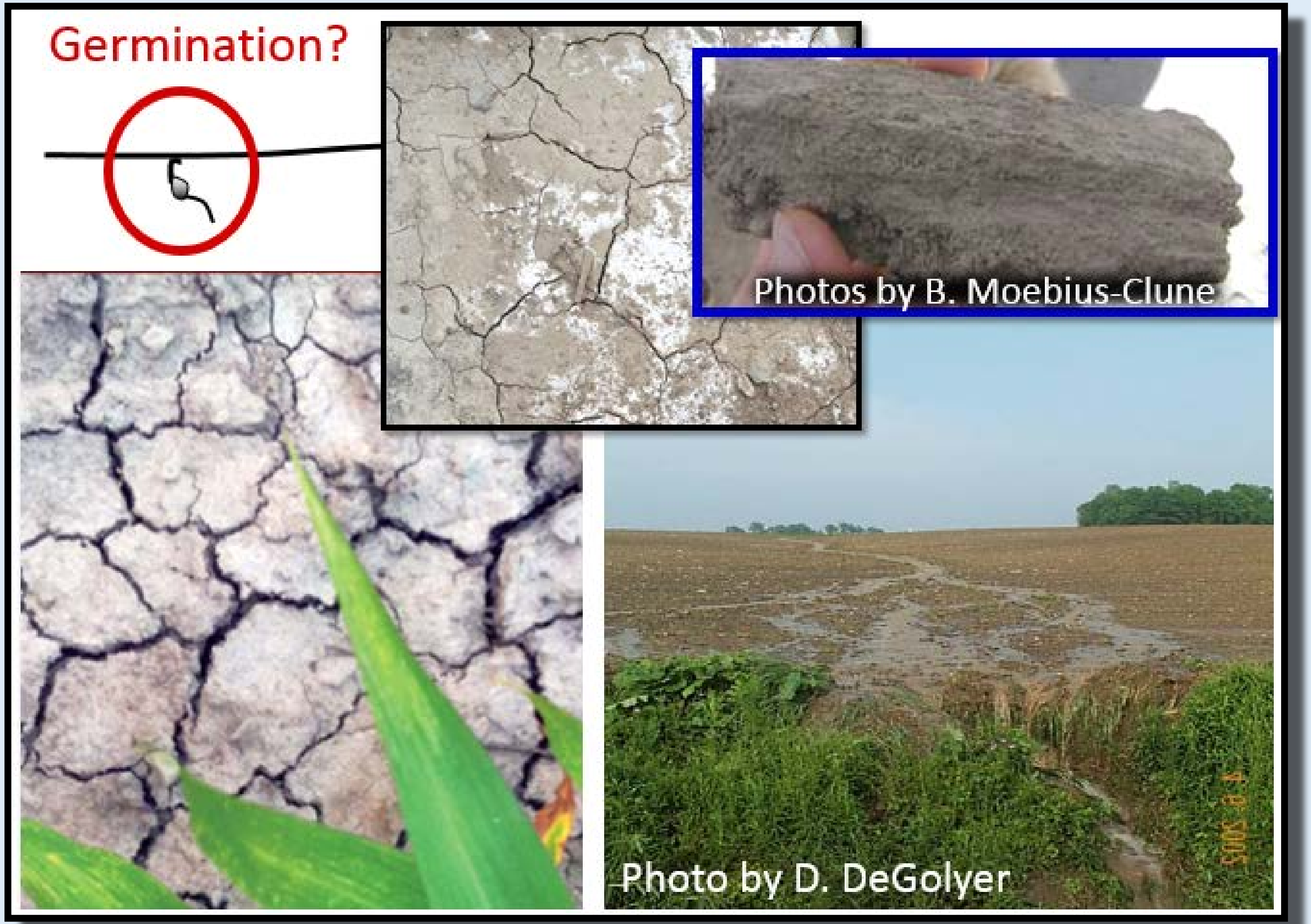
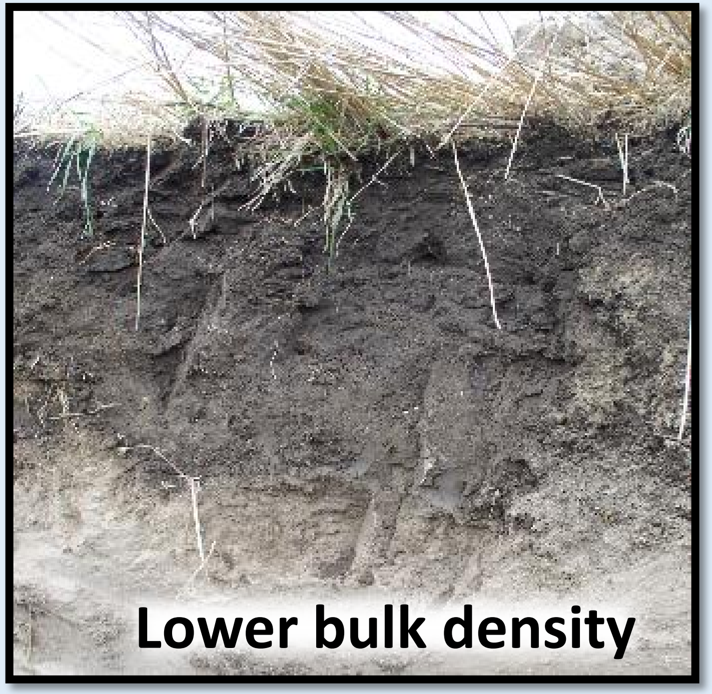


Table 1. General relationship of soil bulk density to root growth based on soil texture.

Soil Texture	Ideal bulk densities for plant growth (g/cm^3)	Bulk densities that restrict root growth (g/cm^3)
Sandy	< 1.60	> 1.80
Silty	< 1.40	> 1.65
Clayey	< 1.10	> 1.47

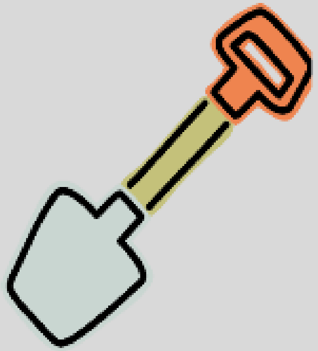

Germination?
Photos by B. Moebius-Clune
Photo by D. DeGolyer


Soil Compaction – soil pit in conventional tilled field, roots growing sideways
Soil Compaction – high bulk density


Lower bulk density

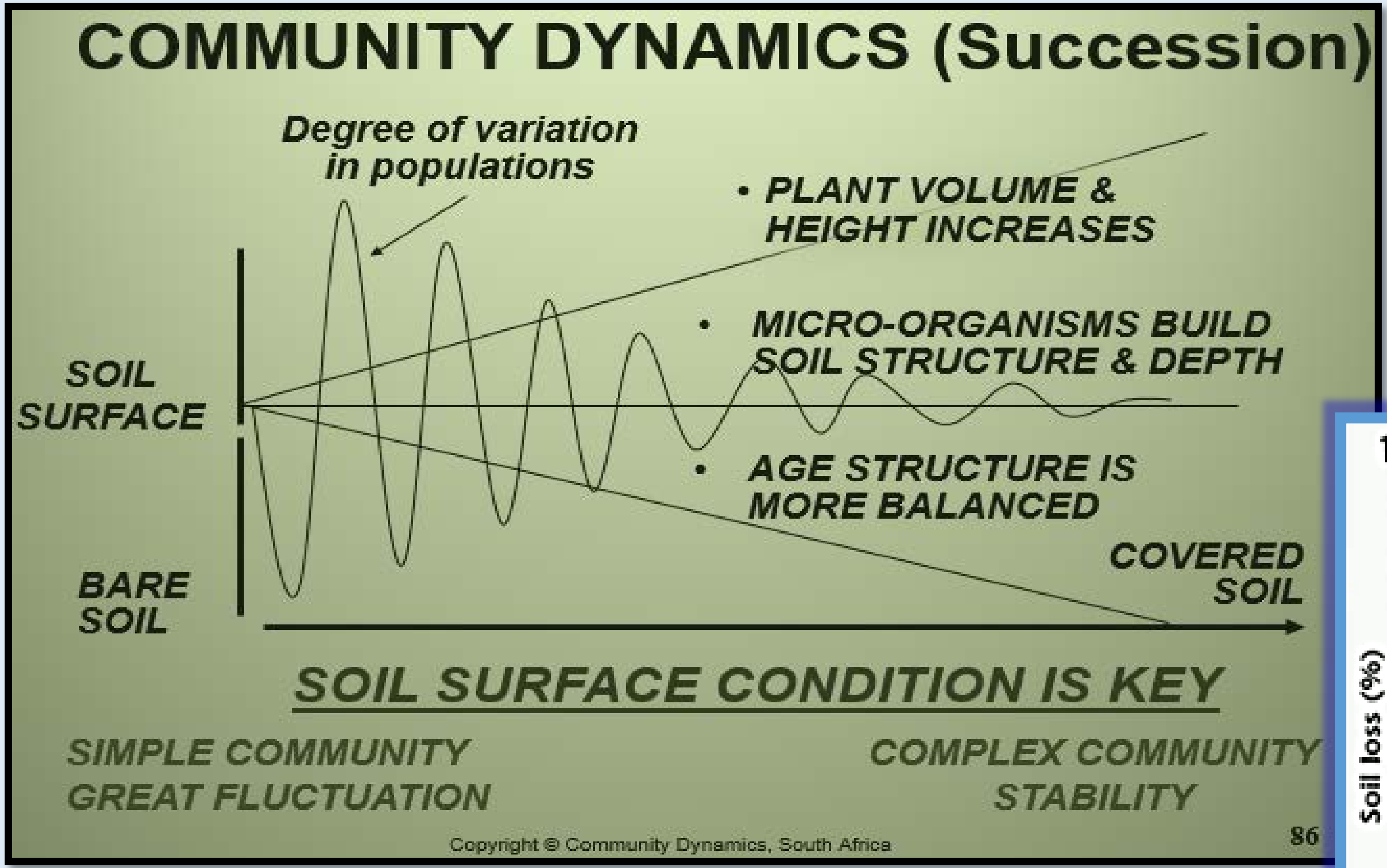
Fields outside the project area: Typical no-till field without cover crops and diversity: Small detritusphere other spheres diminished. Notice the color and horizontal compaction.	**Fields inside the project area:** Ecological farming- no-till with diverse covers (less than 2 years): Notice all 5 well defined spheres present, dark humic color and increased earthworms populations.
	

Shovel:
A Tool to determine soil health



Soil Crusts

Left: Note the surface crust on this soil. The field was in tall fescue sod for 11 years. It was cleared and plowed using conventional tillage methods. Photo courtesy Bobby Brock, USDA NRCS (retired). Right: Collected from a no-till field in Georgia's Southern Piedmont, good structure and aggregation are evident in the soil on the right. The same soil formed a structural crust under conventional tillage. Note the sunlight reflectance of the crusted soil. Photo courtesy James E. Dean, USDA NRCS (retired).



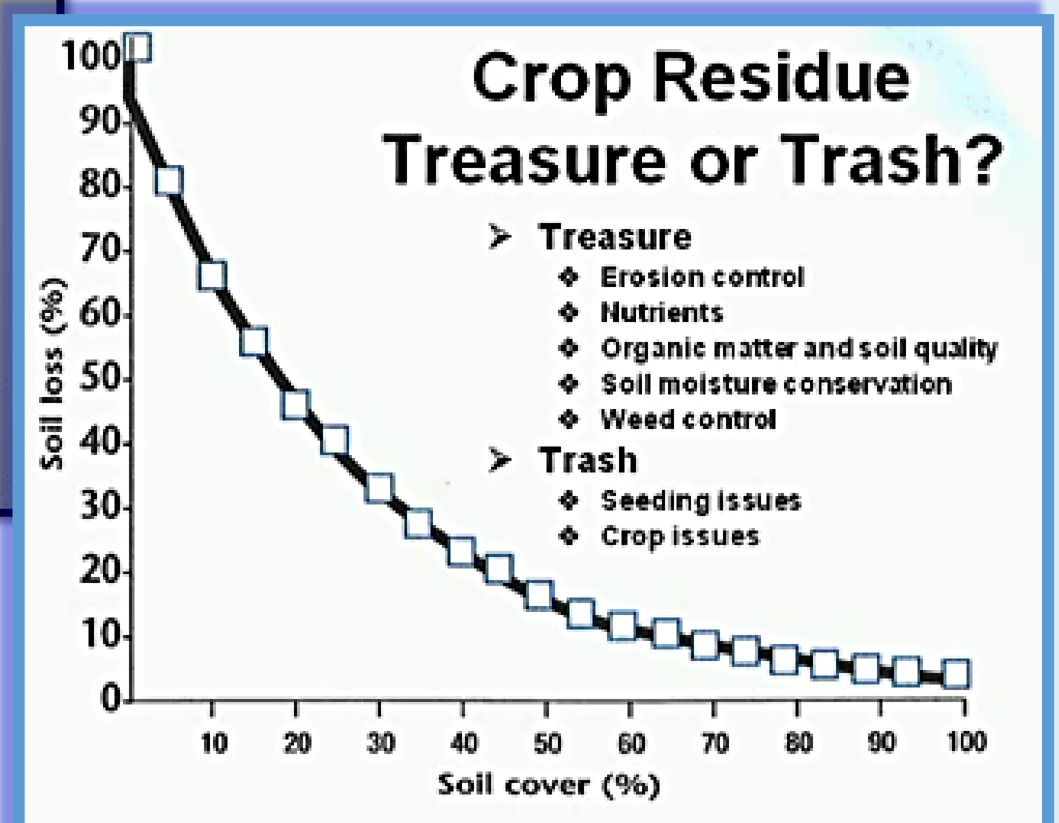


FIGURE 6. Residue cover – relative soil loss relationship. With 30% residue cover, soil loss is reduced 70%.

"Basal" Respiration in-situ and ex-situ

Soil air captured in head-space of cylinder represents ~3" of soil depth.
Solvita Probes compare closely to other analysis methods (GC, Dräger).
Allows estimating field CO2 output (e.g. as lbs/acre per day).

Solvita CO_2 Basal Respiration

SECRETS OF THE SOIL

- Measure the CO_2 at field moisture conditions
- Uses paddle to trap CO_2
- Uses color system to measure

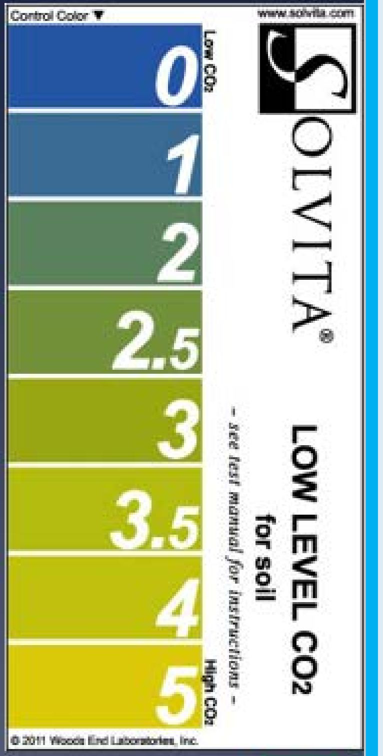
Basal CO_2 in Relation to Soil Improvement Benchmarks

0 – 2 Impoverished soil

2 – 3.0 Borderline (improving / worsening)

3.0 – 3.5 Transition to good condition

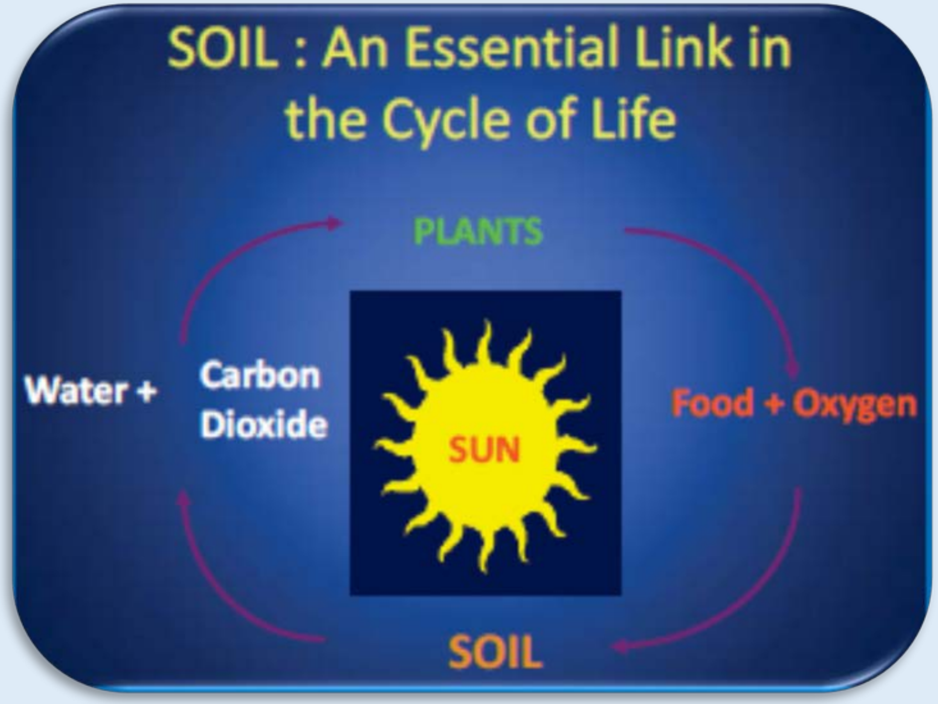
> 3.5 extremely vibrant soil condition



Woods End Laboratories

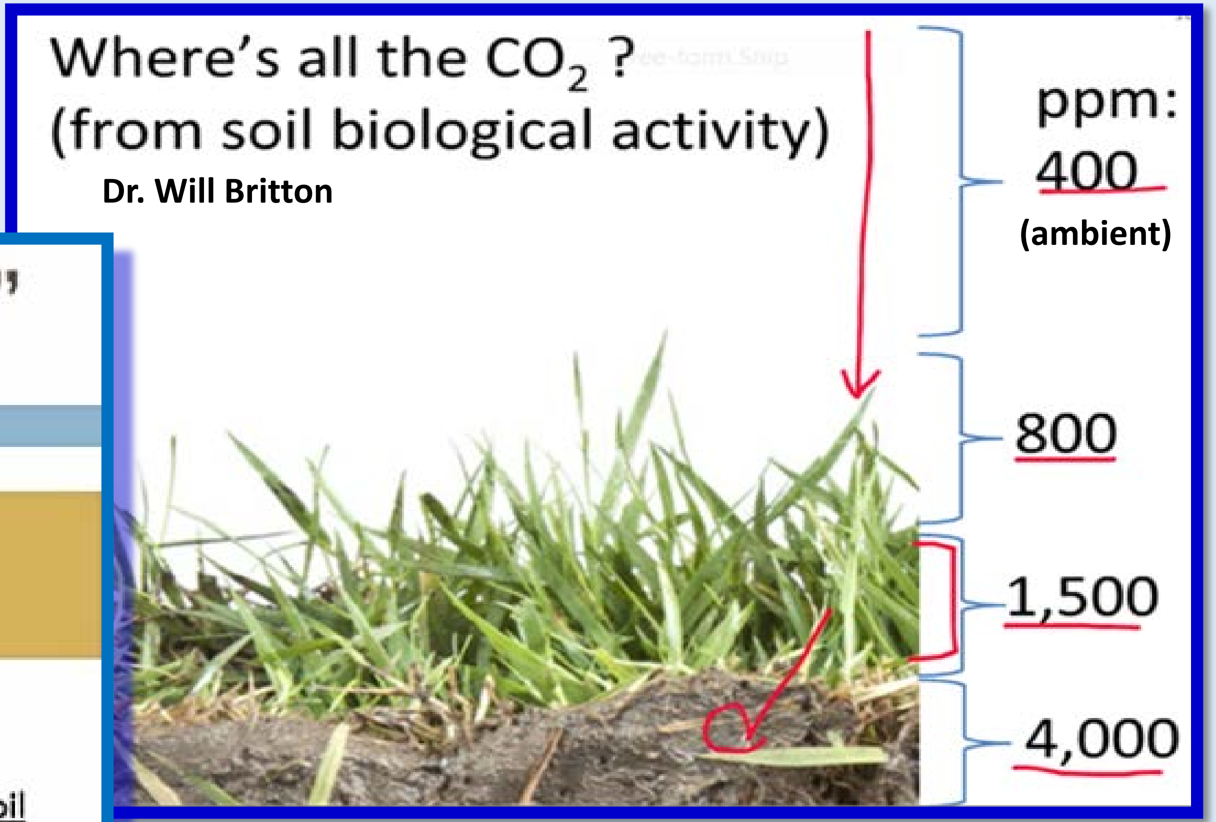
Soil CO_2 Respiration

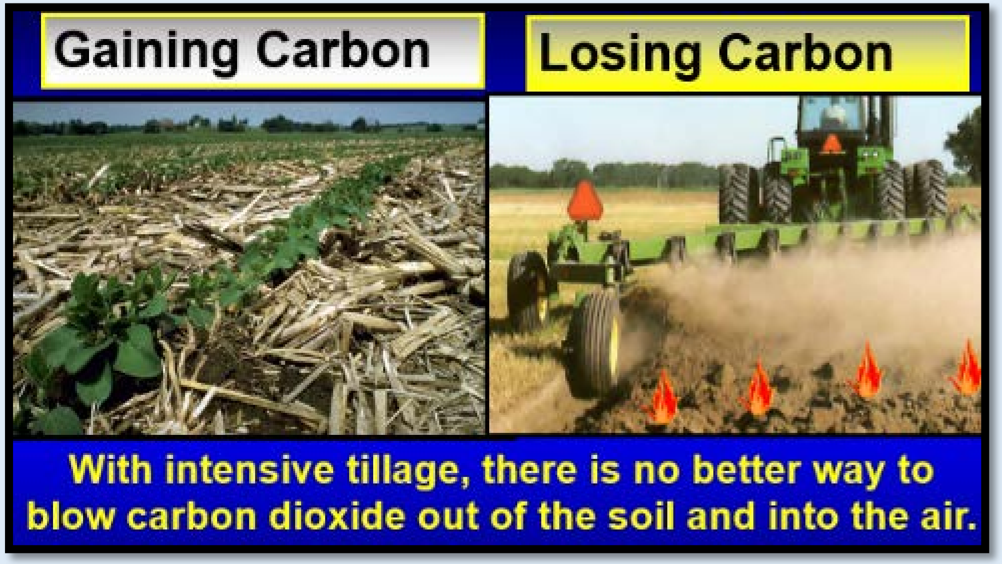
- **Measures soil respiration**
  - **Rate of CO_2 released from decomposition of OM by soil microbes**
  - **Indicates the level of microbial activity**
  - **Correlates to the nutrients contained in OM in forms available to plants**
    - **Phosphate as PO_4**
    - **Nitrate as NO_3**
    - **Sulfate as SO_4**



- **Respiration is the production of CO2 as a result of biological activity in the soil by microbes, live roots and macroorganisms (earthworms).**
- CO2 is colorless and odorless.
- Amount emitted annually by the soil is greater than ALL human activities.
- **Respiration is impacted by soil moisture and temperature**.
- **Inherent soil respiration rates depend on <u>amount</u> and <u>quality</u> of SOM, temperature, moisture, salinity, pH, and aeration**.
- Biological activity of soil organisms varies seasonally, as well as daily.
- Microbial respiration more than doubles for every 10°C (18°F) soil temperatures rise up to a maximum of 35 to 40°C (95 to 104°F).
- **Beyond which soil temperature is too high, limiting plant growth, microbial activity and soil respiration**.

In a Humus Rich Soil, Plant obtain all their CO_2 from soil (We want to recycle all nutrients, including CO_2).





Haney Test
(from Ward Laboratories web site)

Respiration: 24 hour incubation test at 25oC. Sample is wetted through capillary action by adding DI water to a glass jar containing a Solvita® paddle, which is read in a Solvita® digital reader for CO_2-C analysis.

Water extraction: Sample is extracted with 40 ml of DI water and analyzed for NO_3-N, NH_4-N, and PO_4-P. The extract is also analyzed for organic C and total N.

Weak acids extraction: Sample is extracted with 40 ml of H3A and analyzed for NO_3-N, NH_4-N, and PO_4-P. The H3A extract is also analyzed for Al, Fe, P, Ca, and K.

Total N, Inorganic N (NO_3+NH_4), Organic N

Inorganic and organic P

1-day Respiration (Solvita)

Water-extractable organic C and N and C:N ratio

Soil health:

Resp/(orgC:N +WEOC/100+WEON/10)

Available N-P-K and fertilizer recommendations

Soil Health Test Methods

The SHT relies on information gleaned from newly developed soil-testing methods geared towards soil microbial activity and the readily available substrate that they act upon. In other words, we assess the soil as a doctor might assess a living being, using many measurements of health viewed collectively to attain an overall picture of soil vigor.

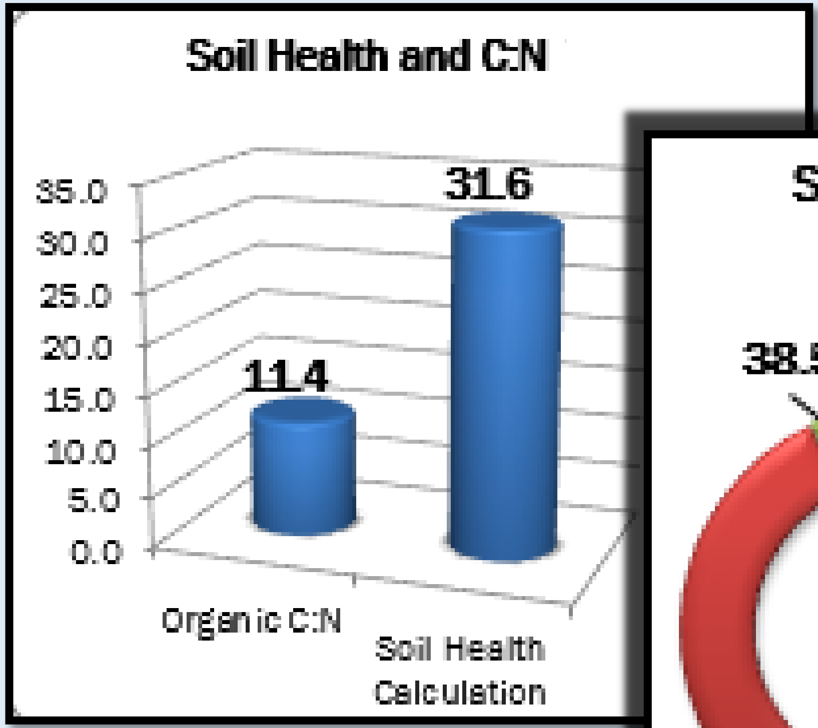
The measurements include:

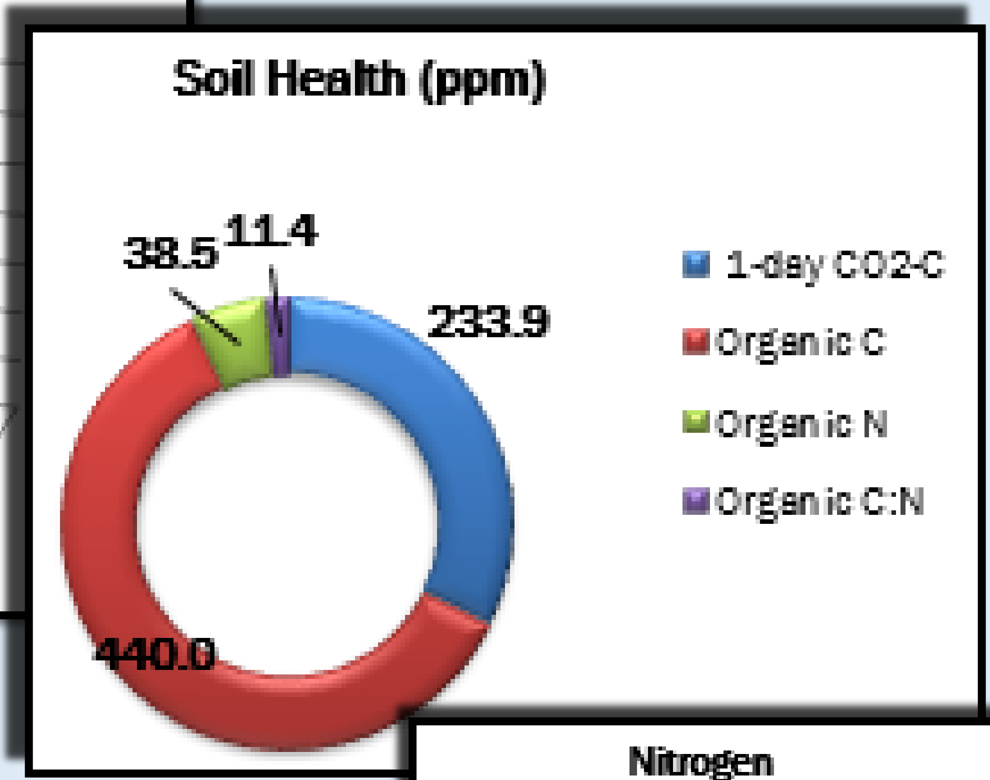
- water extractable organic C (WEOC)
- water extractable nitrogen (WEN)
- water extractable organic N (WEON)
- C: N ratio of the two
- Solvita microbial activity test
- inorganic N and P and K
- H3A extractable aluminum, iron, and phosphate.

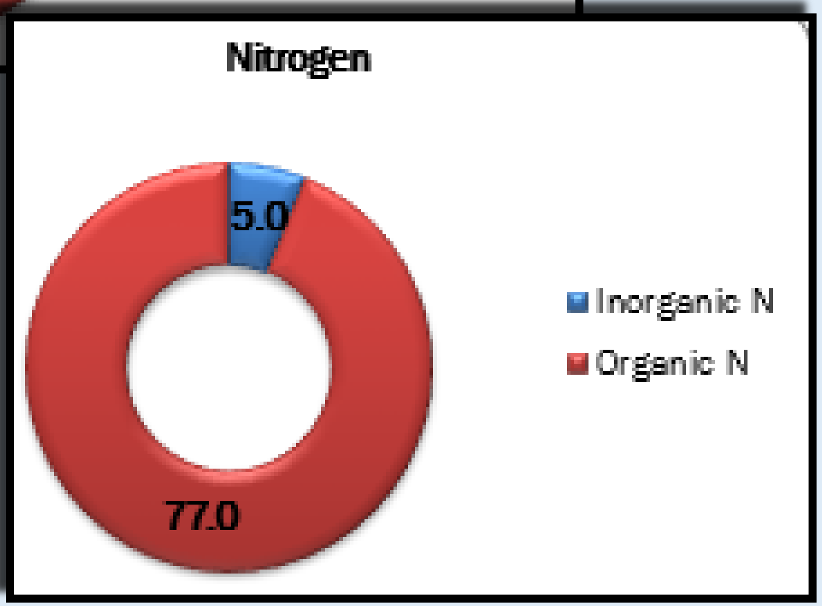
Soil Health Tool
USDA-ARS Temple, Texas
(Haney Test)

Measure soil health and NPK availability by asking our soil the right questions:

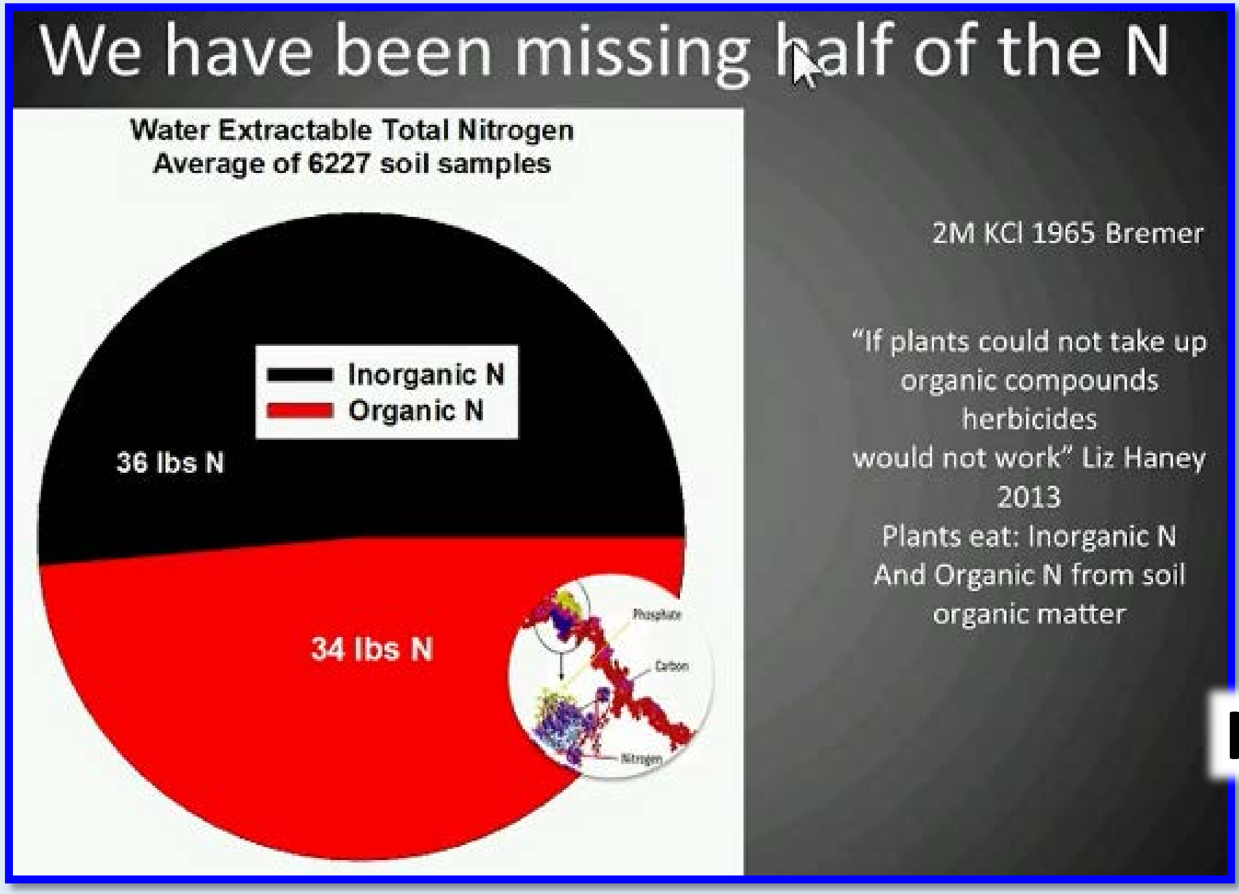
- **What is your condition?**
- **Are you in balance?**
- **How active are your microbes?**
- **What can we do to help?**





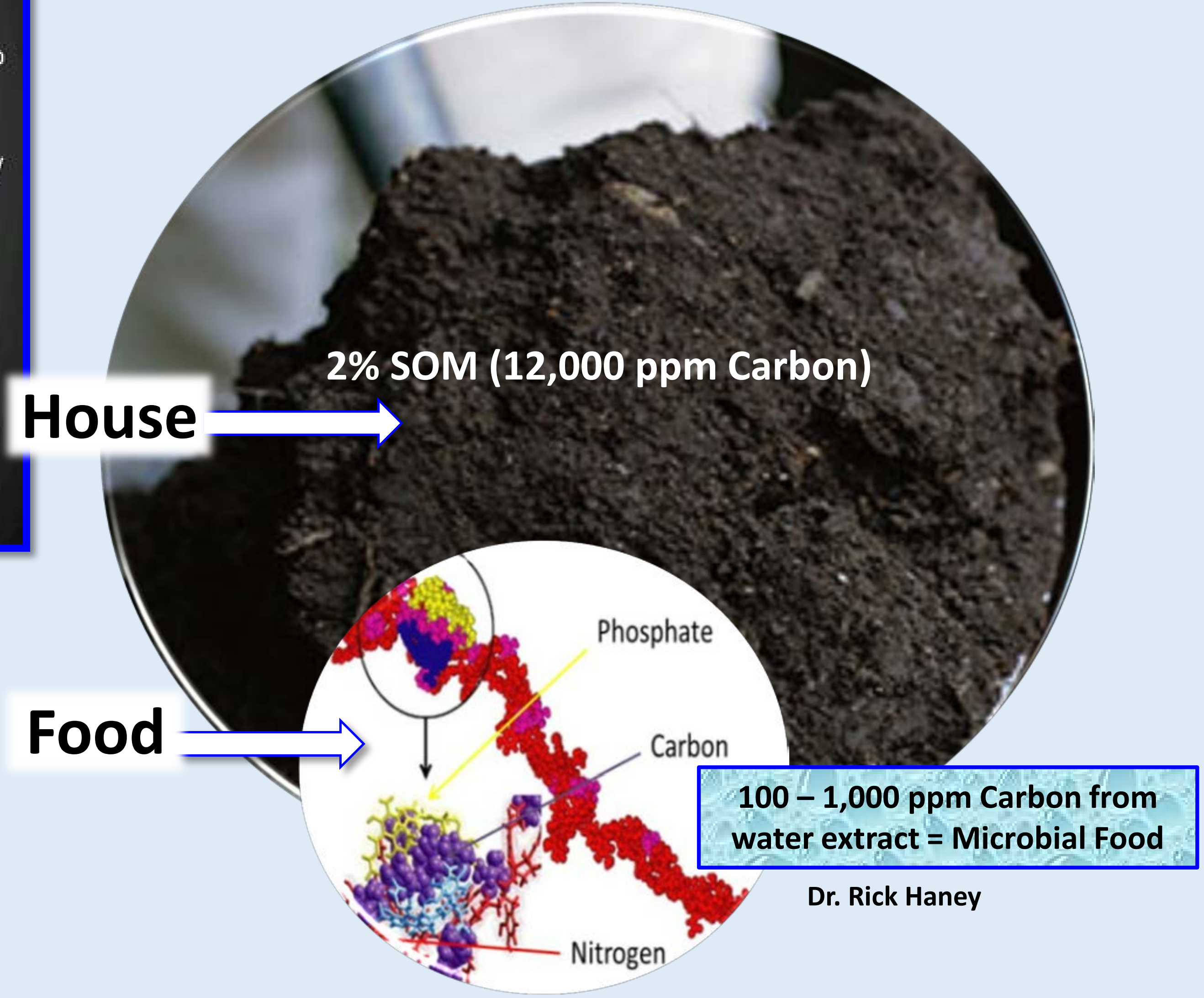


- The **Soil Health Tool** is designed to work with any soil under any management scenario because the program asks these simple, universally applicable questions.
- **This method uses green chemistry, in that, the soil analysis is performed using a soil microbial activity indicator, a soil water extract (nature's solvent), and H3A extractant, which mimics organic acids produced by living plant roots to temporarily change the soil pH thereby increasing nutrient availability.**
- These organic acids are then broken down by soil microbes since they are an excellent carbon source.



Standard Lab Soil Test do not measure Soluble Organic Nitrogen

Soil Organic Matter is the House microbes live in, Water Extractable Organic Carbon is the Food they eat.



Dr. Rick Haney

Pecan Orchard south of Las Cruces, NM. (Temperature measurements with and without cover. Taken on April 20, 2015 at about 2:00 pm)

Surface Temperature: 77 ^{0}F

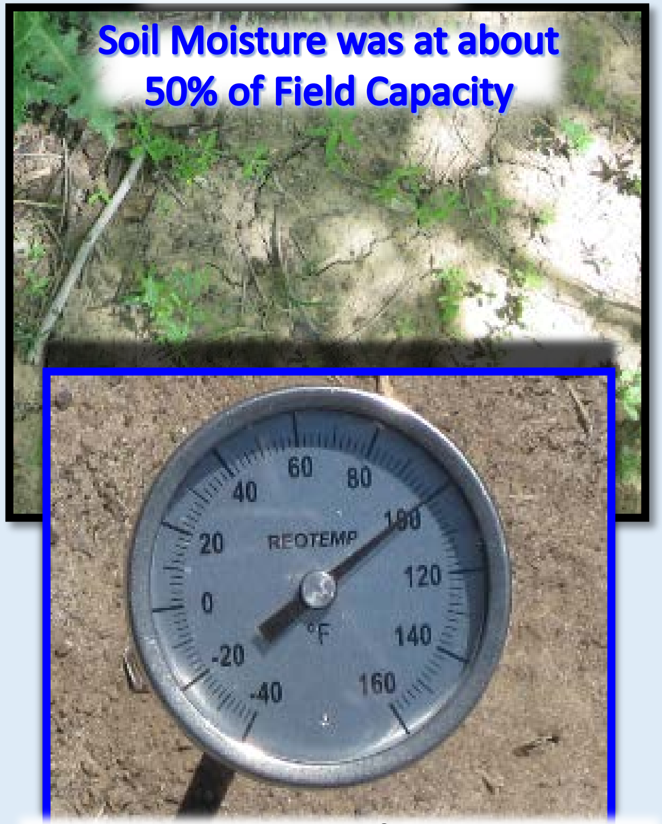
Surface Temperature: 133 ^{0}F

Air Temperature was 76 ^{0}F.

Soil with Cover

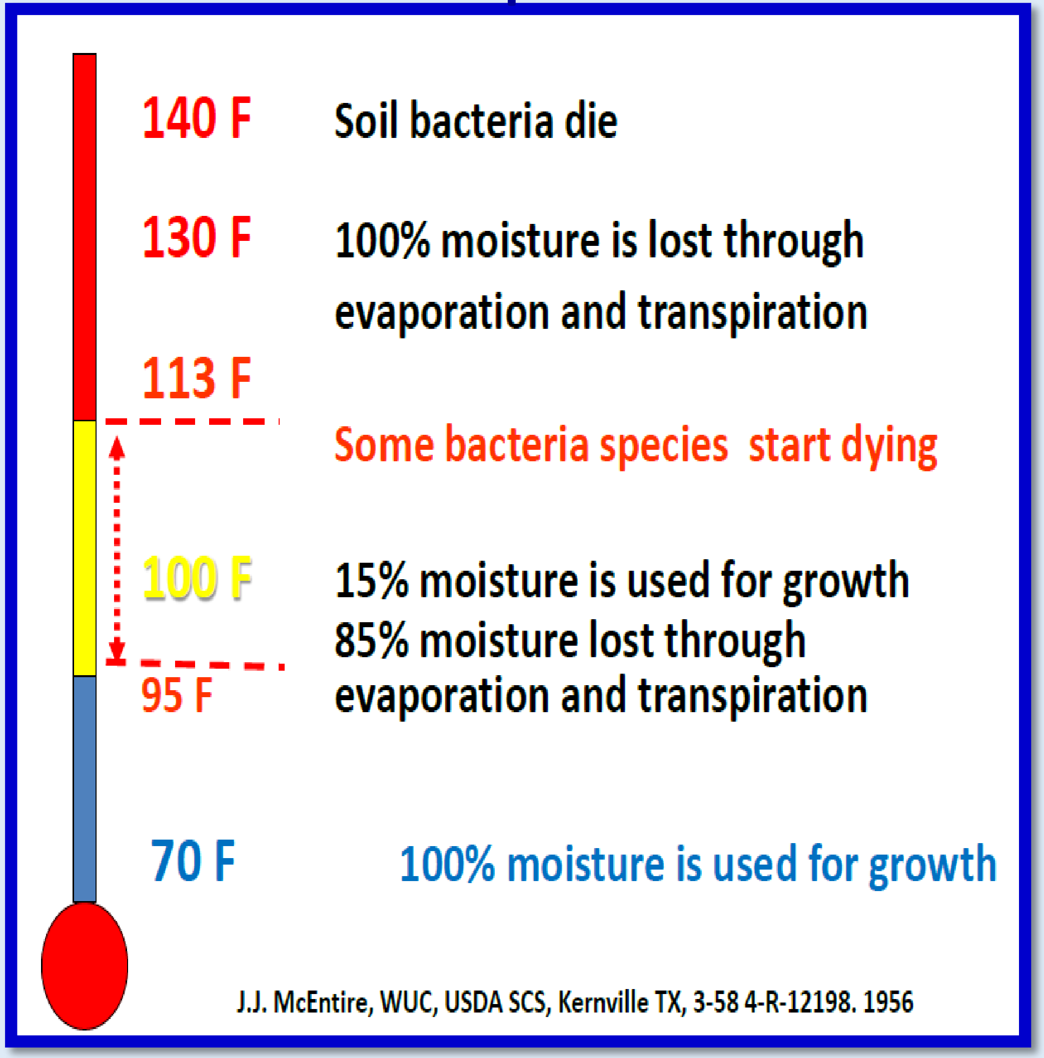
Soil Temperature: 74 ^{0}F at 1 inch depth

Bare Soil

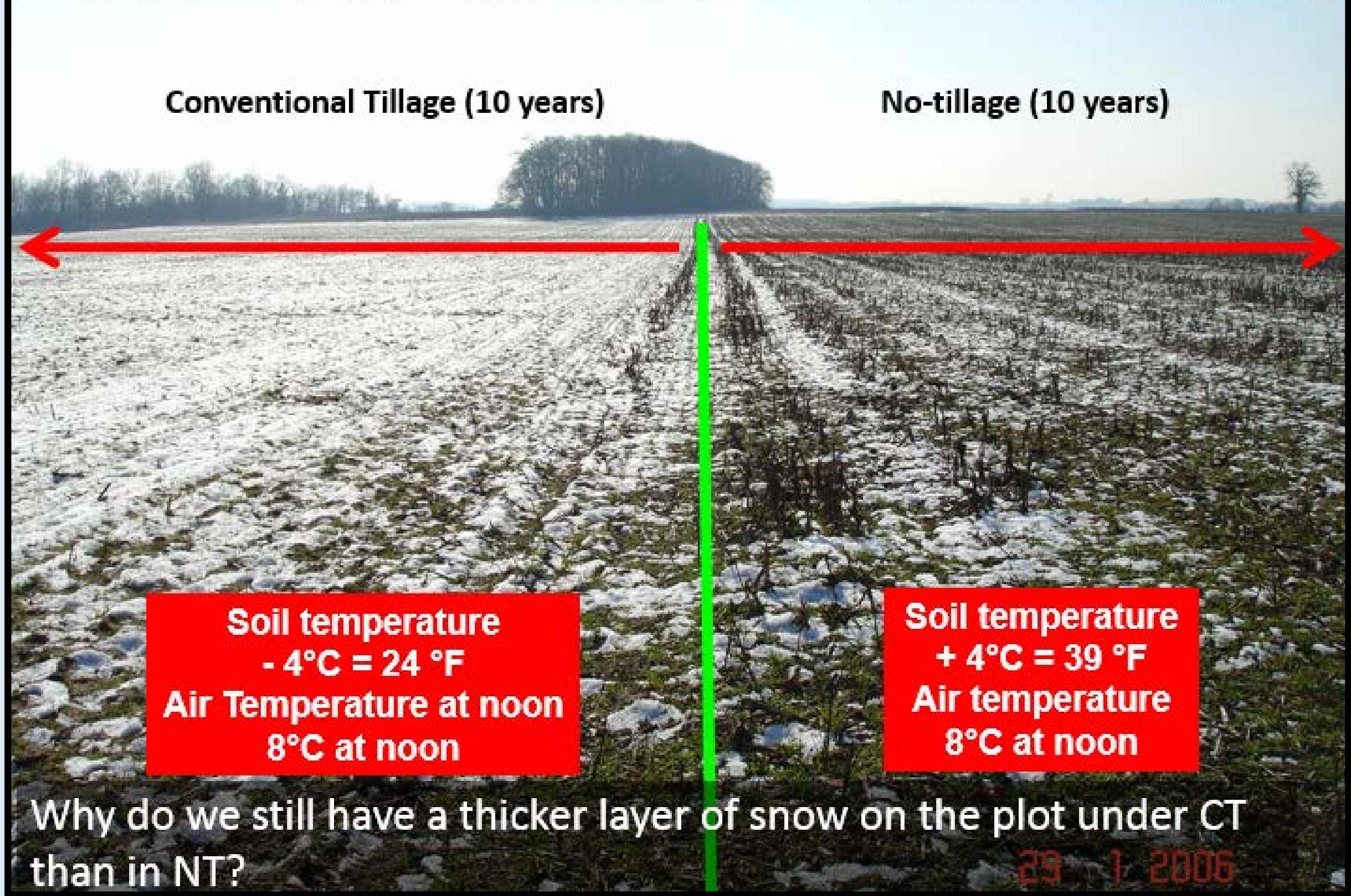


Soil Temperature: 100 ^{0}F at 1 inch depth

When soil temperature reaches



Sandy soil (92 % of sand) – Saint Pierre des Corps – France (47° 23’ North Latitude)



Carbon mat: feeds soil, keeps it cool in the summer, suppress weeds, and protects from rain drop.

Earthworms

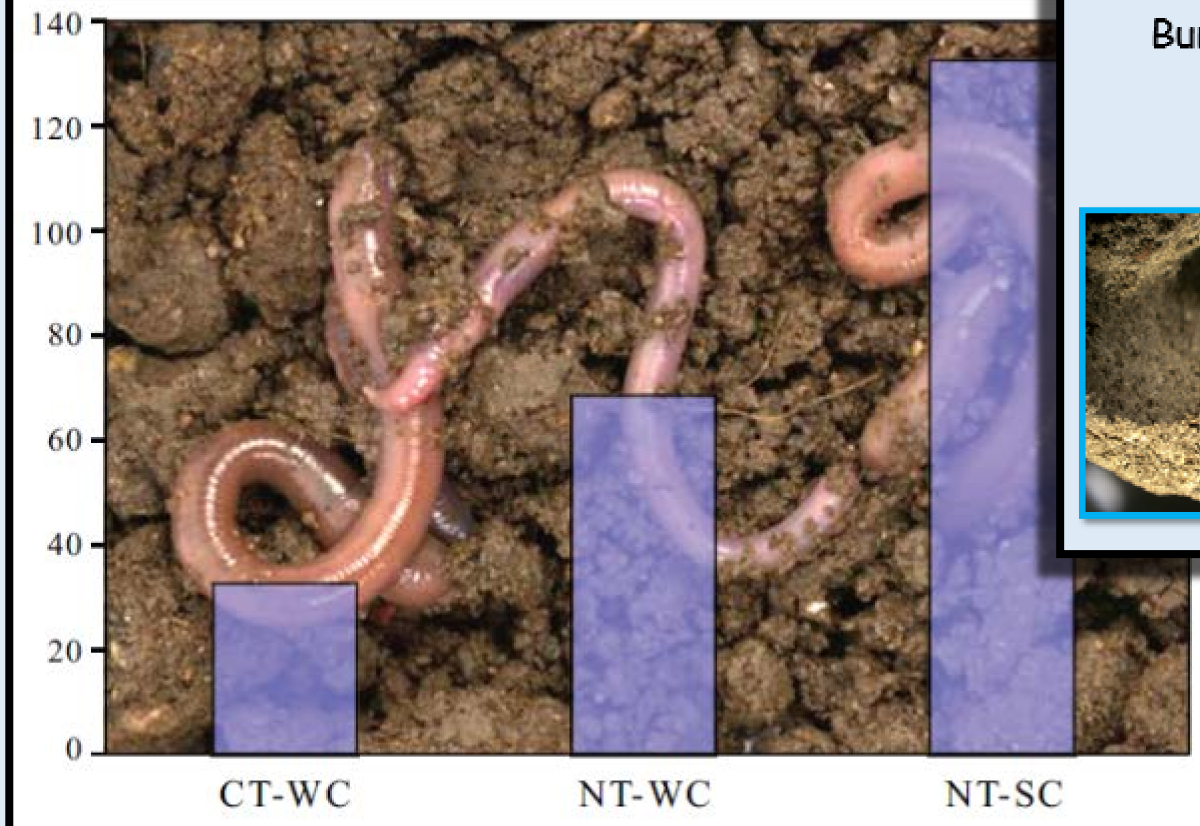


Figure 1. Effect of tillage and crop on earthworm number/m²
CT=conventional till, NT= no-till; W=wheat, C=corn, S=soybean
Adapted from Hubbard, et al. 1999.

Ref.: NRCS Soil Quality Indicators

Earthworms

Poor soils contain 250,000 earthworms per acre while good soils contain 1,750,000 per acre

1 or less per shovel indicates poor soil health

10 or more per shovel indicates good soil health

Burrowing through lubricated tunnels forces air in and out of soil

Earthworm casts contain

11% of the humus

7X the nitrogen

11X the phosphorus

9X the potash

than surrounding soil

A Spade Deep, what it tells You

- Good Soil Tilth
- Sufficient depth

- Shredded Residue
- Signs of life

Looking at a spade full of soil should begin to show evidence of soil health:

- **How hard was it to put the spade in the ground?**
- **Were you able to get to a sufficient depth, 5” to 7”?**
- **Is there sign of life, e.g. worms, millipedes, etc.?**
- **Is the residue shredded?**
- **These are all indicators of what’s happened in the past to impact soil health.**

Brown's Ranch (Same Field)

June 16, 2009
Corn planted into previous years' cover crop residue

Photo are from Gab Brown's farm in ND and demonstrate how quickly residue can breakdown when soils are healthy

July 1, 2009 (Rapid residue decomposition)

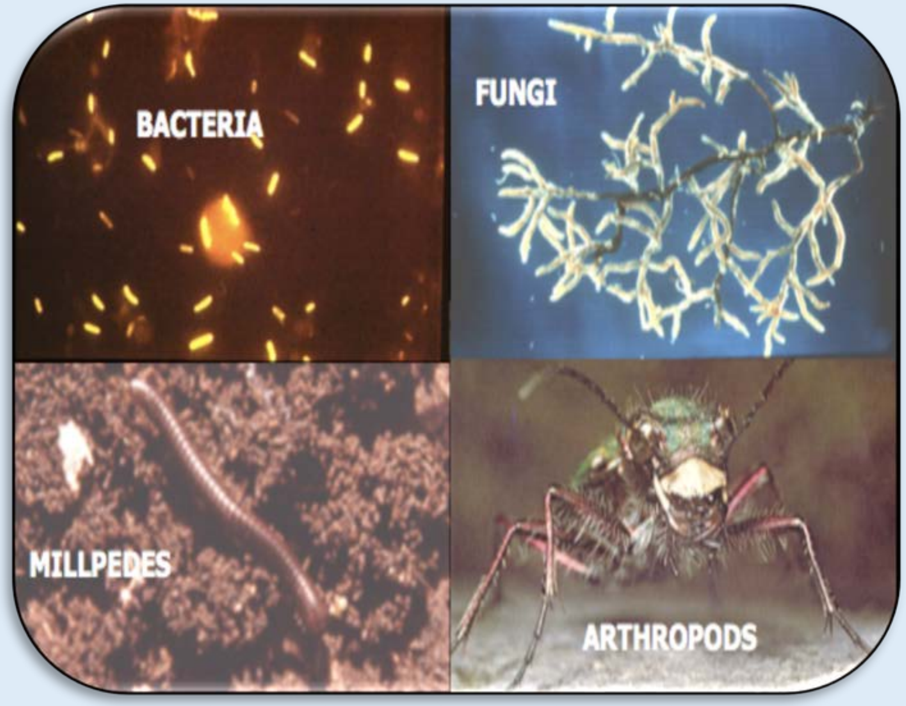
What's residue tell me about soil health?

Residue should be broken down and incorporated into the soil profile in a healthy soil!

Residue is thought to be a good indicator of soil health, lots of residue equals healthy soils, but this is only looking at the erosion aspect.
Residue shouldn't stick around for multiple years, if so than there is something not functioning in the soil, poor microbial action.

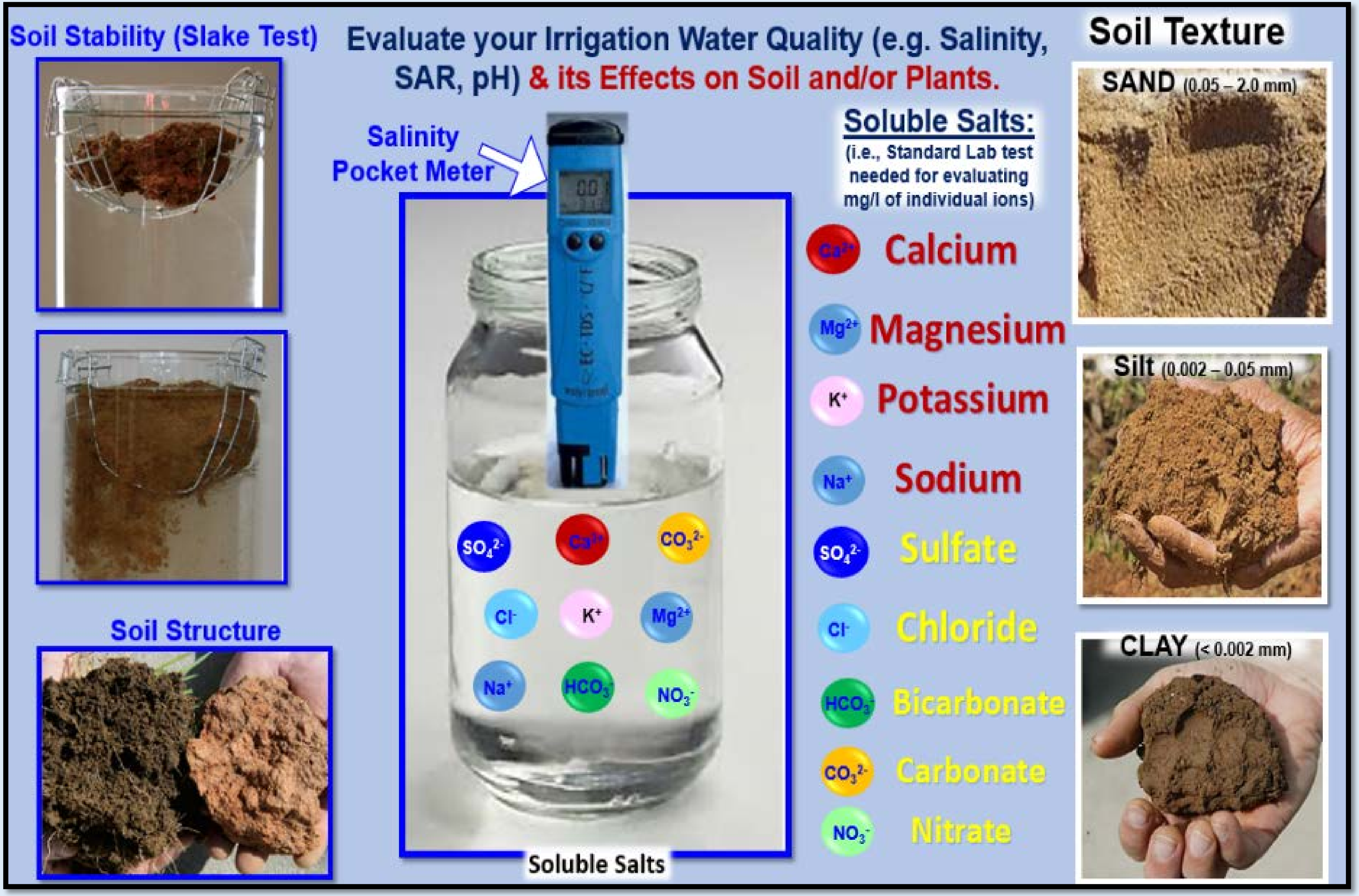
What's under the residue?

Residue should be shredded



Cobwebs evidence of microbe activity

Brushing back the residue should show evidence of soil organisms breaking down residue. Remember this is habitat and if you provide it the organisms will come.



Evaluate your Irrigation Water Quality (e.g. Salinity, SAR, pH) & its Effects on Soil and/or Plants.
Soil Stability (Slake Test)
Soil Structure
Salinity Pocket Meter
Soluble Salts
Soluble Salts:
(i.e., Standard Lab test needed for evaluating mg/l of individual ions)
Ca^{2+} Calcium
Mg^{2+} Magnesium
K^+ Potassium
Na^+ Sodium
SO_4^{2-} Sulfate
Cl^- Chloride
HCO_3^- Bicarbonate
CO_3^{2-} Carbonate
NO_3^- Nitrate
Soil Texture
SAND (0.05 – 2.0 mm)
Silt (0.002 – 0.05 mm)
CLAY (< 0.002 mm)

Table 5. Electrical conductivity measurement and salinity classes for a 1:1 soil:water suspension.

Electrical Conductivity (dS m^{-1} at 25 C)	Salinity class	Crop response	Microbial response
0 - 0.98	Non saline	Almost negligible effects	Few organisms affected
0.98 - 1.71	Very slightly saline	Yields of very sensitive crops restricted	Selected microbial processes altered (nitrification/denitrification)
1.71 - 3.16	Slightly saline	Yields of most crops restricted	Major microbial processes influenced (respiration/ammonification)
3.16 - 6.07	Moderately saline	Only tolerant crops yield satifactorily	Salt tolerant microorganisms predominate (fungi, actinomycetes, some bacteria)
> 6.07	Strongly saline	Only very tolerant crops yield satisfactorily	A select few halophilic organisms are active

Adapted from Soil Survey Staff (1993), Janzen (1993), and Smith and Doran (1996). Conversions from the saturation paste extract to the 1:1 soil:water suspensions were perfomed using the regression equation (y = 2.75 x -0.69) developed by Hogg and Henry (1984).

Ref.: Soil Quality Test Kit Guide

Saline, Saline-Sodic & Sodic Soils

Ref.: The Nature and Properties of SOILS (14^{th} Edition revised)

Saline Soils:

ECe > 4.0 dS/m

ESP < 15 (or SAR < 13)

pH < 8.5

Saline Soils are those soils that contain sufficient salinity to give ECe Values greater than 4 dS/m, but have an ESP less than 15 (or an SAR less than 13) in the saturation extract. Thus, exchange complex of saline soils is dominated by calcium and magnesium, not sodium. The pH of saline soils is usually below 8.5. Because soluble salts help prevent dispersion of soil colloids, plant growth on saline soils is not generally constrained by poor infiltration, aggregate stability, or aeration.

Saline-Sodic Soils:

ECe > 4.0 dS/m

ESP > 15 (or SAR > 13)

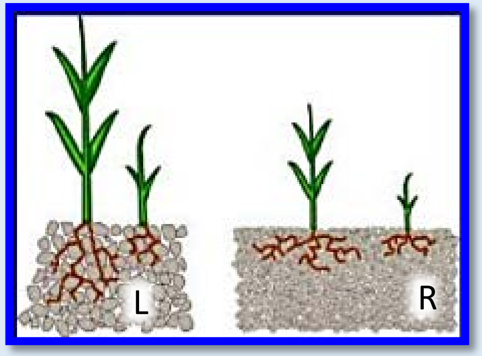
pH < 8.5

Soils that have both detrimental levels of neutral soluble salts (ECe > than 4 dS/m and a high proportion of sodium ions (ESP > than 15 or SAR > than 13) are classified as **Saline-Sodic Soils**. Plant growth in these soils can be adversely affected by both excess salts and excess sodium levels.

Saline-Sodic soils exhibit physical conditions intermediate between those of saline soils and those of sodic soils. The high concentration of neutral salts moderates the dispersing influence of sodium. The salts provide excess cations that move in close to the negatively charged colloidal particles, thereby reducing their tendency to repel each other, or to disperse.

Saline-Sodic Soils have similar salt and pH levels as Saline soils.

Cracks and soil clumps called "aggregates" form when saline-sodic, high-clay soil dries out. Irrigation water flowing into these cracks leaches salts until the aggregates swell and the cracks close up.



(L) Soil with good structure (non-sodic soil); (R) Soil with poor and dense structure (sodic soil).

Sodic Soils:

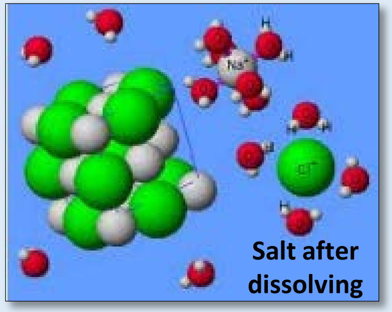
ECe < 4.0 dS/m

ESP > 15 (or SAR > 13)

pH > 8.5

Sodic Soils are, perhaps, **the most troublesome of the salt-affected soils**. While their levels of neutral soluble salts are low (ECe > 4.0 dS/m), they have relatively high levels of sodium on the exchange complex (ESP and SAR values are above 15 and 13, respectively). The pH values of sodic soils exceed 8.5, rising to 10 or higher in some cases.

Osmotic potential, bars ≈ -0.36 (EC)
Where, EC = the electrical conductivity of the soil water (dS/m) -0.36 = the constant that relates EC to osmotic potential in bars. The negative factor indicates that osmotic pressure exerts a suction force on the root. (ASCE, 1996 and USDA Handbook 60)



Dominant Soluble Ions:
Calcium (Ca_2^{++})
Magnesium (Mg_2^{++})
Sodium (Na^+)
Potassium (K^+)
Chloride (Cl^-)
Sulfate (SO_4^{--})
Bicarbonate (HCO_3^-)

Dr. Jamie Iglesias, with Texas Agrilife Center, discussing soil profile characteristics, drainage, water & salinity management, and water table.

In this Pecan Orchard, water table was at about Six foot depth (The importance of proper drainage)

Do you understand your soils profile characteristics?

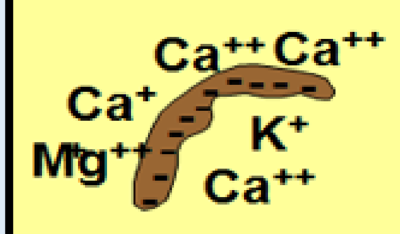
Roles of the three "categories" of organic matter in soils:

Living - Alive organisms. Create stable organic matter and…

1. plant roots: make pores, feed soil life, allelochemicals
2. soil organisms: make nutrients available, suppress disease, produce plant growth promoting hormones, aggregate soils…

Dead - Recently dead organisms and crop residues. Also called "active" or "particulate" organic matter.

1. Feed soil organisms. Help do all above!
2. On surface: maintain soil moisture, prevent erosion.



Cations held on humus CEC

Very Dead - Well decomposed organic materials.

1. High amounts of negative charge holds nutrients.
2. Has high water-holding capacity.
3. Stores (sequesters) C.

SOM'S Revolving Nutrient Bank Account.

- A furrow slice is 6 7/8 inches = 2,000,000 lbs of soil per acre.
- 1.0% SOM X 2,000,000 lbs = 20,000 lbs of SOM per acre.
- 1.0% SOM = approximately 10,000 lbs Carbon, 1,000 lbs Nitrogen, 100 lbs Phosphorous, and 100 lbs of Sulfur.
- Mineralization Rate = 2-3% from Organic N to Inorganic N, which does not stop at harvest time.

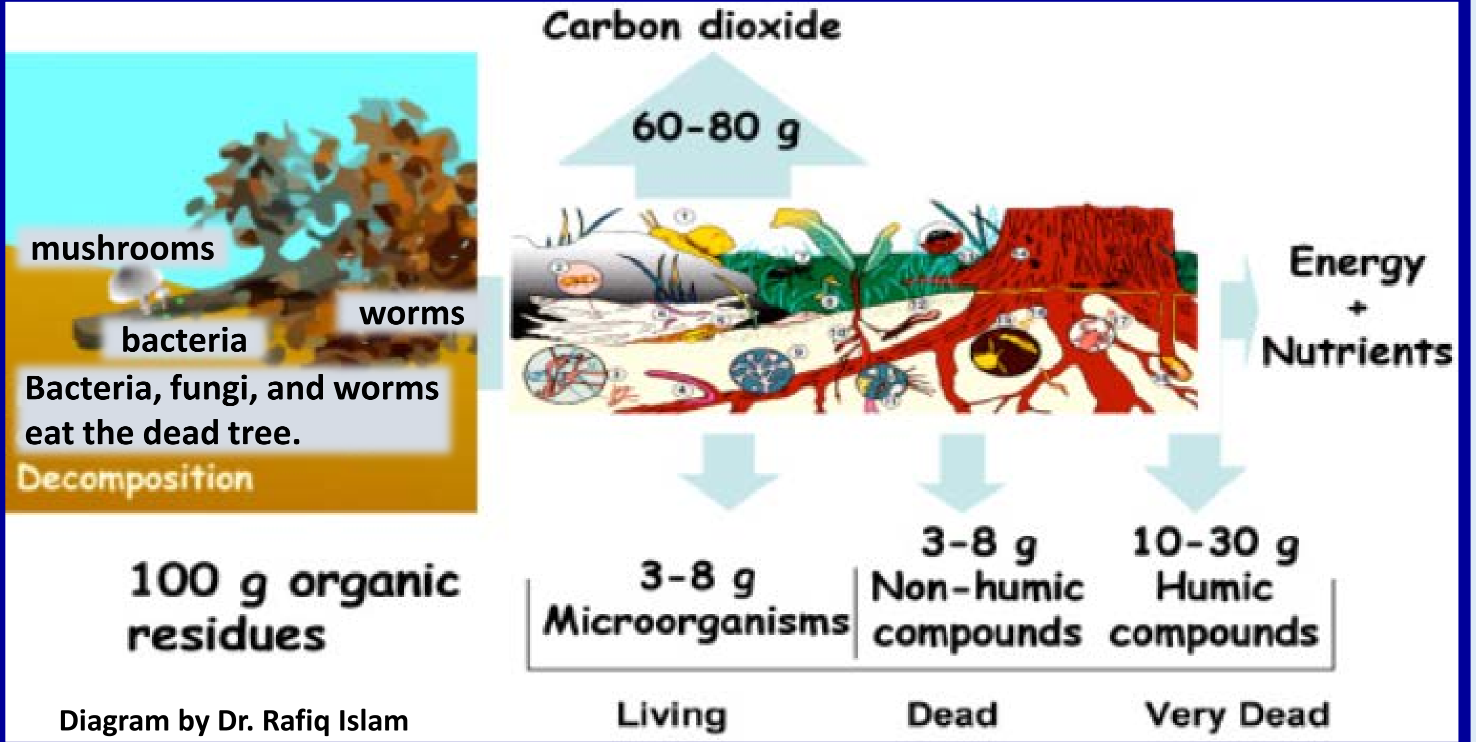


Diagram by Dr. Rafiq Islam

Ref.: NRCS Soil Quality Indicators

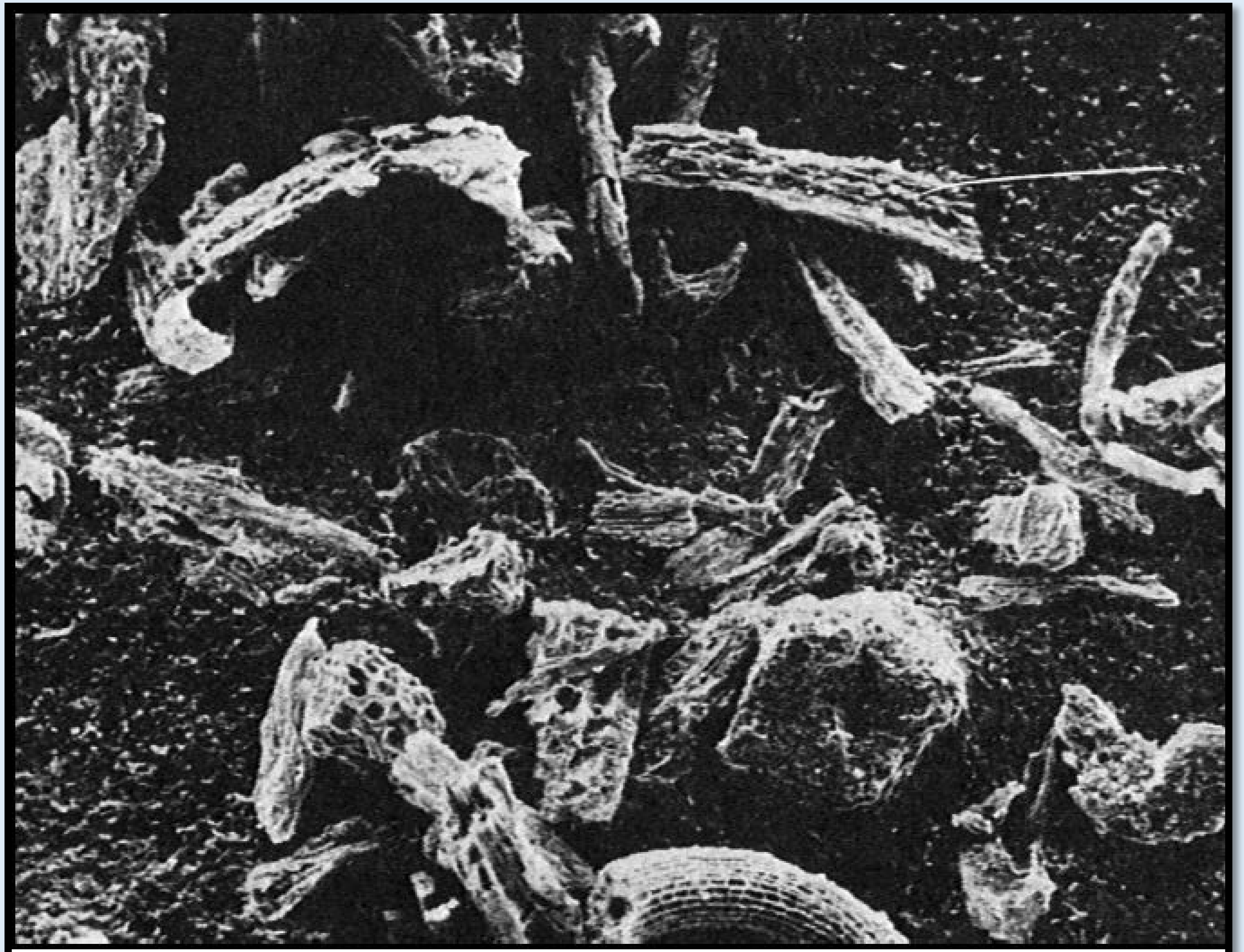


Figure 1. Particulate organic matter from no-till soil. From Cambardella and Elliot, 1992.

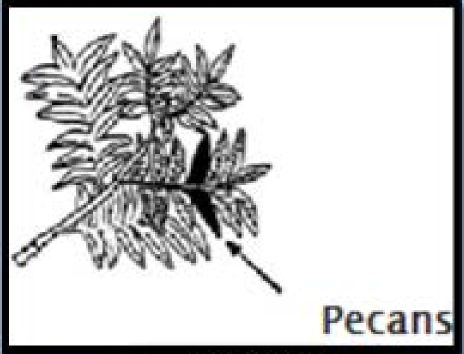
Particulate Organic Matter

Particulate organic matter (POM) fraction referred to in this document comprises all soil organic matter (SOM) particles less than 2 mm and greater than 0.053 mm in size (Cambardella and Elliot, 1992). POM is biologically and chemically active and is part of the labile (easily decomposable) pool of soil organic matter (SOM). Figure 1 shows tiny debris of POM (0.25 mm < POM size < 0.5 mm) at different stages of decomposition isolated from soil under no-till management. Studies have shown that POM accounts for few to large amounts of soil C (20% and more) in some soils of Eastern Canada and the USA depending upon agroecosystems and management practices

Nutrient Management: Irrigation Water, Soil & Plant Tissue Analysis for Pecan)

Pecan Plant Tissue Analysis:

- N = 2.66% Optimum: Sufficiency Range: 2.49 – 2.8%
- P = 0.12% Optimum: Sufficiency Range: 0.11 – 0.3%
- K = 0.95% Optimum: Sufficiency Range: 0.74 - 1.25%
- S = 0.22% Optimum: Sufficiency Range: 0.19 - 0.4%
- Ca = 1.21% Optimum: Sufficiency Range: 0.89 – 1.5%
- Mg = 0.31% Optimum: Sufficiency Range: 0.29 - 0.6%
- Zn = 58.22 ppm Optimum: Sufficiency Range: 49 – 100 ppm
- Fe = 135 ppm Optimum: Sufficiency Range: 49 – 300 ppm
- Mn = 58.1 ppm Low: Sufficiency Range: 99 - 800 ppm
- Cu = 5.8 ppm Low: Sufficiency Range: 9 – 30 ppm
- B = 105.4 ppm High: Sufficiency Range: 29 – 45 ppm
- Na = 0.02% Optimum: Sufficiency Range: 0 – 0.1%



- Sample at Midseason
- Sample midshoot leaflets/leaves
- Sample #: 25 – 60

Soil Analysis:

- Organic Matter = 0.6% (Low)
- Nitrogen Mineralized = 12.0 lbs./ac.
- Nitrate-N = 8.55 lbs./ac. (Low)
- Phosphorus = 5.0 ppm (Low)
- Potassium = 122.0 ppm (Low)
- Sulfate-S = 20.7 ppm (Adequate)
- Calcium = 2,948.0 ppm (High)
- Magnesium = 187.0 ppm (Low)
- Zn = 0.4 ppm (Low)
- Iron = 4.6 ppm (Low)
- Mn = 4.2 ppm (Low)
- Cu = 0.6 ppm (Adequate)
- B = 0.4 ppm (Low)
- Sodium = 2.6% of total CEC (good)

Irrigation is by micro-sprinkler and subsurface drip (These fields were previously flood irrigated).

Water Quality Analysis Pounds per Acre:

- Nitrate-N = 12.2
- Potassium = 89.5
- Sulfate-S = 490.0
- Calcium = 591.0
- Magnesium = 146.2
- Sodium = 592.0
- Chloride = 783.0
- Bicarbonate = 1,911.4
- Carbonate = 26.1
- Iron = 9.3
- Mn = 0.22
- B = 1.31

Total Salts = 5,640.2

Brix and Nutrient Dense Plants

The refractometer is a tool which measures the refractive index of a liquid. When light rays shine through the liquid they strike the carbohydrates, salt and other molecules depending upon the type of calibration used.

When the light rays strike the molecules, they bend or refract. The greater the calibrated molecular concentration of the liquid in question, the greater the refraction.

And the molecular concentration of the plant is:
… the concentration of sugars, vitamins, amino acids, proteins, hormones, and other solids dissolved within the juice of the plant which is measured in **BRIX (ratio of the mass of dissolved solids to water).**

The Brix unit that the refractometer gives is basically the mineral content of the plant; thus, the higher the refraction, the higher the mineral content, the higher the nutrient-density of the plant.

Rotted Fence Post Principle

Most soil microorganisms are aerobic and use oxygen as the electron acceptor in their metabolism.

The zone of greatest microbial activity usually occurs just a few inches below the soil surface where optimal temperature, moisture, oxygen and nutrient conditions exist.

Fence post shows that over time soil microbes have used it as a carbon food source.

Fence post shows that over time soil microbes have used it as a carbon food source.

- Root Pathogen Pressure
  - Pathogen presence

Other add on indicators:

1. **Potentially Mineralizable N:** mineralization during anaerobic incubation

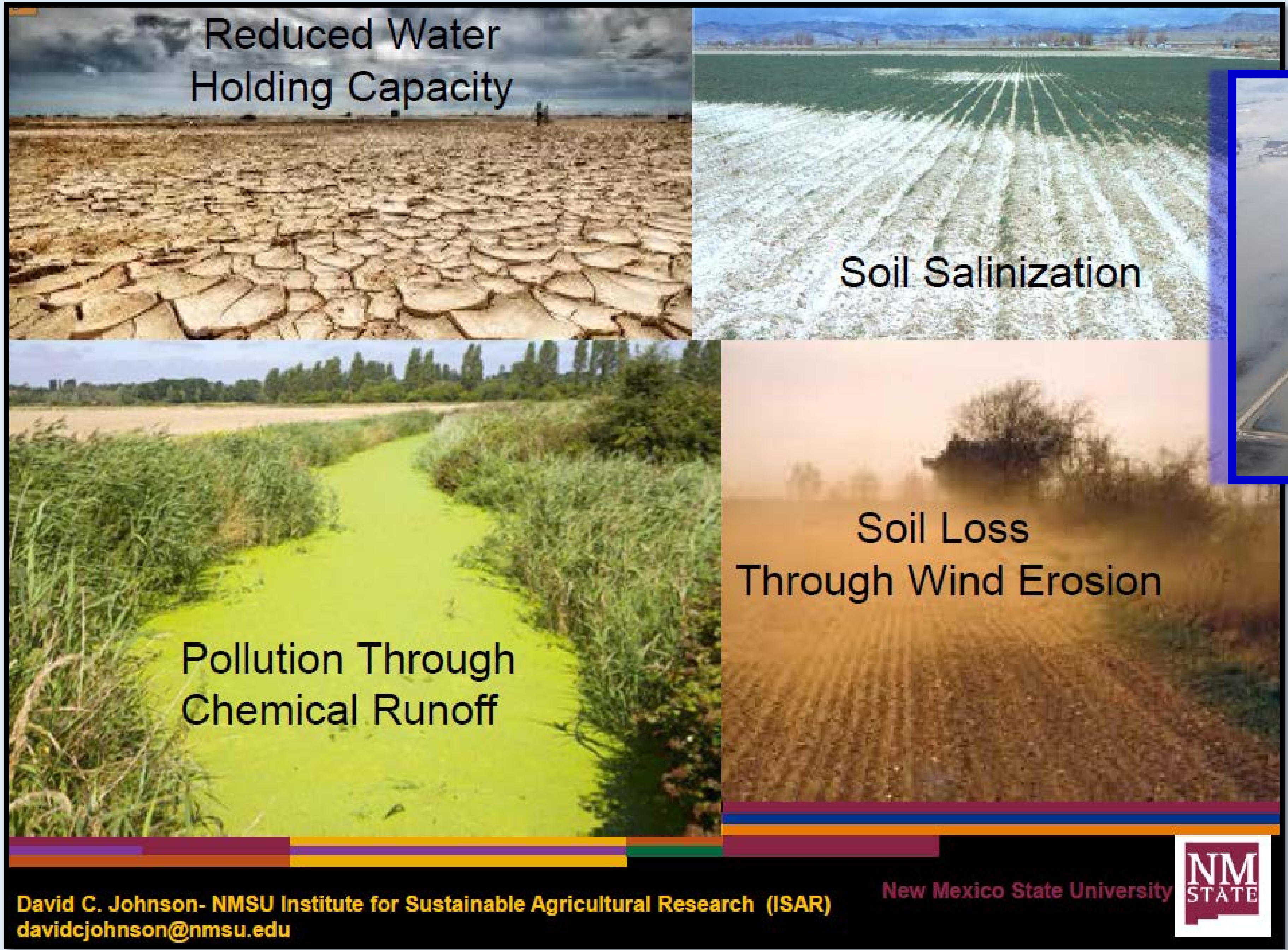
2. **Soluble Salts:** electrical conductivity

   Recommended applications: high tunnels, landscaped areas, lawns and urban areas, heavily composted areas, home gardens

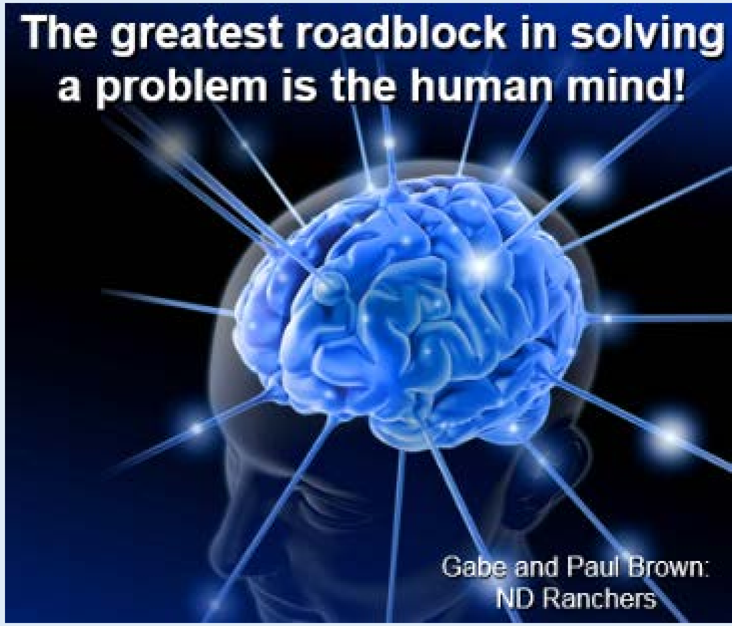
3. **Heavy Metal Screening** (EPA Method 3051-6010)

   Recommended applications: urban areas and gardens, home gardens, playgrounds, brownfields, heavily composted areas

Visual Observations of resource condition



Bare soil harms the natural system in many ways. Rainfall washes away precious organic matter. Organic mater holds many crop nutrients, and OM is the lightest fraction of the soil and the first to be carried off site. Bare ground harms the macro and micro organisms…because of lack of carbon (food) in the soil ecosystem. In a bare ground environment, the soil is in starvation mode with no live root to pump carbon (sugars carbohydrates- plant exudates) into the soil system. No food means little microbial activity. Important to note: Carbon is the energy (food) source in the system. Bare ground also increases soil temperature, making the soil less hospitable to soil organisms. Temperatures on bare soil can raise above 115 degrees, some microbes start shut down at these temperatures.



Natural Systems:

- harvest the maximum amount of sunlight
- leak very few nutrients including CO_2
- have diversity
- tend not to export nutrients
- make maximum use of water and nutrients by having highly developed porosity and VAM webs
- do not do tillage

Rhizosheaths