Soil Health 101

Farming in the 21st Century

"a practical approach to improve Soil Health"

Presentation prepared by the USDA-NRCS
National Soil Health and Sustainability Team
(modified from the original to accommodate notes with photos)

New Mexico Integrated Cropping Systems and Water Management Handbook
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nm/technical/?cid=nrcs144p2_068965

USDA-NRCS: Unlock the Secrets in the Soil
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/

Why in 2013?

- World population is estimated to be at 9.1 billion by 2050
- To sustain this level of growth, food production will need to rise by 70 percent
- Between 1982-2007, 14 million acres of prime farmland in the U.S. was lost to development
- Energy demands
  - Increase use of biofuels (40% of corn used for ethanol)
  - Increase use of fertilizer (use of Anhydrous up 48%, Urea up 93%)

These are key drivers behind the Soil Health campaign, but are not all inclusive. These come from the Soil health Core team that former Chief White put together to look into how NRCS can incorporate soil health into our business model.

The key point is that a growing population is demanding higher quality food to be produced on less acres using finite resources that having competing if not conflicting uses.

-**There's an increasing demand for production**, world population currently at 7 billion expected to rise to over 9 billion by 2050.

-**A decrease in land capacity.**

- And the **US in particular is becoming more dependent on petro-based fertilizers to maintain our production goals**.

Soil Health What is It?

- The continued capacity of the <u>soil to function</u> as a vital living ecosystem that sustains plants, animals, and humans.
  - Nutrient cycling
  - Water (infiltration & availability)
  - Filtering and Buffering
  - Physical Stability and Support
  - Habitat for Biodiversity

This is the definition of Soil health we are using. **The term "Health" was purposely chosen instead of "quality"**.

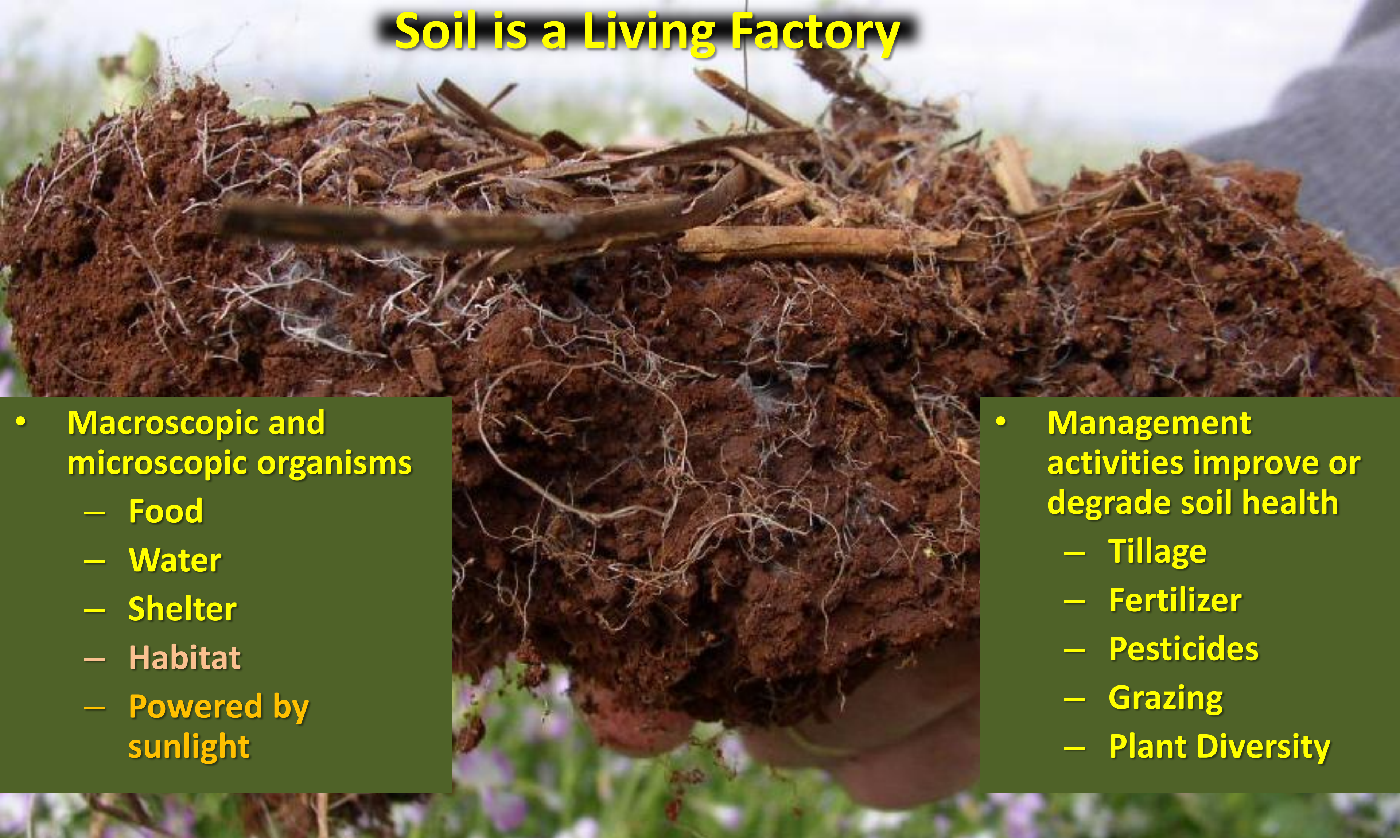
- **Quality implies analysis and quantifying.**
- **Health implies management actions that leads to a condition or state, there is something that can be done to change it in a positive trend.**

The key to the definition is that soil health is:

1. **Continued capacity**—implies rejuvenation and then sustainability
2. **Soil is a living ecosystem**– folks need to recognize the ground beneath them is a living ecosystem
3. **Soil function** – soils need to provide the basic functions below in order for food & fiber production to meet the demands in slide 1

   a) **Nutrient Cycling** - Soil stores, moderates the release of, and cycles nutrients and other elements. During these biogeochemical processes, analogous to the water cycle, nutrients can be transformed into plant available forms, held in the soil, or even lost to air or water.
   b) **Water Relations** - Soil can regulate the drainage, flow and storage of water and solutes, which includes nitrogen, phosphorus, pesticides, and other nutrients and compounds dissolved in the water. With proper functioning, soil partitions water for groundwater recharge and for use by plants and soil animals.
   c) **Biodiversity and Habitat** - Soil supports the growth of a variety of plants, animals, and soil microorganisms, usually by providing a diverse physical, chemical, and biological habitat.
   d) **Filtering and Buffering** - Soil acts as a filter to protect the quality of water, air, and other resources. Toxic compounds or excess nutrients can be degraded or otherwise made unavailable to plants and animals.
   e) **Physical Stability and Support** - Soil has the ability to maintain its porous structure to allow passage of air and water, withstand erosive forces, and provide a medium for plant roots. Soils also provide anchoring support for human structures and protect archeological treasures.

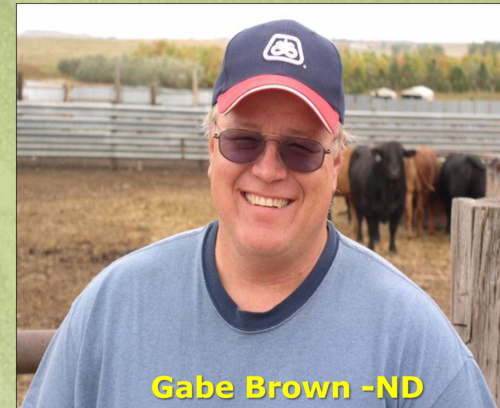
Soil is a Living Factory



- Macroscopic and microscopic organisms
  - Food
  - Water
  - Shelter
  - Habitat
  - Powered by sunlight

- Management activities improve or degrade soil health
  - Tillage
  - Fertilizer
  - Pesticides
  - Grazing
  - Plant Diversity

1. If folks remember anything out of this session it should be this: **"SOIL IS A LIVING FACTORY"** and decisions that farmers make impact how soil functions, e.g. nutrient cycling, regulate water, etc.
2. **All living organisms no matter the size need <u>food</u>, <u>water</u> and <u>shelter (habitat)</u> to survive and flourish and <u>this system in the soil is driven by sunlight.</u>**
3. Introduces the concept of <u>disturbance</u> and how disturbance affects habitat for soil organisms.
4. **Management determine how soil functions.**



The principles of soil health apply to all types of farming enterprises, all sizes and all regions of the country.

1. **Ray Styer**: North Carolina, farms 70 acres of silage corn in rotation with multi speicies cover crop mixes, was an old Tabaco farm, **hasn't used commercial fertilizer in this millennium**.
2. **Dave Brandt**: Corn-Soybean-Wheat farmer from Carroll, OH **has been using no-till and cover crops since the 1970's**, had been using a split row planter to seed a row of tillage radish and a legume, has incorporated multi-species cover crops into his system in the last few years.
3. **Gabe Brown**: east of Bismarck, ND, 2000+ acres of cropland and 4000 acres of grazing (combination of range and pasture), has reduced his inputs (fertilizer, herbicides, etc.) by greater than 75%. Farms in a 16 inch precipitation area, **does not use fallow in his rotation**, **grazes his cover crops.**
4. **Ray McCormick**: Farms in southern IN along the Wabash river, raises corn and soybean using no till and cover crops. **Seeds his cover crops as he is harvesting his crops**, has a special seeder attached to his combine that seeds as he is harvesting.
5. **Brandon Rockey**, Potato farmer from Colorado, **rotates cover crops with potato and companion crops in potato.**

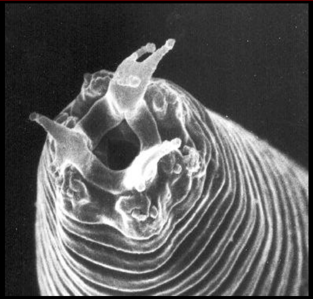
All of these farmers incorporate soil health planning principles into their farm management.

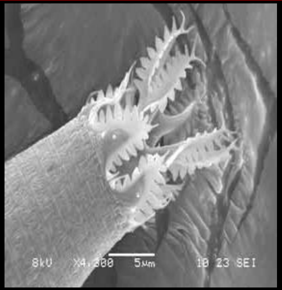
Ecology:

the study of relationships between people, animals, and plants, and their environment.

Interconnectedness

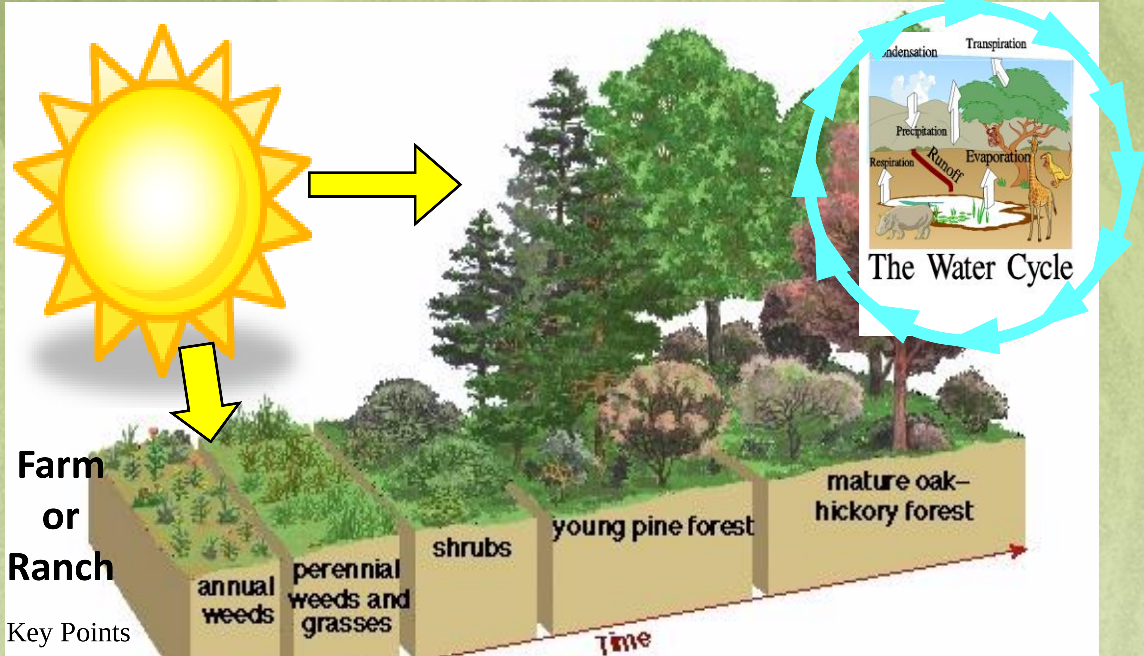
Soil Surface

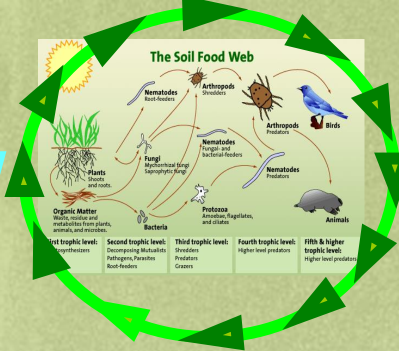




Key Points:

- **Introduces the concept of Ecology and it's role in agricultural systems.**
- **Ecology:** the study of relationships between people, animals, and plants, and their environment.
- **Interconnectedness: The idea that all natural systems are connected and impact each other, that a disruption in one area will ripple out through the system and eventually come back and affect the starting point.**
- **Natural Systems or cycles that are important to agriculture:**
    - **Nutrient cycle**
    - **Water cycle**
    - **Soil Food Web**





Farm or Ranch

Key Points

1. This slide shows the **natural successional** progress from agricultural lands through to a **steady state climax community**.
2. **These will differ across the country but are characterized by having highly functioning ecosystems services, e.g. nutrient, & water cycle and soil food web.**
3. **Most agricultural lands are characterized by having poor functioning ecosystem services.**
4. **These services are driven by sunlight**.
5. **As succession takes place changes** occur in the plant communities and soil biota over time, e.g. plants go from annual to perennials.

<u>**Nature wants to get to a steady state community**</u>

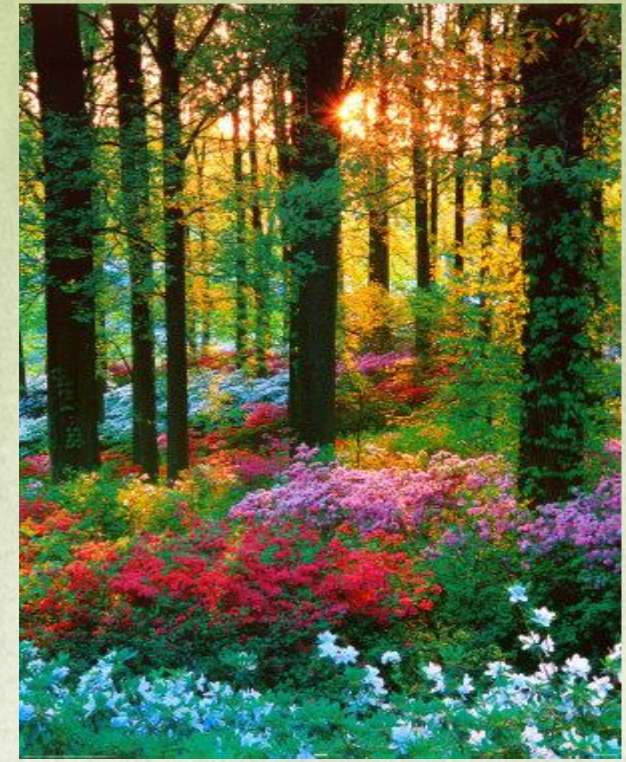
- **Soil is the integrator between different ecosystems**.
- Agricultural lands (crop, grazing, etc.) are part of the earth's ecosystems or biomes.
- In natural ecosystems, the vegetative cover of a forest or grassland prevents soil erosion, replenishes ground water and controls flooding by enhancing infiltration and reducing water runoff (Perry, 1994).
- **In agricultural systems, biodiversity performs ecosystem services beyond production of food, fiber, fuel, and income. Examples include recycling of nutrients, control of local microclimate, regulation of local hydrological processes, regulation of the abundance of undesirable organisms.**
- **These renewal processes and ecosystem services are largely biological**; therefore their persistence depends upon maintenance of biological diversity (Altieri, 1994).
- The net result of biodiversity simplification for agricultural purposes is an artificial ecosystem that requires constant human intervention, **whereas in natural ecosystems the internal regulation of function is a product of plant biodiversity through flows of energy and nutrients**, and this form of control is progressively lost under agricultural intensification (Swift and Anderson, 1993).

Ray Archuleta

How do these Ecosystem flourish without human inputs?

Prairie

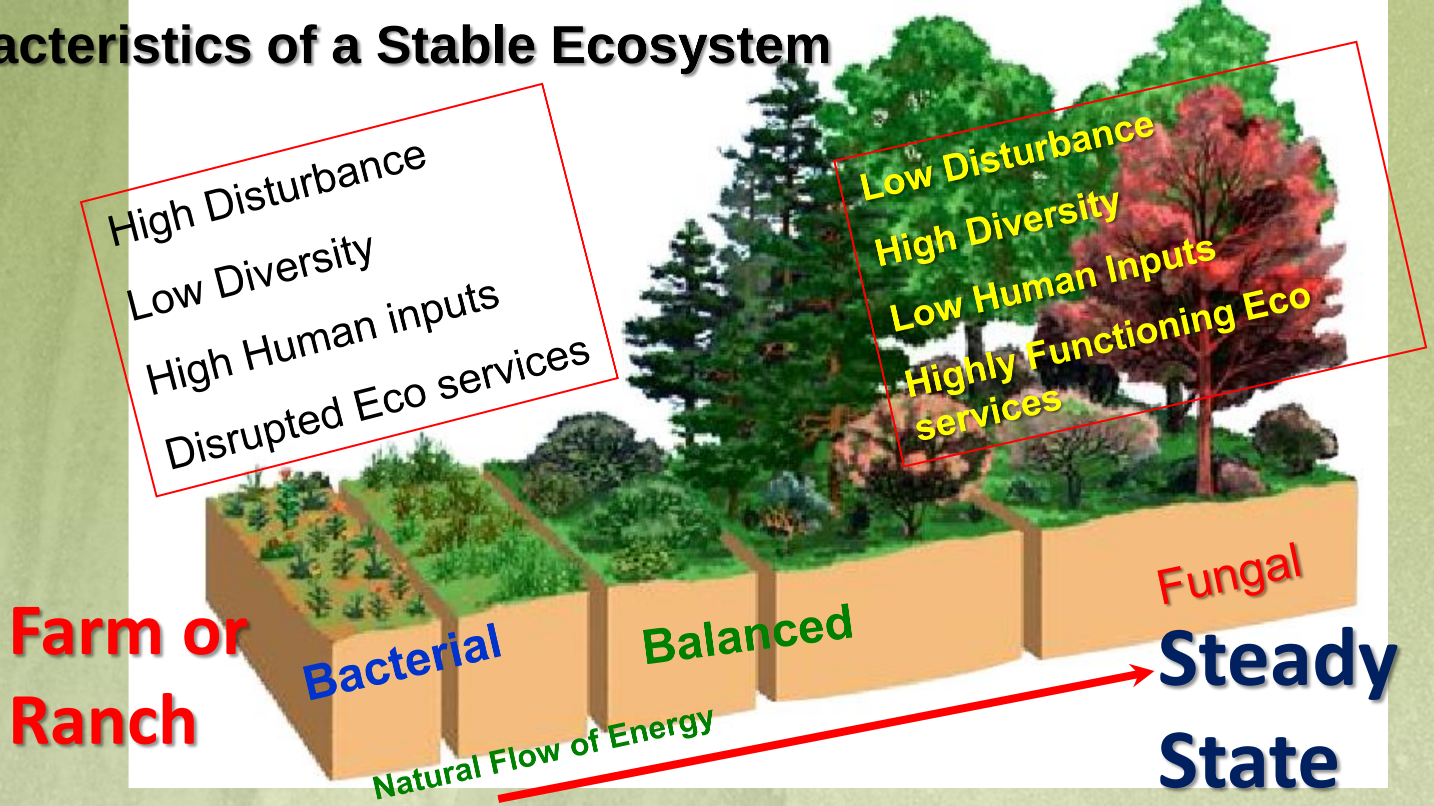
Forest



What do you see in these pictures of climax or steady state communities that would answer this question?

- Lots of diversity
- Minimal amount of disturbance

Characteristics of a Stable Ecosystem



Ecological succession - (ecology) the gradual and orderly process of change in an ecosystem brought about by the progressive replacement of one community by another until a stable climax is established.

- **Natural succession occurs in a plant community and soil communities.**
- Soil that is on the **low successional side** tends to be **dominated by bacteria has high pH and nitrate-nitrogen -** a preferred environment for low successional **plants (weeds)**.
- Soil on the high successional side **have a balanced soil food web**, release nutrients in an environment better suited for higher plants.
- Each step in the successional process leads towards a steady state community but is held back by natural or man induced disturbance.

Characteristics of a Steady (Stable) State Ecosystem:

- Low disturbance
- High diversity in plants, animal and soil biota
- Require low human inputs
- Have highly functioning eco-services, e.g. nutrient cycling, regulating water and diverse soil food web

Characteristics of an early stage successional ecosystem (farm or ranch):

- High disturbance, e.g. physical, chemical and/or biological
- Low diversity (monoculture)
- Require high human inputs
- Have disrupted or non-functioning eco-services

This soil is naked, hungry, thirsty and running a fever!

Conventional Soil Ecosystem

- This landscape photo could be anywhere in the U.S or across the world, **but it shows the current state of soil ecosystems in most of agriculture.**
- **Low successional level and is always kept there due to human activities.**
- Why does Ray say the soil is "Naked, hungry, thirsty and running a fever?"
    - **Bare soil harms the natural system in many ways**. Rainfall washes away precious organic matter. Organic matter 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.
    - **Low organic matter reduces the amount of available water for the planned crop**, also no cover leads to higher evaporation rates.
    - **Bare ground also increases soil temperature, making the soil less hospitable to soil organisms**. Temperatures on bare soil can reach above 115 degrees, some microbes start to go dormant at these temperatures.

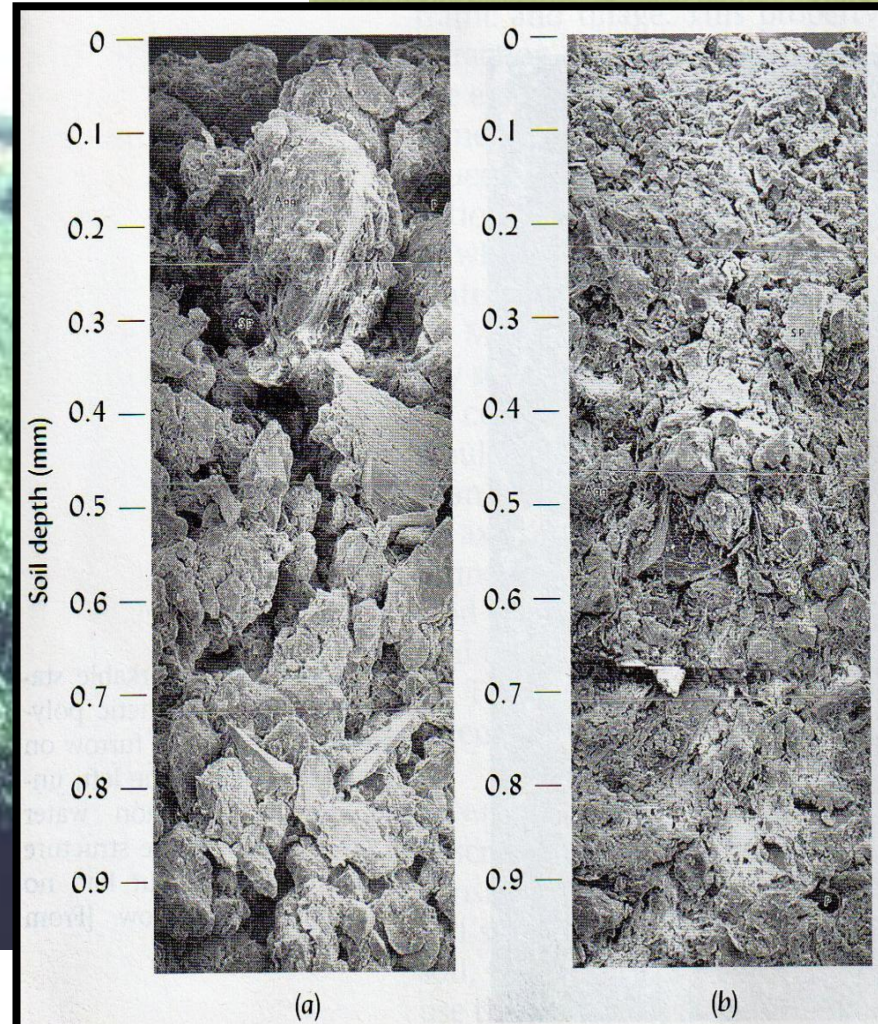
Erosion from bare fields into river

Oklahoma October 2012 I-35

Sediment is still the largest water quality pollutant by volume

Lubbock Texas Oct. 17,2011

In spite of all the conservation efforts over the past 75 years, **sediment is still the largest water quality pollutant by volume** and **dust storms still cause problems in the west**. Lack of understanding about how soil function and the impact that human disturbance have on soil function leads to misapplication of conservation practices.



Changing our Paradigm:

- Changing the way we look at the landscape by changing our paradigms.
- Time to have fun! Use this slide to stress that the soil on the upland is bare but should instead be covered at all times.
- Ask yourself**: "What is wrong with this picture"? "Or where is the resource concern?"**
- Participants in the past focused on the stream channel and the buffer strip….rarely did they focus on the bare ground located on the upland. The whole point of this picture is to elucidate to the participants about bare ground and our paradigms about the landscape.
- This photo illustrates **that unless the ground is covered at all times, you cannot expect single practices like buffers strips to prevent non-point pollution**.
- **The main focus: accentuate that the ground should be covered at all times.**
- The transition photo is from an electron microscope **showing what the surface looks like to a depth of 1 mm**.
  - **Left profile is well aggregated, lots of pore space**
  - **Right profile the surface is collapsed and sealed off, no water can enter the soil**

Agricultural soils do not have a water erosion/runoff problem, they have a water infiltration problem.

- 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, and 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.

Soil Disturbances that Impact Soil Health

- **Physical**
  - Tillage
  - Compaction
- **Biological**
  - Lack of Plant Diversity
  - Over grazing
- **Chemical**
  - Misuse of fertilizer, pesticides, manures and soil amendments

Soil Disturbance – this is an introduction to those activities that impact soil health and disrupt or destroy soil function, the following slides will go through each of these and explain the impacts in more detail.

What is Tillage?

The physical manipulation of the soil for the purpose of:

- **Management of previous crop residue**
- **Control of competing vegetation (weeds)**
- **Incorporation of amendments (fertilizer/manure)**
- **Preparation of a soil for planting equipment**
- **Recreation for folks who don't fish or golf.**

Tillage had a purpose in past agriculture production, but **now we have the technology to plant and harvest nearly any crop without tillage**. Now that we know better, we need to do better.

Tillage Trivia – 5 U.S. states have images of moldboard plows on their flag (KS, MN, MT, NJ & WI). 14 U.S. states have images of moldboard plows on their state seals (AR, IA, KS, MN, MT, NV, NJ, ND, OK, OR, PA, SD, TN & WI). The U.S. Department of Agriculture has a moldboard plow front and center on its seal.

What Tillage does to the Soil

- **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**

Impacts of Tillage

1. **Destroys aggregates**– breaks apart macro-aggregates into micro-aggregates
2. **Exposes organic matter to decomposition** – chops residue into small pieces, stimulates decompostion
3. **Causes compaction** – shearing action of metal on soil compacts soil particles at what ever depth this is being done
4. **Damages soil fungi** -- destroys habitat for soil fungi to flourish
5. **Reduces habitat for all members of Soil Food Web**
6. **Disrupts soil pore continuity**
7. **Increases salinity at the soil surface**
8. **Plants weed seeds**

“The truth is that no one has ever advanced a scientific reason for plowing”

Ploughman’s Folly by E.H. Faulkner

“We have equipped our farmers with a greater tonnage of machinery per man than any other nation. Our agricultural population has proceeded to use that machinery to the end of destroying the soil in less time than any other people has been known to do it in recorded history.”

“The chief trouble with our farming is that we have concerned ourselves with the difficult techniques of supplying our farm crops with new materials for growth, when we could easily take full advantage of the almost automatic provisions of nature for supplying plants with complete rations in secondhand form. We have made a difficult job of what should be an easy one”

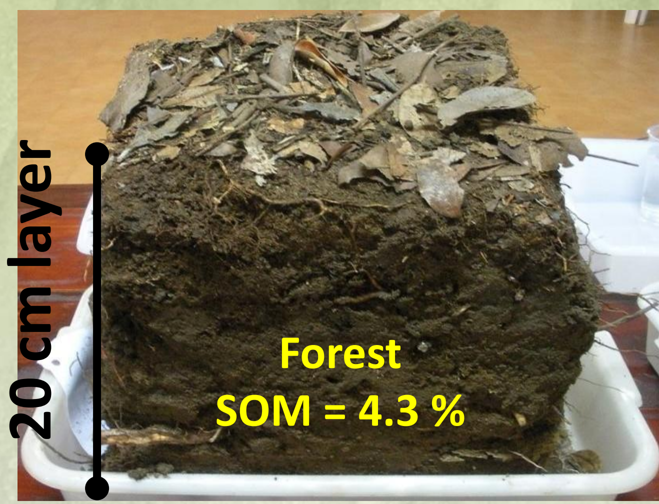
Some great quotes out of Edward H Faulkner’s book entitled “Ploughman’s Folly” written back in the 1940’s. His insights into the impact of plowing on soil health where ahead of his times.

Quote 1 speaks of the fact that we have destroyed our soil organic matter faster than any nation in history, this is supported by research.

Quote 2 speaks of the tremendous effort that goes into supplying crops with nutrients instead of following a more simplified natural approach.

Management Changes Soil Properties & Capacity of Soil to Function

62.8% loss of SOM after 17 yr intensive tillage

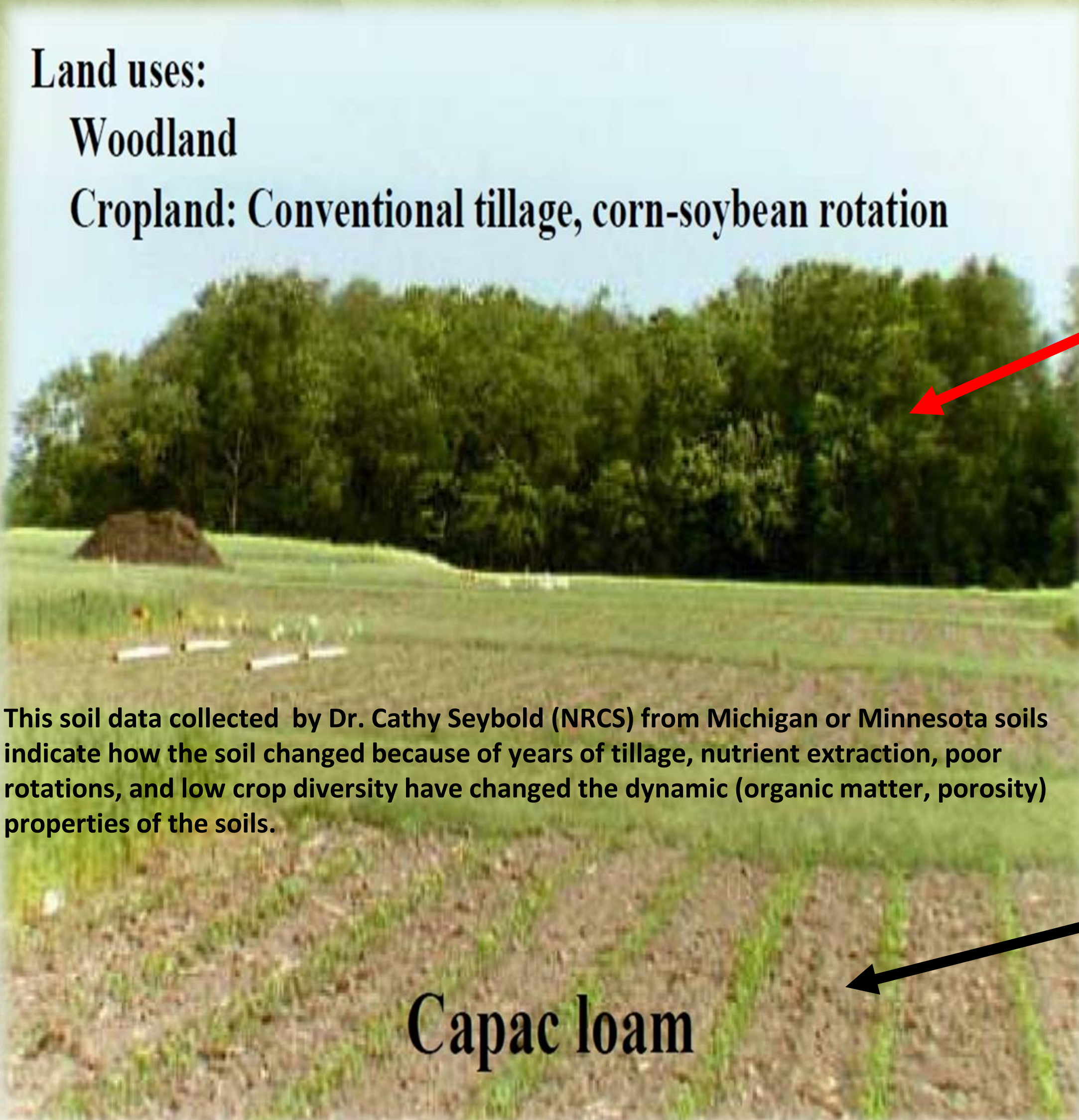


Example of how tillage has changed the dynamic soil properties of this soil, e.g. **Soil organic matter**, **soil structure**, **infiltration rate**, **bulk density** and **water and nutrient holding capacity.**

Key point:

- Forest soil OM was 4.3%
- Cropland soil OM now 1.6%
- **62.8% loss in SOM in 17 years**
- **National over 50% of SOM has been lost in past 100 years, most since the 1950's**

Study: Use-dependent Soil Properties



This soil data collected by Dr. Cathy Seybold (NRCS) from Michigan or Minnesota soils indicate how the soil changed because of years of tillage, nutrient extraction, poor rotations, and low crop diversity have changed the dynamic (organic matter, porosity) properties of the soils.

Wooded Soil: Bulk Density- 1.01 g/cm^3

Infiltration rate	Soil Nitrate loss
5.0 in./hr	1.8 lbs. N/ac.

Woodland

- **Had Low Bulk Density 1.01 g/cm3**
- **High infiltration rate 5.0 in./hr**
- **Low loss of soil nitrate 1.8 #N/ac.**

Conventional Tillage- Corn-Soybean: Bulk Density- 1.40 g/cm^3

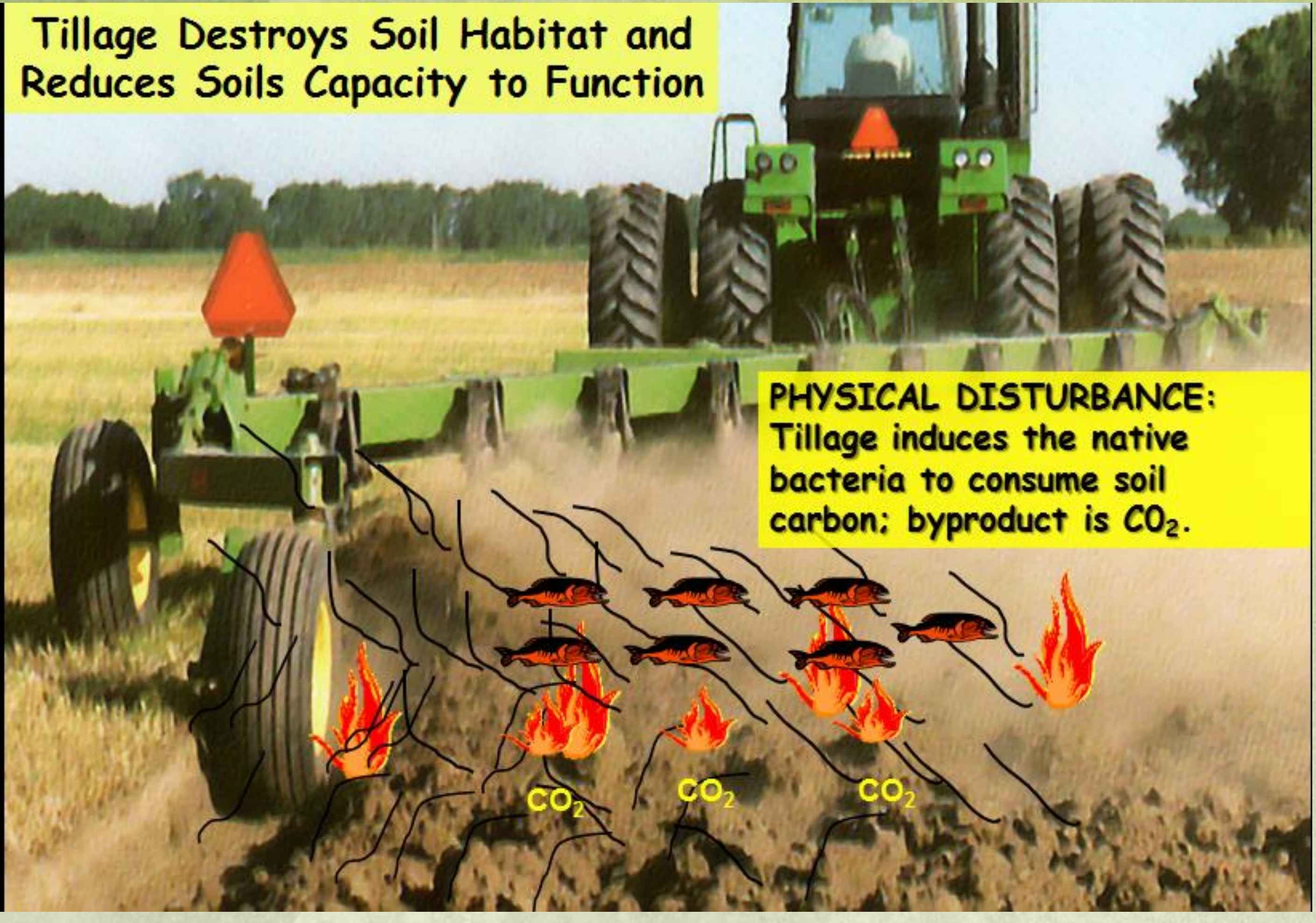
Infiltration rate	Soil Nitrate loss
.50 in./hr	15 lbs. N/ac.

Cropland

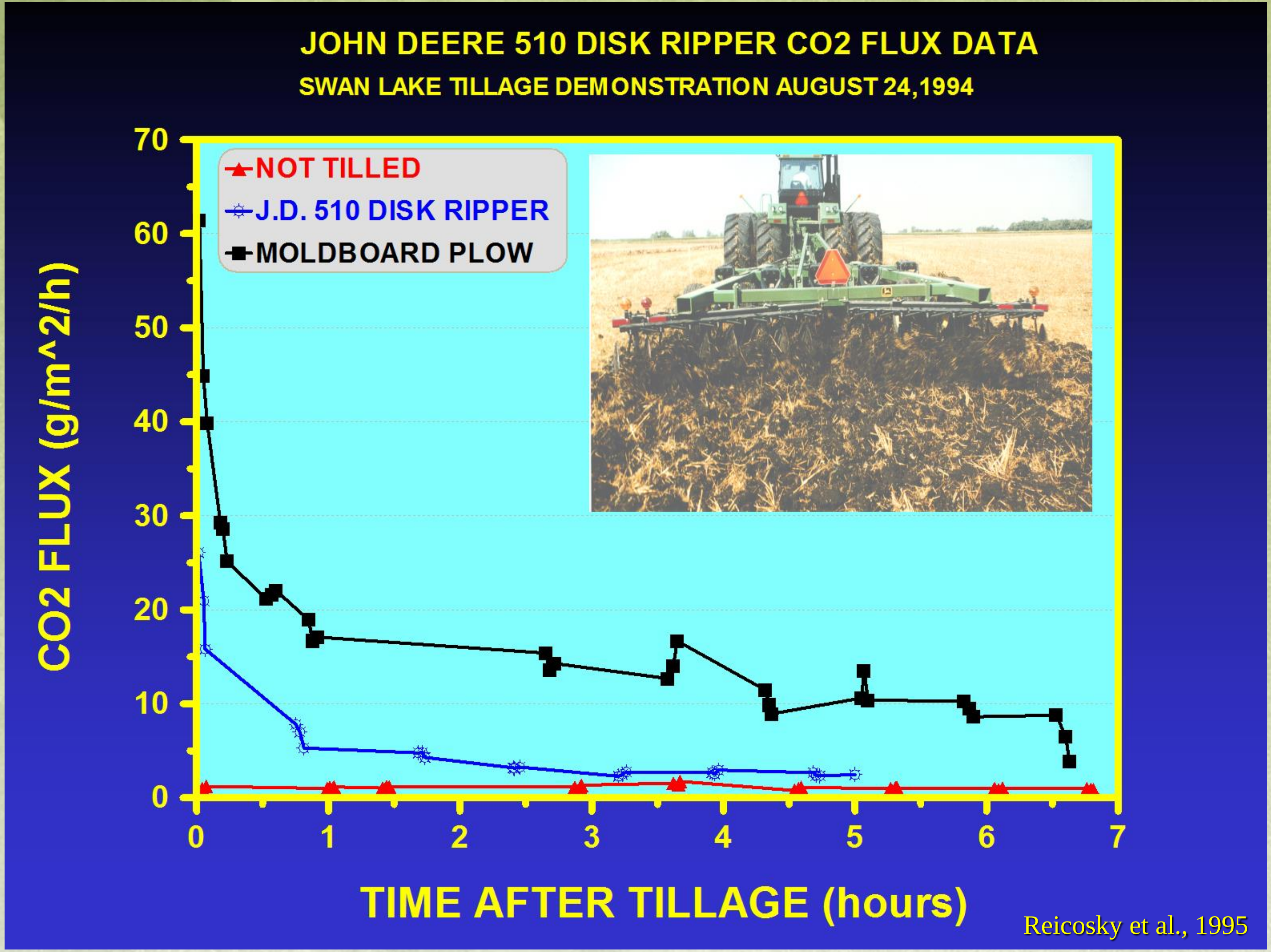
- **High Bulk Density 1.40 g/cm3**
- **Low infiltration rate .50 in./hr.**
- **High loss of soil nitrate 15 #/ac.**

Conclusion

- **Soil function was diminished in this conventional tilled soil**
- **Conventional system is a leaky system allows N to leave**



- **Physical disturbance** causes native bacteria to consume soil carbon once the soil is disturbed.
- This type of disturbance stimulates Zymogenous bacteria (rapid growing bacteria that flourish under nutrient rich environments) and Autochthonous bacteria (organisms living in soils that contain more recalcitrant material- no abundant supply of easily oxidizable substrate- less food).
- **These organisms are stimulated by the influx of oxygen into the soil ecosystem**. Once stimulated by the influx of oxygen, these organisms will consume the carbon based glues created by fungi.
- **SOM is lost as CO2 into the atmosphere**.
- Polysaccharides and other organic compounds bind individual soil particles together into tiny **micro-aggregates** into larger agglomerations called **macro-aggregates**. The gooey glyco-protein created by mycorrhizal fungi is called Glomalin and is a very effective cementing agent.
- Bacteria also produce polysaccharides and other organic glues as they decompose plant residues. These compounds are very important for keeping the soil pores intact. **No soil pores, no porosity, no infiltration**.



Work completed by Dr. Reicosky, Soil Scientist, USDA ARS NC Soil Conservation Research Lab Morris MN

Work shows the release of CO_2 within 7 hours after tillage was done.

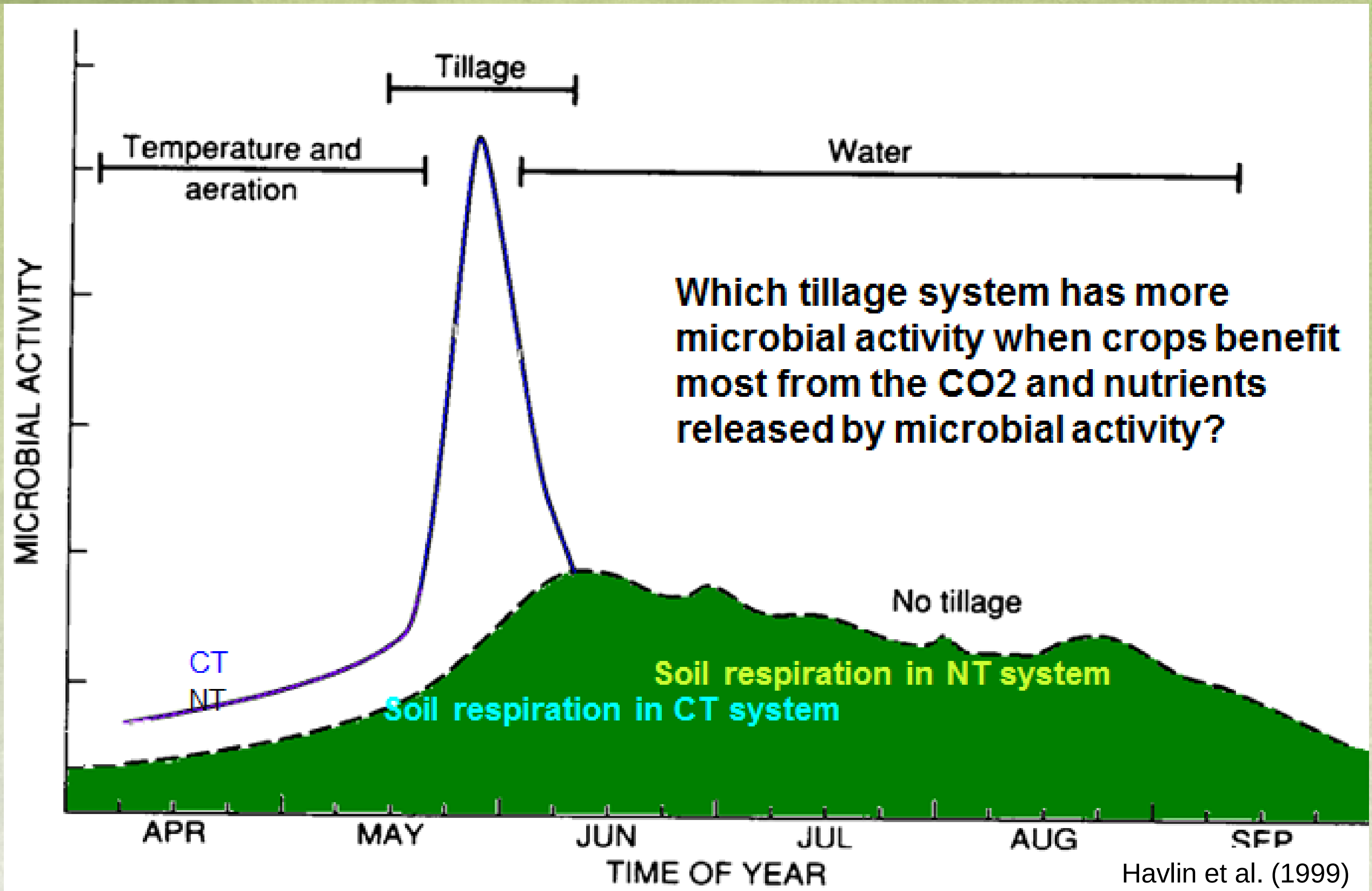
- Plowing had a high initial flux and the rapid decline to a higher value than NT or conservation tillage tool
- Conservation tillage tool has high initial flux that approaches the NT treatment.
- **No-till is very low near the zero line**

Different tillage = Different rates of Carbon loss

Loss of CO2 varies by tillage implement used and depth of tillage.

- Some tools that are considered as conservation tillage tools still release a lot of CO2 which means they are burning up SOM.

Effect of tillage on microbial activity



Havlin et al. (1999)

Soil respiration is an indicator of microbial activity:

- **Microbial activity releases nutrients into the soil**, e.g. N & P (mineralization).
- **Conventional Tillage** has a quick spike and rapid decline immediately after tillage is done. This results in release of nutrients at a time when plants may not need them, and can be utilized by weeds or lost to leaching.
- **No Till System has a much lower spike (40% of CT) but maintains soil respiration over the remainder of the growing season.** This results in slow release of nutrients for plant utilization over the course of the growing season.

Biological Disturbance

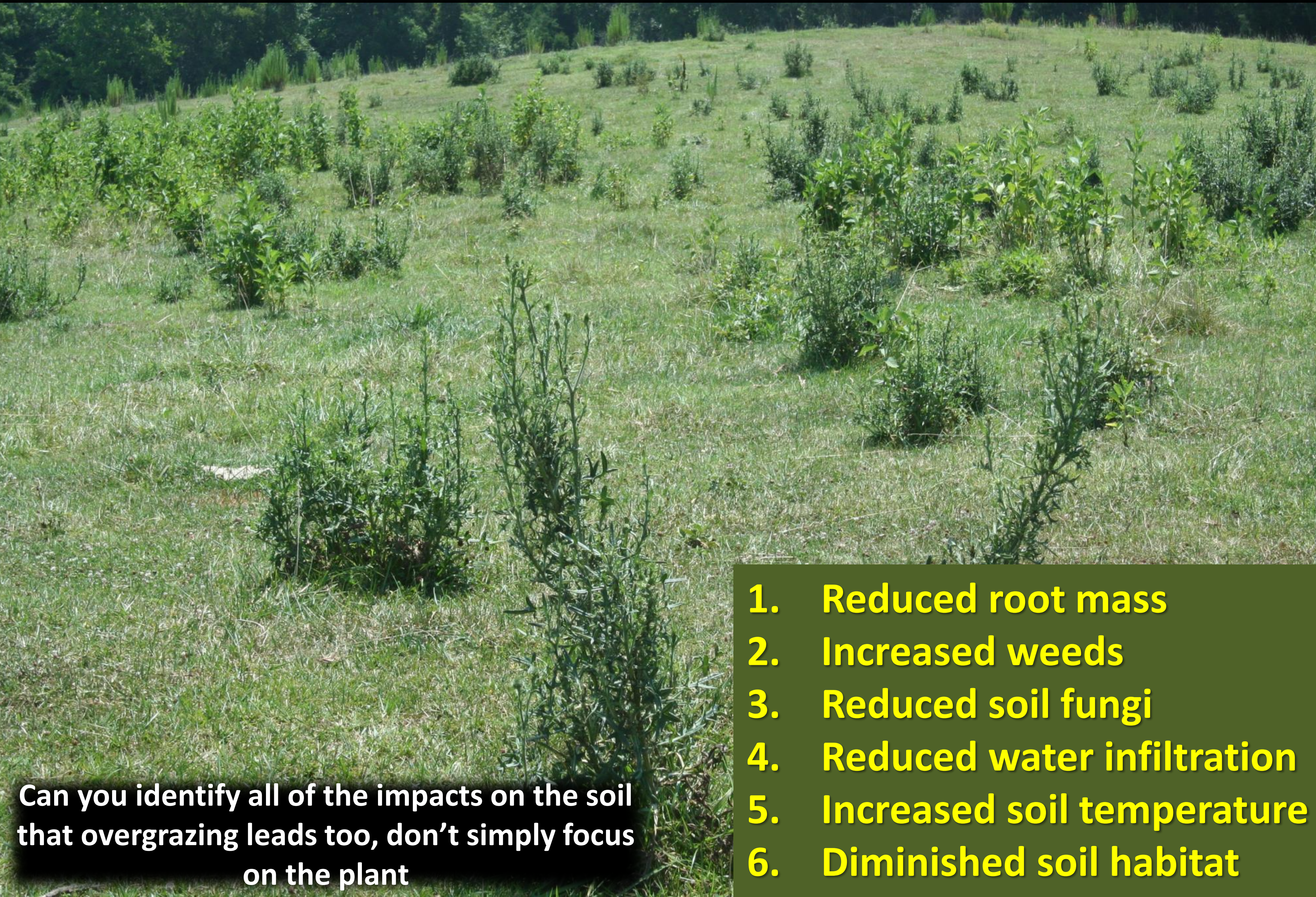
- No crop rotation diversity
  - Growing single species or few crops in rotation
  - Lack of diversity limits diversity of plant root exudates
  - Hampers the development of a diverse soil biota
- Overgrazing
  - Plants are exposed to intensive grazing for extended periods of time, without sufficient recovery periods

Disturbance to the soil habitat caused by biological means; don't think that miss application of biological activities can have an negative impact on soil health and function.

- **Monoculture** – growing a single species or limited number of crops in a planned rotation.
  - **Plant exudates attract specific soil microbes**, feeding the soil only a limited range of exudates will limit the number of species and different kinds of species in the soil food web.
  - Impacts nutrient cycling, building of soil aggregates and soil organic matter, etc.
  - **Limits the number of functional groups in the soil**, e.g. decomposers, photosynthesizers, bacterial or fungal feeders, results in imbalance, diseases, etc.

- **Overgrazing** – exposing plants to intensive grazing for extended periods of time, **without sufficient recover periods.**
  - Next slide goes into detail as to the impacts.

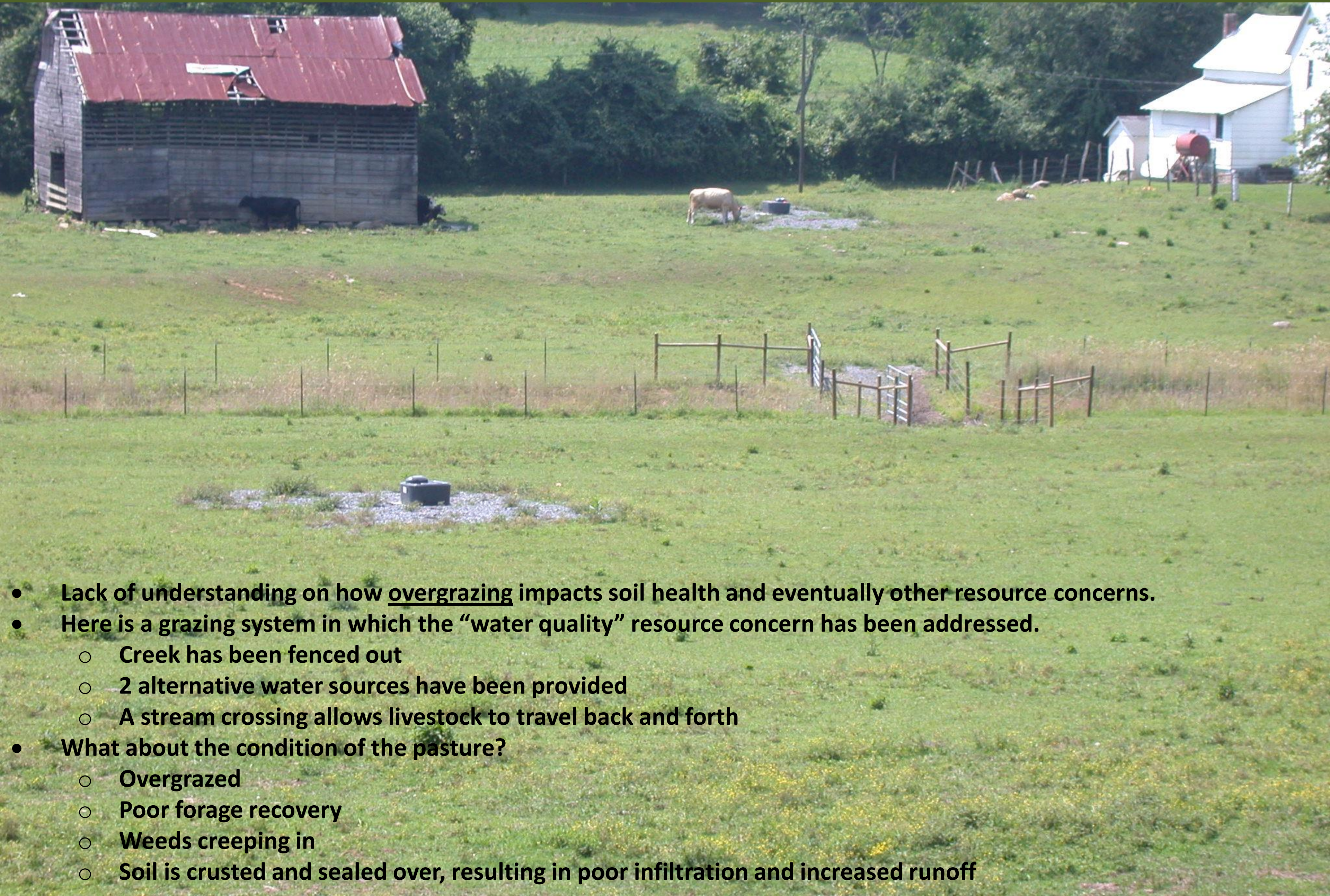
Biological Disturbance of Overgrazing



1. Reduced root mass
2. Increased weeds
3. Reduced soil fungi
4. Reduced water infiltration
5. Increased soil temperature
6. Diminished soil habitat

Can you identify all of the impacts on the soil that overgrazing leads too, don't simply focus on the plant

Alternative water sources & controlled access to stream but **no** control of grazing time on watershed



- **Lack of understanding on how overgrazing impacts soil health and eventually other resource concerns.**
- **Here is a grazing system in which the "water quality" resource concern has been addressed.**
  - **Creek has been fenced out**
  - **2 alternative water sources have been provided**
  - **A stream crossing allows livestock to travel back and forth**
- **What about the condition of the pasture?**
  - **Overgrazed**
  - **Poor forage recovery**
  - **Weeds creeping in**
  - **Soil is crusted and sealed over, resulting in poor infiltration and increased runoff**

Chemical disturbances: <u>over-application</u> of pesticides, fertilizers, amendments & manures

Chemical disturbance is the impact on soil health that the <u>over-application</u> of pesticides, fertilizer and manures have.

Impact of Pesticides on Soil Health

- Impacts non-target organisms
  - not well understood
  - Fungicide takes out mycorrhizal fungi
- Pesticides simplify, not diversify
- May restrict crop rotation
- May restrict cover crop diversity

- **Pesticides are non discriminating** in that the don't distinguish between the beneficial and non-beneficial organisms.
- **They can disrupt an entire trophic level** in a soil food web which would impact nutrient cycling and disease control.
- Since they are non-discriminating they simplify the soil biota, reducing the number of species and functional groups that should exist.
- **Potential carry over impact on the next crop** can limit planting options, leads to a monoculture rotation.
- Same principles applies to the selection of plants in a cover crop mix.
- **"Every chemical-based pesticide, fumigant, herbicide and fertilizer tested, harms or outright kills some part of the beneficial life that exists in the soil**, (or on the leaf surfaces) even when applied at rates recommended by their manufacturers... Less than half of the existing active ingredients used as pesticides have been tested for their effects on soil organisms."

Dr. Elaine Ingham, 2002, Soil Food Web, Oregon State University

Impact of Fertilizer on Soil Health

- **Short-circuits the rhizosphere & P cycle**
- **Depresses activity of natural N fixers**
- **Stimulates bacterial decomposition of SOM**
- **Excess N at risk for leaching or denitrification**
- **Increased soil salinity (Synthetic fertilizers are salts)**

Short-circuits the rhizosphere

- The rhizosphere: the area adjacent to the root that has the most biological activity taking place, mineralization (nutrient release) and disease prevention occur here.
- Excessive fertilizer discourages this area from developing to it full potential.

Depresses N-fixing bacteria in soil

- N-fixing bacteria have a mutualistic relationship with legume plants, producing N in exchange for food, when N is available to the plant then they don't establish or foster these relationship.

Stimulates bacterial decomposition of Soil Organic Matter

- Morrow plots in Illinois have shown that addition of N **has led to the loss of 50% of the SOM** since they began using it in the plot in the 1950.
- This has been accomplished by stimulating the bacteria through out the soil profile to decompose organic matter.

N at risk for leaching or denitrification

- Fertilizer N is applied in one of two forms, NH4+ or nitrate both are inorganic and **very water soluble** can leach or leave field through surface runoff, field tile etc.

Synthetic fertilizers are salts

- Over application can lead to osmotic shock in plant roots.

Impact of Manure on Soil Health

- Can add organic matter and carbon
- Build up of P to excessive levels
  - Greater than 100 ppm discourages plants from feeding mycorrhizal fungi
- Other issues
  - Heavy metals
  - Salts
  - Pathogens
  - Soil compaction from application/incorporation

- The addition of animal manure is generally good, increases organic matter, provides C source for microbes, etc.
- Excess application of manures leads to High P level that discourage plants to develop mycorrhizal fungi relationship, so plant might be getting P from the soil but they miss out on the other benefits that can be obtained, water, other nutrient exchange.
- Manure can contain toxic compounds depending on the food supplements that are being feed. These concentrate in the manure and can build up in the soil.

Soil is a Living Factory

- Macroscopic and microscopic organisms
  - Food
  - Water
  - Habitat
  - Powered by sunlight

- Management can improve or degrade soil health
  - Tillage
  - Fertilizer
  - Livestock
  - Pesticides

Remember that the Soil is a Living Habitat that needs to be managed in order for soil microbes to flourish and provide those soil functions that are necessary for food and fiber production.

In order to do this requires a shift in our Paradigm (covered in next slide).

Paradigm Shifts

- **Paradigm shift #1 Stop treating the symptoms of dysfunctional soil; solve the problem of dysfunctional soil.**
- **Paradigm shift #2 Restoring soil function can be accomplished without going broke.**
  - **Apply basic principles of ecology to create quality habitat.**
  - **There is no waste in Nature.**
- **Paradigm shift #3 Conservation practices do not restore soil health, understanding soil function restores soil health.**

This slide explains itself, these are the major paradigm shifts that we hope to accomplish with the soil health campaign that can transform the USDA-NRCS agency.

Managing for Soil Health

- Minimize Disturbance of the soil
- Maximize Diversity of plants in rotation/cover crops
- Keep Living Roots in the soil as much as possible
- Keep the soil covered at all times with plants and plant residues
- Create the most favorable habitat possible for the soil food web

Four simple principles for improving soil health by **creating the most favorable habitat for the soil food web**.

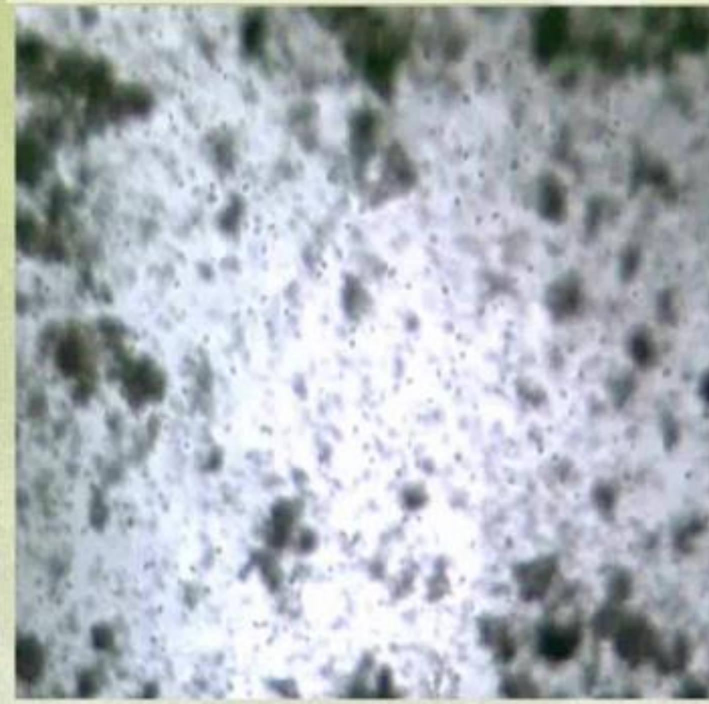
Soil Health Is Understanding How the Soil is Designed to Function and Managing it Accordingly

Inorganic Based Soluble State

- 40 to 60 % N and P Loss Cassmen 2002
- Bare fallows 4-8 months
- Decoupled C,N,P cycle

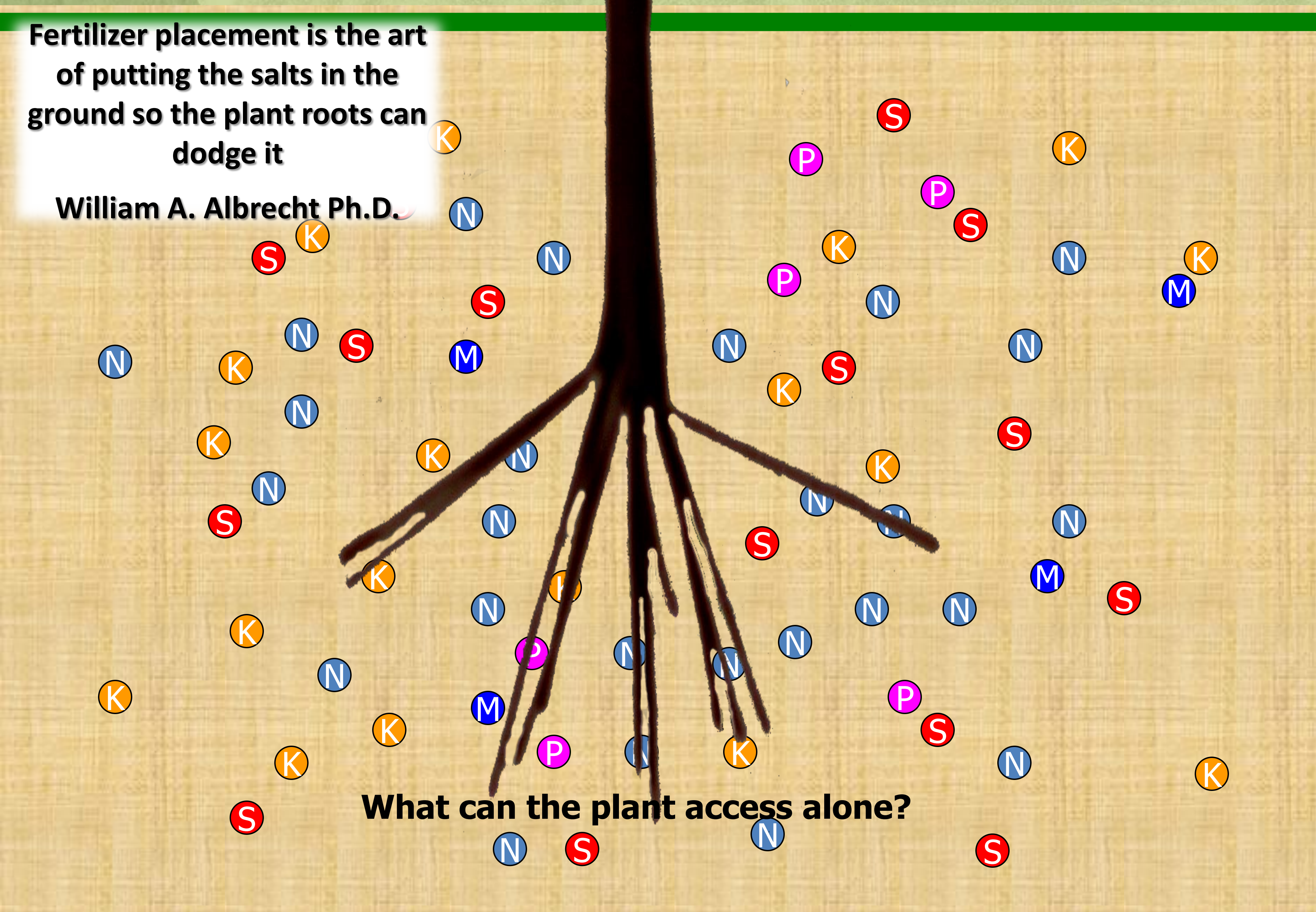
(Dr.Drinkwater, Dr. Swift)

Ecologically Based



- Organic-mineral pools
- Microbially plant mediated process
- Strategic use of variable nutrients sources

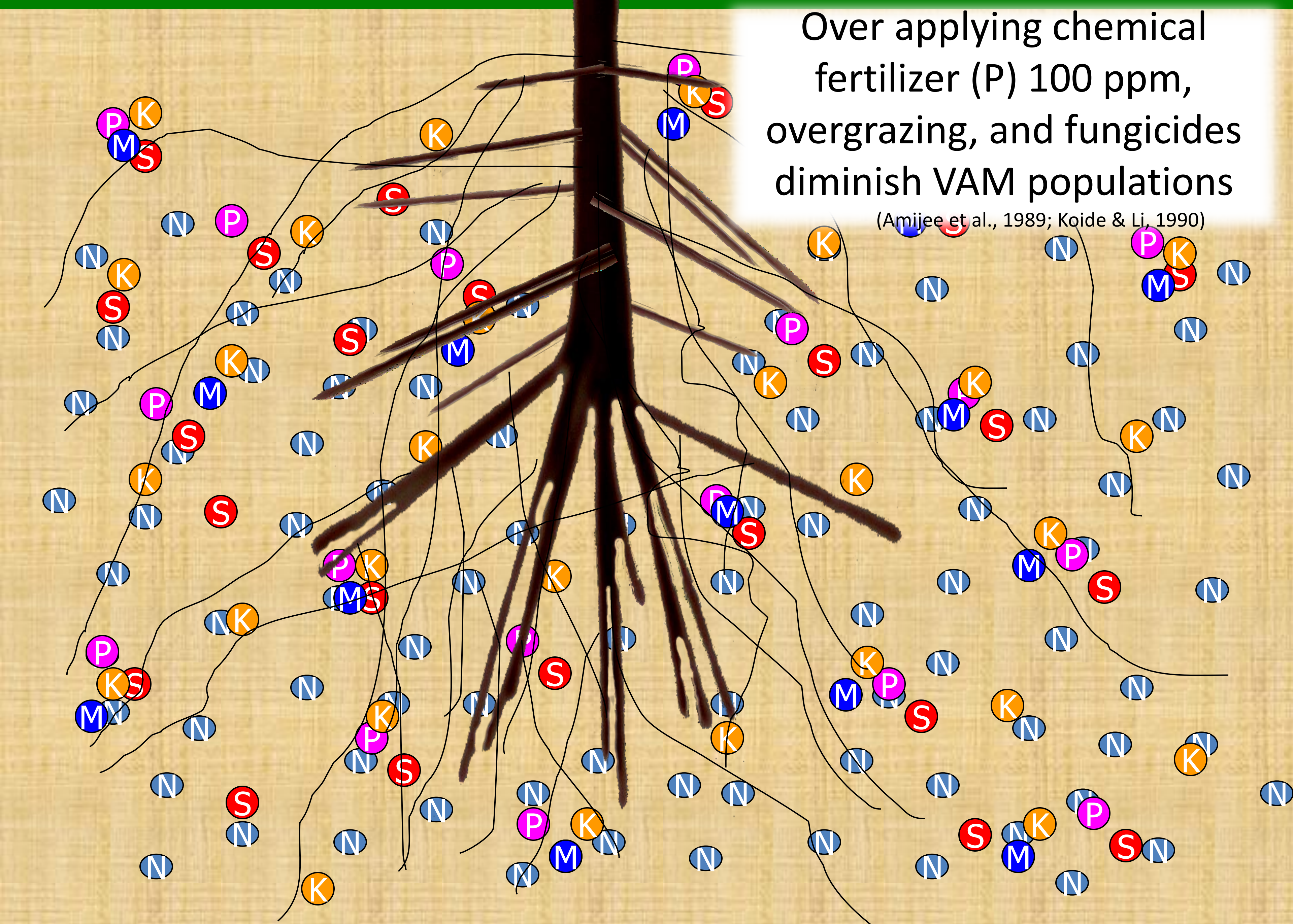
Soil the black box: There are many things that interact with soil solution. Plants absorb nutrients from soil solution.
Soils exchange cations with soil solution. Minerals release nutrients into soil solution.
OM releases nutrients to soil solution through mineralization.
Roots both living and dead exchange CO_2 & O_2 with soil solution.
Nutrients can be added to soil solution by artificial fertilizer and rain water. The soil is not a chemistry set or the black box.



To build more on the point of collaboration, consider this simple model. This is what it looks like in the soil system when roots are trying to gather available nutrients. **Plant roots are <u>not</u> very efficient at absorbing moisture and nutrients on their own. They need help**.

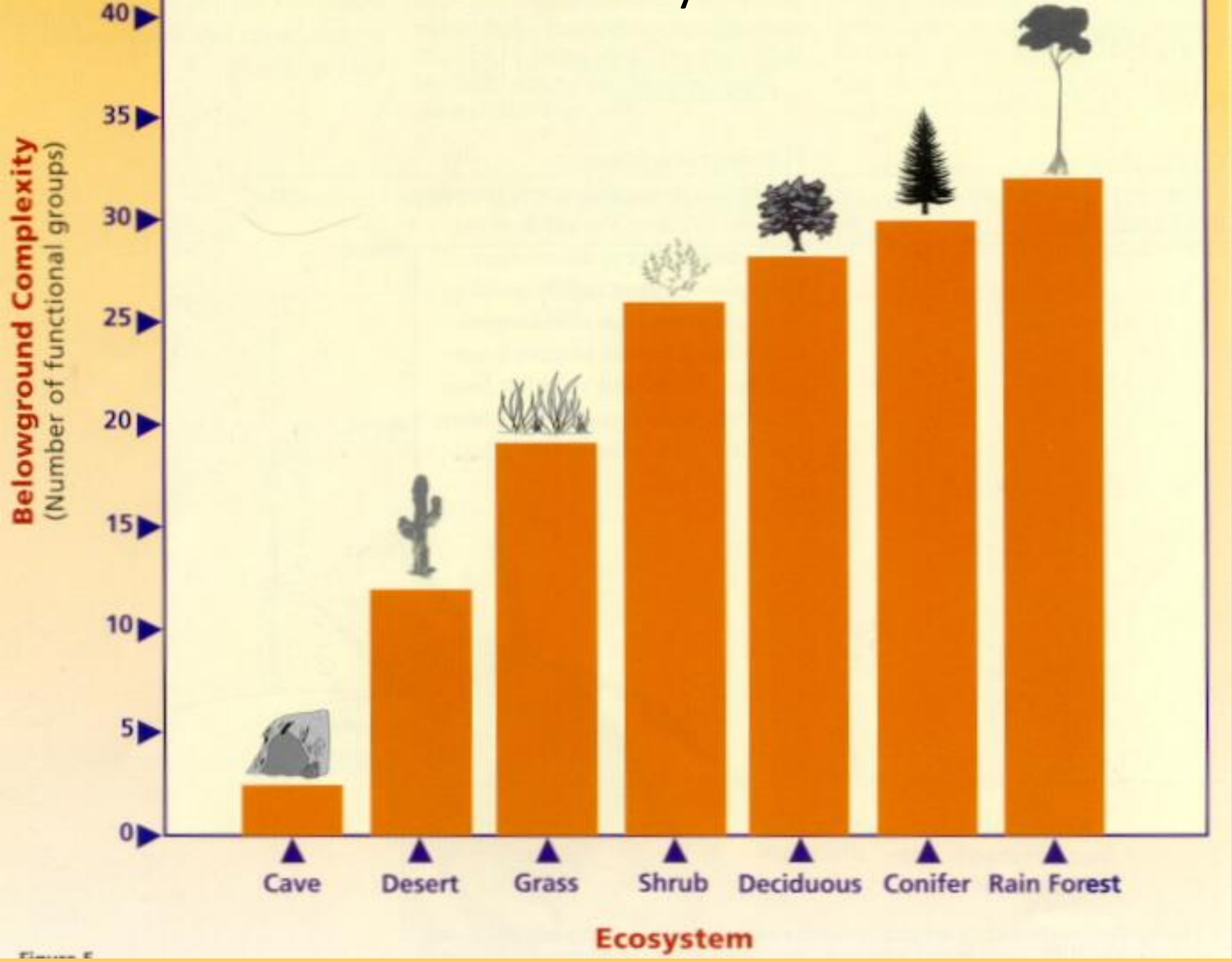
Over applying chemical fertilizer (P) 100 ppm, overgrazing, and fungicides diminish VAM populations

(Amijee et al., 1989; Koide & Li, 1990)



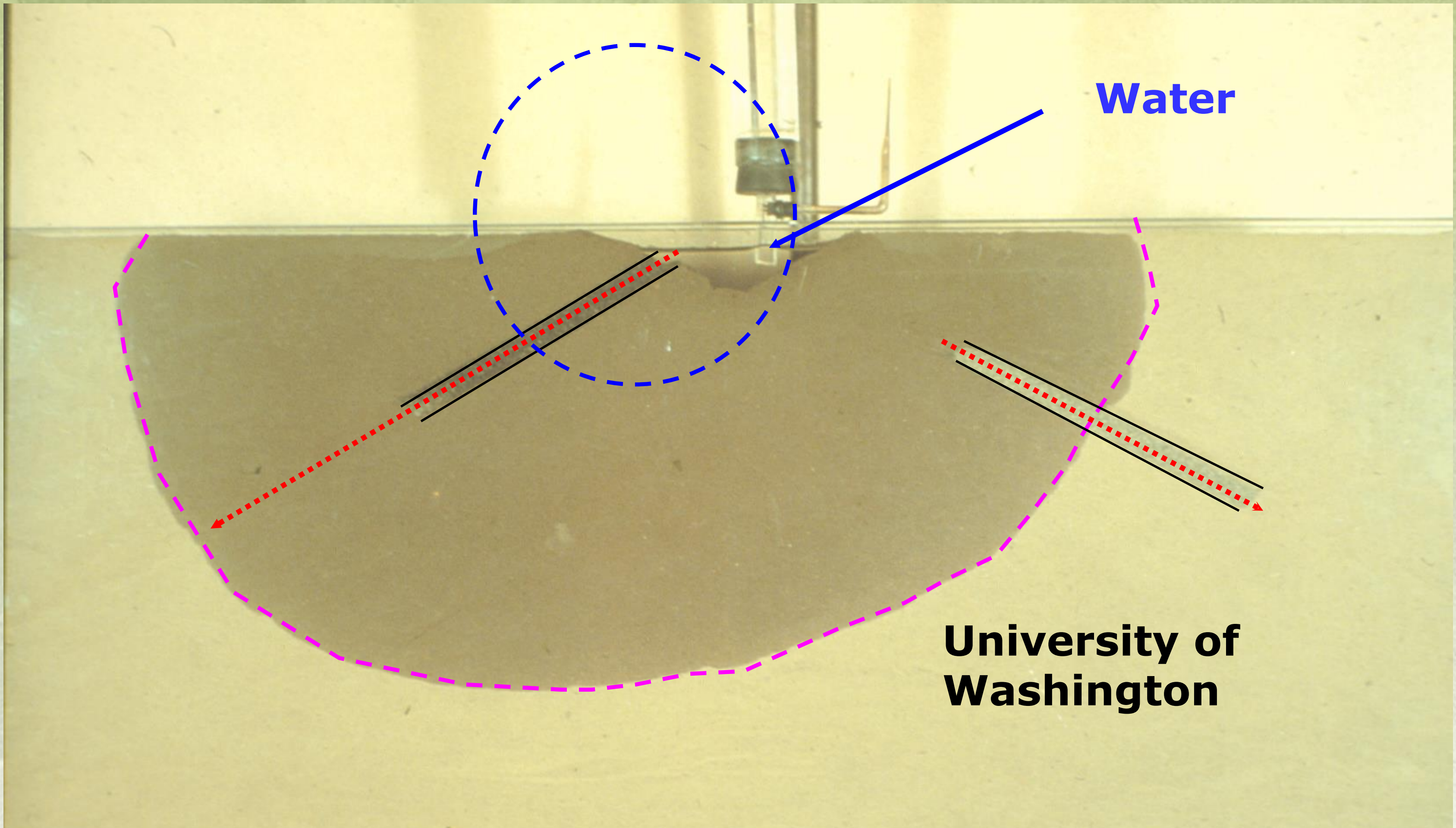
<u>Collaboration</u> between roots and fungi in the soil increase surface area for nutrient absorption.

Complexity of the Soil Food Web in Several Ecosystems



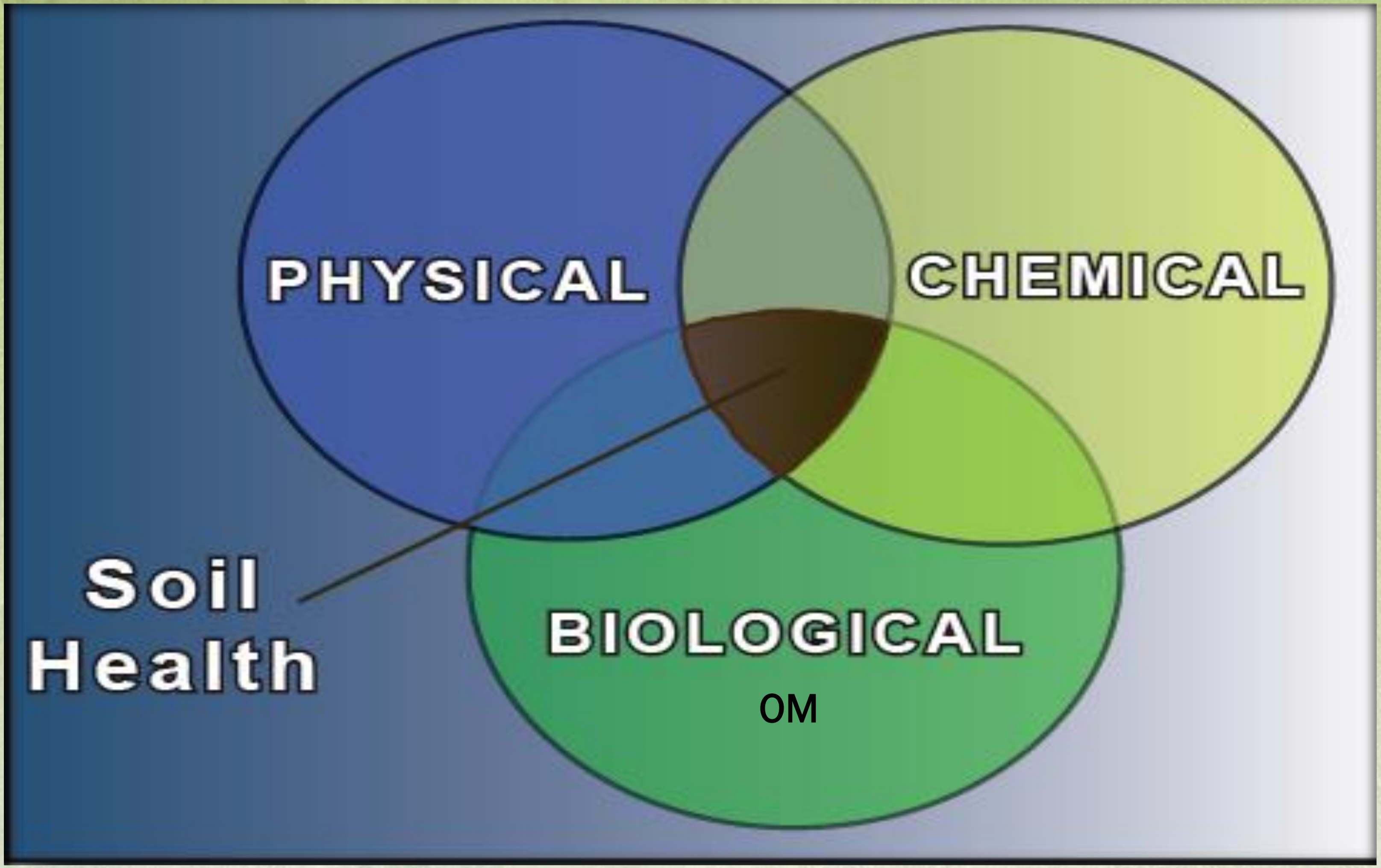
Woodland systems are typically more diverse than grassland or shrub ecosystems.

Only Pores Connected to Surface Increase Flow Rate



This slide shows how important it is to have a continuous connection of pores to the soil surface. On the left, the pores spaces are well-connected to the surface, allowing water to move further out and into the soil profile. Pores on the right are less connected. Water movement is not as far out into the soil.

Evaluate How Your Soil System is Functioning



All parameters are important; typically we focus on physical and chemical- but Biology is King!

Typical Agriculture as we know it emphasizes the Physical/Chemical side of the Soil – <u>we ignore</u> the Biological side of the soil.

We are taught to treat the soil system as a machine instead of recognizing it as a living biological system.

WE ARE TAUGHT IN CONVENTIONAL AGRICULTURE REDUCTIONIST SCIENCE – HOW MANY OF YOU WERE TAUGHT THIS WAY IN SCHOOL – **You have a weed –kill it –you have a bug Kill it**.
We need to step back and use a Holistic view of these systems – tie the dots together and help farmers farm – **Learn how to make our soils function! It's called ECOLOGY!**

DID WE CREATE THE PROBLEM/SYMPTOM? DO WE NEED TO CHANGE SOMETHING IN OUR MANAGEMENT TO TRULY CORRECT THESE PROBLEMS?

We need to Farm in nature's image – We are not here to talk about individual tools (Conservation Practices) that address the symptoms or results of our actions – **We start with understanding of how the soil system works.** Talk about understanding, **then we talk about tools to help us change the soil dynamic properties**, those that give us a soil that functions. (this is Conservation Planning (SHMS) – What can be done to improve the soil?

Remember this quote - Nature Acts, Man Argues! (Voltaire) – **The Agroecosystem will react to whatever you throw at it.**

Typically the chemical and physical have been the major focus for nutrient management, especially in conventional agriculture. We will discuss the Soil Fertility and Crop Nutrient Management in relation to Soil Ecology.

3 Forms of Nitrogen – Ammonium (NH_4^+), Nitrite (NO_2^-) and Nitrate (NO_3^-) – these forms arise either from the normal aerobic decomposition of soil orgnanic matter or from their additions to the soil of various commercial fertilizers. These 3 forms represent about 2-5% of the total soil nitrogen.

Initially N is in the Ammonium form (NH_4), this is converted to Nitrite (by Nitrosomonas) then to Nitrate (by Nitrobacter). <u>This is a Biological Process – not a Chemical Process!</u> As we go from Conventionally tilled Farming to No-Till/Strip-Till Farming – you will go from much available Nitrate in the soil to one that has more Ammonium (NH_4). Caused by increase/stability of microbes. Want to solve your incidence of Nitrates getting into the water – work at getting biology back into the soil with Organic Matter and you will increase infiltration – also will increase the Cation Exhange Capacity – which means you will hold more nutrients – this is how to increase fertility of the soil (add carbon which has been depleted) … NH_4 is positively charged.

Nitrites must be converted to nitrates because accumulated nitrites are toxic to plant life.

Rhizobium Bacteria have symbiotic relationships with Legume plants. Rhizobium fix Nitrogen – what form of nitrogen comes from Rhizobia? Produce ammonia in exchange for carbohydrates.

Fixes N_2 into form the plant can use. Nitrogen is fixed by binding it to hydrogen and making it into ammonia which the legume plant can use. Rhizobia benefit as the plant provides carbohydrates to the rhizobia which are required as a source of energy. The carbohydrate produced by the legume plant are transported to the nodules where they are used by the rhizobia as a source of hydrogen in the conversion of nitrogen to ammonia (NH_3).