SOIL SMaRTS

Specific Management and Resources Trainings for Soil Health in Tennessee

TRAINING CURRICULUM

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Southern SARE
Sustainable Agriculture Research & Education

UT Extension
Institute of Agriculture
The University of Tennessee

USDA United States Department of Agriculture

This curriculum was developed through a Southern SARE grant and collaboration between Tennessee State University, the USDA-NRCS, and the University of Tennessee. The objective of this curriculum is to provide training on soil health and sustainable management practices for soil health to extension agents and local officials so that they may disseminate this information to their stakeholders.

Soil Smarts Training Curriculum

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MODULE 1. SOIL HEALTH BASICS

Learning objectives:

Participants will be able to:

- define and demonstrate the importance (why) of soil health in agricultural systems
- define soil health and list primary ecosystem functions necessary for food and fiber production
- identify soil health principles

Materials:

- PowerPoint® slides "Module 1: Soil Health Basics"
- Lesson guide: Use the notes in this lesson guide to present information for each presentation slide.
- Questions found at the end of this lesson guide can be used to test participants' knowledge at the end of the presentation. This can be combined with clickers to improve audience engagement and create discussion.
- An evaluation of the presentation can be found in this lesson guide following the lesson questions.

Topics

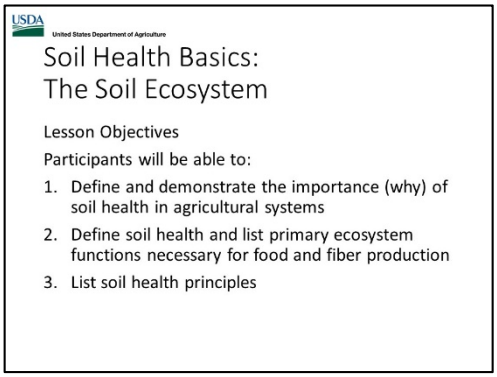
What is soil health?
Stable ecosystems
Effects of tillage
Effects of biological disturbance
Effects of pesticides and fertilizers
Managing for soil health

Slide 1

This discussion will provide a basic overview of soil health.

Slide 1

Slide 2



Slide 2

Slide 3

Ag Media has been very supportive of soil health, you can't hardly pick up an ag-publication that doesn't contain an article about soil health.

The Furrow, John Deere Magazine even had a special issue devoted to Building Better Soils a few years back, ironic that a publication name after the plow furrow would highlight soil health that is devoted to eliminating the furrow….

Slide 3

Slide 4

NRCS undertook a national soil health campaign in the fall of 2012, and rolled out the "Unlock the Secrets of the Soil" website with a lot of soil health information

Contains: Videos, articles, and the science of soil health series

Slide 4

Slide 5

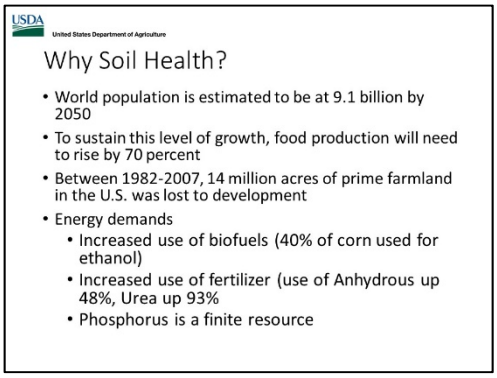
Even mainstream media is picking up on soil health as attested by numerous articles in newspapers and magazines. The article "Farmers Put Down the Plow…." was found by an NRCS employee in a newspaper in India while traveling.

Slide 5

Slide 6

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

-There is an increasing demand for production, world population is currently at 7 billion and expected to rise to over 9 billion in less than 30 years
-There is a decrease in land capacity
-Energy demands for commodity crops have resulted in increased use of synthetic fertilizers

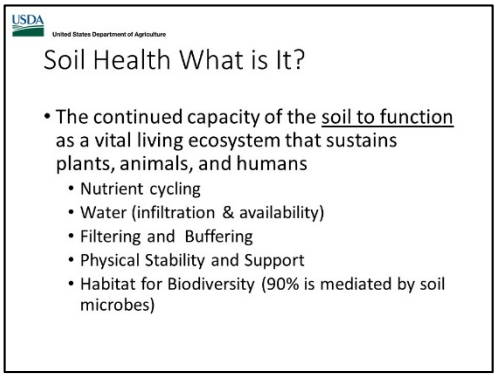


Slide 6

-Phosphorus is a finite resource with known available sources in place that are difficult to access for environmental reasons

Slide 7

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 lead to a condition or state, there is something that can be done to change it in a positive way.



Slide 7

The key to the definition is that soil health is:
Continued capacity—implies rejuvenation and then sustainability

Soil is a living ecosystem– folks need to recognize that the ground beneath them is a living ecosystem

Soil function – soils need to provide the basic functions below in order for food & fiber production to meet the demands in the previous slide

- 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.
- Water Relations - Soil can regulate the drainage, flow, and storage of water and solutes, which include 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.
- 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.
- 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.
- 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.

Slide 8

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.

All living organisms, no matter the size, need food, water and shelter (habitat) to survive and flourish and this system is driven by sunlight

Introduces the concept of disturbance and how disturbance affects habitat for soil organisms

Management determines how soil functions

Slide 8

Slide 9

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

Ray Styer: North Carolina, farms 70 acres of silage corn in rotation with multi-species cover crop mixes, was an old tobacco farm, hasn't used commercial fertilizer in this millennium

Slide 9

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.

Gabe Brown: east of Bismarck, ND, 2000+ acres of cropland and 4000 acres of grazing (combination of range and pasture). He 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

Ray McCormick: Farms in southern IN along the Wabash River. He 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.

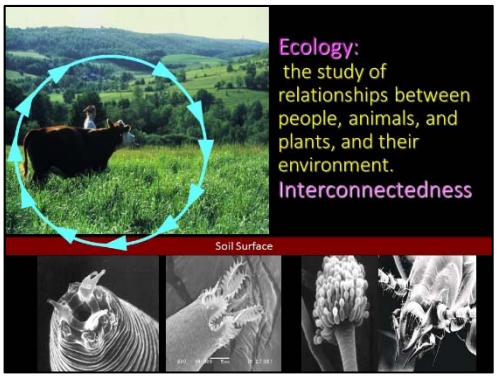
Brandon Rockey: Potato farmer from Colorado, rotates cover crops with potato and companion crops in potato

Tennessee Soil Health Heroes are featured on tnacd.org., soil health heroes. Currently (August 17, 2018), there are 46 published.

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

Slide 10

Key Points:
Introduces the concept of ecology and its role in agricultural systems



Slide 10

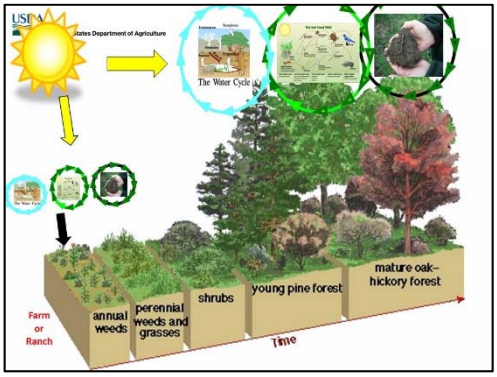
Ecology: the study of relationships between people, animals, plants, and their environment

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

Slide 11

Key Points



Slide 11

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

Nature wants to get to a steady state community

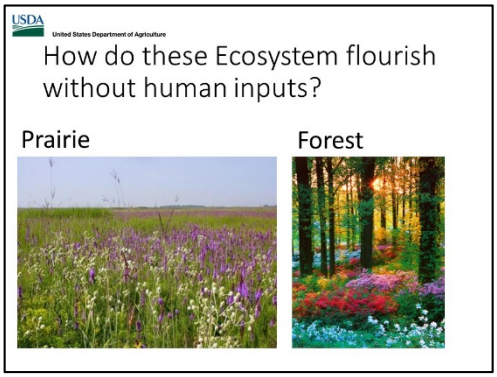
- Soil is the integrator between different ecosystems.
- Agricultural lands (crop, grazing, etc.) are part of the earth's ecosystems or biomes
- In natural ecosystems, the vegetative cover of a forest or grassland prevents soil erosion, replenishes ground water and controls flooding by enhancing infiltration and reducing water runoff (Perry, 1994).

- In agricultural systems, biodiversity performs ecosystem services beyond production of food, fiber, fuel, and income. Examples include recycling 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).

Slide 12

Ask participants what they see in these pictures of climax or steady state communities that would answer this question?

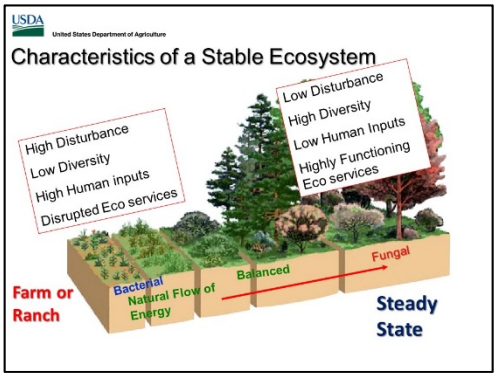
- Lots of diversity
- Minimal amount of disturbance



Slide 12

Slide 13

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



Slide 13

- Natural succession occurs in a plant community and soil communities
- Soil that is on the low successional side tends to be dominated by bacteria and has high pH and nitrate-nitrogen - a preferred environment for low successional plants (weeds).
- Soil on the high successional side has a balanced soil food web and releases 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 human-induced disturbances

Characteristics of a Steady (Stable) State Ecosystem

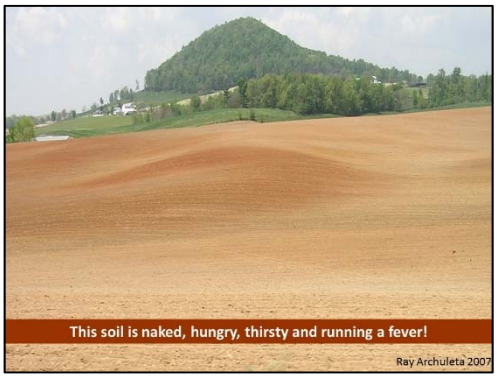
- Low disturbance
- High diversity in plants, animal and soil biota
- Require low human inputs
- Have highly functioning eco-services, e.g. nutrient cycling, regulating water and diverse soil food web

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

Slide 14

Conventional Soil Ecosystem



Slide 14

- 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 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 (OM). Organic matter holds many crop nutrients, and OM is the lightest fraction of the soil and the first to be carried offsite.
    - Bare ground harms the macro and micro organisms due to a lack of carbon (food) in the soil ecosystem. In a bare ground environment, the soil is in starvation mode with no live roots 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.

Slide 15

Despite all of 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. A lack of understanding about how soil functions and the impact that human disturbance can have on soil function leads to misapplication of conservation practices.

Slide 15

Slide 16

Ask the participants, "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 talk to participants about bare ground and our paradigms about the landscape.
- Illustrate to the group that unless the ground is covered at all times you cannot expect single practices like buffers strips to prevent non-point pollution.

Slide 16

- 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

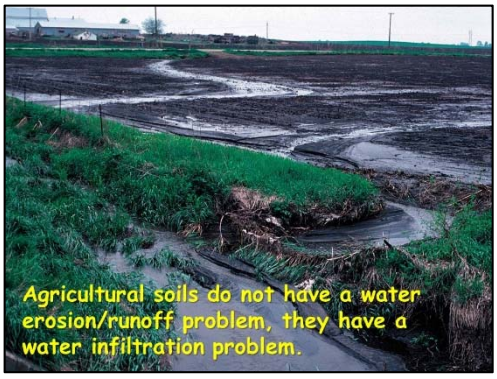
- Left profile is well aggregated, lots of pore space
- Right profile the surface soil is collapsed and sealed off, no water can enter the soil

Slide 17

NRCS has always tried to deal with runoff at the field level, accepting the fact that runoff occurs. It 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. This is reactive rather than proactive.

Improving soil health will improve infiltration and reduce surface runoff.

Managing for soil health treats the problem of soil dysfunction.



Slide 17

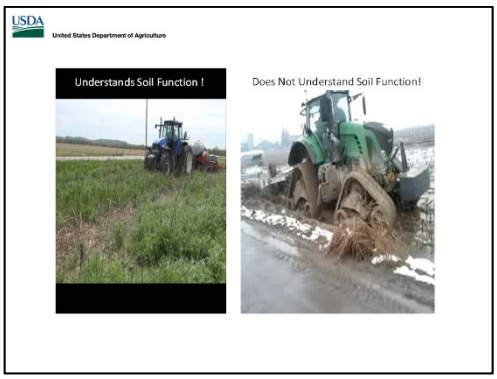
We must have a soil that will allow water to infiltrate where the raindrop lands, and not where it leaves the field.

Example of lack of understanding impacting how resources are managed:

Jay Fuhrer became District Conservationist in Burleigh County, ND in the late 1980's, built a lot of waterways to deal with the gully erosion caused by excessive runoff in a region of the country that gets 16 inch of rain. A lack of understanding of how soils are supposed to function, led to accepting these conditions. After gaining insights in soil health and how changing management impacts soil function they no longer build waterways in Burleigh County, and most rainfall infiltrates and doesn't runoff. They've also eliminated "fallow" as part of a crop rotation due to increased soil moisture.

Slide 18

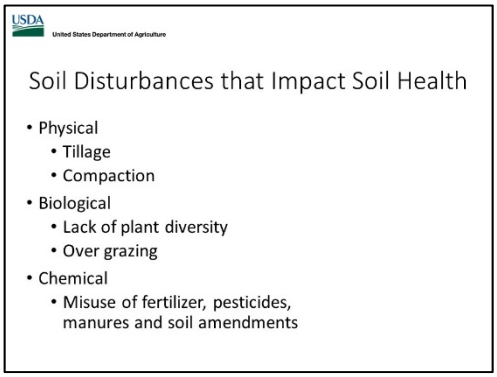
A light-hearted comparison between a farmer who understands soil function and one that doesn't.



Slide 18

Slide 19

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.

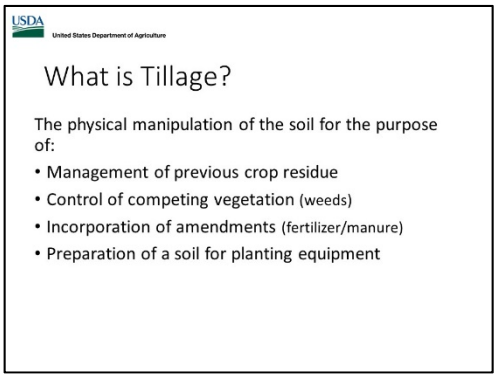


Slide 19

Slide 20

Tillage had a purpose in past agricultural 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.

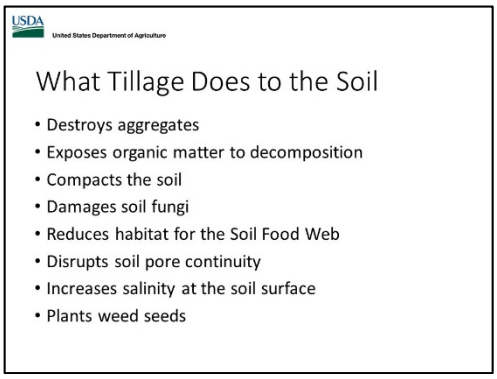


Slide 20

Slide 21

Impacts of tillage:

- Destroys aggregates– breaks apart macro-aggregates into micro-aggregates
- Exposes organic matter to decomposition – chops residue into small pieces which stimulates decomposition
- Causes compaction – shearing action of metal on soil compacts soil particles at any depth
- Damages soil fungi – destroys habitat for soil fungi to flourish
- Reduces habitat for all members of the Soil Food Web
- Disrupts soil pore continuity
- Increases salinity at the soil surface
- Plants weed seeds



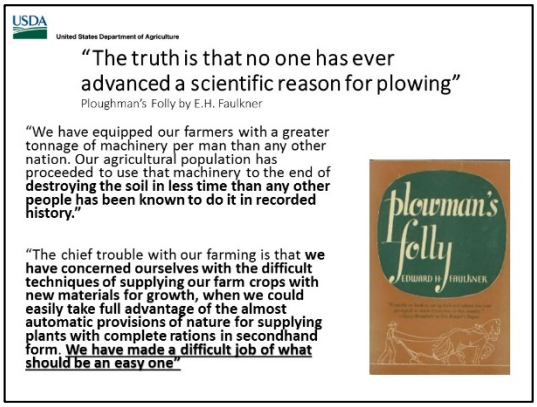
Slide 21

Slide 22

These are 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 were ahead of his time.

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

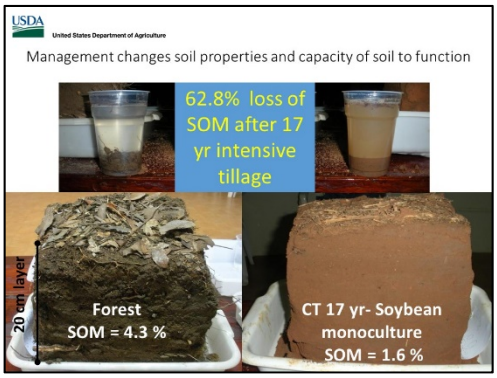
Quote 2 speaks to the tremendous effort that goes into supplying crops with nutrients instead of following a more simplified natural approach



Slide 22

Slide 23

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).



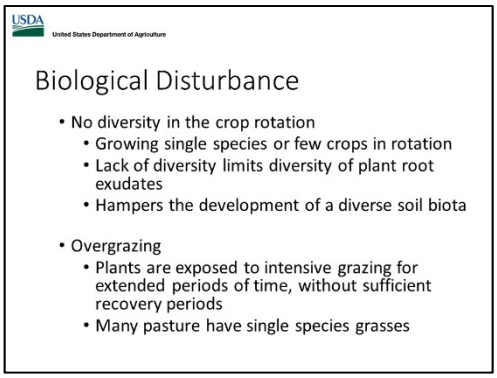
Slide 23

Key points:

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

Slide 24

We don't think that misapplication of biological activities can have a negative impact on soil health and function.



Slide 24

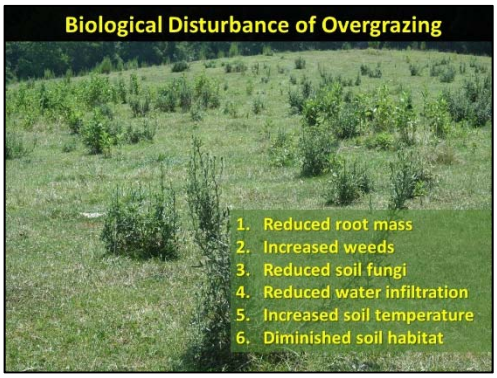
Monoculture – growing a single species or limited number of crops in a planned rotation

- 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 which results in imbalance, diseases, etc.

Overgrazing – exposing plants to intensive grazing for extended periods of time, without sufficient recovery periods

Slide 25

Have participants identify all of the impacts on the soil that overgrazing leads to, don't simply focus on the plant.



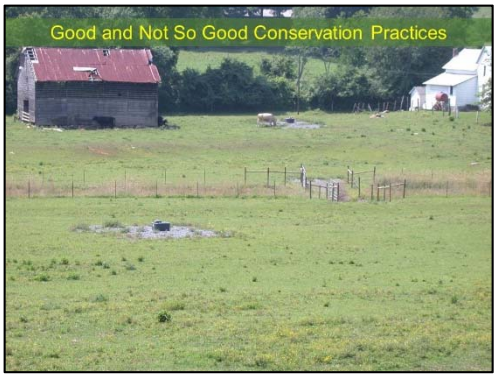
Slide 25

Slide 26

There is a lack of understanding on how overgrazing impacts soil health and eventually other resource concerns.

In the image 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



Slide 26

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

Slide 27

Chemical disturbance is caused by the over-application of pesticides, fertilizer and manures.

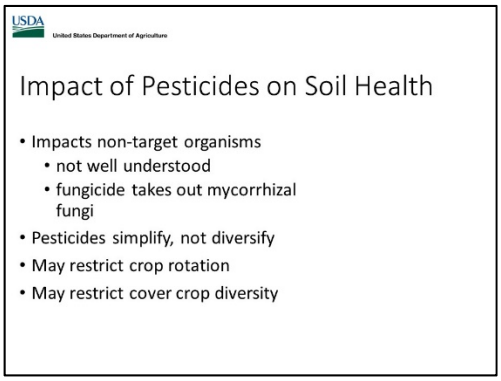
Slide 27

Slide 28

Pesticides are non-discriminating in that they don't distinguish between 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.



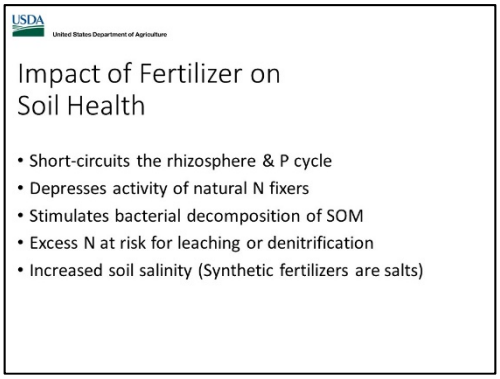
Slide 28

Potential carryover impact on the next crop can limit planting options, leads to a monoculture rotation. Same principles apply 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

Slide 29

Short-circuits the rhizosphere:
The rhizosphere is the area adjacent to the root that has the most biological activity taking place (mineralization [nutrient release] and disease prevention. Excessive fertilizer discourages this area from developing to its full potential



Slide 29

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 they don't establish or foster these relationships

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's
This has been accomplished by stimulating the bacteria throughout the soil profile to decompose organic matter

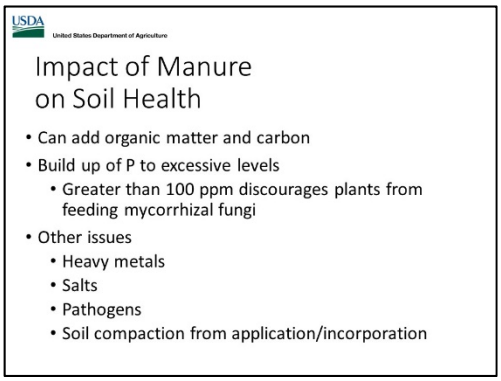
N at risk for leaching or denitrification
Fertilizer N is applied in one of two forms, NH4+ (ammonium) or NO3- (nitrate). Both are inorganic and very water soluble and can leach or leave field through surface runoff, field tile etc.

Synthetic fertilizers are salts
Over application can lead to osmotic shock in plant roots

Slide 30

The addition of animal manure is generally good as it increases organic matter, provides a C source for microbes, etc.

Excess application of manures leads to high phosphorus (P) levels that discourage plants from developing mycorrhizal fungi relationships, so plant might be getting P from the soil but they miss out on the other benefits that can be obtained (water and other nutrient exchange).

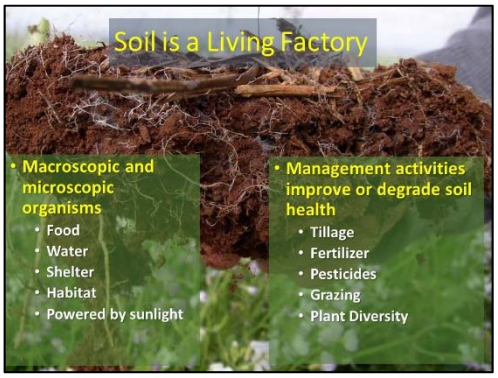


Slide 30

Manure can contain toxic compounds depending on the food supplements that are being fed. These concentrate in the manure and can build up in the soil.

Slide 31

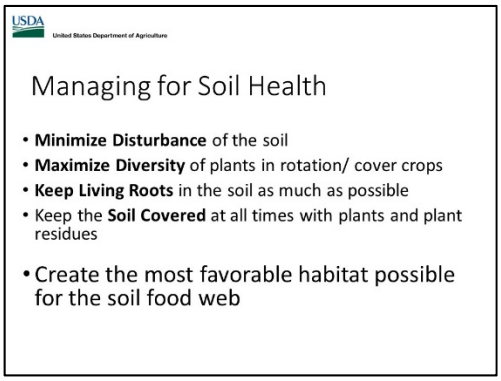
Revisit that Soil is Living and a habitat that needs to be managed in order for soil microbes to flourish and provide those soil functions that are necessary for food and fiber production. In order to do this requires a shift in our paradigm which leads to next slide.



Slide 31

Slide 32

There are four simple principles for improving soil health by creating the most favorable habitat for the soil food web. This slide leads to the next presentation.



Slide 32

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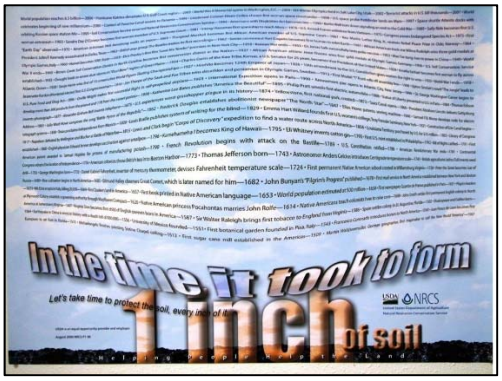
We've tried to "guilt" farmers into protecting topsoil because it takes so long to develop, but this is the wrong approach for several reasons:



Slide 33

- We aren't talking about geological soil formation from parent material like this slide implies
- There isn't much hope in this message, most farmers only farm for 40 years, what possible impact can they make if it takes hundreds of years to form an inch of topsoil?
- Changes in soil health can occur must faster, e.g. many farmers adopted no-till because fields were firmer in the fall, no rutting during harvest. While this might be difficult to measure, it is a change in soil function that occurred quickly. It is also reasonable to achieve increases in soil organic matter of 0.1% to 0.15% in a year if a complete soil health management system is followed. There is hope in this message……

Test their Knowledge - Questions for the audience

Q: Why is soil health important?
A: Increasing populations, greater demand for fertile cropland, increased use of fertilizers and pesticides

Q: What is soil health?
A: The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans.

Agricultural systems involve a simplification of __biodiversity__ that creates an artificial ecosystem requiring constant __human intervention___.

Q: What are examples of the physical, biological, and chemical disturbances caused by conventional agriculture?
A: Tillage, compaction (physical); low diversity, over-grazing (biological); misuse of fertilizers, pesticides, manures, and soil amendments (chemical)

The negative attributes of tillage include __destroying soil aggregates, exposing organic matter to decomposition, compaction, damaging soil fungi, reducing habitat, disrupting soil pore continuity, increasing soil salinity at soil surface, and planting weed seeds____.

Overgrazing can lead to __reduced root mass, increased weeds, reduced soil fungi, reduced water infiltration, increased soil temperature, diminished soil habitat___.

Q: What is the impact of pesticides on soil health?
A: They are non-discriminating so they can affect beneficial microbes, they create simplification of plant and soil ecosystems rather than diversity

Q: What is the impact of fertilizers on soil health?
A: They can reduce the activity in the rhizosphere, depress N-fixing bacteria, stimulate bacterial decomposition of organic matter, increase risk of leaching or denitrification (N), shock plant roots due to high salt content.

Soil Health Evaluation

Name of Activity: Basics of soil health	Date of Activity:

	A. Instruction	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1.	The agent/specialist was well prepared.	①	②	③	④	⑤	⑥
2.	The agent/specialist presented the subject matter clearly.	①	②	③	④	⑤	⑥

	B. General Learning and Change	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1.	I have a deeper understanding of the subject matter as a result of this session.	①	②	③	④	⑤	⑥
2.	I have situations in which I can use what I have learned in this session.	①	②	③	④	⑤	⑥
3.	I will change my practices based on what I learned from this session.	①	②	③	④	⑤	⑥

	C. Specific Learning How much *did you / do you* know about these subjects?	*Before this program I knew…*					*Now I know….*				
		Very little	Little	Some	Much	Very Much	Very little	Little	Some	Much	Very Much
1.	*The importance of soil health in agricultural systems*	①	②	③	④	⑤	①	②	③	④	⑤
2.	*The impact of soil disturbances (i.e. physical, chemical, and biological) on soil health*	①	②	③	④	⑤	①	②	③	④	⑤
3.	*Soil health principles*	①	②	③	④	⑤	①	②	③	④	⑤

	D. Specific Practices To what degree *did you / will you* do the following?	*Before this program I did…*					*In the future I will realistically do….*				
		Very little	Little	Some	Much	Very Much	Very little	Little	Some	Much	Very Much
1.	*Measure different field indicators of soil health*	①	②	③	④	⑤	①	②	③	④	⑤
2.	*Incorporate sustainable agricultural methods for soil health*	①	②	③	④	⑤	①	②	③	④	⑤
3.	*Seek additional NRCS information on financial and/or technical assistance for improving soil health*	①	②	③	④	⑤	①	②	③	④	⑤

	E. Satisfaction with Activity	Strongly Disagree	Disagree	Somewhat Disagree	Somewhat Agree	Agree	Strongly Agree
1.	*I would recommend this program to others.*	①	②	③	④	⑤	⑥
2.	*As a result of this program, I am more likely to seek additional information from UT/TSU Extension.*	①	②	③	④	⑤	⑥

F. Any suggested changes, additions, etc. to the curriculum?

Thank you for participating in this survey!