SOIL SMaRTS

Specific **M**anagement **a**nd **R**esources **T**rainings for **S**oil Health in Tennessee

TRAINING CURRICULUM

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Tennessee State University Cooperative Extension

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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This curriculum has been divided into 8 different sections:

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

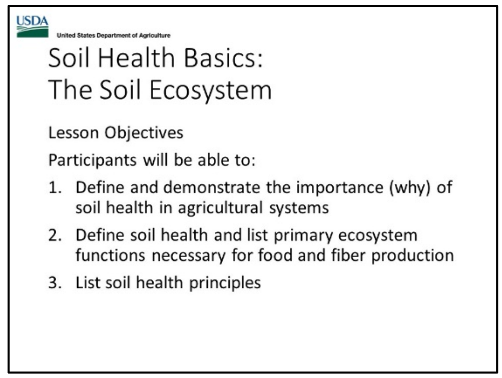
What is soil health?
Stable ecosystems
Effects of tillage
Effects of biological disturbance
Effects of pesticides and fertilizers
Managing for soil health

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

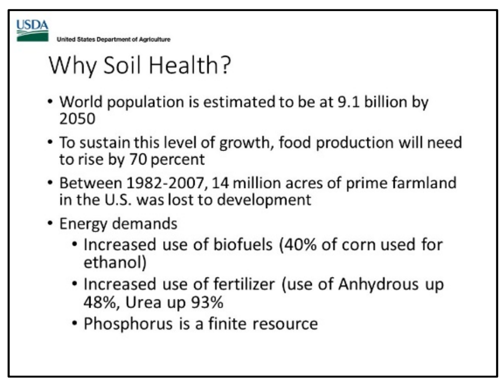
The key point is that a growing population is demanding higher quality food to be produced on less acres using finite resources that have competing if not conflicting uses.

-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

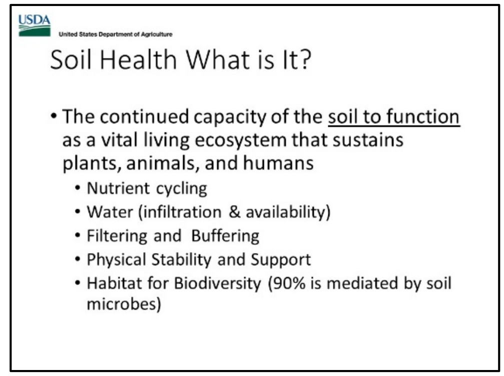
-Phosphorus is a finite resource with known available sources in place that are difficult to access for environmental reasons



Slide 6

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.

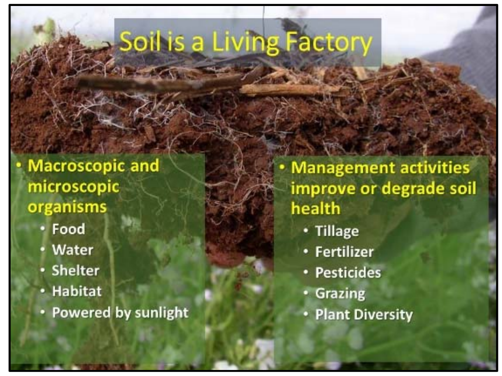
Slide 8

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

Slide 9

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

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

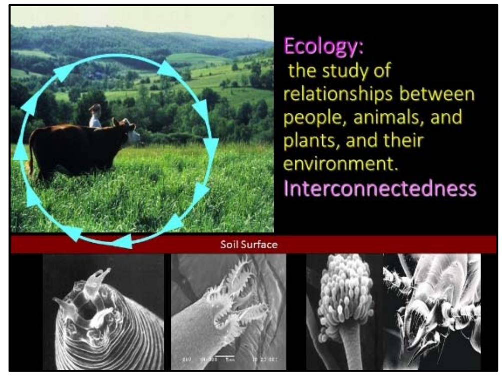
Tennessee Soil Health Heroes are featured on tnacd.org., soil health heroes. Currently (August 17, 2018), there are 46 published.

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:

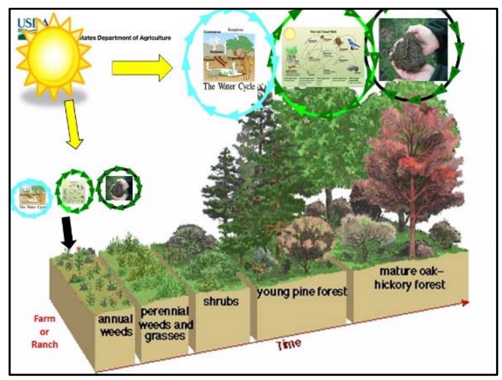
Nutrient cycle

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

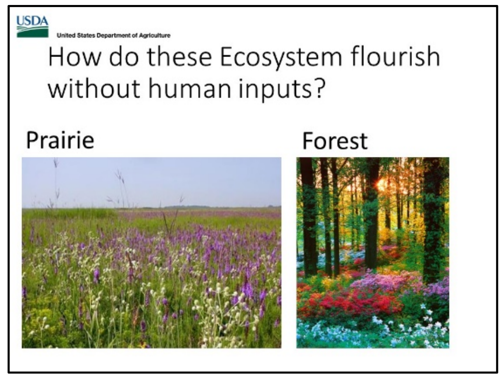
- Soil is the integrator between different ecosystems.
- Agricultural lands (crop, grazing, etc.) are part of the earth's ecosystems or biomes
- In natural ecosystems, the vegetative cover of a forest or grassland prevents soil erosion, replenishes ground water and controls flooding by enhancing infiltration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

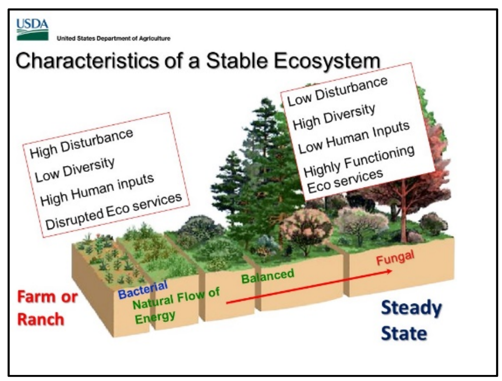
- Lots of diversity
- Minimal amount of disturbance



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.
- The main focus: accentuate that the ground should be covered at all times.

Slide 16

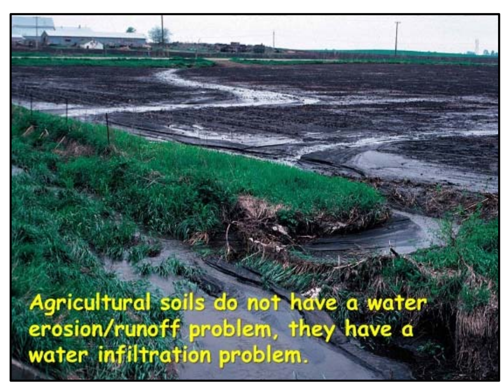
The transition photo is from an electron microscope showing what the surface looks like to a depth of 1 mm

- 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.

<u>Example of lack of understanding impacting how resources are managed:</u>

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.

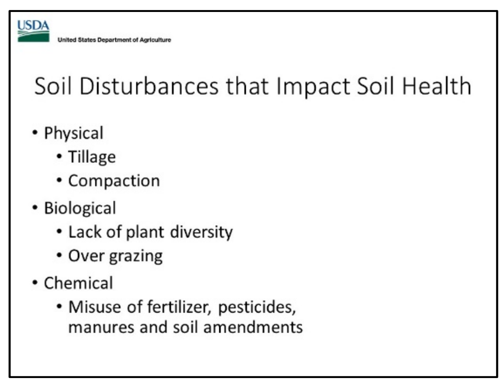
Slide 18

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.

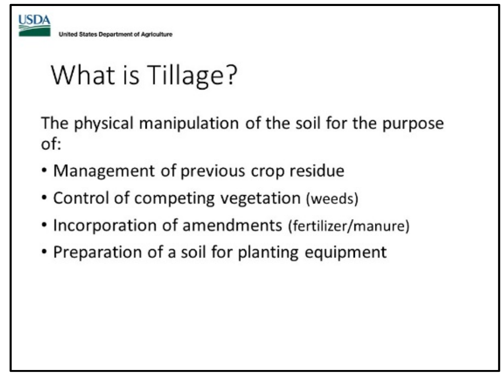


Slide 19

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.

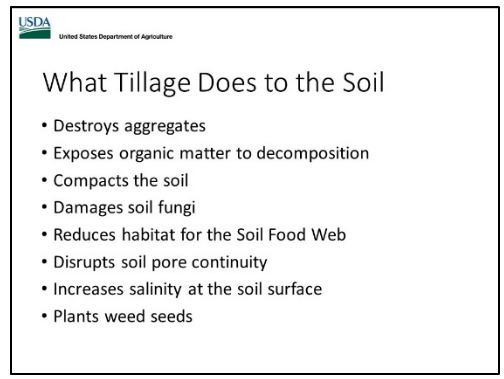


Slide 20

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



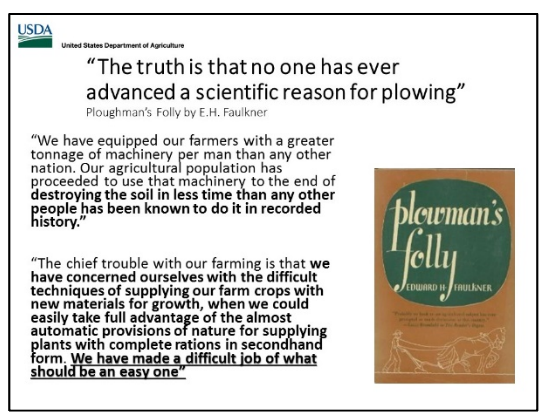
Slide 21

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

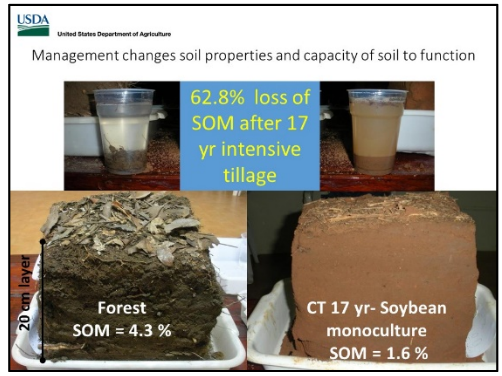
Quote 2 speaks to the tremendous effort that goes into supplying crops with nutrients instead of following a more simplified natural approach



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).



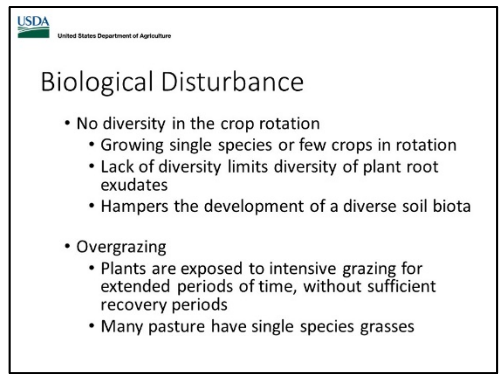
Slide 23

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

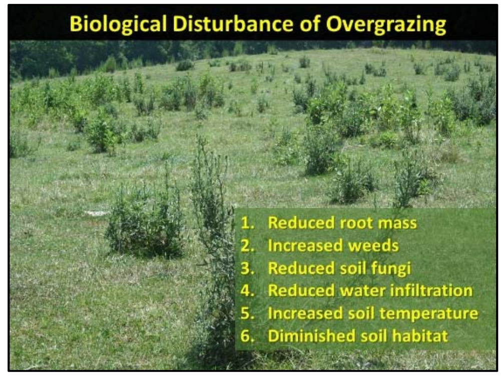
Monoculture – growing a single species or limited number of crops in a planned rotation

- 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.



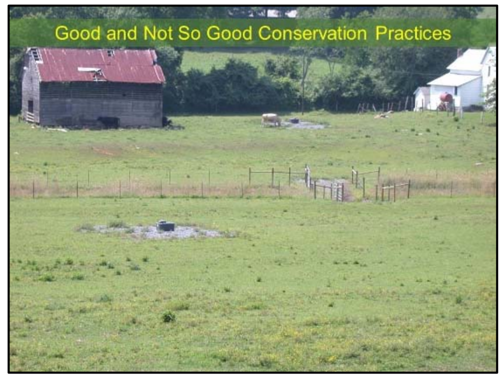
Slide 25

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.

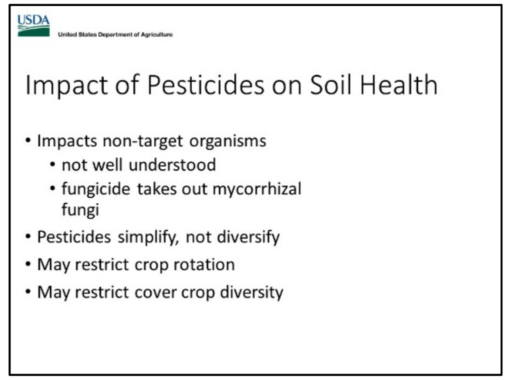
Slide 27

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

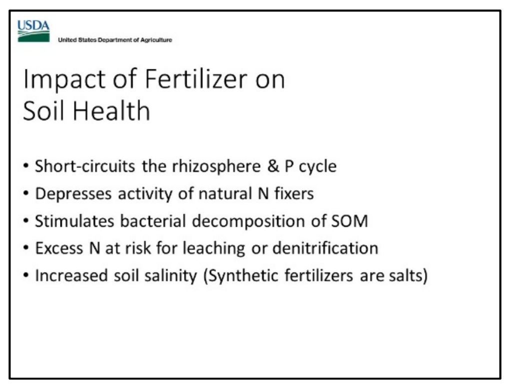
Potential carryover impact on the next crop can limit planting options, leads to a monoculture rotation. Same principles apply to the selection of plants in a cover crop mix.

"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

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



Slide 29

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

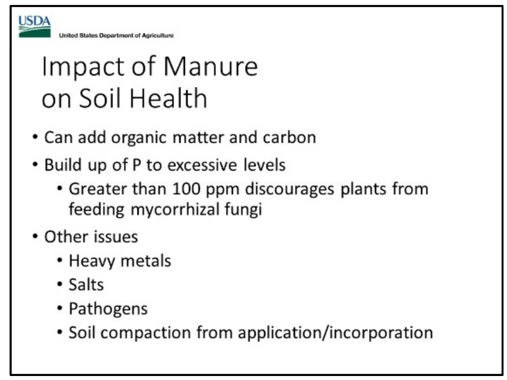
N at risk for leaching or denitrification
Fertilizer N is applied in one of two forms, NH_4^+ (ammonium) or NO_3^- (nitrate). Both are inorganic and very water soluble and can leach or leave field through surface runoff, field tile etc.

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.

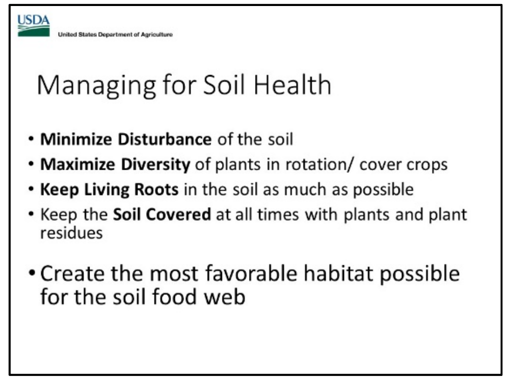
Slide 31

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.

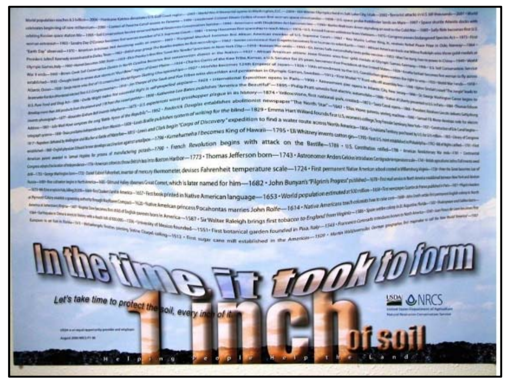


Slide 32

Slide 33

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:

- 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……



Slide 33

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!

MODULE 2. SOIL BIOLOGY

Learning objectives:

Participants will be able to:

- list at least six functions that soil microbes perform.
- define and describe the three broad functional groups used to categorize soil organisms and list a few key organisms for each group.
- identify and define biological hot spots in soil and key organisms living in each zone/sphere.
- describe how the soil health principles influence soil biology and soil function.

Materials:

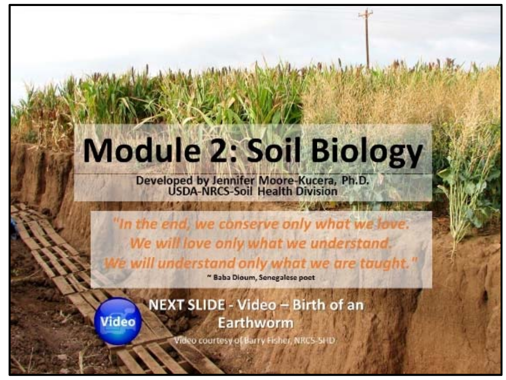
- PowerPoint® slides "Module 2: Soil Biology"
- Lesson guide: Use the notes in this lesson guide to present information for each presentation slide.
- Questions found at the end of this lesson guide can be used to test participants' knowledge at the end of the presentation. This can be combined with 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:

Soil organisms as chemical engineers
Soil organisms as biological regulators
Soil organisms as ecosystem engineers
Optimal conditions
Litter layer (Detritusphere)
Earthworm and root channels (Drilosphere)
Pore space (Porosphere)
Aggregate surfaces (Aggregatusphere)
Root zone (Rhizosphere)
Benefits
Soil health principles

Slide 1

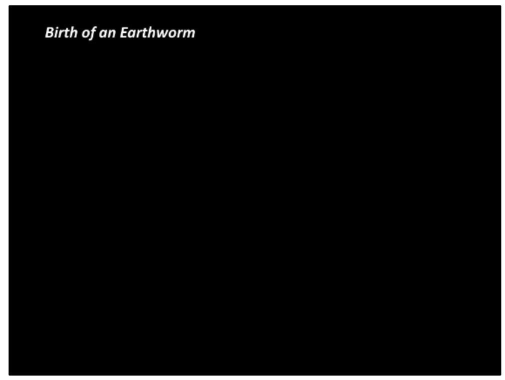
This module will focus on soil biology and its importance in achieving good soil health.



Slide 1

Slide 2

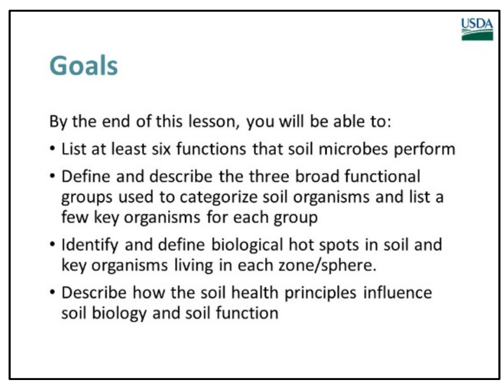
This slide is a video that shows the birth of an earthworm.



Slide 2

Slide 3

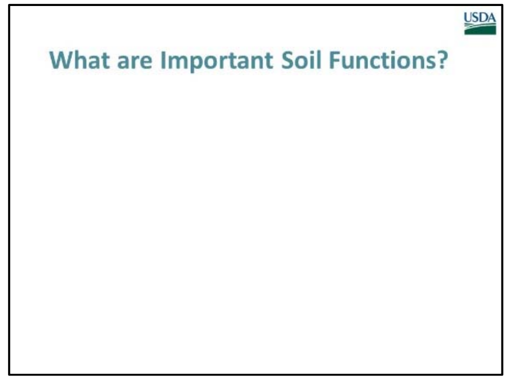
Follow material on presentation slide.



Slide 3

Slide 4

Time required: ~10 min….write these on a whiteboard or flipchart

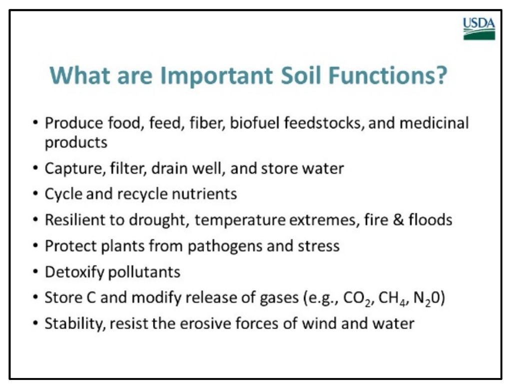


Slide 4

Ask participants to make a list of soil functions important for agriculture/range/forest production. Given that this module follows the Soil Health Basics presentation, they should come up with something in line with the following functions of healthy soils (**this is a good review/recap of important soil functions):

Produce food, feed, fiber, biofuel feedstocks, and medicinal products
Capture, filter, drain well, and store water
Maximizes internal nutrient cycling
Resilient to drought, temperature extremes, fire and floods
Protects plants from pathogens and stress
Detoxifies pollutants
Stores C and modifies release of gases (e.g., CO2, CH4, N20)
Stable, resisting the erosive forces of wind and water

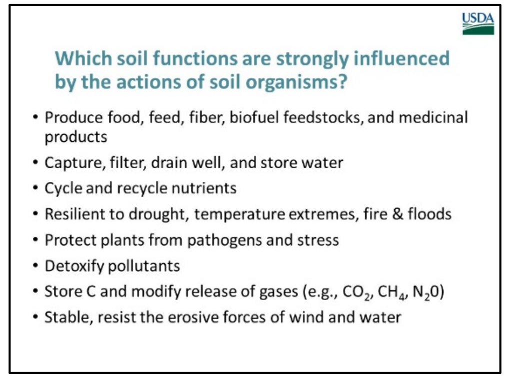
Slide 5



Slide 5

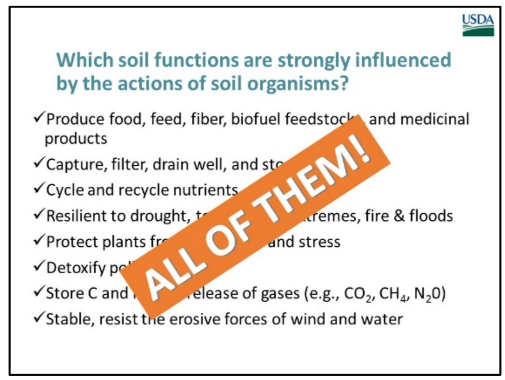
Slide 6

After the list is created, ask them to put a star next to the functions that are driven by the actions and interactions of soil organisms. All of them should have a star next to them!



Slide 6

Slide 7



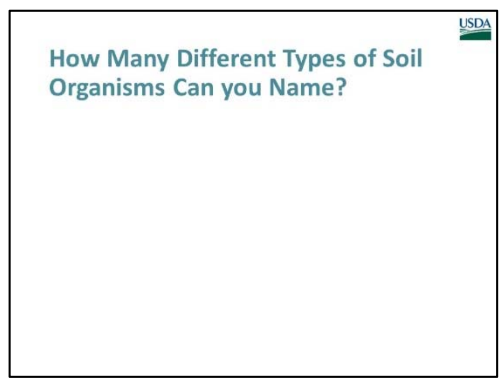
Slide 7

Slide 8

Regardless of how we define diversity and measure it, soils are home to vast abundance and types of organisms. Likely you already are familiar with many of them.

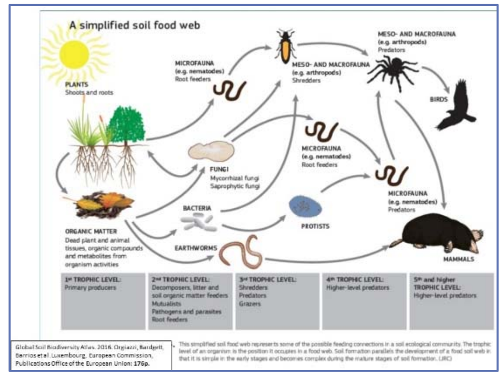
Ask participants to name soil organisms they know and write on board/flipchart or simply take notes and then read the combined list at the end. This should take only 1-3 minutes.

Answers may include: bacteria, fungi, algae, ants, beetles, mites, spiders, nematodes, earthworms



Slide 8

Slide 9



Slide 9

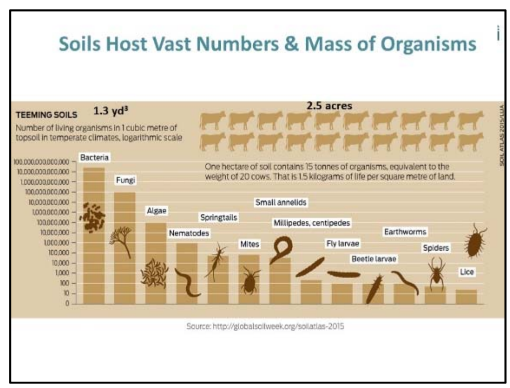
Historically, soil biodiversity was studied by mapping the soil food webs. This approach details the chain of energy transfer in soil and is based on grouping organisms according to their trophic role and food preferences. In a very simplistic manner, the food web is fueled by plants and photosynthetic bacteria that fix C from the atmosphere through photosynthesis. Other organisms then obtain their energy by breaking down plant residues and organic compounds or by consuming other organisms. During decomposition and consumption, nutrients are converted from organic to inorganic forms and made available to plants and other soil organisms (Paraphrased from Turbe et al., 2010).

Pros of the food web approach: Very useful for understanding nutrient cycling and energy flows and provided the foundation to study functional soil biodiversity.

Limitations: overlooks other important processes not based on feeding relationships, such as soil structure development, parasitism and pathogenesis. Relies on biomass and species composition, whereas activity provides a better understanding of soil biological function.

Slide 10

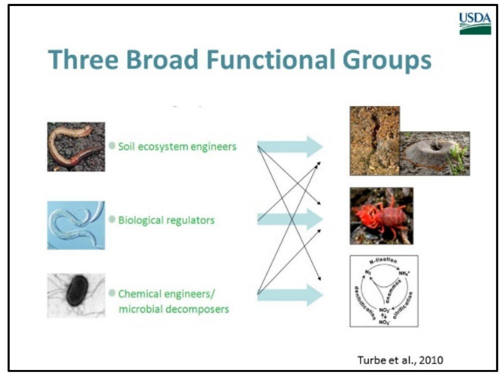
2.5 acres contains the weight of 20 cows of microbes in the soil. This is equivalent to about 3 lbs per square yard of soil. Source: Global soil biodiversity Atlas.



Slide 10

Slide 11

Soil organisms have coevolved for hundreds of millions of years and interact in positive (mutualistic) and negative (e.g. predator versus prey) ways. Conserving biodiversity also translates to conservation of important functions or services that the biological community provides. Keeping in mind that soil, soil biodiversity, and soil functions are complex interactions between inherent soil properties, climate, management, and the life within the soil, a simplistic view is to categorize soil organisms into the following broad functional groups. These include the soil ecosystem engineers, the biological regulators, and the chemical engineers (aka microbial decomposers).



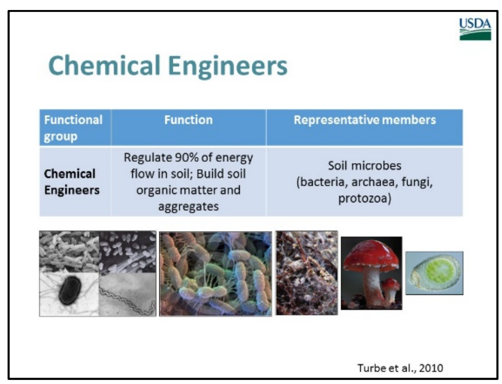
Slide 11

The following slides will explain:
what these groups are primarily responsible for, key representatives will be identified and a brief overview of specific functions, where they are found in soils, and their abundance

The arrows crossing among and between the different groups are an indication that the groups are not exclusive to certain members and multiple members can be influential on other functions but in order to follow some structure and help us understand key groups, we will go through them by identifying the dominant players.

Slide 12

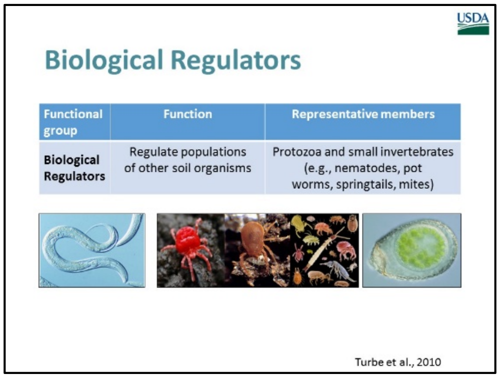
Chemical engineers involve soil microbes, regulate 90% of energy flow in soil and are responsible for decomposition of plant organic matter into nutrients that are available for plants. Soil microbes are also responsible for stimulating plant growth, plant protection and the production of multiple antibiotics used for human and animal health.



Slide 12

Slide 13

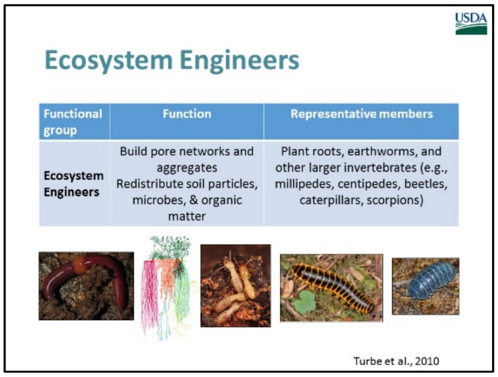
Biological regulators include small invertebrates such as protozoa, nematodes, pot worms, springtails, and mites. Through grazing, predation or parasitism, these organisms regulate populations of other invertebrates and microbes.



Slide 13

Slide 14

Ecosystem engineers are the larger organisms such as earthworms, ants, termites, etc. as well as plant roots that modify or create their own habitat and, in doing so, create biopores that channel air and water, mix organic materials during burrowing, and help build resistant soil aggregates. By regulating resources and redistributing and regulating access to resources, these organisms create 'hotspots' that support high numbers of microorganisms.



Slide 14

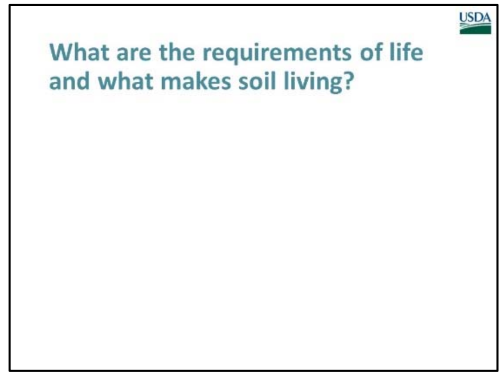
A large source that fuels the entire soil system relate to the impacts of plant roots, which is the first group of ecosystem engineers to discuss. Plant roots can cause physical weathering as they grow and expand inside cracks in the rocks. Roots and decaying vegetation also produce organic compounds such as solvents, acids and alkalinity that enhance the actions of percolating rainwater.

The two main types of root systems are fibrous and taproot. Fibrous roots are the traditional structures formed by primary and secondary roots branching in all directions in the soil. By contrast, taproots are characterized by a single firm root growing straight down, with minor roots developing on either side. Other specialized roots do exist; for example, the tuberous roots of sweet potato are modified for the storage of nutrients and water.

The number of known plant species has been estimated to be around 400,000.

Slide 15

Reiterate the definition of soil health…"The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans". Then ask participants to compile a list of what it takes to be considered alive on a chart or white board (ALL PROCESSES BELOW CAN BE DIRECTLY RELATED TO THE BIOLOGICAL HOT SPOTS)

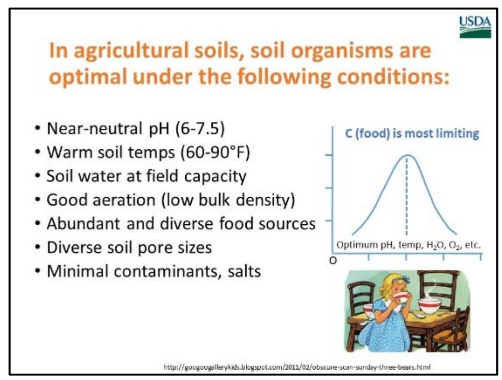


Slide 15

Should include:
Breathing—respiration/gas exchange
Shelter—aggregates/pores
Food source—detritus layer
Reproduction—pores/water films
Elimination—nutrient cycling
Death

Slide 16

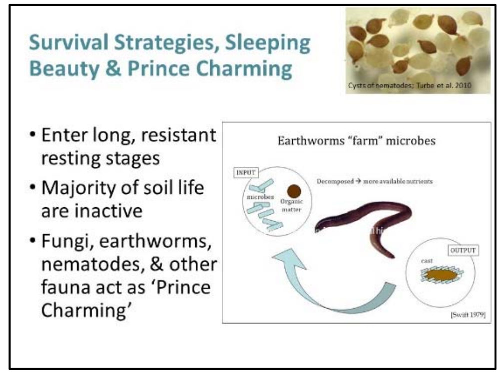
There are numerous factors that influence biodiversity and activity of soil organisms. Although microbes can exist in the most extreme environments possible, most agricultural soils benefit from the following conditions:
Near-neutral pH (6-7.5)
Warm soil temps (60-90°F)
Soil water at field capacity (moist with no excess water draining out)
Good aeration (low bulk density)
Abundant and diverse food sources
Diverse soil pore sizes
Minimal contaminants, salts



Slide 16

Equate these conditions to Goldilocks, needs to be "just right".

Slide 17



Slide 17

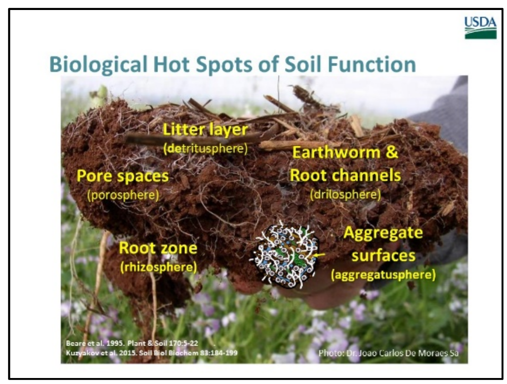
The majority of life in soil is not in an active state but often remain in a resting stage that allows them to stay alive when conditions are not conducive but rebound quickly when conditions improve.

For example, over 90% bacteria in soil are inactive because they have not been able to move towards an organic substrate to use but spring to life quickly upon rewetting of soil to redistribute soluble organic C and nutrients.

If we want to encourage a diverse and healthy habitat for microorganisms we must provide food, nutrients, proper aeration, pH, water, etc.

Protists and nematodes form cysts, bacteria form endospores, fungi form spores, bacteria and fungi change cell chemistry, microarthropods can enter a state of 'crytobiosis' (suspended metabolism to survive extreme temperatures or dryness)

Slide 18



Slide 18

A hierarchical view of biodiversity as it influences the diversity in structure and function of ecosystems.

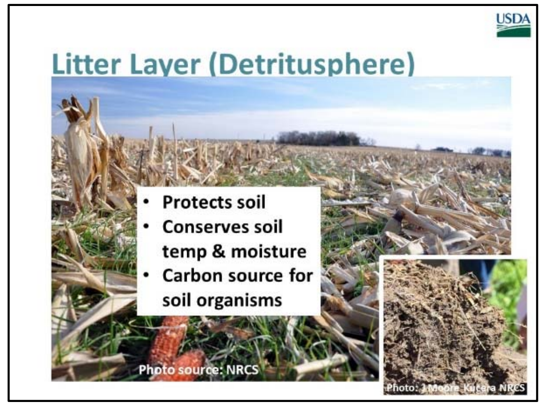
Activity idea: Collect soil from different management practices and give to different groups to identify the zones of biology within the management

The slide illustrates the places where microbes live—if any are missing then soil health is degraded. To begin to understand how to evaluate the health of a soil from a biological perspective, we need to change our view of how soil functions. Instead of looking at profiles and texture, we need to look at the biological processes or spheres of influence that are taking place working in concert together. The following slides will run through each of these independently.

- Soils can be viewed as being composed of a number of biologically relevant spheres of influence that define much of their spatial and temporal heterogeneity.
- They are formed and maintained by biological influences that operate at different spatial and temporal scales. Although not mutually exclusive, each sphere has fairly distinct properties that regulate the interactions among organisms and the biogeochemical processes that they mediate.
- Probably more than any other biological factor, the composition and structure of plant communities determine, directly or indirectly, the physical, chemical and biological properties of soils. Individual plants can have markedly different zones of influence in soils.

Slide 19

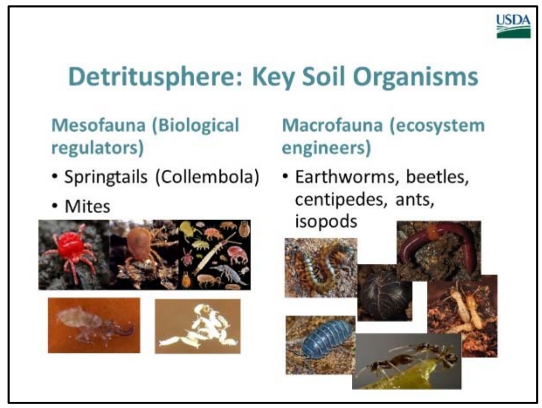
This is the zone above the mineral soil surface.
It contains recognizable plant and animal detritus undergoing decay
It contains high concentrations of saprophytic fungi, mites, nematodes and some macrofauna (e.g., beetles, centipedes, etc.)



Slide 19

Slide 20

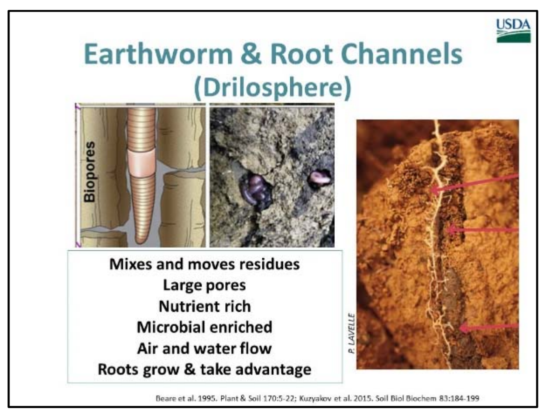
Springtails and mites are tiny arthropods that eat bacteria and fungi associated with decaying vegetation.
The macrofauna help to shred, mix, and fragment residues at the surface. This increases surface area for saprophytic fungi and bacteria to release specialized enzymes that breakdown residues. They also disperse microbial spores and influence microbial activity and nutrient cycles.



Slide 20

Slide 21

Earthworms ingest labile (easily moved/broken down) and recalcitrant (not easily moved/broken down) organics and processes them within the hindgut of earthworms and other soil organisms (mainly invertebrates) at various depths
Redistribute plant litter "carbon" throughout the soil the profile
Enrich soils with N, P, and humified organic matter
Increase water infiltration
Provide a biopore for plant roots
Homogenize the soil surface
Increase biodiversity in soils



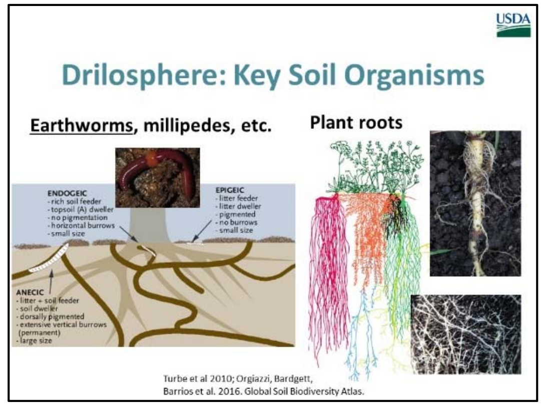
Slide 21

Slide 22

Zone of influence by earthworms and other microarthropods & millipedes

Function: shred and redistribute plant litter from the detritusphere throughout the soil profile

Earthworm Functions:



Slide 22

- Decompose & relocate organic matter
- Stimulate & move microbial community
- Increase available N and P
- Create stable aggregates
- Consume and redistribute seeds
- Invasive in northern forests
- Creates large pores important for water infiltration and air exchange
- Transport of soil microbes and labile and recalcitrant materials

Epigeic earthworms are those that live in the superficial soil layers and feed on undecomposed plant litter.

Endogeic earthworms forage below the soil surface in horizontal, branching burrows. They ingest large amounts of soil, showing a preference for soil that is rich in organic matter. Endogeics may have a major impact on the decomposition of dead plant roots, but are not important in the incorporation of surface litter.

Anecic earthworms build permanent, vertical burrows that extend deep into the soil. This type of worm comes to the surface to feed on manure, leaf litter, and other organic matter. This class of earthworms, such as the night-crawlers, have profound effects on organic matter decomposition and soil structure.

- Most common are members of the family Lubricidae (220 species)
- May account for 50% of total soil faunal biomass in grasslands and up to 60% in some forests
- 10-50/ft^2 to 200/ft^2 in pastures with several thousand species

Slide 23

The lungs and circulatory system of the soil:

Regulates water and air flow

Impacts N, P mineralization

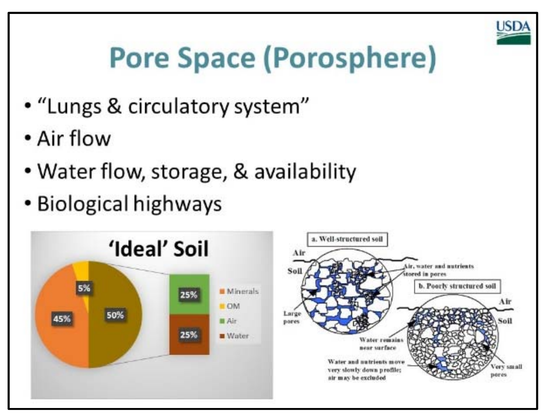
Impacts soil organism biomass and diversity

Site of nutrient exchange

Site of mycorrhizal entanglement and sequestration of water and nutrients

Root interface

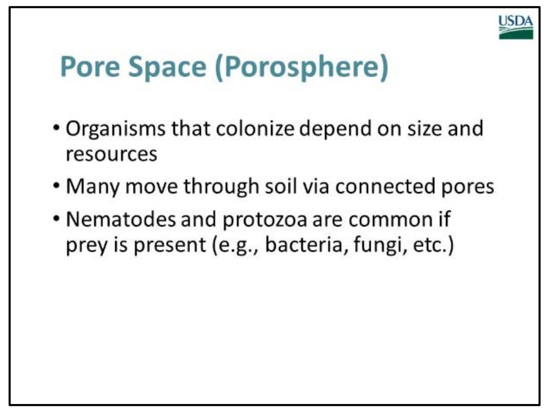
Part of the water cycle



Slide 23

Plant roots, earthworms and other arthropods can rearrange soil particles to create smooth, cylindrically shaped macropores (biopores)
Biopores can extend a considerable distance in the soil, forming channels for preferential flow of water and nutrients
Good air exchange in the soil creates habitat in which aerobic organisms can thrive
Poor air exchange leads to anaerobic conditions, organisms that can tolerate this habitat tend to be those that cause disease and produce byproducts that inhibit root growth, e.g. alcohols
A mix of different sized pores is important
Collapse of space and large pores disrupts air, water, nutrient flows, and biological highways

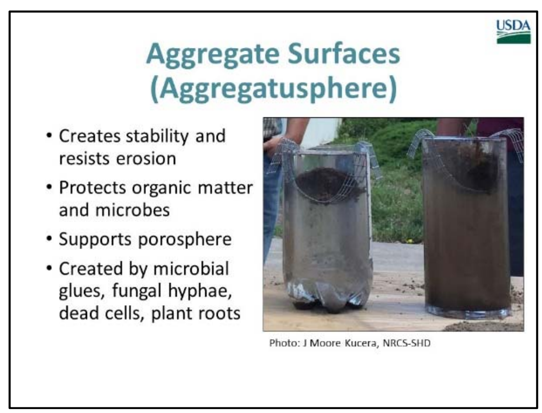
Slide 24
Related to biopores but includes medium, small, and micropores
Regulates H_2O & air flow
Pore networks help redistribute microorganisms, nutrients, etc.
Different sizes house and protect organisms and promote a diverse habitat
Bacteria, protozoa, fungal hyphae, nematodes, etc.
Most sensitive to disturbances
Protects microbes from larger predators



Slide 24

Slide 25
Lack of good soil aggregation results in compacted soils that:

- Restrict root growth
- Provide poor root zone aeration
- Have poor drainage

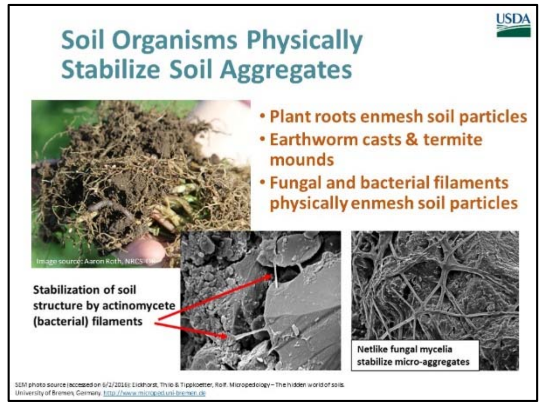


Slide 25

Soil compaction has always been thought of as a physical soil problem caused by excessive tillage and heavy equipment squeezing the soil pore space.
Compaction is actually due to a loss of soil organic matter and destruction of soil aggregates. These need to be replaced in the soil in order to provide a stable soil base in which to produce food & fiber
Soil compaction is a biological problem related to decreased production of polysaccharides and glomalin in the soil and a lack of living roots and mycorrhizal fungus in the soil.

Slide 26

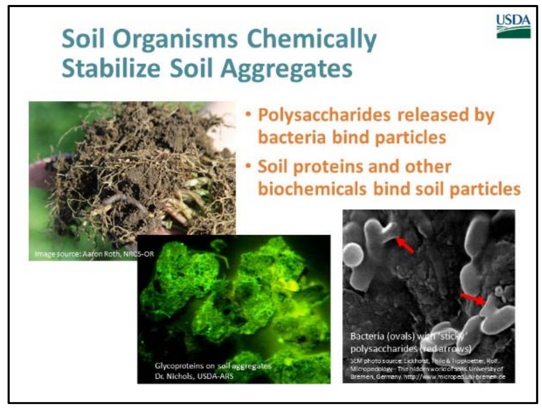
Follow material on presentation slide.



Slide 26

Slide 27

Tillage tends to reduce overall numbers of soil organisms, especially fungi that form hyphae and earthworms, important for soil aggregation and other soil functions. It also tends to favor increased bacterial populations and their predators (Protists and nematodes shift to bacterial-feeders). In contrast, no-till or reduced till favors higher overall populations, especially fungi and earthworms and nematodes shift to fungal-feeders.



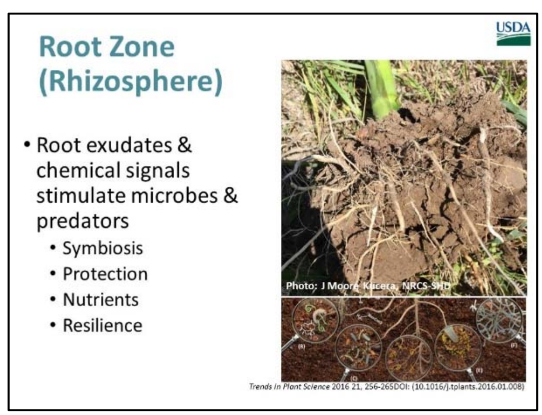
Slide 27

Forming soil aggregates requires both biological and physical actions:

- Need conditions that will allow for Arbuscular Mycorrhizal Fungi (AMF) colonies to be established
- AMF release glues as hyphae work their way out through the soil
- Hyphae entangle soil particles, realign them
- Create alternating wetting/drying cycles helping to bind particles together

Slide 28

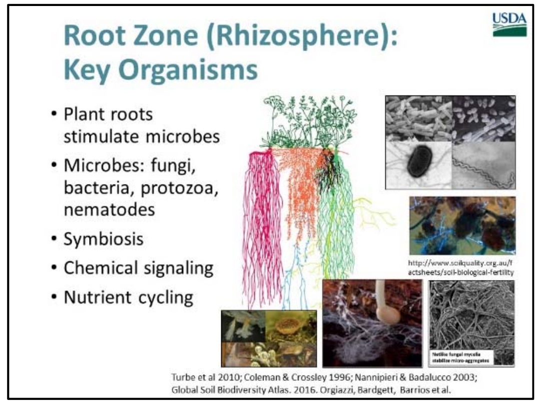
Highest density of roots is in the A horizon but can occur throughout profile.
Roots are important for a number of reasons: Anchor (keeps plant in soil, prevents soil erosion, holds stem upright), Absorption (water and dissolved minerals), Storage (starch and other nutrients), Habitat (provides nutrients to microbes, helps with aggregation)



Slide 28

Slide 29

Different plants attract and support a different microbial community. Additional factors influencing biodiversity composition include composition of plant components, nutrient content in tissues, tissue senescence and temperature, moisture, and inherent soil properties.



Slide 29

Slide 30

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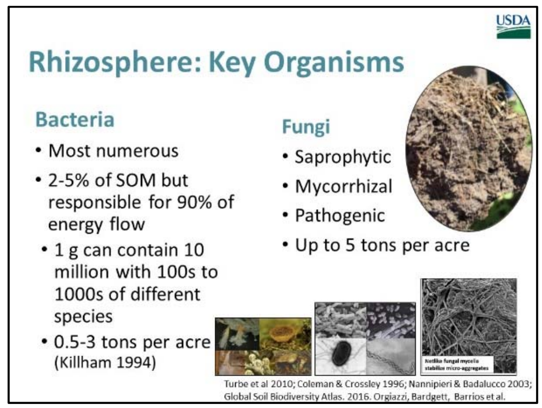


Slide 30

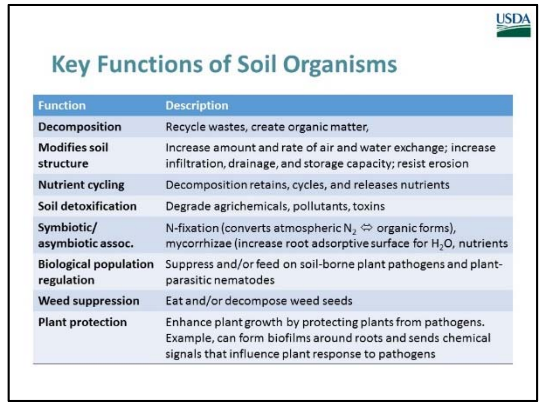
Slide 31

1 gram can contain 10 or more nematodes!
One acre may contain 200 pounds of nematodes!
1 gram can contain 10,000+ protists!
One acre may contain the weight equivalent of 2 sheep of protists!

Slide 31

Slide 32

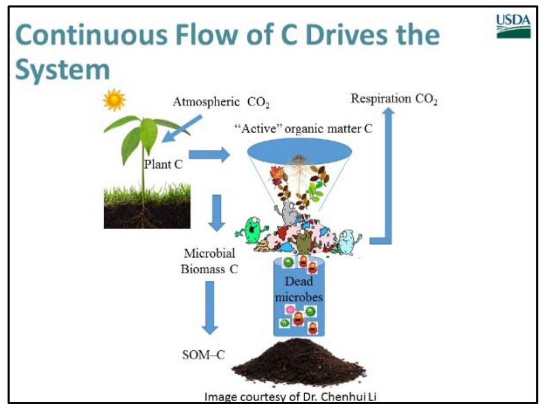
Follow material on presentation slide



Slide 32

Slide 33

This diagram shows how the flow of active organic matter (organic C) is the driving force of the microbial biomass and their activities.



Slide 33

Slide 34

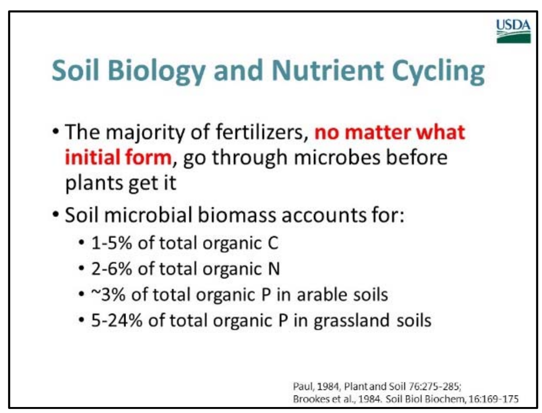
Fertilizer Use Efficiency (Annual Crops)

N: 30-70%

P: 5-40%

K: 50-80%

NUE cereal: 30-35%

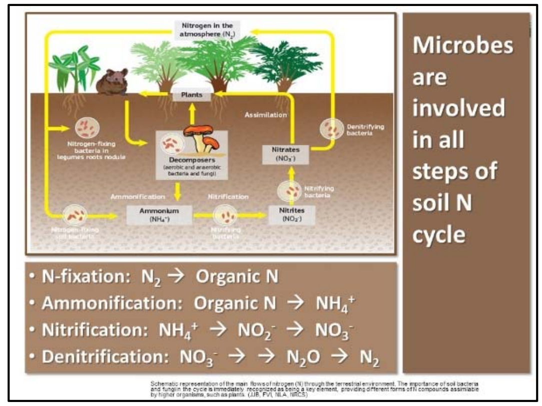


Slide 34

Slide 35

Oftentimes <50% of N added is taken up into plants immediately (referenced source showed 30-70% for N; source is Agron Journal 91:357-363)

Uptake is regulated by relationships between soil microorganisms and plants



Slide 35

Slide 36

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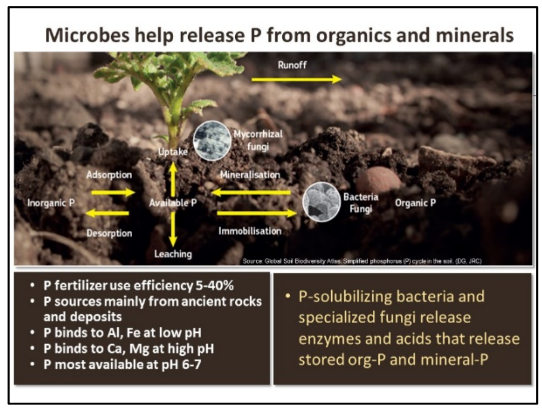
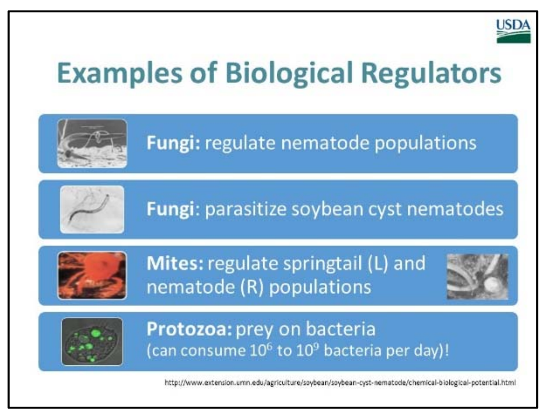


Slide 36

Slide 37

Examples of population control through predation, grazing, and parasitism



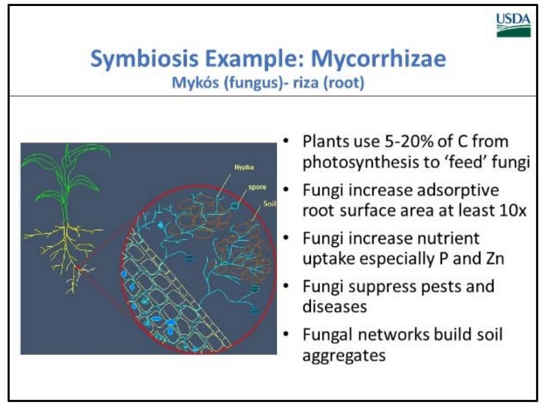
Slide 37

Slide 38

Greek word meaning fungus root

Most crops are mycorrhizal including onions, corn, cotton, wheat, soybeans, potatoes, alfalfa, sugarcane, cassava, rice, most vegetables, beets, apples, grapes, citrus fruit, trees (lumber and fiber), cacao, coffee, rubber.

Some non-mycorrhizal crops have been shown to inhibit mycorrhizae in the next crops according to researchers at Penn State. These include canola, buckwheat, forage radish, camelina, and mustards.



Slide 38

Slide 39

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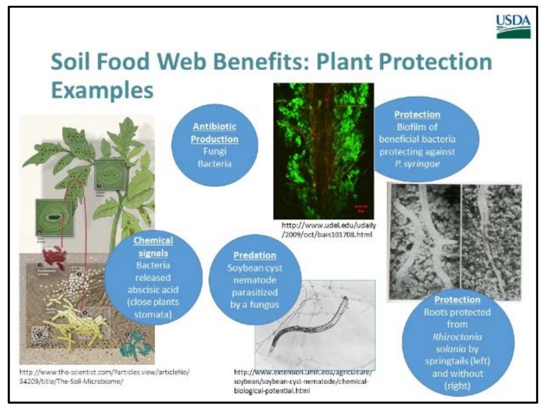
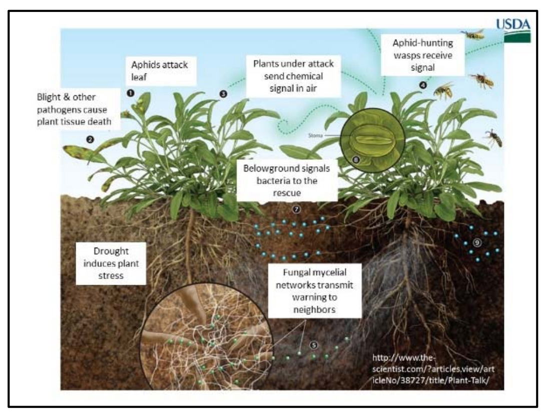


Slide 39

Slide 40

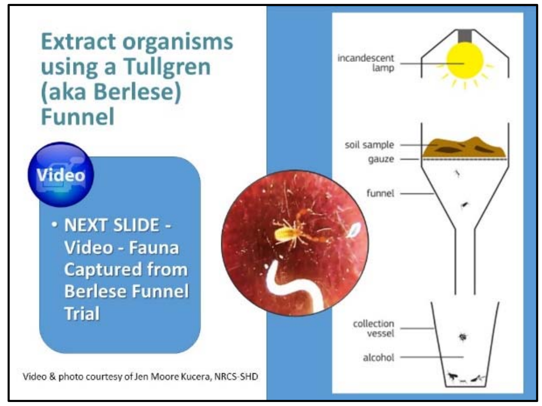
An example of the interconnected nature of the soil/plant system…Aphids and other organisms may attack the plant because it is under stress from drought. The plant can send chemical signals through the air and soil to engage other organisms (i.e. wasps and bacteria) to attack these pests which provides food for these organisms.



Slide 40

Slide 41

This is a method that allows you to capture soil organisms and microorganisms from a sample of soil.



Slide 41

Slide 42

This slide includes a video of some captured soil organisms and microorganisms using the technique.

Slide 42

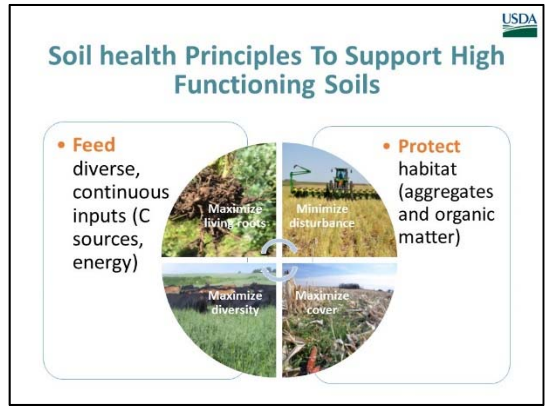
Slide 43

Not surprisingly, many biologically friendly practices are similar or same as those recommended by NRCS.

Slide 43

Slide 44

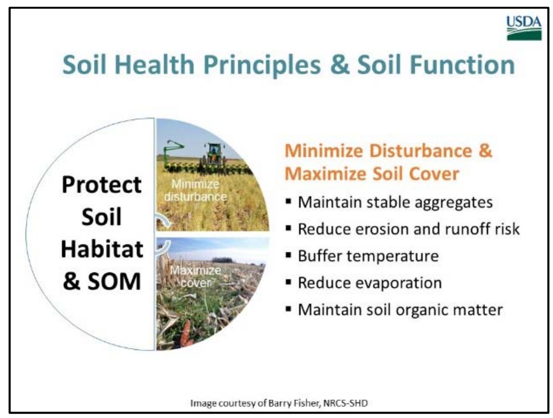
This is the answer to the question on the previous slide.



Slide 44

Slide 45

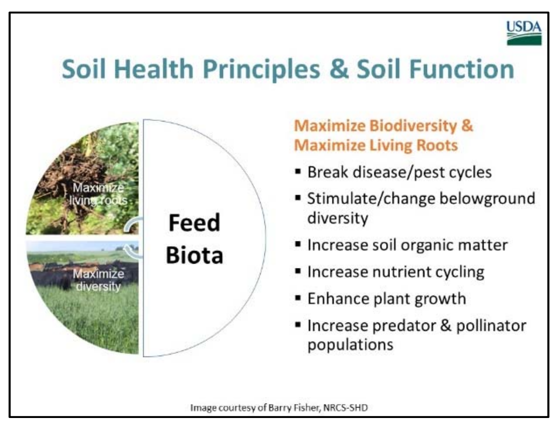
The first two principles focus on protection of the soil habitat: minimizing disturbance and maximizing soil cover maintains or increases stable soil aggregates and soil organic matter (SOM), and protects the fragile surface of the soil that is most susceptible to the degrading forces of wind and water. Covering the soil also buffers against extreme swings in temperature that stress plants and soil organisms, reduces evaporation rates, and increases water-use efficiency. SOM is highest at the soil surface and is critical for stabilizing soil aggregates. Maintaining SOM helps support additional soil functions including water infiltration and storage, nutrient-holding capacity and release, and habitat for soil biota.



Slide 45

Slide 46

The second two principles focus on feeding the organisms inhabiting soil. Maximizing the diversity of food (energy and carbon inputs) and aboveground biodiversity through increased plant, animal, or soil amendments increases the diversity of soil organisms, microorganisms, and activities. Diversity not only refers to food sources, but also aboveground diversification of plants and animals, and microbial diversification underground. Diversification stimulates a host of additional benefits including breaking disease cycles, providing habitat for pollinators, wildlife, and beneficial predators, and stimulating plant growth.



Slide 46

Slide 47

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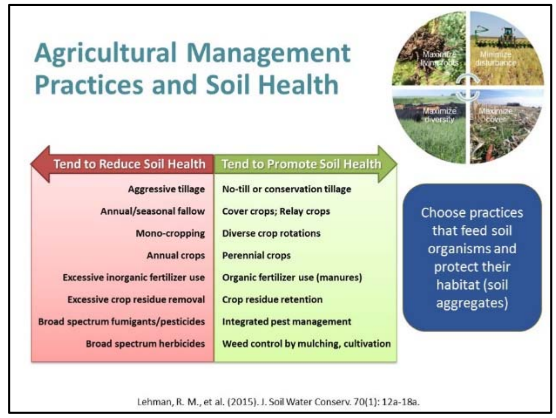

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Slide 48

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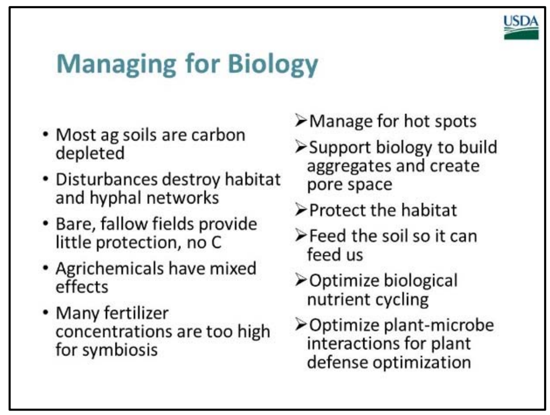

Slide 48

Slide 49

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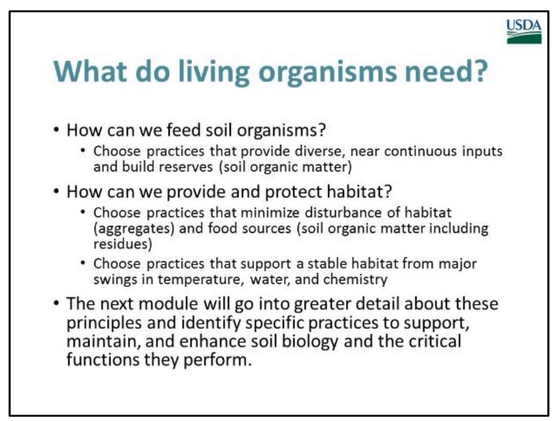


Slide 49

Test their Knowledge - Questions for the audience

Q: What are the three broad functional groups of soil organisms?

1. Soil ecosystem engineers (i.e. earthworms)
2. Biological regulators (i.e. nematodes)
3. Chemical engineers/microbial decomposers (i.e. bacteria and fungi)

List 5 biological hotspots in the soil.

1. Litter layer (Detritusphere)
2. Earthworm and root channels (Drilosphere)
3. Pore space (Porosphere)
4. Aggregate surfaces (Aggregatusphere)
5. Root zone (Rhizosphere)

What are optimal conditions for soil organisms?

1. Near neutral pH (6-7.5)
2. Warm soil temperatures (60 - 90°F)
3. Soil water at field capacity
4. Good aeration (low bulk density)
5. Abundant and diverse food sources
6. Diverse soil pore sizes
7. Minimal contaminants, salts

Soil microbial biomass accounts for __2-6%__ of total soil organic nitrogen.

Q: What does denitrification create?
A: It creates nitrogen gas from nitrate.

Q: What microbe helps to regulate nematode populations?
A: Fungi

Q: What are some benefits of fungi?
A: They increase the adsorptive root area by at least 10x, they increase nutrient uptake (especially P and Zn), they suppress pests and diseases, they help build soil aggregates.

Soil Health Evaluation

Name of Activity: Soil biology	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	*Before this program I knew...*					*Now I know....*				
How much ***did you / do you*** know about these subjects?	Very little	Little	Some	Much	Very Much	Very little	Little	Some	Much	Very Much
1. *The broad functional groups of soil organisms*	①	②	③	④	⑤	①	②	③	④	⑤
2. The important role soil biology plays in soil health	①	②	③	④	⑤	①	②	③	④	⑤
3. The five biological hotspots of soil function	①	②	③	④	⑤	①	②	③	④	⑤
4. Soil health principles	①	②	③	④	⑤	①	②	③	④	⑤

D. Specific Practices	*Before this program I did...*					*In the future I will realistically do....*				
To what degree ***did you / will you*** do the following?	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!

MODULE 3. SOIL HEALTH PRINCIPLES

Learning objectives:

Participants will be able to:

- define and describe soil health principles and their impact on soil health ecosystem functions
- identify key words within the soil health definition
- identify conservation practices and activities that address each soil health principle
- describe key soil health indicators

Materials:

- PowerPoint® slides "Module 3: Soil Health Principles"
- 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:

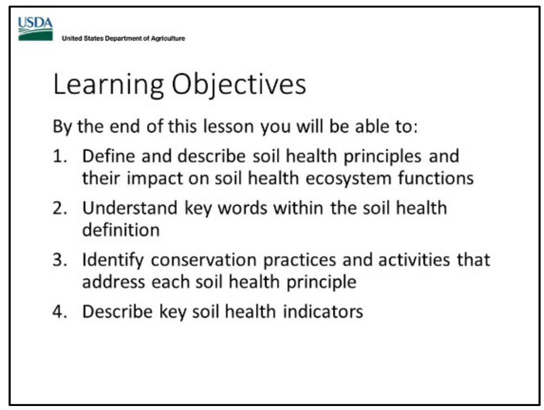
Soil degradation
Soil health principles
Agricultural disturbance
Cover crops
Crop rotation

Slide 1

This module covers soil health principles. When these principles are followed, we should be able to monitor key indicators (Module 4) to track our soil health regeneration.

Slide 1

Slide 2

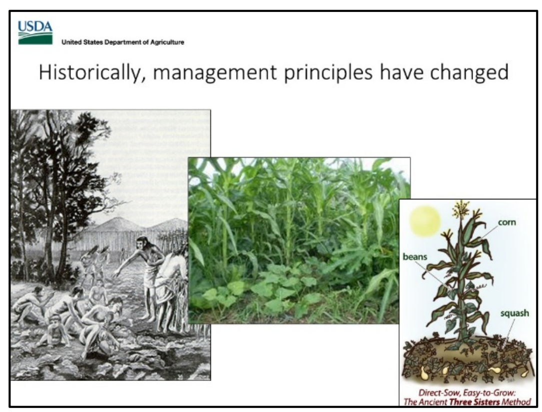


Slide 2

Slide 3

The Adena Indians (for example) used tools made of stone, animal bone, and tortoise shell to grow crops of squash, pumpkins, gourds, sunflowers and maize. The primary agricultural product of the Ohio Indians, shortly after the introduction of agriculture to Knox County, was maize.

We've all seen picture and renditions of "the 3 sisters".



Slide 3

Slide 4

As long as our tools involved wood and our horsepower was supplied by horses, or oxen, then we pretty much had to work with nature.

When the tools became steering wheels and push buttons and our power was supplied by hundreds of horses packed into a diesel engine, then our natural drive led us to management principles for controlling nature.

John Deere invented the steel plow in 1837 when the Middle-West was being settled. The soil was different than that of the East and wood plows kept breaking.

Slide 4

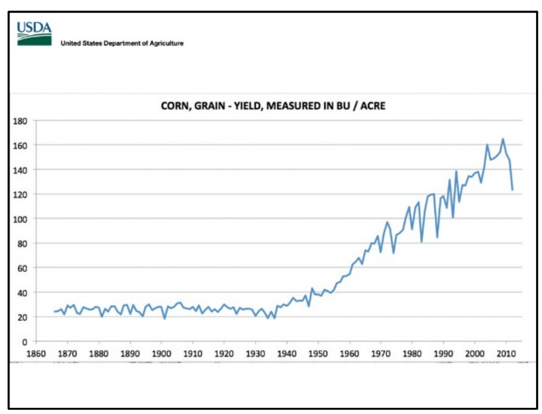
Slide 5

In no way is this a judgement against tradition or agriculture as a whole, but speaks to why change isn't easy for most of us. Some of the complacency among farmers (and some of our staff) for not changing management or looking harder into soil health systems, is that the deep prairie soils still reward them for the intensive tillage they have done or observed throughout their lifetime. We miss the realization that the Mediterranean and European style agriculture practices only arrived, in earnest, on this continent a couple of centuries ago.

Slide 5

Slide 6

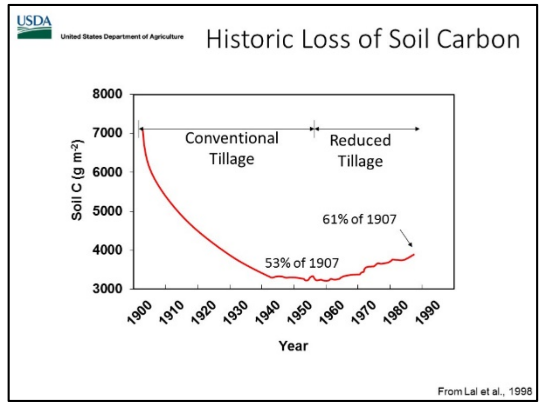
The current agricultural intensification only took hold a few decades ago. So while our current methods seem to be working fine, that is largely due to the facts: that we haven't been at them here for very long and cheap energy inputs, mostly from finite resources, are still readily available. If we look at regions of the world where these farming methods have been in place for millennia or on poorer soils to begin with, then we see what a totally depleted resource brings (hunger, disease and war).



Slide 6

Slide 7

This graph shows simulated total soil carbon changes (0 - 20 cm depth) from 1907 to 1990 for the central U.S. corn belt and a portion of the Great Plains. This indicates that soil organic carbon levels dropped to 53% of precultivation levels in the 1960s and increased subsequently with the adoption of conservation tillage practices and the advent of higher yielding varieties which produce more crop residues (Lal et al., 1998). Not sure the increase has happened as predicted in this model.

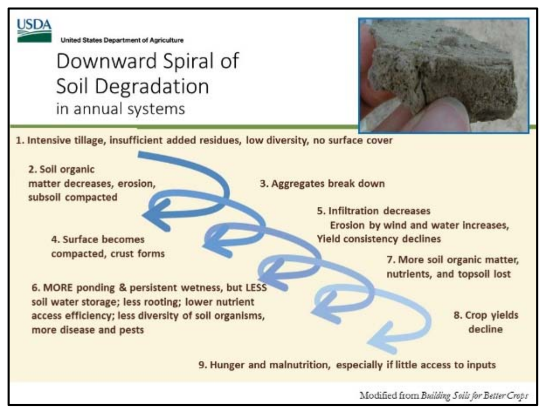


Slide 7

Relate this loss in carbon to the potential of soil to sequester carbon. The soil has the potential to put back or store all this lost carbon. The potential is about 40% of the pre-cultivation soil carbon.
In general, the C content of soil organic matter is about 58%. Soil organic matter is a key indicator of soil quality and is an integrated measure of change in soil function. Generally, increases in soil organic matter reflect increases in soil quality. Soil can function as a sink for atmospheric carbon, and therefore has the potential to decrease atmospheric carbon and aid in mitigating global climate change.

Slide 8

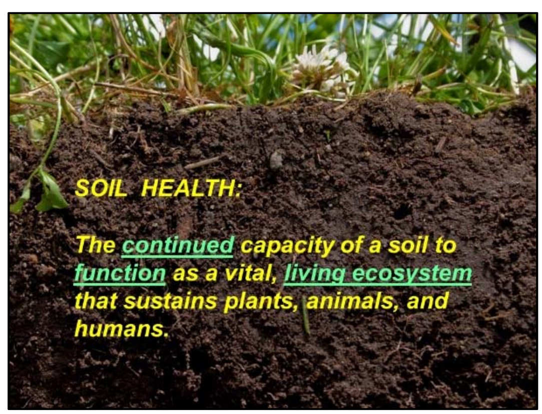
If current management principles include intensive tillage, insufficient addition of residues, low diversity, no surface cover….follow the graphics.
Over time, the way we manage our soil can, and has, led to degraded soil functions. (mention the functions that we discussed earlier).



Slide 8

Slide 9

This definition which has been accepted by most stakeholders, focuses on the importance of soil function and the reality of soil as a living resource. When we speak of soil health, we are talking about improving the capacity of soil to function as a vital, living ecosystem that sustains plants, animals, and humans.
"Health" is usually used in the context of a living organism so managing soils for optimum health, in a way, ensures they are sustainable/alive for future generations.



Slide 9

Slide 10

Farmers like these all across the nation are now planning every operation and management decision around the guiding principles for soil health. They are leading many of the advancements in SH.

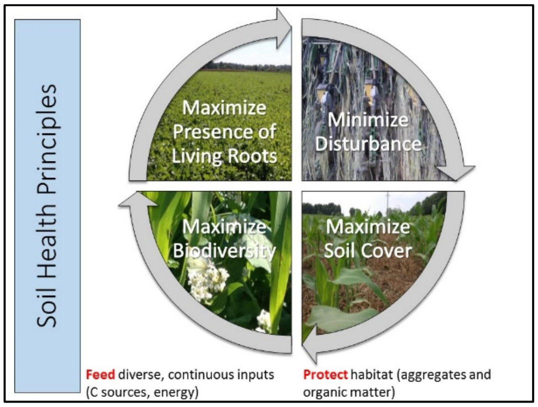
Slide 10

Slide 11

You were introduced earlier to the "principles" of soil health. To truly improve soil health, we must integrate 4 key management principles into every aspect of management decisions. So in this session we will dive deeper into why each principle is important and how each must be integrated into a system where it complements the rest.

By the end of this training, these principles should role off of your tongue when discussing soil health.

As part of the discussion we need to be pragmatic about these principles.



Slide 11

The principles tend to do one of two things, they either feed soil microbes by providing a continuous source of C or they protect the habitat

Slide 12

Most farmers who have studied yield maps have seen these principles at work. Ask- what happens to the yield map when you cross an old fence row, or maybe an old pasture that has been brought into production? … Most farmers in the room will start giving the thumbs up sign.

July 31, 2015 Aerial photo. In an extremely wet year why would this narrow part of the field look so much better?...Judging from this tract boundary line, there used to be a fence row there. The yield map would likely show an even greater advantage.

Slide 12

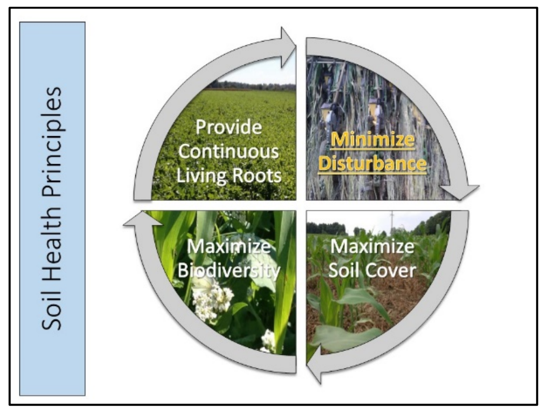
Slide 13

Those fence rows that are now in production had all of the principles in place for longer that the rest of the field. The purpose of this section is to see if we can integrate management that regenerates soil function like the fence row all across the field…farm…landscape.

Slide 13

Slide 14

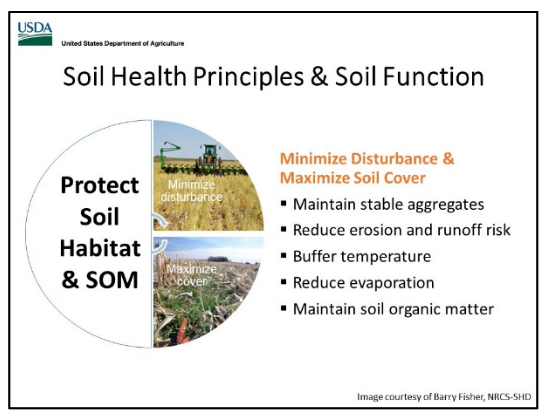
To start we will focus on the minimize disturbance portion of these principles and work our way clockwise around the circle.



Slide 14

Slide 15

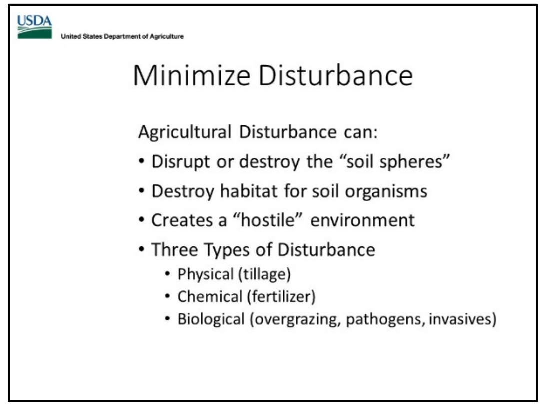
The first two principles focus on protection of the soil habitat: minimizing disturbance and maximizing soil cover maintains or increases stable soil aggregates and soil organic matter (SOM), and protects the fragile surface of the soil that is most susceptible to the degrading forces of wind and water. Covering the soil also buffers against extreme swings in temperature that stress plants and soil organisms, reduce evaporation rates, and increase water-use efficiency. SOM is highest at the soil surface and is critical for stabilizing soil aggregates. Maintaining SOM helps support additional soil functions including water infiltration and storage, nutrient-holding capacity and release, and habitat for soil biota.



Slide 15

Slide 16

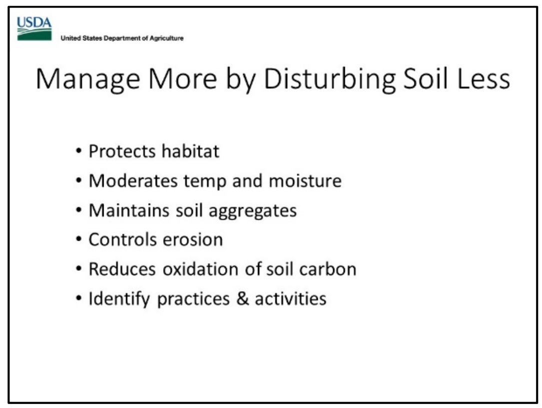
Who can name some types of disturbance? The kinds of disturbances we've become accustomed to seeing in much of agriculture, and thought of as "normal", aren't really normal in nature and weren't occurring during the development of our great soils.



Slide 16

Slide 17

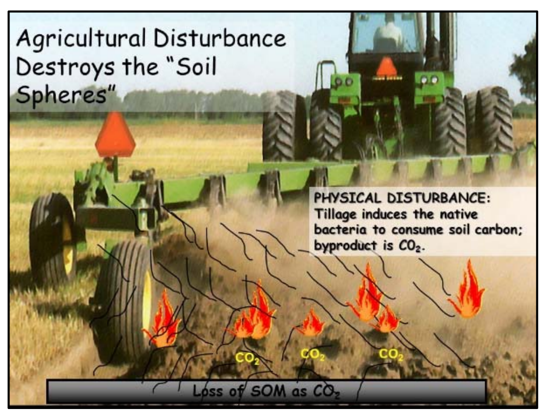
We truly need to minimize disturbance to the extent possible and practical to realize these benefits.



Slide 17

Slide 18

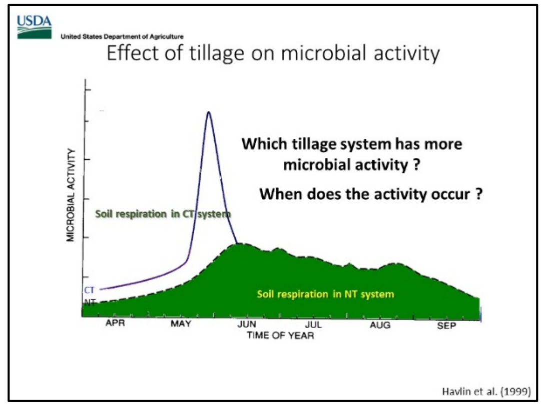
Tillage disrupts the pore space which impacts the water cycle. Physical disturbance causes native bacteria to consume soil carbon once the readily available food supply is exhausted. As the disturbance continues, the bacteria-driven soil can become adapted or "addicted" to the high disturbance environment.



Slide 18

Slide 19

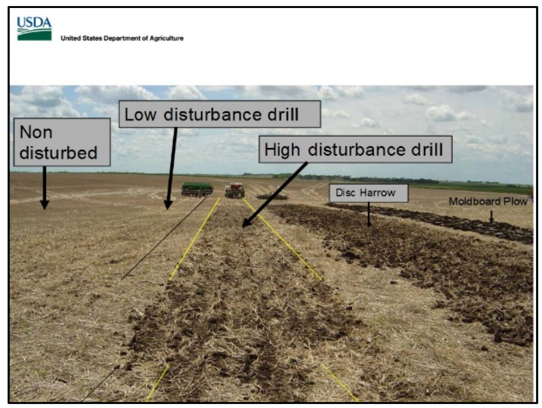
To evaluate microbial activity, scientists often look to respiration or CO_2 production. Just like humans, microbes eat, drink and breathe. The more they eat, drink and breathe (or the more active they are, the more CO_2 they produce. The timing of this respiration is important- is it just lost or is it captured by the crop canopy and used for photosynthesis?



Slide 19

Slide 20

You can see the difference in disturbance made by different tillage techniques. The more soil exposed, the greater the chance for the decomposition of carbon and loss through erosion.



Slide 20

Slide 21

No-till can be an important step toward building a soil health management system. In this slide the roots are happy because there is organic matter present and good aggregation in the soil.

Slide 21

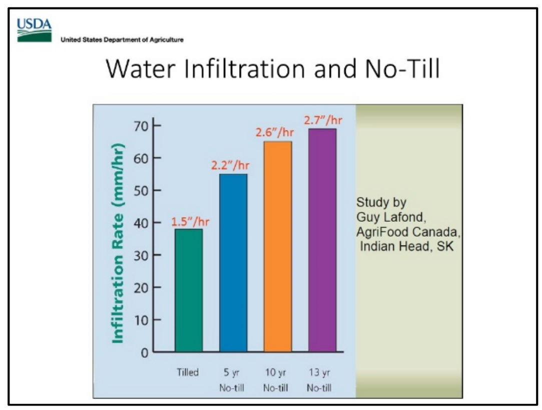
Slide 22

In this slide, however, even though no-till has been implemented, there are still issues with the soil. Eliminating disturbance alone will not always improve soil health. No-till can be an important step, however, not all no-till is created equal. There have been some studies that report no improvement in SOM, aggregate stability, or water infiltration. Few studies provide a detailed account or analysis of the no-till system. It would be a mistake to assume that the mere absence of tillage in a given year would achieve significant soil health benefits. The quality of the no-till system should be a part of any study. A "Quality No-till System" will integrate more than the single principles of reduced physical disturbance. It will be complemented by reductions in other types of disturbance and additional principles. We will cover more on practices and systems in a later session.

Slide 22

Slide 23

Many studies have concluded that No-till can improve aggregate stability and thus improve water infiltration.



Slide 23

Slide 24

The traffic involved in tillage can also create compaction, particularly under wet conditions. The slide shows ponding in these compacted areas.

Slide 24

Slide 25

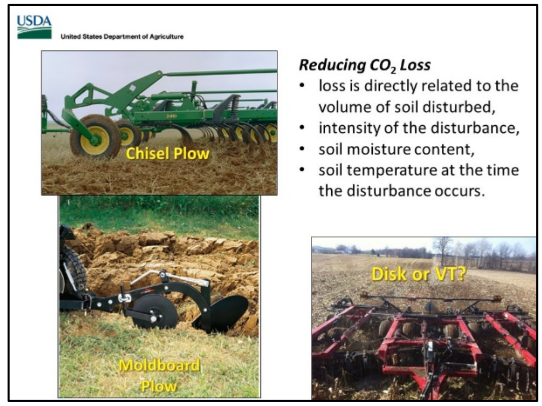
Shallow soil disturbance (1-3 inches) releases less CO_2 than deeper operations.

When deep soil disturbance is performed, such as by subsoiling or fertilizer injection, make sure the vertical slot created by these implements is closed at the surface.

Planting with a single disk opener no-till drill will release less CO_2 than planting with a wide-point hoe/chisel opener air seeder drill.

Soil disturbance that occurs when soil temperatures are below 50° F will release less CO_2 than operations done when the soil is warmer.

There are many brands and types of tillage tools and all have varying degrees of soil engagement and residue "management".



Slide 25

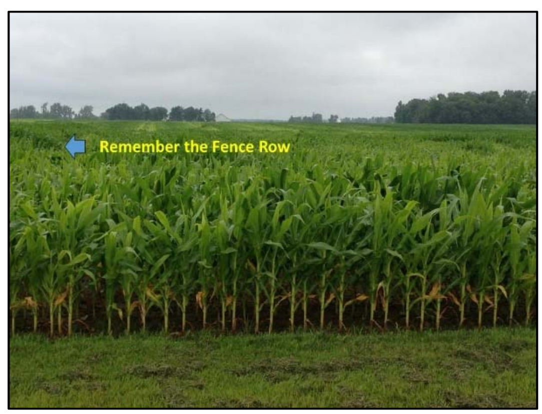
Slide 26

We can see that ponding and flooded crops were the norm for much of this region.

Slide 26

Slide 27

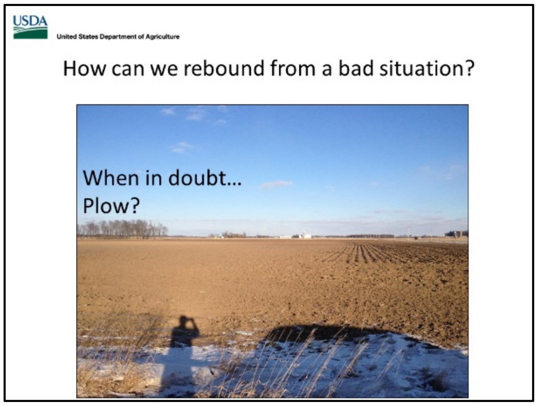
We can blame a lot on the weather, however, certain parts of the field revealed significant differences in soil health. The area to the left seems to be far more resilient to the extreme saturation. In fact it was an old fence row that had been brought into production a few years ago. This area, by coincidence, had the 4 principles in place until recently. Our goal is to replicate the fence row across the landscape.



Slide 27

Slide 28

Unfortunately, once the crop was determined failed or immediately after the crop was harvested, most fields received "Iron" therapy. This was probably good therapy for the frustrated farmers, but had little to no effect on improving the soil.



Slide 28

Slide 29

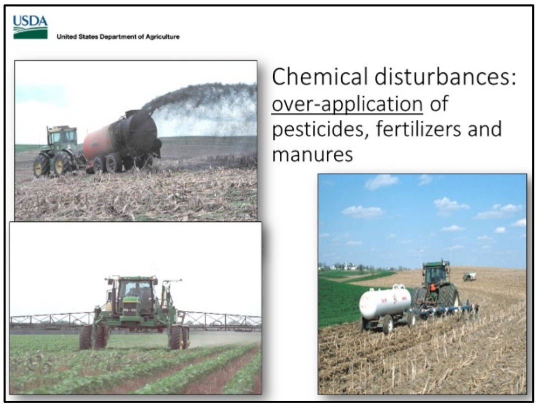
A few farmers took a different approach with a different mindset (when in doubt-plant).

Need to change our paradigm to look at soil health principles as the solution.

Slide 29

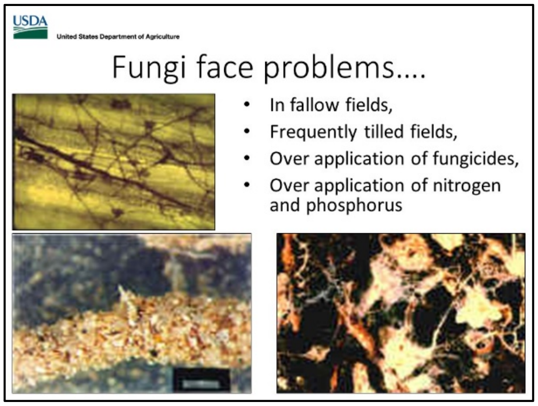
Slide 30

Other disturbances relate to chemicals where overapplication of pesticides, fertilizers, and manures can cause issues for the soil biology.



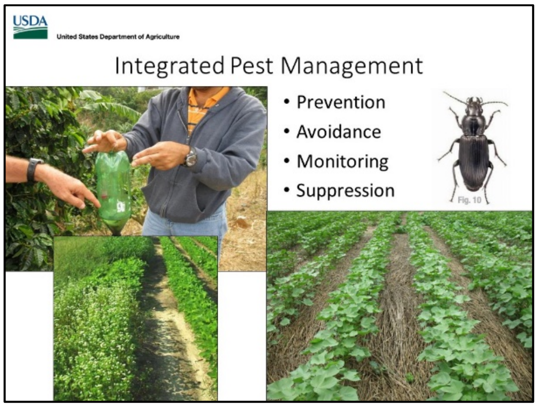
Slide 30

Slide 31
This can also be a biological disturbance.



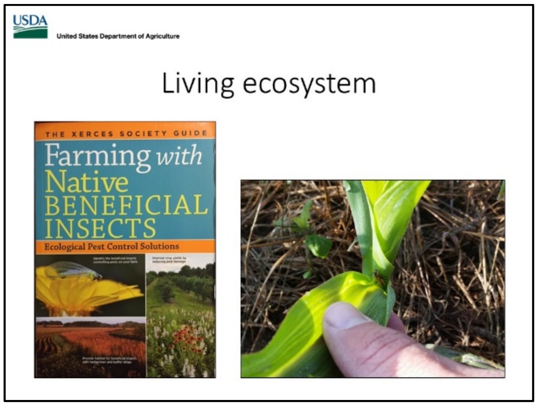
Slide 31

Slide 32
Integrated pest management is similar to soil health management in that it focuses on sustainable management principles. IPM can aid in improving soil health by engaging in these sustainable practices and reducing pesticide use.



Slide 32

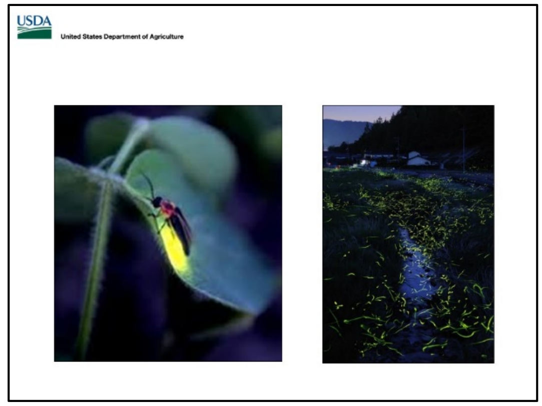
Slide 33
Remember, you are creating and managing a living ecosystem! Widespread use of pesticides may be wiping out organisms critical for soil health.



Slide 33

Slide 34

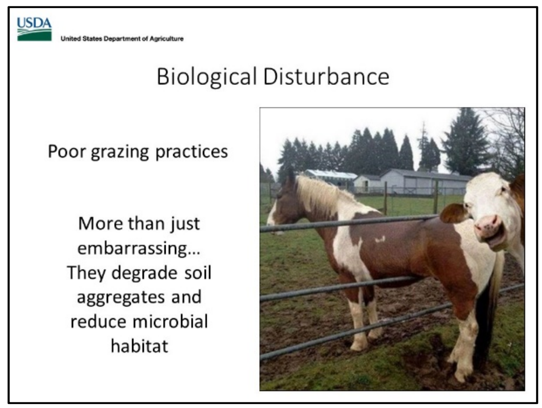
As an example, fireflies feed on egg masses of caterpillars, slugs, etc. many of the pests that we fight in agriculture.



Slide 34

Slide 35

As we mentioned, biological disturbances can occur through the use of chemical applications but they can also be implemented through other management systems like grazing.

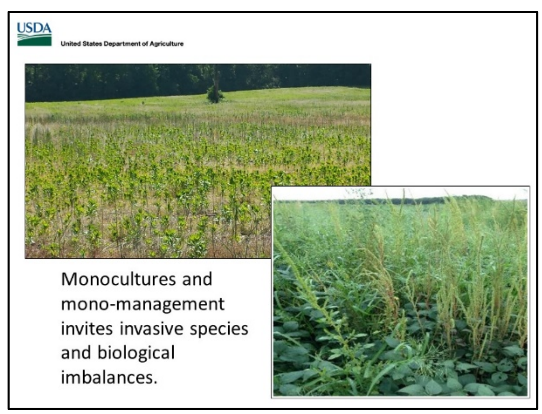


Slide 35

Slide 36

Ask the class to think of other biological disturbances.

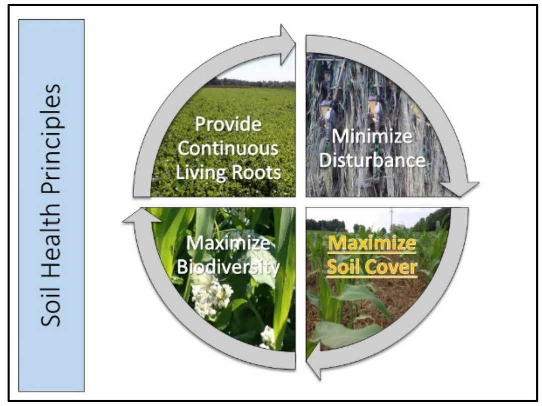
Monoculture systems are a biological disturbance in that they don't provide a diversity of food and cover for soil microbial communities.



Slide 36

Slide 37

Now we will focus on management systems that maximize soil cover.



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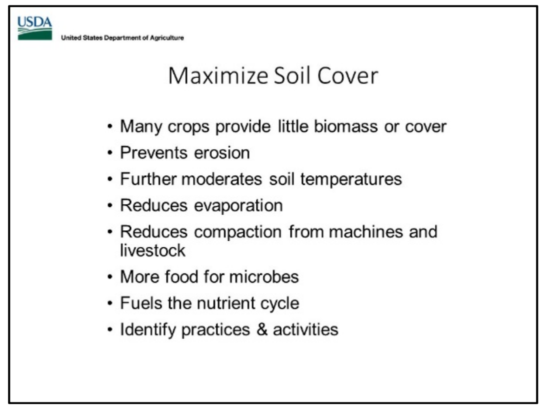


Slide 38

Slide 39

The more cover you can have over the soil, the better. Also, more species diversity in cover crops can enhance soil health properties. Cover crops can also provide additional cover for low biomass crops.

Slide 39

Slide 40

For many farmers, the concept that more is better is difficult. We here often-"my soil is too cold and wet" . Billions if not trillions of $ have been spent on equipment and technology to mechanically warm and dry the soil.

Slide 40

Slide 41

And yet, is tilled soil always warmer?...It depends on a number of factors including time of day, time of the season, moisture content, etc.

Slide 41

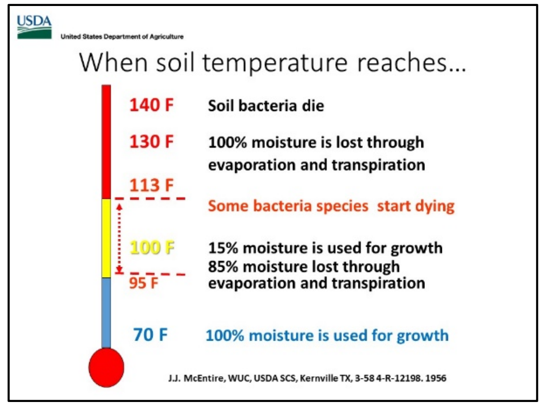
Slide 42

If you mechanically warm your soil in the spring are you giving up moisture, air, and habitat in the summer.

Slide 42

Slide 43

Soil temperatures are a way of determining the health of your cropland and pastures. By placing a temperature gauge on the surface can show you what kind of microclimate you have created. Soil temperatures can exceed ambient air temperatures by 10 to 20 degrees.



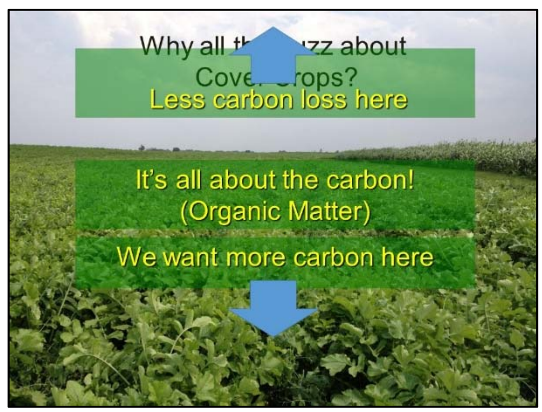
Slide 43

Plant use of moisture is directly linked to soil temperature. At 70 F soil temps 100% of the moisture is used for growth, none is loss. At 100 F you lose 85% of your moisture through evaporation-transpiration. At 113 F 100% of soil moisture is lost through evaporation-transportation, no plant growth is occurring. A plant's natural reaction to hot temperatures is to evaporate soil moisture through their system to cool itself. Protein cooks at 120 F. Thus the plant will avoid being cooked by using all the moisture you have caught in the soil for air conditioning. At 130 F, soil organisms start to die.

So it is important to manage for cool soil conditions. This is the biggest loser of soil moisture. Hot ground means you have created a drought even during moist years.

Slide 44

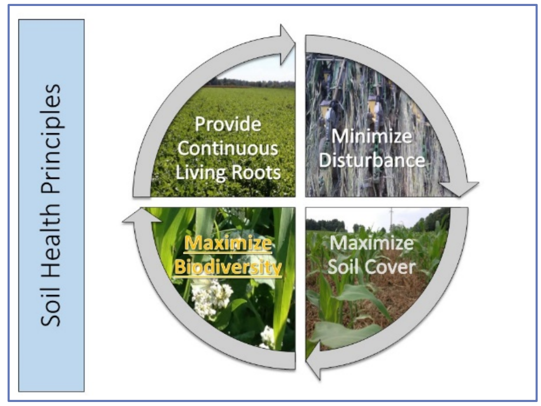
It's really all about the carbon cycle. We can build it so much faster in the soil if we grow more biomass and stop losing carbon to the atmosphere through tillage.



Slide 44

Slide 45

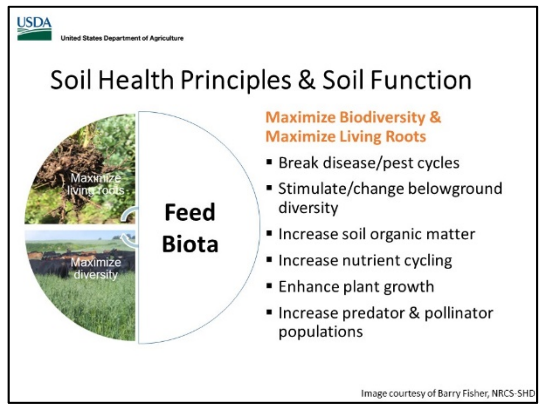
Now we will discuss some management practices that can help maximize biodiversity in the field which is our third soil health principle.



Slide 45

Slide 46

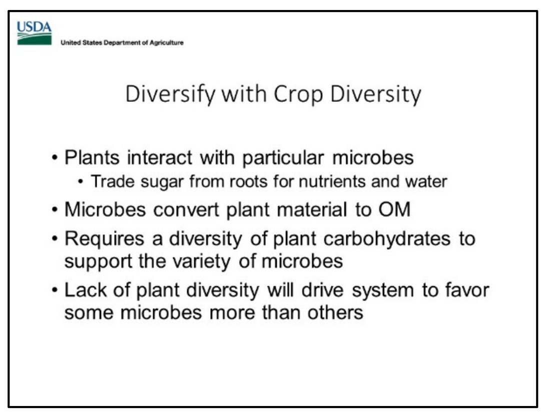
The second two principles focus on feeding the organisms inhabiting soil. Maximizing the diversity of food (energy and carbon inputs) and aboveground biodiversity through increased plant, animal, or soil amendments increases the diversity of soil animals, microorganisms, and activities. Diversity not only refers to food sources, but also aboveground diversification of plants and animals, as well as microbial diversification underground. Diversification stimulates a host of additional benefits including breaking disease cycles, providing habitat for pollinators, wildlife, and beneficial predators, and stimulating plant growth.



Slide 46

Slide 47

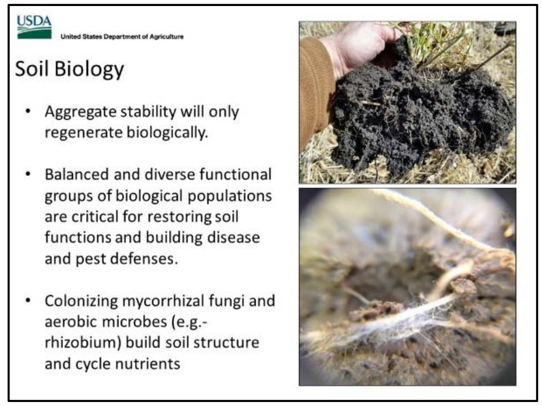
This slide focuses on how crop diversity can create diversity in soil biology.



Slide 47

Slide 48

Maximizing diversity is really all about habitat for soil organisms… build it and they will come….feeding the soil biology. As we discussed before, without habitat, beneficial soil biology, such as mycorrhizal fungi and rhizobia bacteria that build structure and tilth, may also be lost. Without a balance of these organisms, the soils lose key functions and are subject to compaction, crusting, and high bulk density.

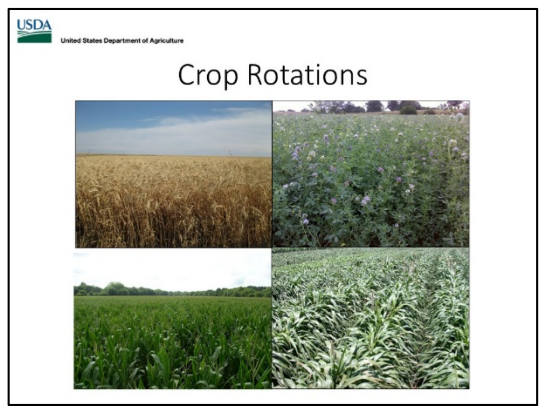


Slide 48

Observations in Tennessee…monoculture legumes will show poor to no defined aggregation. Speculation: Soil biology needs energy and will find and will digest it in and between aggregates causing them to collapse. No cover or plant growth will cause no aggregation or poor aggregation, platy structure. Aggregates require active carbon.

Slide 49

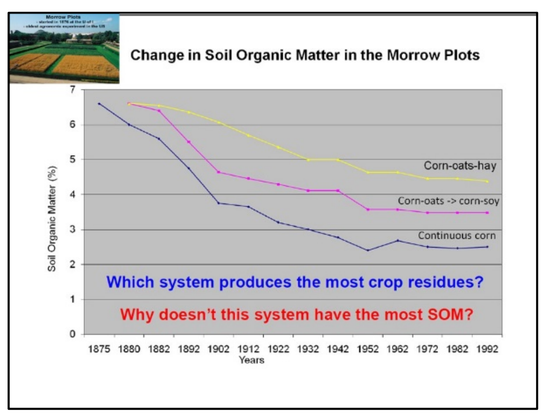
One of the most obvious ways to increase biodiversity is through crop rotations.



Slide 49

Slide 50

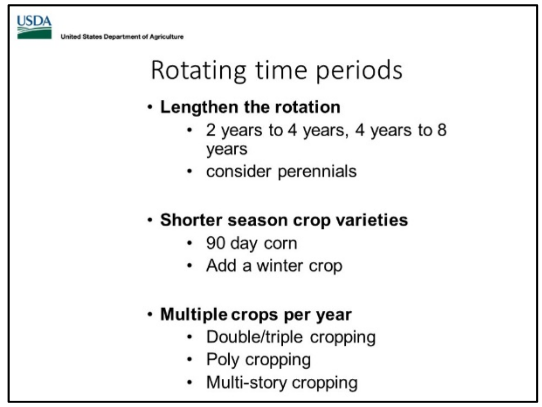
Morrow Plots at the University of Illinois is the oldest agronomic experiment in the US (started in 1876). They show a steady loss in soil organic matter but there is not as much loss in systems that have more diversity.



Slide 50

Slide 51

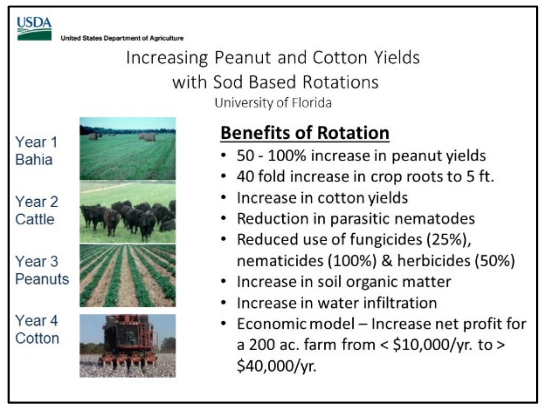
Rotation strategies for improving soil health



Slide 51

Slide 52

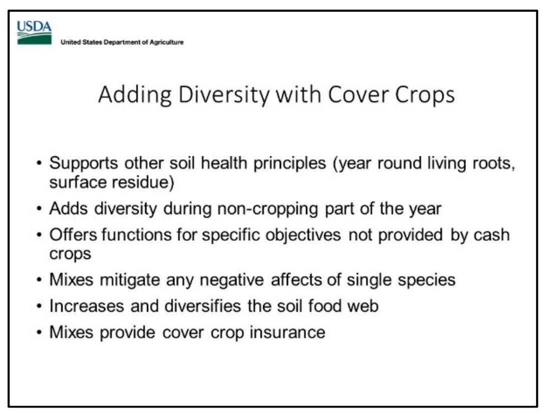
Example that uses crop rotation to increase peanut and cotton yields.



Slide 52

Slide 53

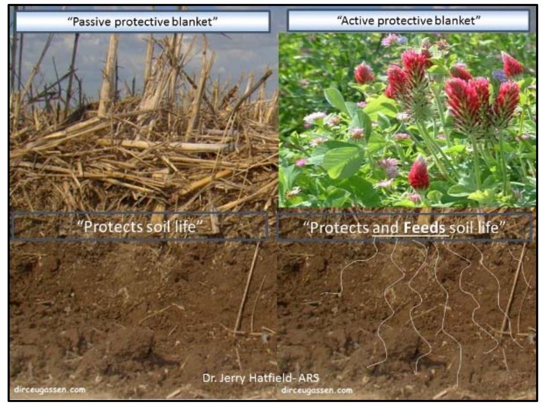
Examples of how cover crops can increase diversity



Slide 53

Slide 54

Cover is important as protection of soil life…a diverse and active cover not only protects but also feeds soil life. Like us, sooner or later they need to eat, and it can't always be shredded wheat.



Slide 54

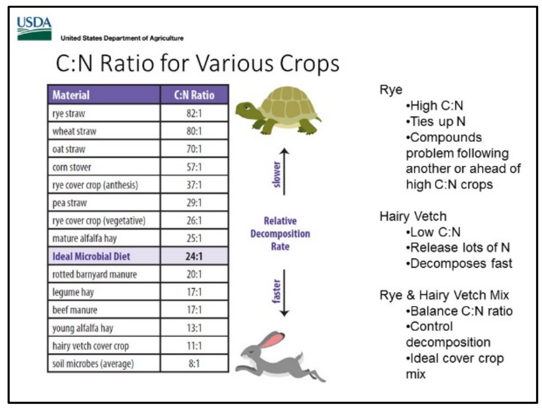
Slide 55

Not all cover crops are created equal. We need to use covers that complement our crop rotation, provide desirable habitat and address resource concerns. Understanding differences in the Carbon:Nitrogen ratio between plants is critical for this selection.

Ask the class what drives C:N –is it the C or the N? Discuss that most plants contain 40-50% carbon so it is the N that is the driver (it is the limiting nutrient).

Ask the class how you can change the N in a plant. Vegetative vs mature, N fertilizer or N fixation by legumes.

Ask class what effects a high or low C:N ratio cover crop may have on the next crop; nutrient cycles; residue decomposition.

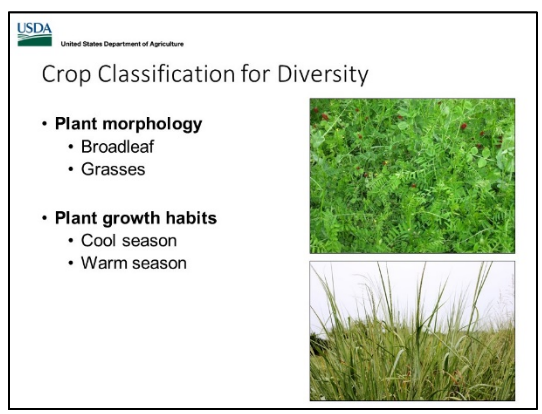


Slide 55

Slide 56

So if plant diversity is this important, maybe we should have a basic strategy that applies to most situations. For cropland, we try to at least get all crop types growing at some point in a rotation or together.

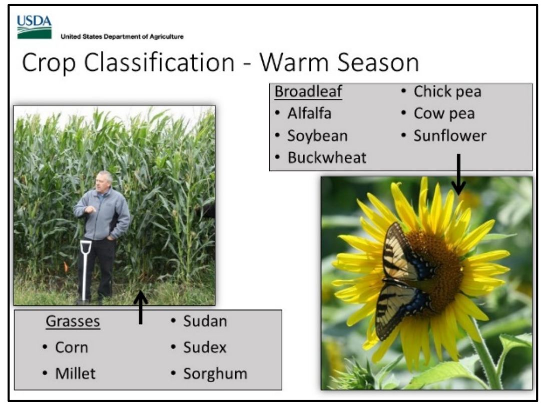
Why - ask the class for input. Basically, each crop type may provide a different function, food and outcome. We've known for years that certain crops of different crop types can be synergistic to each other (i.e. grasses and legumes). We know that different plants secrete different compounds that feed and attract different organisms.



Slide 56

Slide 57

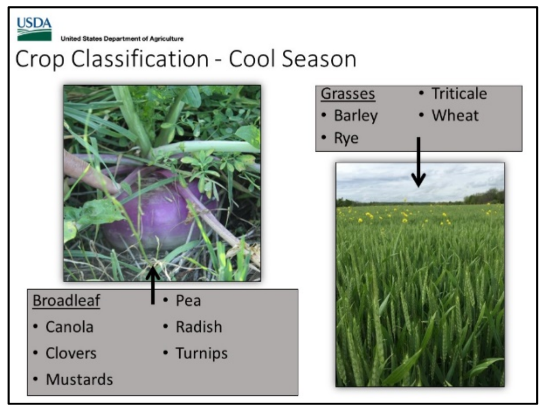
These are some examples of warm-season grasses and broadleaf crops.



Slide 57

Slide 58

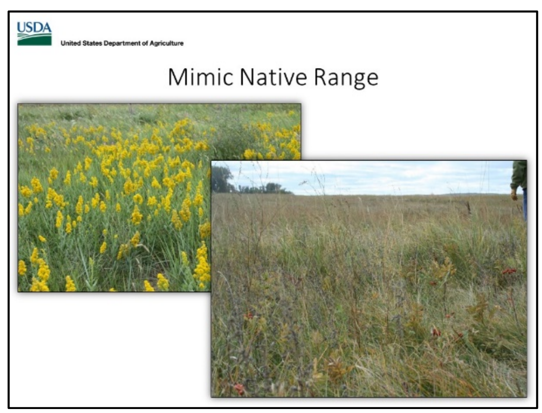
These are some examples of cool-season grasses and broadleaf crops.



Slide 58

Slide 59

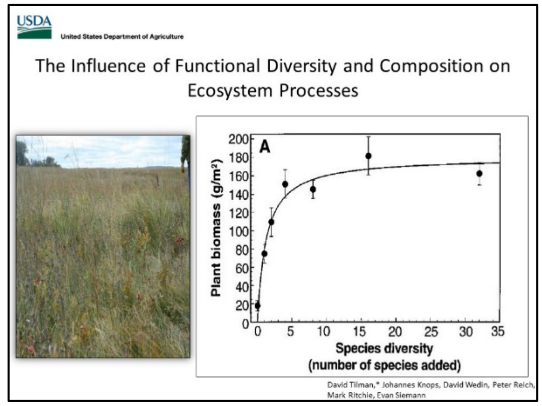
Mimicking native range can also mimic the positive soil health attributes found in these kinds of soils.



Slide 59

Slide 60

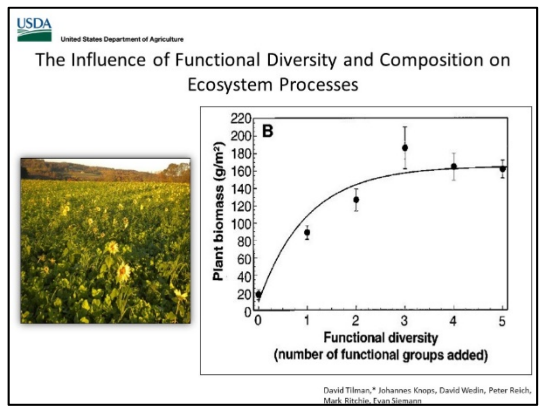
Aboveground biomass relates to site productivity. Therefore, up to a certain point, the greater the number of species present, the greater the productivity can be.



Slide 60

Slide 61

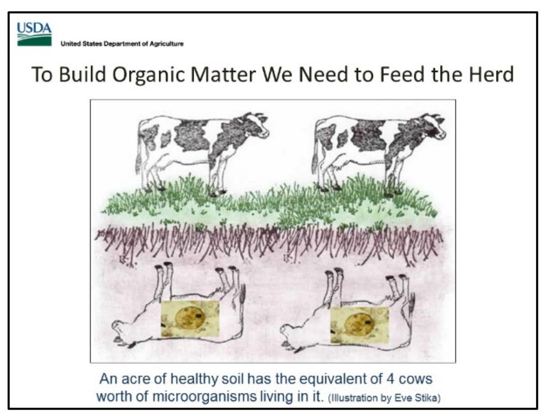
This is another way of showing the information, similar to the previous slide. In this case we are seeing that an increase in functional diversity (functional groups include legumes, cool-season grasses, warm-season grasses, woody plants, and forbs), up to a certain degree, also increases site productivity.



Slide 61

Slide 62

You can no more starve your way to a healthy heart than you can starve your way to a healthy soil. Continuous, diverse living cover is the best food source.



Slide 62

Slide 63

The bison roamed around eating the grass. Primarily it was warm season grass and forbs but there was a tremendous amount of diversity. There is still discussion about exactly how the bison grazed. There were a lot of factors that came into play (i.e. time of year, growing or dormant grasses, available water, what areas burned, what didn't burn). Some writings and accounts say they were in small groups grazing only in the burned areas for the entire year. These burned areas would have been grazed pretty hard while unburned areas were almost ungrazed and then the next year they moved to another burned area. There are also accounts of large herds numbering in the hundreds of thousands. As you can imagine when a large herd like this moved through an area everything probably got grazed and/or trampled pretty hard. In either of these scenarios the grasslands were severely grazed and then rested for a long period of time, severely grazed and then rested. It was this type of management that developed some of the most fertile soils in the world. I think we can use different forms of this type of management to repair our eroded and worn out soils.

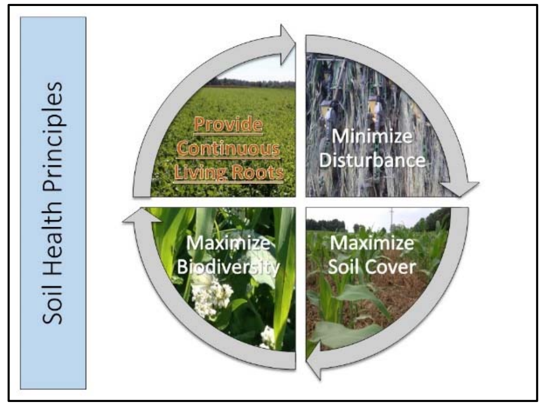
Slide 63

Slide 64

At first glance this may seem like too much disturbance, but in this system the rest period allows for rapid regeneration from the improved cycling of carbon and nutrients.

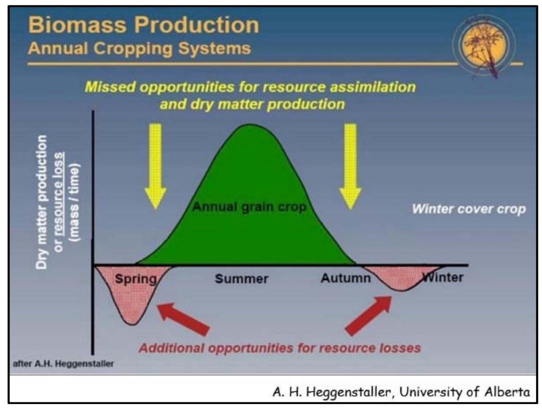
Slide 64

Slide 65
We'll now move on to our last soil health principle, Provide Continuous Living Roots.



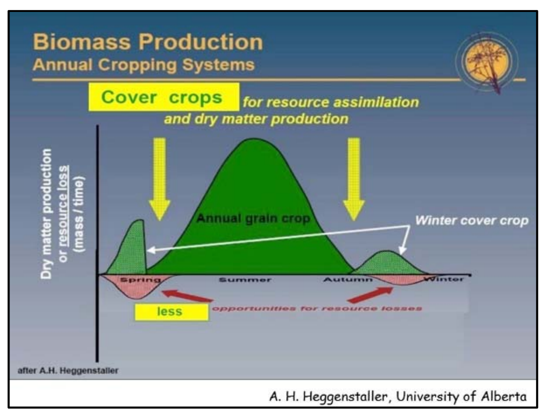
Slide 65

Slide 66
Without the winter cover crop, we can see the expected losses of resources in winter and spring when there is no crop being grown.



Slide 66

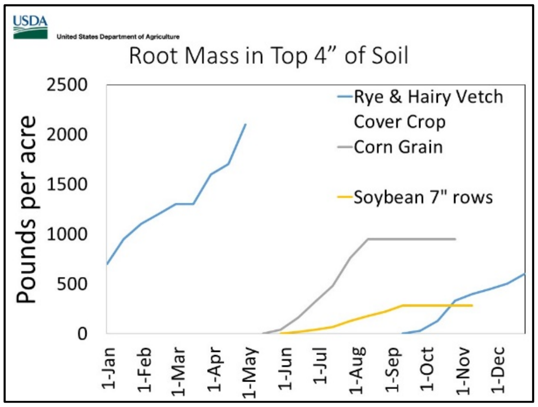
Slide 67
With cover crops, you can see the expected losses are smaller and dry matter production occurs. In some cases, sacrificing a whole crop system may be worth consideration to
maximize benefits to the soil ecosystem.



Slide 67

Slide 68

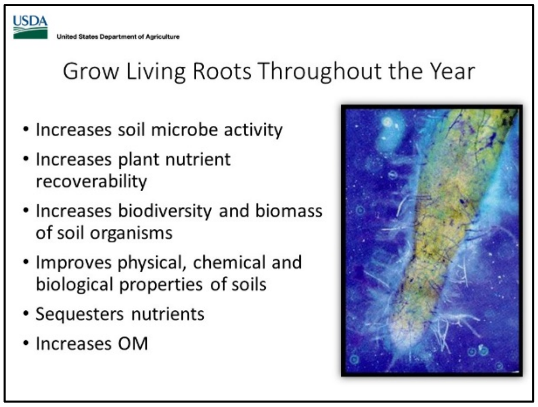
In a very short window, extensive root mass is possible. This adds to the soil carbon pool and greater production/maintenance of stable aggregates.
Corn produces approx. 950 lbs. of root mass in the top 4”
Soybeans/cotton produce approx. 400 lbs.
The cover crop produces over 2500 lbs. of root biomass planted in September and terminated in mid-April.



Slide 68

Slide 69

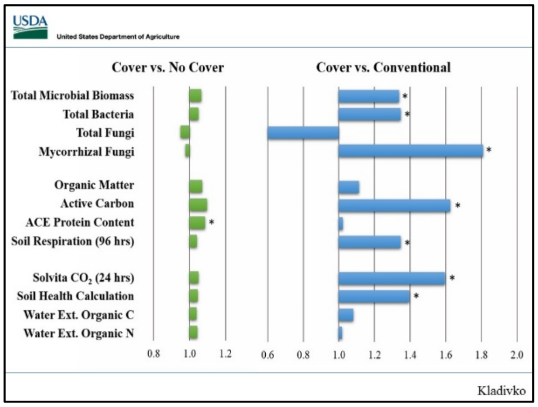
In addition to cover the root production can jumpstart soil biology and function.



Slide 69

Slide 70

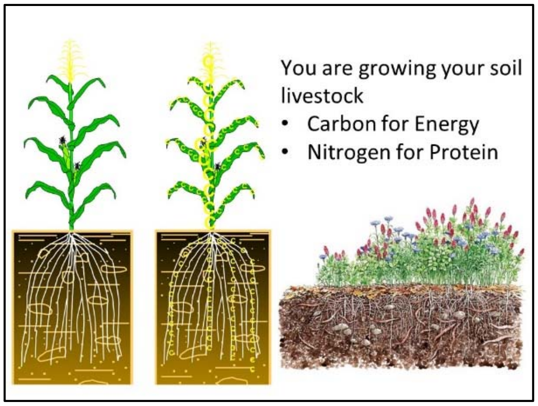
This slide shows response ratios of 12 soil health measures for 2016 sampling in NW Indiana. Values greater than 1 indicate a positive effect of the cover crop compared to either no cover (left) or the conventional neighbor (right) while values below 1 indicate a negative effect of cover crops relative to their comparison. Treatment pairs that were significantly different at 0.10 level are indicated by asterisks.



Slide 70

Slide 71

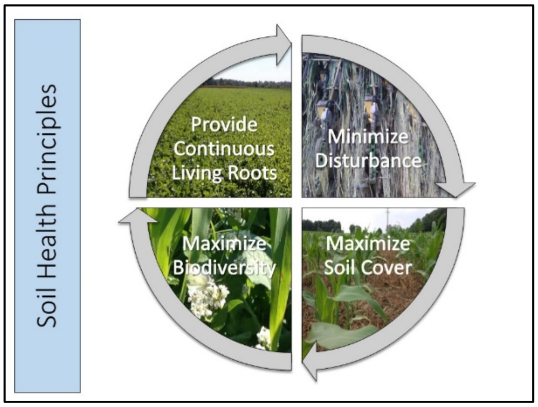
The growing roots also feed the biology (through dead root cells and root exudates) in the soil that is responsible for forming stable aggregates.



Slide 71

Slide 72

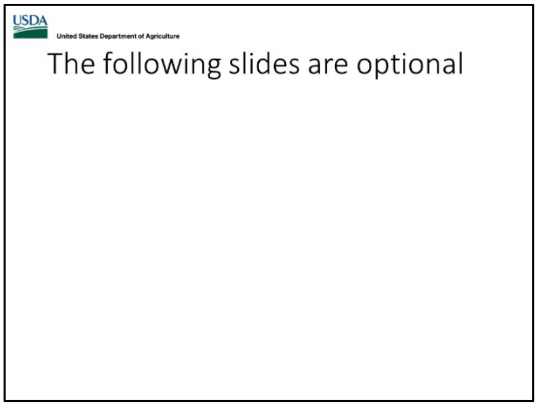
So, we've gone through the four soil health principles and discussed why they are important for soil health. Hopefully, once you leave this workshop, these principles will roll off of your tongue when discussing soil health. Next, we will identify the indicators in the field that will show us how well, or not so well, we are doing at adhering to these principles.



Slide 72

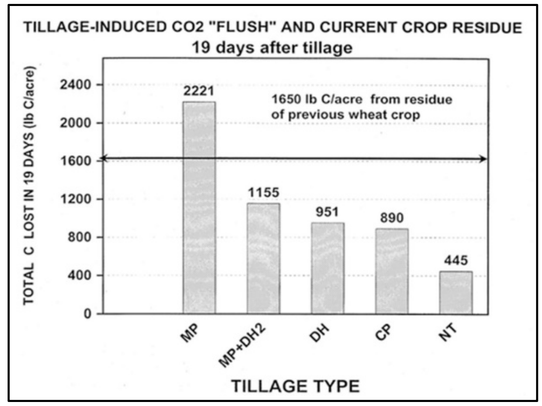
Slide 73

The following slides are optional and may be incorporated into specific sections of the presentation depending on the trainer and audience.



Slide 73

Slide 74
MP = moldboard plow
MP + DH2 = moldboard plow plus disk harrow twice
DH = disk harrow
CP = chisel plow
NT = no-till
How long we leave the soil open is a factor as well.



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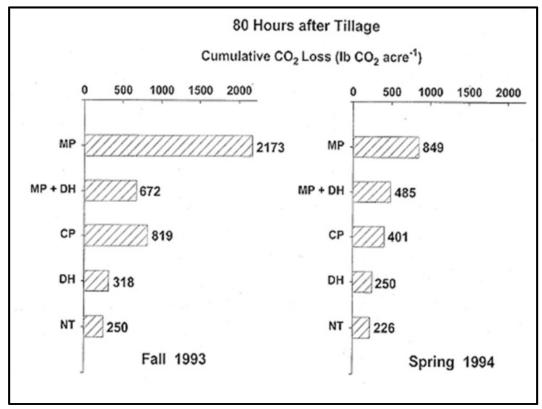
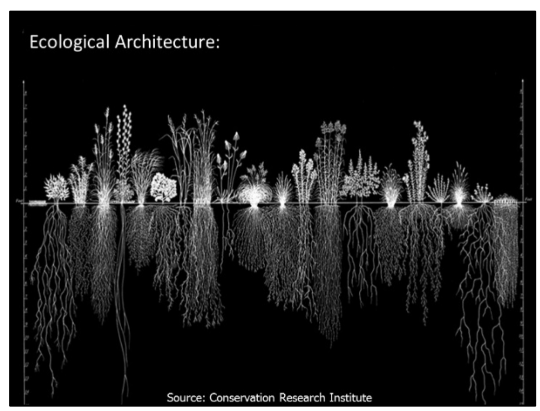


Slide 75

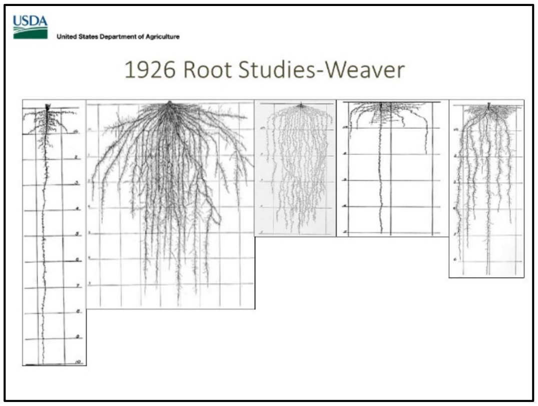
Slide 76
Plants have a diversity of rooting systems and rooting architecture.



Slide 76

Slide 77

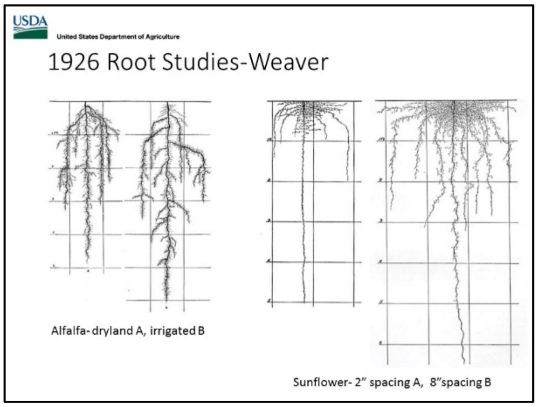
We've been studying diversity of plants for awhile.



Slide 77

Slide 78

Nature responds and adapts to environment



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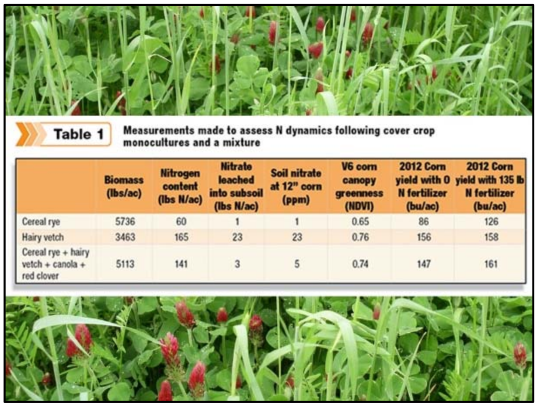
Slide 79

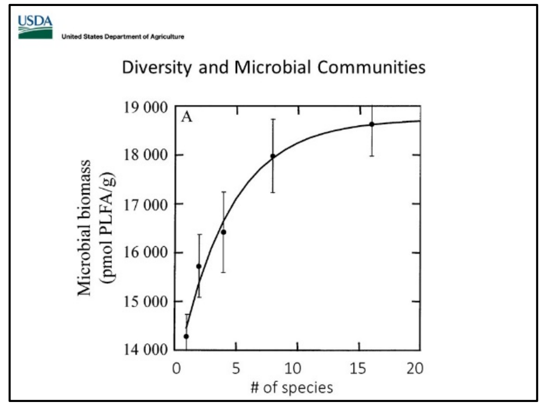


	Biomass (lbs/ac)	Nitrogen content (lbs N/ac)	Nitrate leached into subsoil (lbs N/ac)	Soil nitrate at 12" corn (ppm)	V6 corn canopy greenness (NDVI)	2012 Corn yield with 0 N fertilizer (bu/ac)	2012 Corn yield with 135 lb N fertilizer (bu/ac)
Cereal rye	5736	60	1	1	0.65	86	126
Hairy vetch	3463	165	23	23	0.76	156	158
Cereal rye + hairy vetch + canola + red clover	5113	141	3	5	0.74	147	161

Slide 79

Slide 80

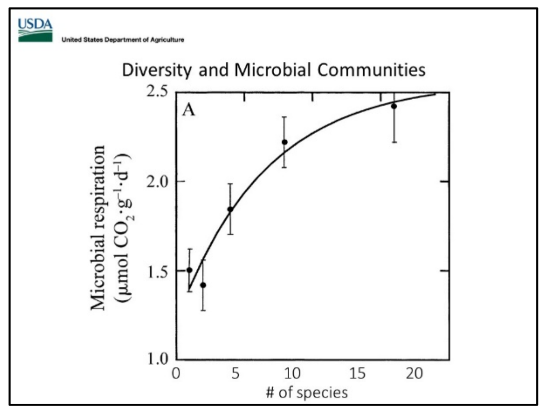
This slide indicates that as plant diversity increase so does the amount of microbial biomass in the soil as measured using the PLFA assessment.



Slide 80

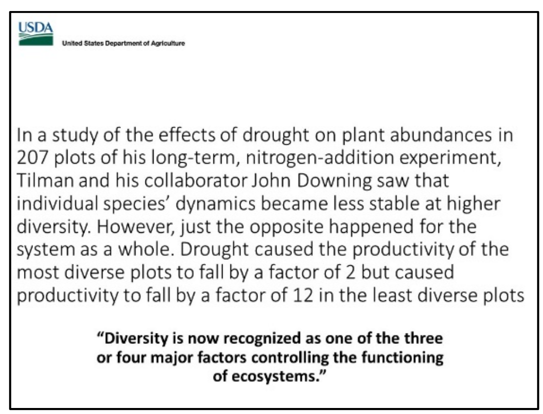
Slide 81

This slide look at the amount for microbial respiration, it increases as the number of plant species increases. Respiration is an indicator of activity, the more respiration the more biological activity taking place (e.g. increase nutrient cycling).



Slide 81

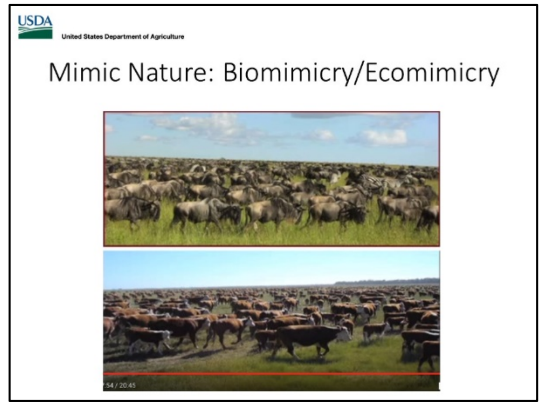
Slide 82



Slide 82

Slide 83

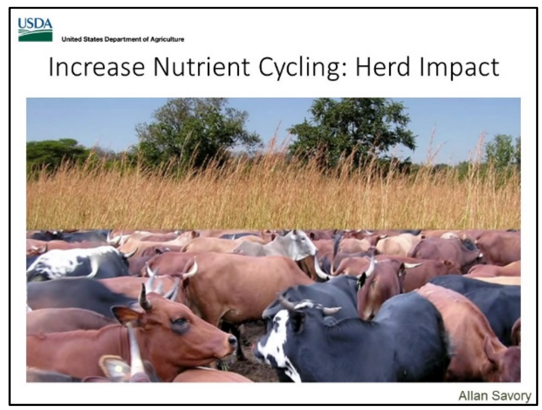
The great prairie soils of the world were developed with herd/livestock interaction. The animals moved in dense herds for protection from predators. They left behind dung and urine and kept moving. This will be discussed further in a later session.



Slide 83

Slide 84

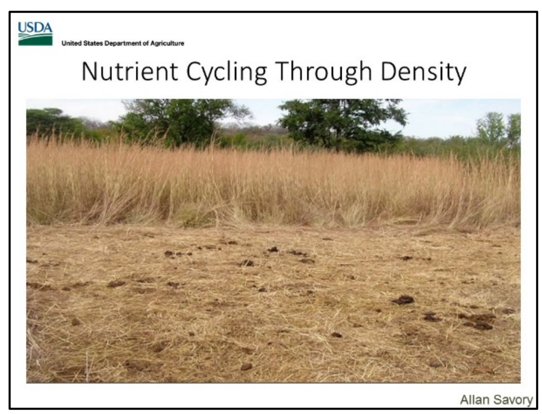
Depending on the agenda and location it may be good to show Allan Savory's Ted Talk video.



Slide 84

Slide 85

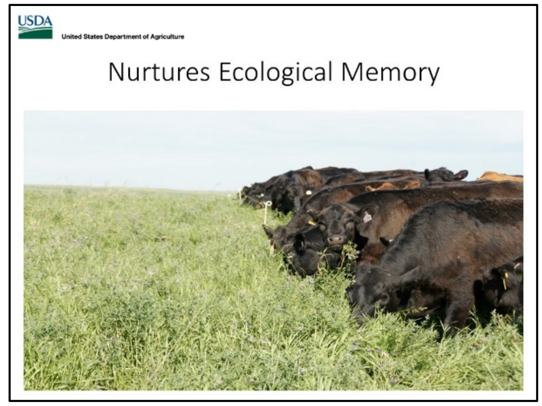
The animal rumen provides additional biodiversity with organisms designed to process the fiber.



Slide 85

Slide 86

It should be noted that management is key. Merely putting some livestock on the land doesn't assure success. We will discuss this in greater detail in later sessions.



Slide 86

Test their Knowledge - Questions for the audience

Soil health involves the __continued__ capacity of a soil to __function__ as a vital, __living ecosystem__ that sustains plants, animals, and humans.

The soil health principles are:

1. Minimize disturbance
2. Maximize soil cover
3. Maximize biodiversity
4. Maximize the presence of living roots

Q: Which soil health principles relate to protecting the habitat of soil organisms (aggregates and organic matter)?
A: Minimize disturbance and Maximize soil cover

Q: Which soil health principles relate to feeding diverse, continuous inputs to soil organisms (carbon sources and energy)?
A: Maximize biodiversity and Maximize the presence of living roots

The three types of agricultural disturbance include:

1. Physical (i.e. tillage)
2. Chemical (i.e. fertilizer)
3. Biological (i.e. overgrazing, pathogens, invasives)

Diversity in the soil ecosystem can be increased by using __crop rotations__ and __cover crops__.

Q: What does it mean that cover crops provide an "active protective blanket".
A: Cover crops not only protect the soil ecosystem (passive protective blanket) but they also provide food to this ecosystem.

Q: What is the concern with growing cover crops that together have either a high C/N ratio or a low C/N ratio?
A: Decomposition will be either too slow (high C/N ratio) or too fast (low C/N ratio). The ideal ratio is 24/1.

Up to a certain point, the greater the number of cover crop __species__ or __functional groups__, the greater the __site productivity__.

Q: What benefits to living roots provide?
A: They can (1) increase soil microbial activity, (2) increase plant nutrient recoverability, (3) increase biodiversity and biomass of soil organisms, (4) improve physical, chemical and biological properties of soils, (5) sequester nutrients, and (6) increase soil organic matter.

Soil Health Evaluation

Name of Activity: Soil health principles	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. *Soil health principles*	①	②	③	④	⑤	①	②	③	④	⑤
2. Benefits that each soil health principle provides to the soil	①	②	③	④	⑤	①	②	③	④	⑤
3. Conservation practices related to each soil health principle	①	②	③	④	⑤	①	②	③	④	⑤
4. Cover crops	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!

MODULE 4. SOIL HEALTH INDICATORS

Learning objectives:

Participants will be able to:

- describe what soil health indicators are and which ones are used to evaluate soil health in the field and/or laboratory.
- describe how soil health indicators provide information about a range of critical soil processes, and build upon each other for an understanding of soil health status.
- describe how key soil health indicators are linked to the soil health principles
- explain soil organic matter, the various SOM pools and their role in soil health.
- explain aggregate stability, its role in soil function and how it can be affected by management.
- explain how nutrient cycling is affected by degraded soil function.
- describe the “Regenerative Systems” for healthy soils.

Materials:

- PowerPoint® slides “Module 3: Soil Health Indicators”
- 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:

Soil organic matter
Aggregate stability
Water infiltration
Available water capacity
Nutrient cycling
Balancing and diversifying soil biology
Erosion

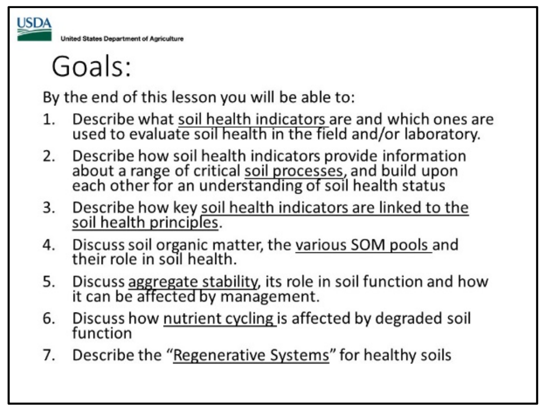
Slide 1

In this module we will be identifying soil health indicators that can be identified in the field to determine how well the soil health principles are being applied.

Slide 1

Slide 2

The learning objectives for this module.



Slide 2

Slide 3

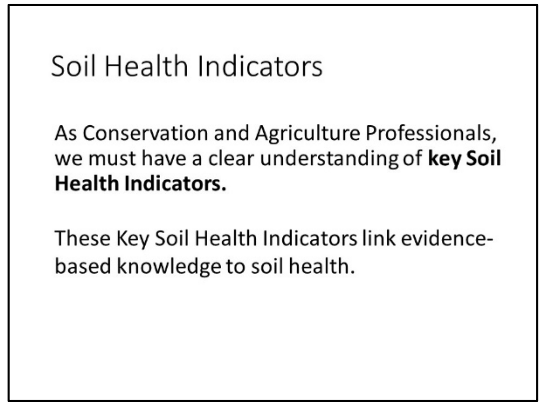
There are many indicators of soil health and soil quality. Most of these can be measured and quantified in a lab or a field assessment. For example, indicators like organic matter content and water stable aggregates need to be measured in a lab but soil morphological features that relate to soil health along with testing for water infiltration or pH/EC can be done in the field with the right equipment. (This is the equipment that is part of your soil health test kits!).

Slide 3

Qualitative measurements are based more on observation and professional judgment whereas quantitative measurements are usually done with laboratory or field equipment.

Slide 4

Again, these soil health indicators relate to how well the soil health principles are being applied.



Slide 4

Slide 5

There are many indicators of soil health and soil quality. Key indicators are broadly understood as important soil characteristics for production and ecosystem services.

Slide 5

Slide 6

Soil health assessments are important to know where you are (a baseline). A soil quality assessment can also tell you what are the inherited soil traits as well as current levels of dynamic soil properties.

Standard soil tests provide some indicators related to the chemical side of the soils, but don't give a complete analysis of what is taking place with the biology or the physical nature of the soil.

Slide 6

Slide 7

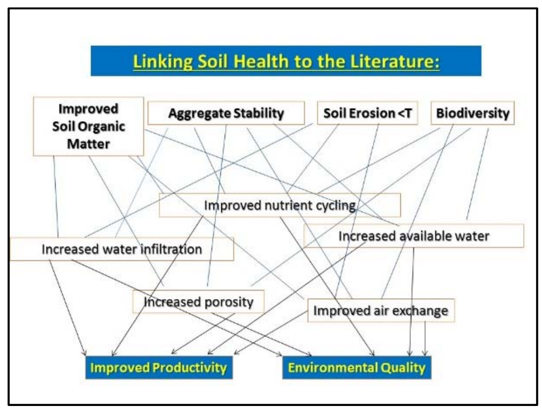
Soil health is a constant building process, and implementing conservation cropping and grazing systems that improve soil health should meet or fulfill all the objectives identified on the slide. These objectives will be relevant to farmers and most landowners. Looking at ways to "constantly" improve. These are actions that don't stop. They build on each other.

Slide 7

Each one of these indicators relate to the soil health principles of 1) Minimizing disturbance, 2) Maximizing soil cover, 3) Maximizing biodiversity, and 4) Maximizing the presence of living roots. Measuring these indicators will indicate how well the soil health principles are being followed.

Slide 8

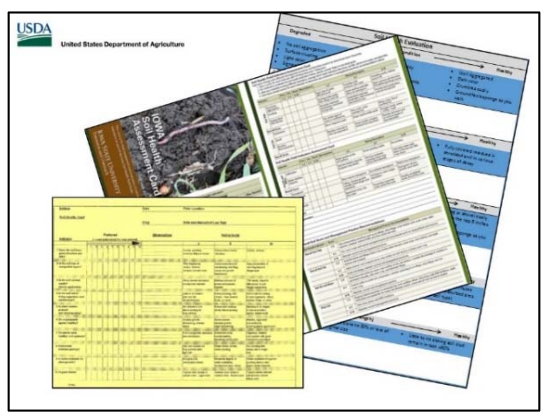
While there is little scientific literature found that quantify the benefits of soil Health, journals contain a lot of evidence of benefits (production and environment) observed from the soil health indicators. The scientific basis for the pursuit of soil health is mostly found within the key indicators. The slide shows how these indicators are linked to these benefits.



Slide 8

Slide 9

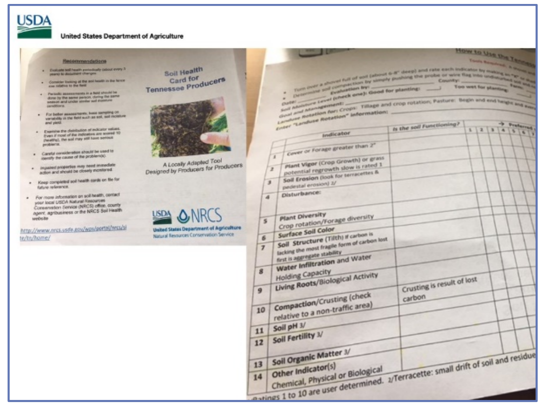
Many of these indicators are found in both qualitative and quantitative field assessments. Examples shown in the slide include lab analysis and field Soil Health Score Cards.



Slide 9

Slide 10

These are examples of other soil health score cards (they vary by state) which provides a qualitative measure of soil health.



Slide 10

Slide 11

In reality, producers who implement conservation cropping systems build soil rather than sustain or degrade it – our goal is for producers to go beyond sustainability.

Slide 11

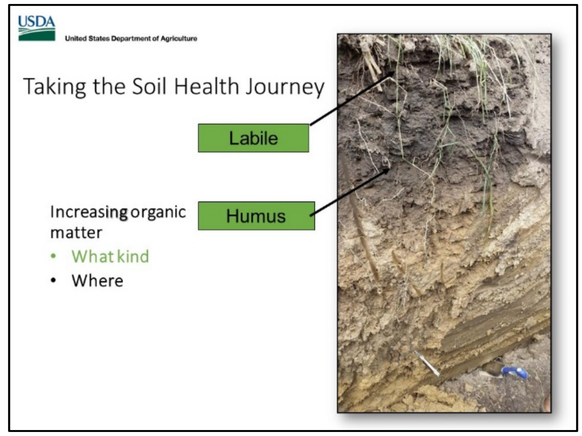
Slide 12

The first soil health indicator we will focus on is organic matter.

Slide 12

Slide 13

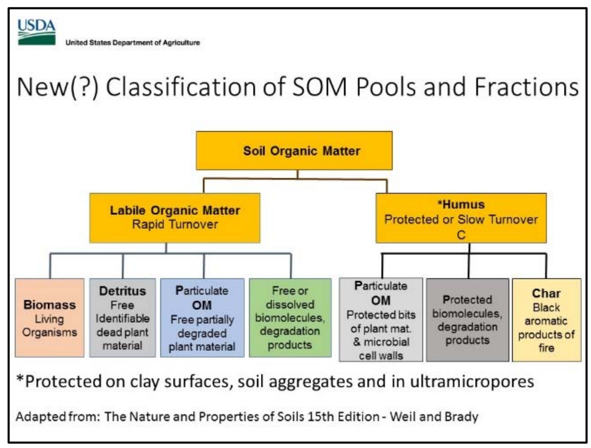
Increasing organic matter (OM) is the foundation of improved soil health. All OM isn't the same, however. Newer, more reactive carbon is referred to as labile and older, more stable is referred to as humus. Labile OM is closer to the surface while humus is distributed throughout the profile more evenly.



Slide 13

Slide 14

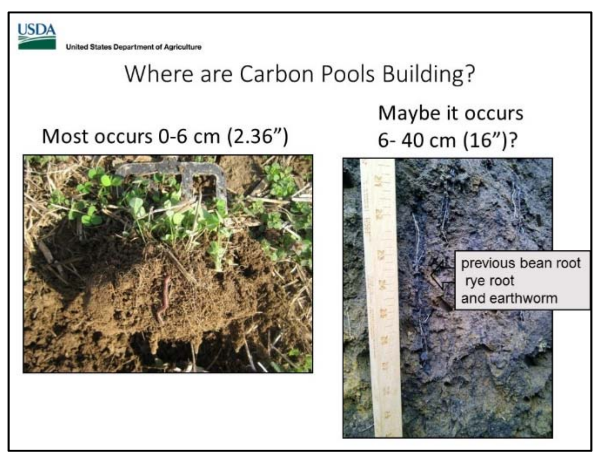
This slide depicts the different types of organic matter related to labile OM and humus. Labile OM is the most readily available for use by soil microbes. It is the first to be lost and is affected more by management, e.g. tillage.
Humus is more protected.
Some of these pools do not show up in standard soil test conducted in the lab.



Slide 14

Slide 15

Historically, most studies and measurements of SOM have been performed using samples from the 6-8" depth. Spend much time at soil health field days - in soil pits that are in long term SHMS and you'll find there is more to the story. Wherever SOM pools are being built, those new additions are very fragile. If we do even shallow tillage, most reactive carbon will be lost. If we do no tillage and add cover, then over time we can built a bank of reactive carbon deep in the soil profile as we expand the rhizosphere and drillosphere. This can eventually become more stable over time by transforming into humus.



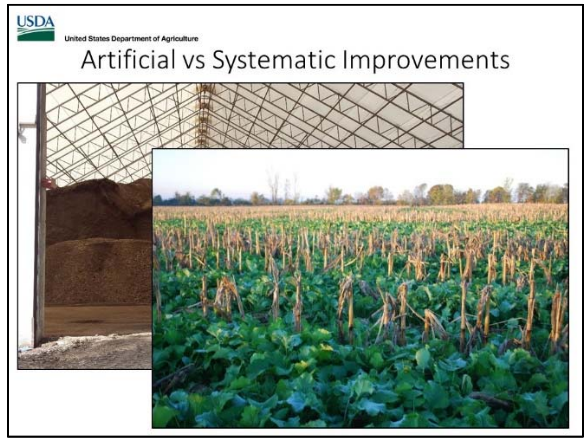
Slide 15

Slide 16

Both artificial and systematic options are available for improving soil function. We need to know more about sources to make sure we do no harm.

Artificial improvements are usually associated with applying amendments or hauling in biomass. They can be easily over applied, or in some cases contain undesirable materials.

Systematic tends more toward using management (Soil Health Management Principles) to enhance natural process like photosynthesis and biodiversity to enhance function. The latter tends to be more sustainable over the long haul.



Slide 16

Slide 17

We will now focus on the importance of aggregate stability as a soil health indicator.

Slide 17

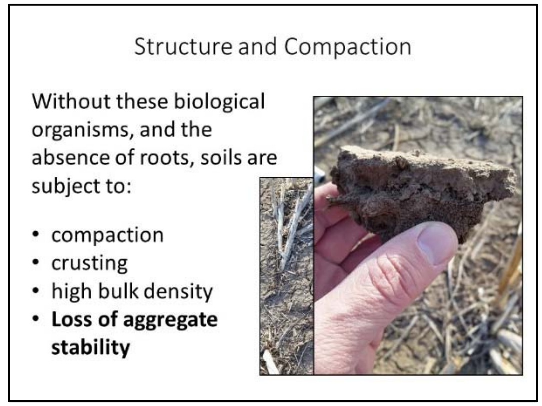
Slide 18

Aggregate stability is critical for infiltration, water holding capacity, and nutrient cycling. It allows the soil to breathe, giving oxygen to diverse organisms. Field investigation with a shovel or maybe a field microscope can be very revealing. The only way to truly improve aggregate stability is by improving the soil biology.

Slide 18

Slide 19

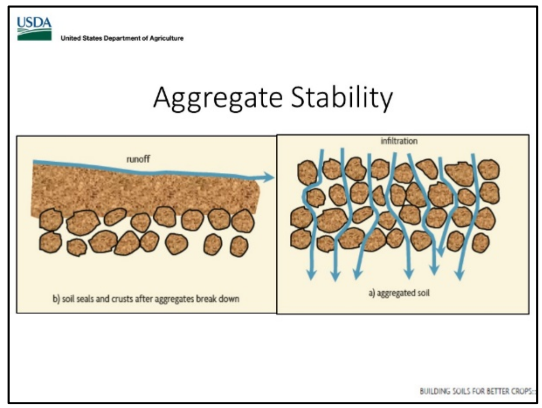
Fields saturated for long periods lose soil structure, especially at the surface. No-till by itself doesn't increase aggregate stability, you need the roots and biological organisms to achieve water stable aggregates. Stable aggregates can withstand the impact of a raindrop and individual soil particles (sands, silts, clays) stay together. Erosion problems occur when these particles are separated and can be transported by wind or water.



Slide 19

Slide 20

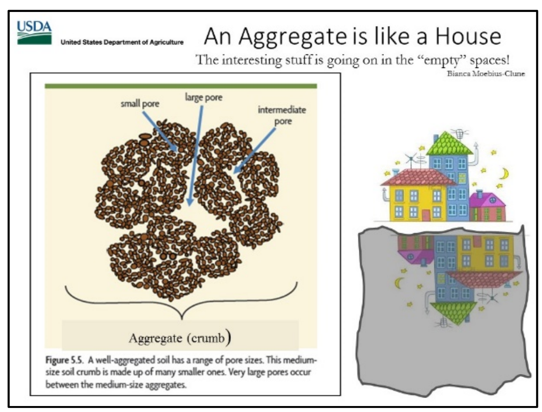
This slide shows how much more easily water can infiltrate into the soil when there is good aggregate stability (right). When there is not, the aggregates fall apart and plug pore spaces, leading to runoff under rain events where any kind of slope occurs (left).



Slide 20

Slide 21

Rebuilding water stable aggregates must be a top priority. Rebuild the house as opposed to cutting all the 2x4s into 6" pieces and tearing off the roof (i.e. tillage).



Slide 21

Slide 22

There is an interrelationship between the amount of fines (silt and clay) in a soil and the amount of organic matter needed to produce stable aggregates. The higher the clay and silt content, the more organic matter is needed to produce stable aggregates. This is because clay and silt have more surface area so more OM is needed to occupy the surface sites on the minerals during the process of organic matter accumulation. In order to have more than half of the soil composed of water stable aggregates, a soil with 50% clay may need twice as much organic matter as a soil with 10% clay (Building Soils for Better Crops).

Slide 22

You can't improve aggregate stability with a piece of tillage equipment, you need to create a favorable habitat for those soil microbes that play a role in this process.

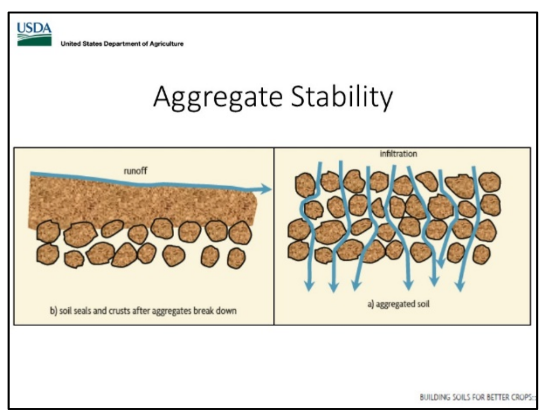
Slide 23

Next, we will discuss water infiltration as an important soil health indicator.

Slide 23

Slide 24

As you remember, aggregate stability is directly related to water infiltration. We can measure water infiltration rate in the field (using equipment in your soil health test kit) which can help us assess this.



Slide 24

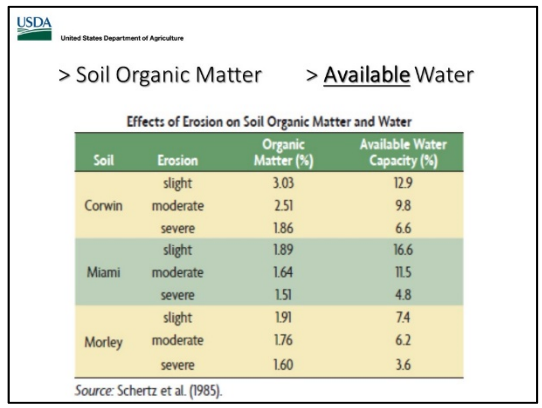
Slide 25

Now we will focus on available water capacity as a soil health indicator.

Slide 25

Slide 26

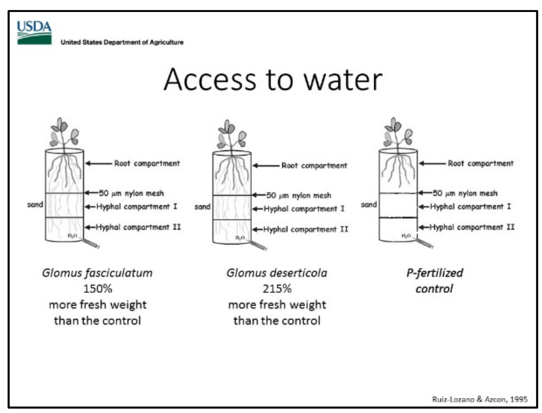
Soil health management systems can increase available water in several ways. Even old data confirms that more OM increases available water.
Studies looked only at top 6 inches and don't account for plants being able to access deeper in the soil profile.



Slide 26

Slide 27

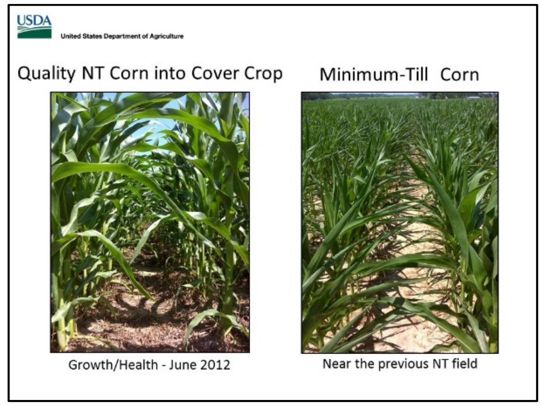
Soil fungi can also help to increase the amount of water available to plant roots. On the slide, the fungi that were added in the first two containers could access water that the plant roots couldn't, thereby bringing water up the soil profile. This lead to greater water availability and greater fresh weight than in the container on the right that had no added fungi.



Slide 27

Slide 28

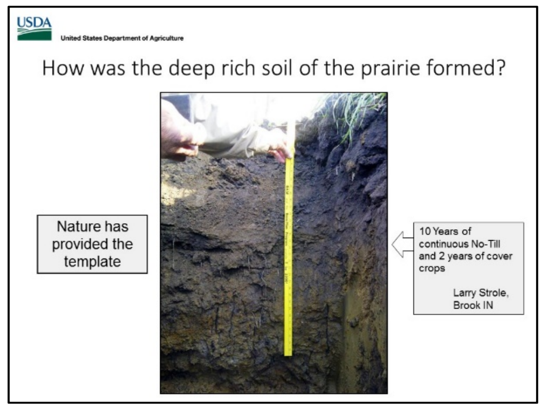
Example: The minimum-till field on the right actually looked better early in the growing season but lacked the resilience to make it to the end. 2012 was the worst drought on record in Indiana (this drought also occurred here in Tennessee). In the end, the field on the left out-yielded the minimum-till field by 70 bu.



Slide 28

Slide 29

The soil on the slide was put into no-till for 10 years and cover crops for 2 years. This helped to "rhizo-engineer" the soil at the sublevel, following similar processes that formed the deep rich prairie soils by using the 4 soil health principles.



Slide 29

Slide 30

Next, we will discuss nutrient cycling as an important soil health indicator.

Slide 30

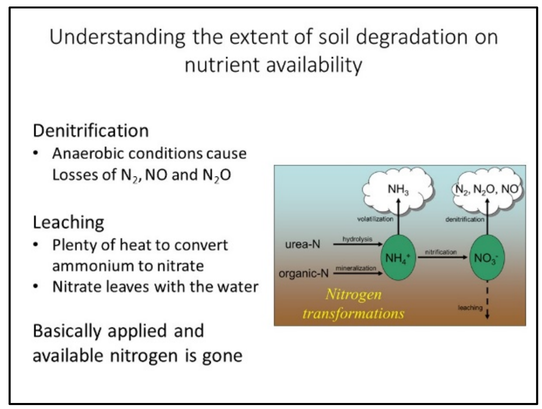
Slide 31

Highly disturbed soil will continue to lose basic functions. We often overlook the offsite impact of loss of soil function on soils that have no erosion problems. Loss of nutrient cycling can lead to excess nutrients in water.

Slide 31

Slide 32

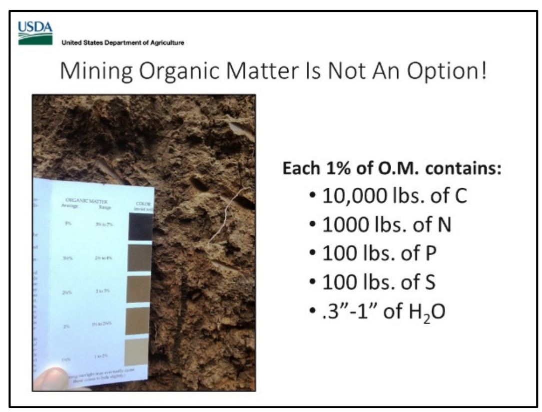
Let's take a look at the important soil functions/processes that are affected by these saturated conditions. We can have losses of N from the field when they are saturated through the processes of denitrification and leaching. Under denitrification, N is lost as a gas whereas with leaching it is lost through the water.



Slide 32

Slide 33

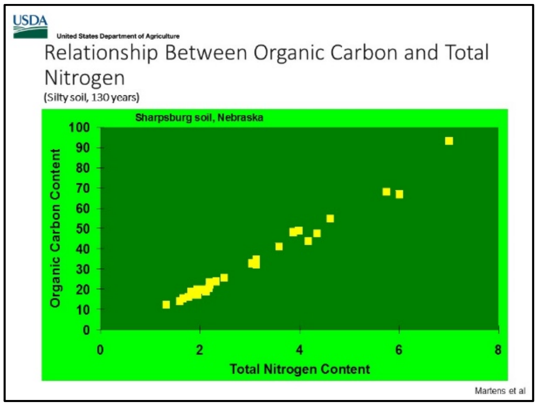
Over much of our cropland, we have been living off the annual withdrawal of nutrients from SOM. We cannot afford to burn off our organic soil carbon if we intend to be sustainable. This is our production bank account. It is also our water bank due to its ability to retain moisture in the soil. When SOM is removed (erosion, volatilization, etc.), the elements needed to increase yields are at risk of being lost. These are also some of our most troublesome elements that impact air and water quality.



Slide 33

Slide 34

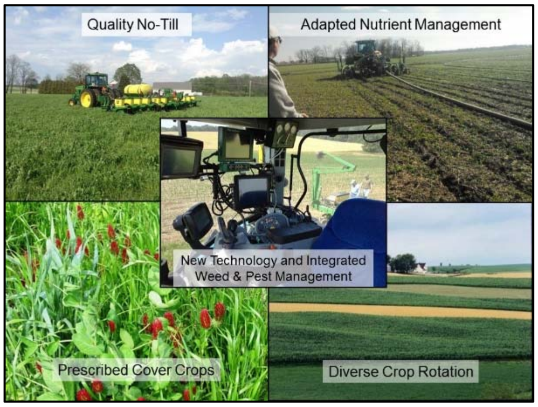
As organic carbon increases in the soil, total soil nitrogen content also increases. Bottom line, it takes protein to increase life in the soil. Consider this your nitrogen bank account where every pound saved is quite literally one that didn't get lost through erosion. There's no better contamination filter than carbon, so we all benefit when we install the conservation practices that improve the earth's filtration system.



Slide 34

Slide 35

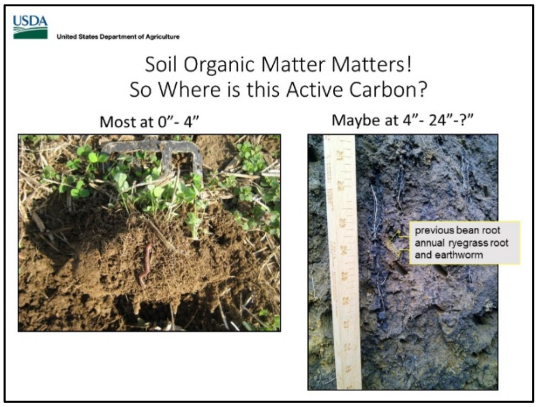
As depicted in the slide, improving soil function is about optimizing and understanding all aspects of the conservation cropping system such that soil health is the central focus with every operation. Each practice should complement and enhance the others of the system.



Slide 35

Slide 36

As mentioned previously, if we do no-till and add cover, then over time we can built a bank of reactive carbon deep in the soil profile as we expand the rhizosphere. This will allow for better nutrient cycling.



Slide 36

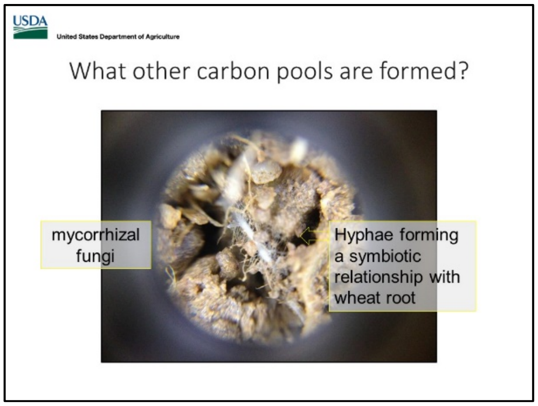
Slide 37

We will now revisit the importance of soil biology briefly since this was mentioned in greater detail in Module #2.

Slide 37

Slide 38

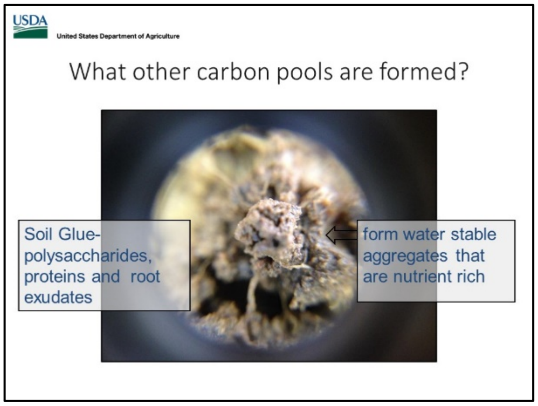
As we've already mentioned, soil biology is greatly important for creating/maintaining stable soil aggregates and increasing available water which provide important soil health functions. The slide shows a hyphae involved in "rhizo-engineering" at the sublevel through its symbiotic relationship with plant roots and binding ability within the soil.



Slide 38

Slide 39

Plant roots and microbes also engage in this "rhizo-engineering" at the sublevel by producing carbon compounds that can chemically bind soil to form aggregates.



Slide 39

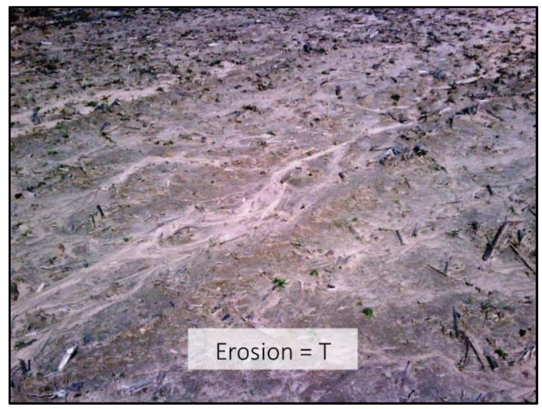
Slide 40

Lastly, erosion is another soil health indicator whose complete elimination is part of the goals of soil health management systems.

Slide 40

Slide 41

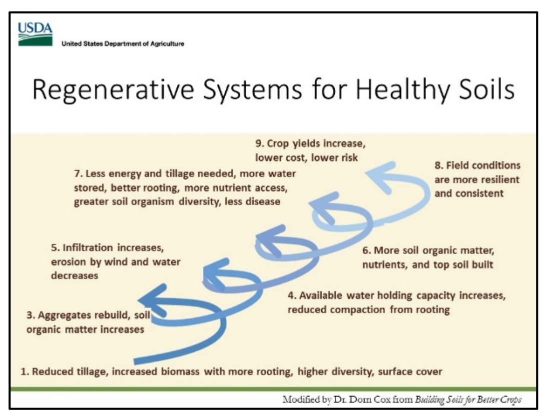
T refers to the soil loss tolerance rate which is the maximum rate of annual soil loss that will still allow sustainable crop productivity now and in the future. In the minds of many soil health producers there is no "tolerable" soil loss, they have moved beyond this. Identification of erosion in the field can involve evidence of disintegrated aggregates across a change in slope as well as rilling or gully formation on the soil surface.



Slide 41

Slide 42

This slide shows the logical order of regeneration.



Slide 42

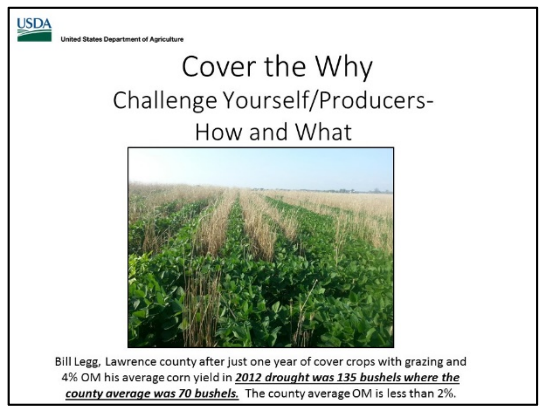
Slide 43

Selecting high biomass cover crop mixes will help rebuild organic matter in the topsoil. Cover crops, especially if part of a quality no-till system, will add organic biomass both above and below ground to rebuild topsoil quicker than if left to grow weeds, and especially if managed for no cover. The growing roots also feed the biology in the soil that is responsible for forming stable aggregates. This response can happen faster than you might think as shown in the slide after one season.

Slide 43

Slide 44

These are just a few management strategies that could bring us a long way back to full production potential even under extreme conditions (see slide) and, if continued, soil health regeneration can be the path to greatly improved production, efficiency and resilience.



Slide 44

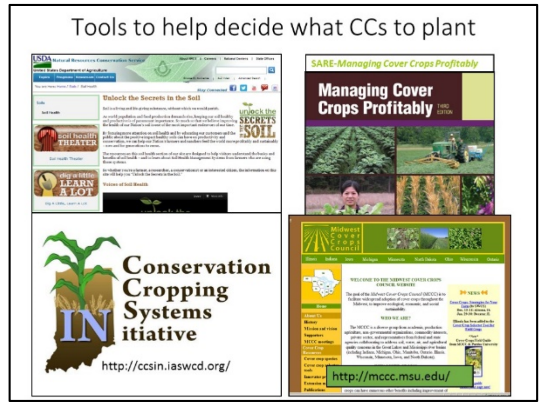
Slide 45

Preparation is key and there are a number of resources that can help.

Slide 45

Slide 46

These are some examples of available resources from the Natural Resources Conservation Service (NRCS) and Sustainable Agriculture Research and Education (SARE) Program among others.



Slide 46

Slide 47

For additional information from the NRCS on soil health, search online for "NRCS Soil Health".

Slide 47

Test their Knowledge - Questions for the audience

Q: What are soil health indicators used for?
A: They monitor how well the four soil health principles are being applied.

Q: What are some examples of soil health indicators that are used?
A: organic matter, aggregate stability, water infiltration, available water capacity, nutrient cycling, soil biology, erosion, structure, respiration, enzymes, cation exchange capacity (CEC), pH, bulk density, earthworms

Qualitative measurements of soil health involve things like __soil health score cards__ whereas quantitative measurements involve __lab testing__.

Q: What are the two general types of organic matter and how do they differ?
A: Labile OM is more reactive and closer to the soil surface whereas humus is older, more stable and found evenly distributed throughout the profile.

Aggregate stability is important for maintaining good __water infiltration__.

The higher the silt and clay content of a soil, the __more organic matter__ is required to produce stable aggregates.

Q: What increases the amount of water available to plant roots?
A: Organic matter and fungi

When the soil is saturated, nitrogen can be lost through __denitrification and leaching__.

Soil Health Evaluation

Name of Activity: Soil health indicators	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. *How soil health indicators provide information on a range of critical soil processes*	①	②	③	④	⑤	①	②	③	④	⑤
2. How soil health indicators relate to the soil principles	①	②	③	④	⑤	①	②	③	④	⑤
3. The role of aggregate stability in soil health	①	②	③	④	⑤	①	②	③	④	⑤
4. The role of organic matter in soil health	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!

MODULE 5. COVER CROP MANAGEMENT

Learning objectives:

Participants will be able to:

- Identify management strategies to integrate cover crops into soil health management systems.
- Discuss the impact that cover crops have on soil functions, e.g. water infiltration & availability, nutrient cycling.
- Identify benefits of cover crops in agricultural systems.
- Understand key concepts for successful cover crop management, including planting, termination and species selection.
- Design a cover crop (mono and multi-species) strategy to address identified resource concerns
- Discuss key concepts to troubleshoot problem cover crop plantings
- Discuss differences in cover crop planning and management across various geographic regions

Materials:

- PowerPoint® slides "Module 5: Cover Crop Management"
- Lesson guide: Use the notes in this lesson guide to present information for each 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:

Agricultural benefits
Needs for success
Cover crop diversity
Identifying needs of the producer
Establishment methods
Types of cover crops and blends
Soil moisture management
Herbicide restrictions
Termination methods
Seeding rates
Local examples
Ideas
Planning tools

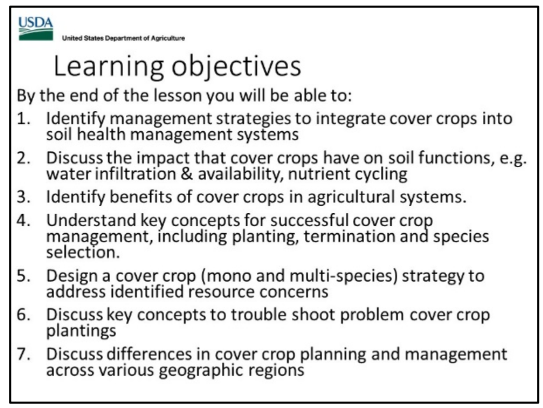
Slide 1

This module will cover a number of aspects of cover crops including their benefits, types and blends, planting and termination, and tools for further assistance.

Slide 1

Slide 2

Follow material on presentation slide.



Slide 2

Slide 3

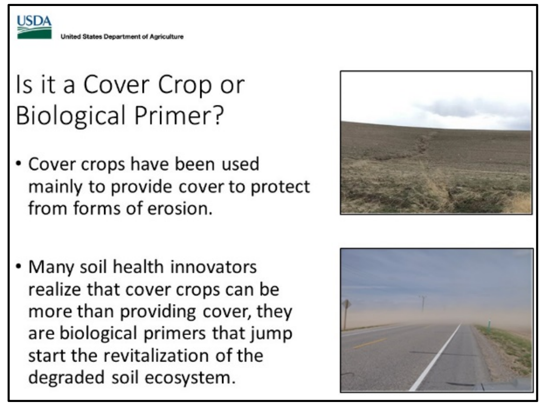
Photos…Upper left corner going to the right:
Grazing cover crops
Rhizobium on hairy vetch
Turnip and radish
Purple top turnip making soil aggregates

Some people get really excited about seeing a big radish or turnip, but we need to understand how the tool (cover crop) helps to improve soil function.

Slide 3

Slide 4

Do you understand the use of cover crops as biological primers? Food Security Act policy has driven the agency to think about cover crops to be used to prevent erosion to meet Highly Erodible Land Conservation compliance. When we understand how a soil functions we see that cover crops are more than annual crops used for erosion protection but are used as biological primers that can build the health of soil when accompanied by a management system that follows the principles of soil health.

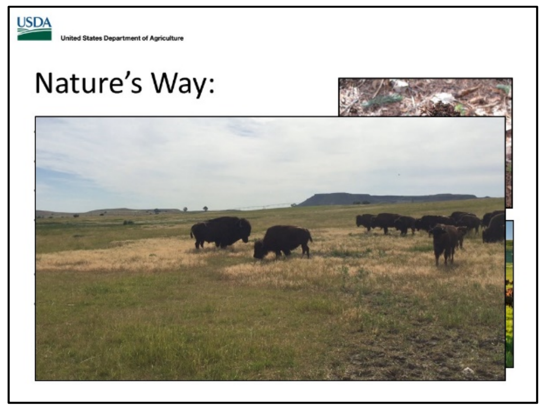


Slide 4

Slide 5

We want to mimic nature in our current farming practices. By following the soil health management principles we can relate our current systems back to times when large herds of bison moved across the landscape.

Soil works for you if you work for the soil by using management practices that improve soil health and increase productivity and profitability immediately and into the future. A fully functioning soil produces the maximum amount of products at the least cost. Maximizing soil health is essential to maximizing profitability. Soil will not work for you if you abuse it.



Slide 5

Managing for soil health (improved soil function) is mostly a matter of maintaining suitable habitat for the myriad of creatures that comprise the soil food web. This can be accomplished by disturbing the soil as little as possible, growing as many different species of plants as practical, keeping living plants in the soil as often as possible, and keeping the soil covered all the time.

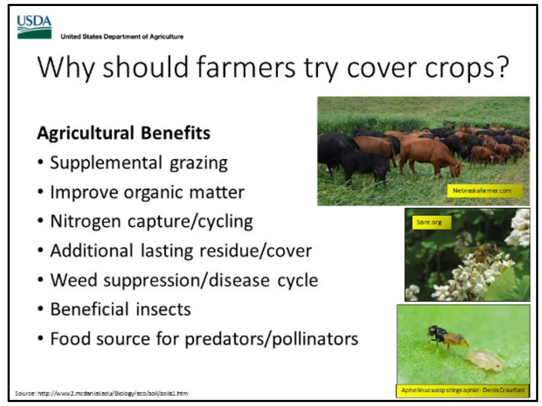
What practice does all this? The use of cover crops integrated into existing rotations can allow the soil to start being rebuilt. It is crucial to integrate and follow all soil health management principles in order for the soil to become and remain healthy.

The video shows buffalo grazing.

Slide 6

As much as 10 metric tons of material may pass through the bodies of earthworms on a hectare of land each year, resulting in nutrient rich "casts" that enhance soil stability, aeration, and drainage (Lee 1985).

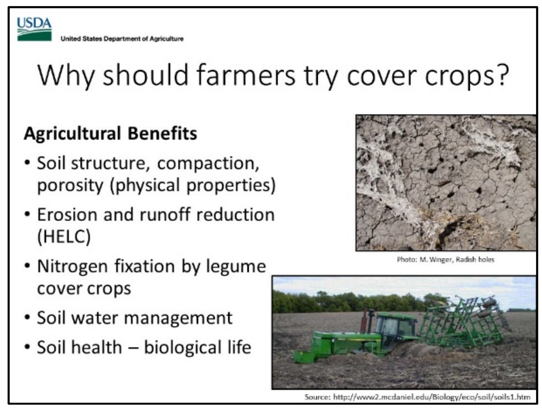
Some bacteria are responsible for "fixing" nitrogen, a key element in proteins, by drawing it out of the atmosphere and converting it to forms usable by plants and, ultimately, human beings and other animals.



Slide 6

Slide 7

It's a long list of benefits which can improve the productivity of the soil.



Slide 7

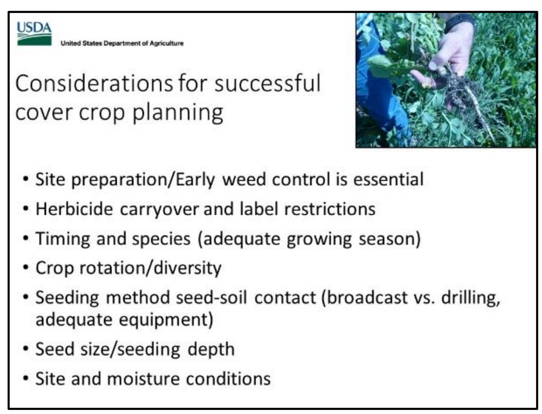
Slide 8

Herbicide carryover is very critical when planting subsequent cover crops, some common herbicides may have an up to 18 month plant back restriction.

Adjust and learn local conditions that could have a positive or negative effect on the next crop

What resource concerns am I trying to solve with this cover crop mix?

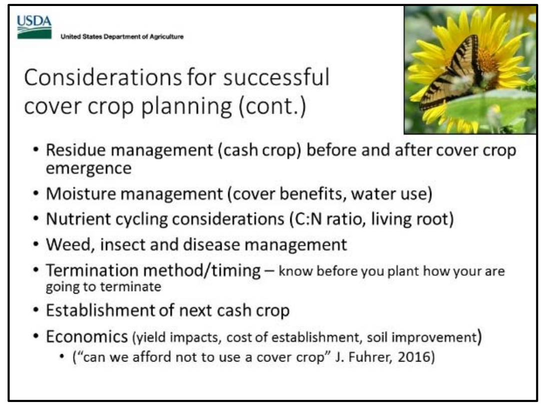
Some cover crops will work when flown on but the best way to establish a successful CC is to drill it.



Slide 8

Slide 9

More things to keep in mind…there is definitely some planning involved in keeping a continuous cover over the soil.

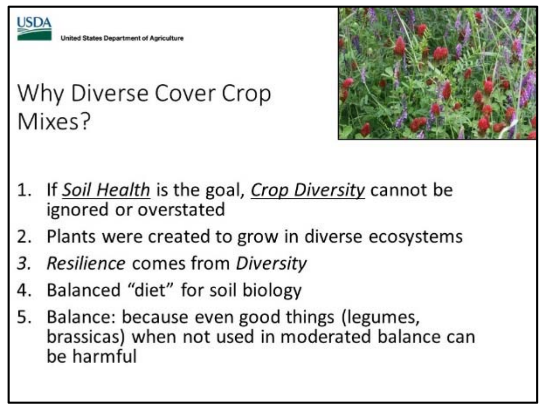


Slide 9

Slide 10

Crop diversity is a major player when improving soil health on your farm. Take a minute and look at nature, plants were created to grow in diverse ecosystems, not monocultures.

If we are trying to regenerate a resilient soil that can handle multiple stresses, this resilience comes from diversity. It is just like a 401K retirement plan…if your portfolio is not diverse then you are at great risk.



Slide 10

If we plant a cover crop with just legumes and/or brassicas we may not be solving resource concerns. For example, the Carbon:Nitrogen ratio is very low with legumes and brassicas and very little if any residue will be left over the winter to provide armor on the soil surface.

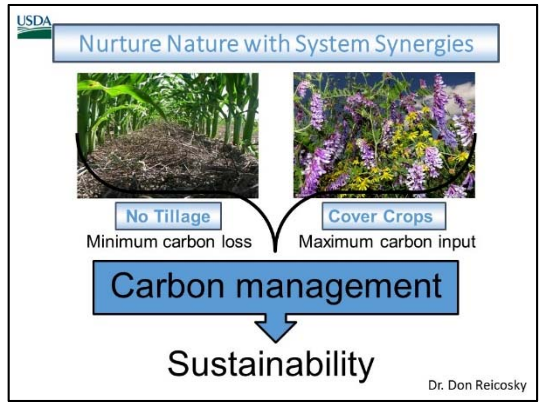
Slide 11

Slide shows a picture of a mixed species seed mix. Producers are used to and comfortable seeding one species of seed but when faced with the task of seeding a very diverse mix like the picture above, growers may be intimidated. The above mix can be commercially bought and delivered in prepared bags ready to be seeded. Also producers can buy individual seeds and mix themselves on the farm through the use of concrete mixers, feed mixers, farm built blenders, mixed by hand in the seed box, or using multiple seed boxes. Seeds can be commercially spread, broadcast by hand, ground or aerial equipment, or by a seed drill or planter. Producers will have different objectives and different seeding methods.

Slide 11

Slide 12

Cover crops help to manage carbon in the soil but they need to be combined with a no-till system.
No-till minimizes carbon loss and adding cover crops into rotation increase the carbon input.

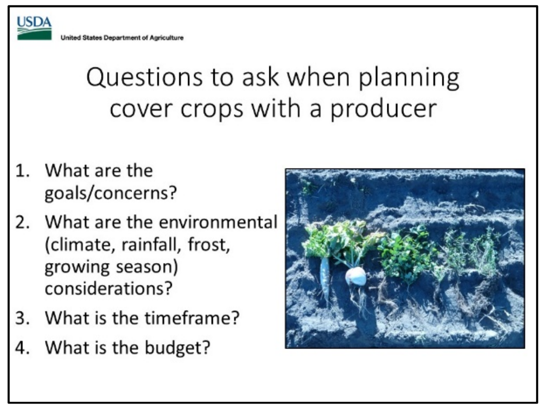


Slide 12

Slide 13

Photo (left to right): radish, purple top turnip, pea, crimson clover, hairy vetch

Make sure we have addressed the goals and concerns from the producer using the questions on this slide. Know when certain cover crops can be planted.
Be careful of the money spent on cover crops as it is easy to get to costly, so look for alternative species, try small seed covers.

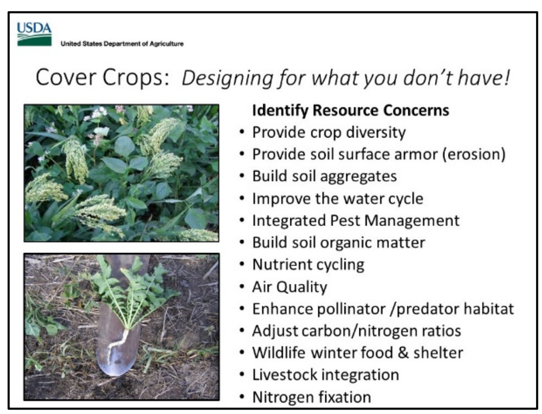


Slide 13

There are innovative cover crop companies out there that have calculators (i.e. SmartMix Calculator by Green Cover Seed) to help you practice developing alternative multi species cover crop mixes, some even provide a real time quote or cost per acre estimate.

Slide 14

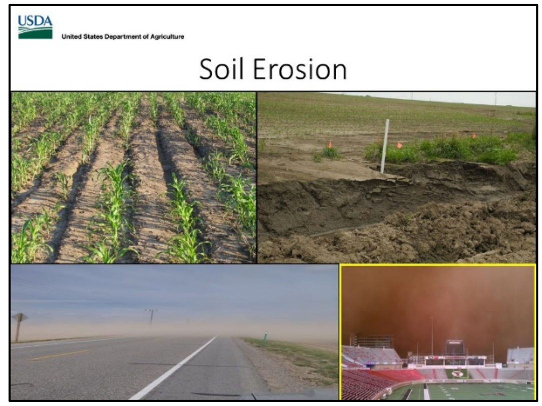
A good soil health consultant should be very aware of the resource concerns that are facing the farming operation, review this short list with your producer when in the planning and inventory stage of conservation planning



Slide 14

Slide 15
Bottom left: wind erosion 50+ tons per acre loss
Bottom right: Lubbock Texas, wind erosion

Cover crops provide a continual cover during those times of the year when erosion from wind and water is most likely to occur.



Slide 15

Slide 16
Cover crops suppress weeds by:
Outcompeting them for available resources
Smothering them with a thick organic residue layer
Some cover crops have chemical (allopathic) effects

Caption picture: $12/ac weed control program in soybeans. Proof that cover crops with crimped biomass adds money in your pocket. This field is in the heart of Palmer pigweed country. This is its third year in rolled biomass.

Slide 16

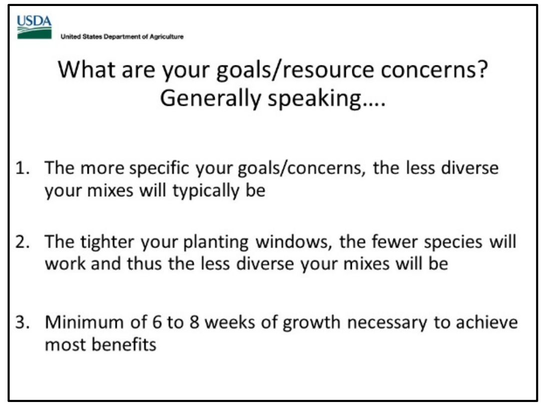
Slide 17
Here is a great side by side comparison on Palmer amaranth and mares tail control with the addition of heavy biomass cover crops. The picture speaks for itself. The field on the left is a long-term, no-till soybean field without cover crops. The field on the right has soybeans planted into 10,000 lbs. of biomass cover crops consisting of crimson clover, hairy vetch, Austrian winter pea, daikon radish, wheat, cereal rye, triticale, and canola rolled down with a cultipacker. The field on the right has had a burndown application and one post application of herbicide. Trying to control herbicide resistant weeds with herbicides alone will always be an uphill battle. The better we manage the biomass, the better weed suppression we will have.

Slide 17

Second picture: Same field from two months prior (6/22/16). Notice the armor on the soil!

Slide 18

It is important to tie these goals back to how they will meet the soil health management principles.



Slide 18

Slide 19

No-till drill

Broadcast + Bush hog

Broadcast + Stalk chopper

Aerial seeded post harvest

Tractor, Combine, Sprayer mounted seeders

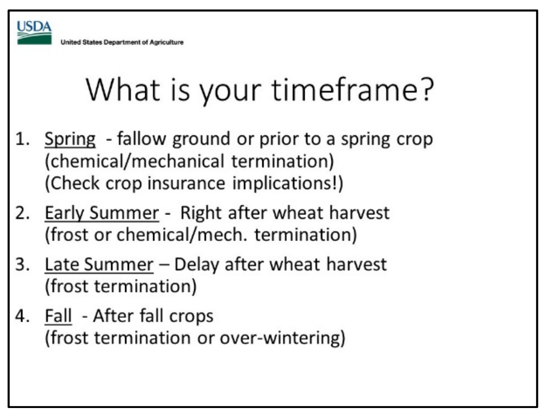
Slide 19

Slide 20

When can the producer plant cover crops in their rotation? The easiest in most rotations is behind small grain crops.

Be aware of crop insurance implications, they seem to be a constant moving target.

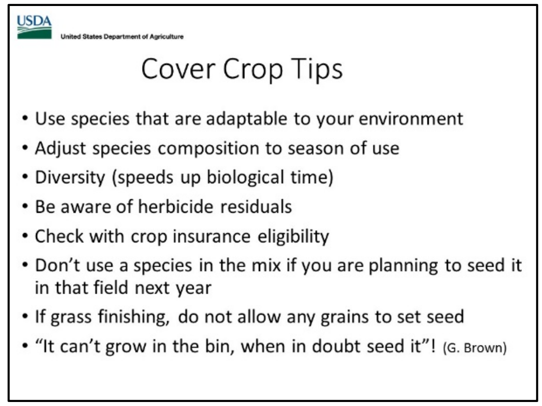
There may be short windows to grow cover crops ex. 60 days between cash crops to build diversity, scavenge nutrients, and suppress weeds.



Slide 20

Slide 21

It is good to use some common sense thinking when including cover crops into your operation. Consider this list from a producer who fully implements cover crops on his operation.

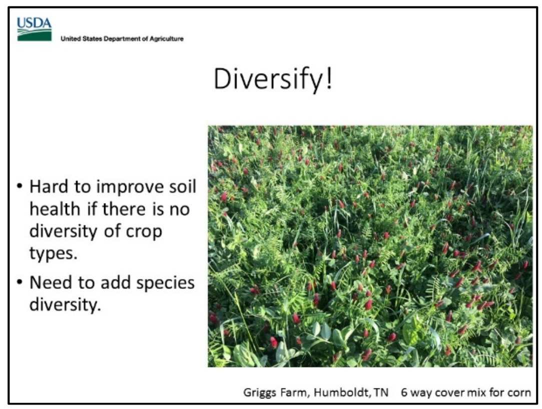


Slide 21

Slide 22

Photo from Matt Griggs' farm in Humboldt, TN
On a per acre basis, the mix includes 10 lbs cereal rye, 2 lbs annual ryegrass, 10 lbs oats, 10 lbs crimson clover, 10 lbs Austrian winter pea, 6 lbs vetch

To diversify and promote soil biota it will take a diversity of plant roots to provide these services and build this habitat. Most crop rotations and pasture forages contain few species and usually lack diversity.



Slide 22

Slide 23

"In early stages of development plants give priority to roots so the biomass below ground may be 10 times the biomass above ground" (Nature and property of soils, p. 467)

Compaction relief with cover crops – radish (shown in slide). Use a shovel to look at root development. Some folks may look at a little 3 inch radish and say its "a failure" they never took the time to use a shovel and look at the compaction relief being accomplished belowground.

Slide 23

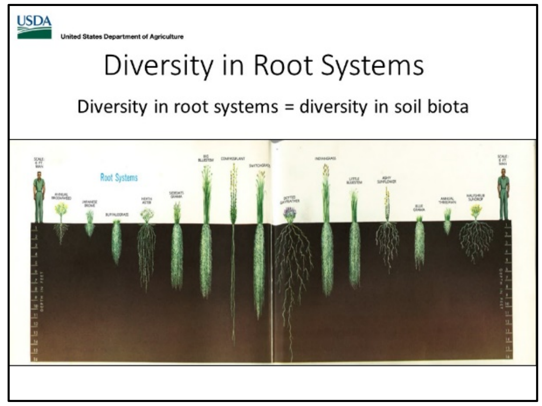
Slide 24

We are also looking at below ground root diversity, we need tap roots for deep compaction relief, and to bring up leached nutrients to the soil surface.

We need fibrous roots to build surface aggregates.

We could use bulb type roots for late winter grazing, once the tops have long been frozen and lost.

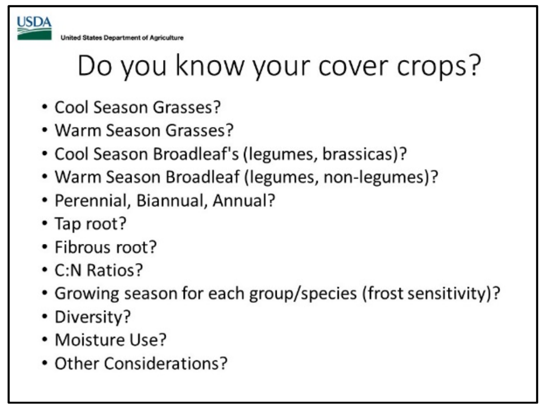
We need roots that explore different depths of the soil, to extract nutrients, water and to get carbon to deeper depths.



Slide 24

Slide 25

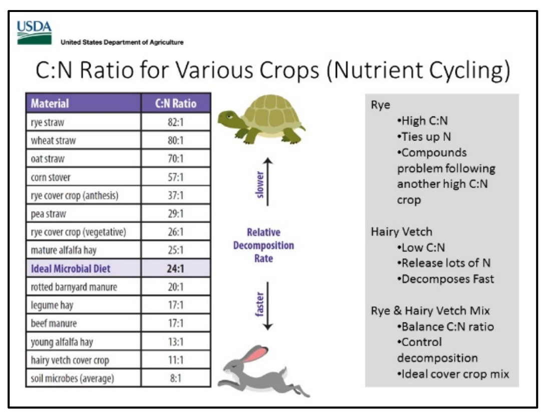
When designing a cover crop system, planners need to have a knowledge about certain characteristics of the plants they are using. Review this list quickly, as you'll go through more in detail in other slides.



Slide 25

Slide 26

- Cover crops added to a cash crop rotation can help manage nitrogen and crop residue cover in a cropping sequence.
- A low C:N ratio cover crop containing legumes (pea, lentil, cowpea, soybean, sunn hemp, or clovers) and/or brassicas (turnip, radish, canola, rape, or mustard) can follow a high C:N ratio crop such as corn or wheat, to help those residues decompose, allowing nutrients to become available to the next crop.



Slide 26

- Similarly, a high C:N ratio cover crop that might include corn, sorghum, sunflower, or millet can provide soil cover after a low residue, low C:N ratio crop such as pea or soybean, yet decompose during the next growing season to make nutrients available to the following crop.
- Understanding carbon to nitrogen ratios of crop residues and other material applied to the soil is important to manage soil cover and crop nutrient cycling.

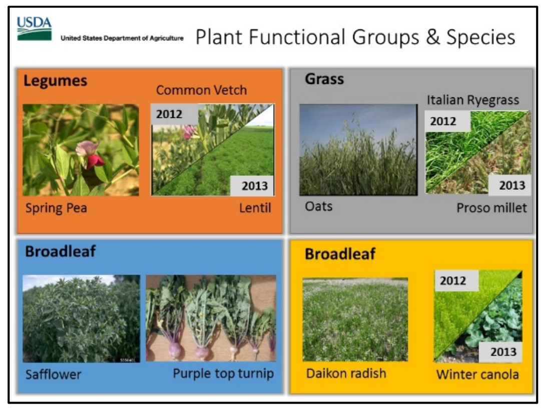
Slide 27

Right species: use species that address specific resources concerns or client objectives
Right inoculants: Try to find a cover crop dealer that knows about rhizobium (inoculant)
Right seeding rates: 30 to 40 lbs per acre is a pretty common rate, but you can easily go lower with small seeded species.
Right seeding time: Different species have different planting date requirements. Keep these in mind when creating and planting a blend.

Slide 27

Slide 28

According to the NRCS, the four functional groups include cool-season broadleaf, cool-season grass, warm-season broadleaf, warm-season grass. A cover crop blend does not have to have all four functional groups to be successful.

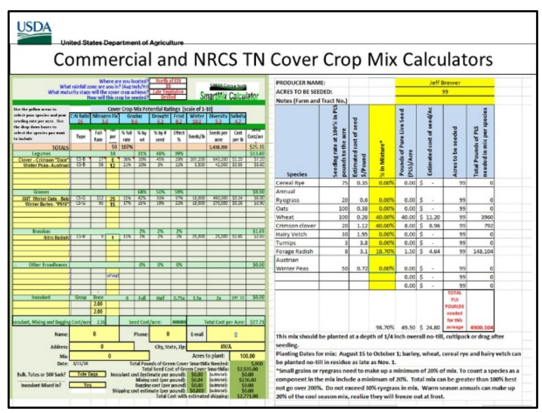


Slide 28

Slide 29

Example of a state cover crop seed calculator from TN and Green Cover Seed Smartmix calculator
The various components of these calculators include:

- Cover crop categories, e.g. legumes, grasses, brassicas & broadleaf
- Type of cultivar
- Seed rate lbs. per acre
- Seeds per lb.
- Seeds per acre
- Total PLS planned (in lbs.) for the field



Slide 29

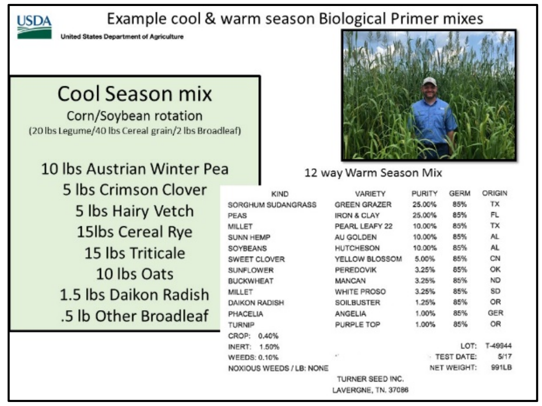
Slide 30

The cool season mix shown in the slide worked well for a corn/soybean rotation in Coffee county, TN.

The photo is of a warm season mix. They skipped soybeans in rotation and planted a 12 species summer blend to see what strides could be made to make the field more productive for a 2018 corn crop.

No matter what…plant diverse mixes, never monocultures, if mimicking nature and increasing soil health is your goal.

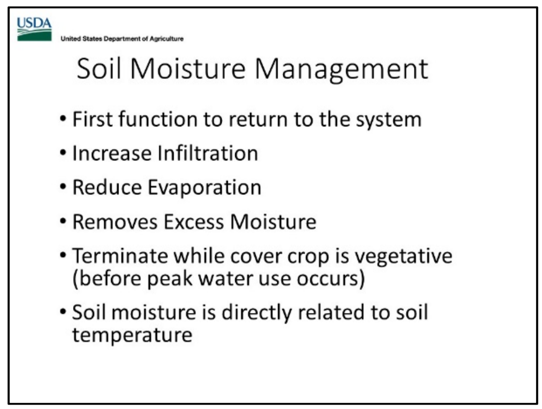
High plant diversity = High biological diversity



Slide 30

Slide 31

Cover crops as part of a soil health management system have the potential to nearly address all resource concerns on a producer's operation. Increased infiltration can occur from the continued use of cover crops by replacing dead roots of a cover crop or cash crop with roots of another cover crop. Vacant root channels and channels made by the soil biology provide conduits into the soil profile. Cover crops when rolled down on the soil surface provide a thick mat of residue that can intercept the sun's rays to reduce evaporation from the soil profile. Cover crops can also be managed to grow longer into the next growing season to take up excess moisture to aid in planting the next cash crop. Or, the cover crop could be terminated while still in the vegetative stage, before peak water use, to make and develop seed.

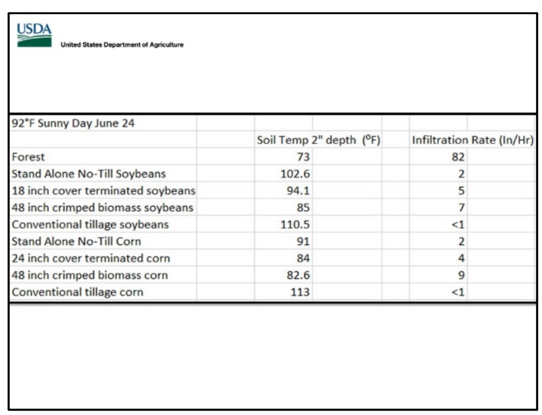


Slide 31

Slide 32

Note: When soil temperature reaches 95 degrees 15% of moisture is used for growth and 85% is lost through evaporation and transpiration.

It is important when evaluating the health of agricultural fields to also evaluate the closest natural ecosystem, such as a forest. Notice how the management systems that more closely mimic nature show temp. and infiltration trending closer to the forest.

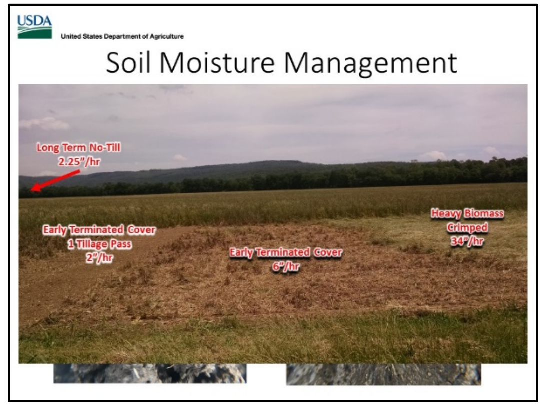


92°F Sunny Day June 24	Soil Temp 2" depth (°F)	Infiltration Rate (In/Hr)
Forest	73	82
Stand Alone No-Till Soybeans	102.6	2
18 inch cover terminated soybeans	94.1	5
48 inch crimped biomass soybeans	85	7
Conventional tillage soybeans	110.5	<1
Stand Alone No-Till Corn	91	2
24 inch cover terminated corn	84	4
48 inch crimped biomass corn	82.6	9
Conventional tillage corn	113	<1

Slide 32

Slide 33

The image on the left is of a field managed with absence of tillage for over 60 years with cover crops implemented the last 7 years. It has an average infiltration rate of 20 in/hr. The image on the right is a field that is long-term no-till corn/soybean rotation with no cover crops for over 25 years. It has an average infiltration rate of 2 in/hr. It will take some time to get the field to the right rejuvenated, but it can be done.
The next images show the soils at 10x magnification. You can easily see the differences in aggregation which relate to the differences in infiltration rate.
In the final image, notice how a single tillage pass can impact how water enters the soil.



Slide 33

Slide 34

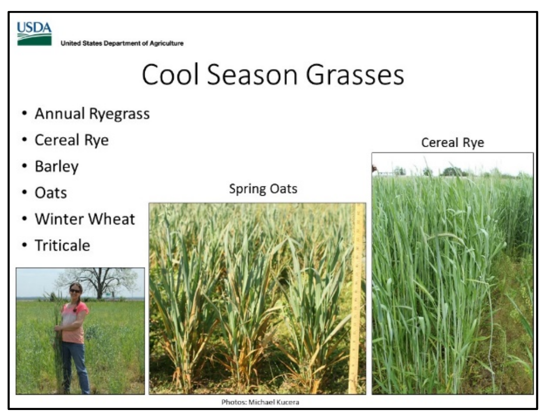
Things to monitor closely when planting a cash crop into cover crops:

- Ensure good seed to soil contact
- Soil temp and moisture must be right
- Ensure you're getting the seed at the correct depth
- Ensure proper closing on seed trench
- Ensure down pressure is set correctly

Slide 34

Slide 35

Examples of cool-season grasses for cover crops.



Slide 35

Slide 36

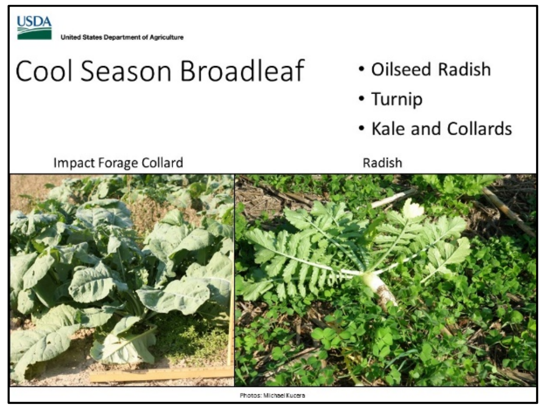
Examples of warm-season grasses for cover crops.

Brown mid rib types are favorites for those that implement grazing into the farm system. They have better digestibility.

Slide 36

Slide 37

Examples of cool-season broadleaf for cover crops.



Slide 37

Slide 38

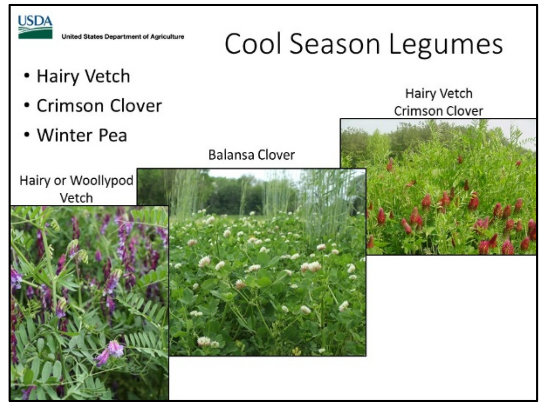
Examples of warm-season broadleaf for cover crops.

Buckwheat planning restrictions (2 yr from a wheat crop)

Slide 38

Slide 39

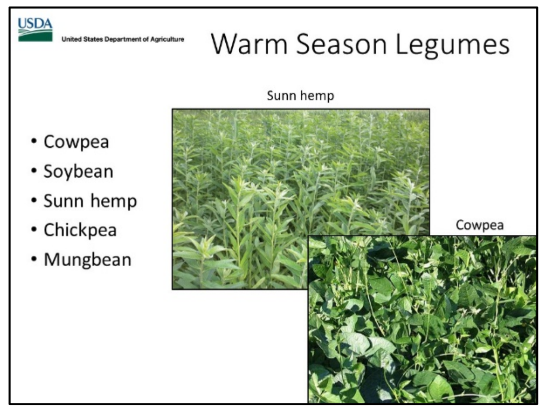
Examples of cool-season legumes for cover crops.



Slide 39

Slide 40

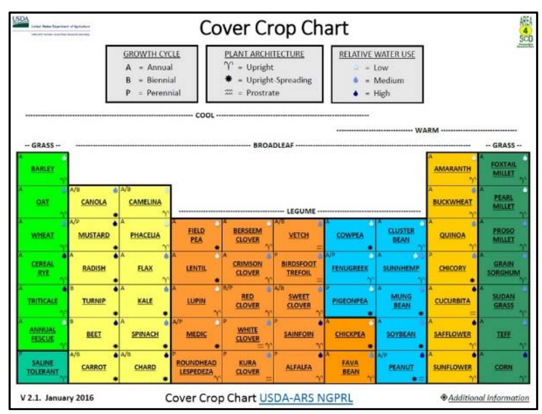
Examples of warm-season legumes for cover crops



Slide 40

Slide 41

This is a picture of an interactive "periodic table" that provides a lot of good information about many different cover crops.



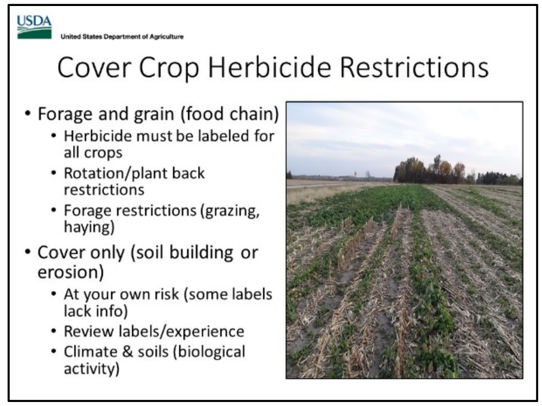
Slide 41

The interactive chart is part of your downloads available on the flash drive included with this curriculum. Let folks know where they can get it and show them how it works.

Periodic table is from the following website: https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/docs/cover-crop-chart

Slide 42

There are several considerations to look at when planning or planting cover crops. Herbicide residuals could terminate desired species in cover crop mixes.



Slide 42

Slide 43

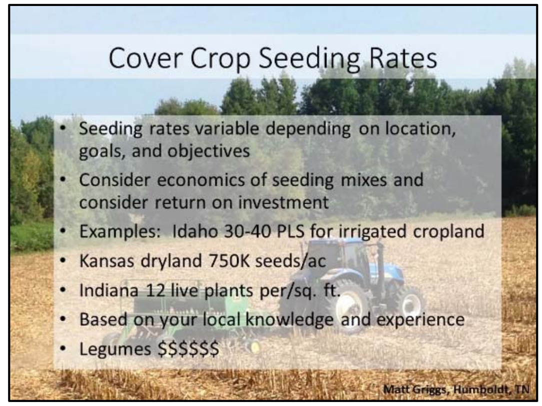
There are many ways to terminate cover crops and a lot will depend on the climate and the objective of the producer. There are many variables when considering termination methods. Be aware of crop insurance guidelines.

Slide 43

- Crimper/Roller: Can be used independently or as combination. To be used independently, crimper/roller must snap, crimp, or break vegetation stems to stop flow of nutrients throughout the plant. Must be completed when target species reaches early maturity before viable seed.
- Herbicide burn down: popular method on grain operations. Completed before or after planting operation by applying herbicide to kill vegetation.
- Grazing: Use of animals to graze and trample cover crop vegetation to aid in termination. Time grazing period close to early maturity of vegetation. Implement take half leave have rule to support soil biology and soil health management principles.
- Combination of methods: Producers may use two or more methods to kill cover crops. For example, herbicide burn down to kill the cover crop followed by roller crimper to place residue on the ground for maximum weed suppression and to provide easier planting.

Slide 44

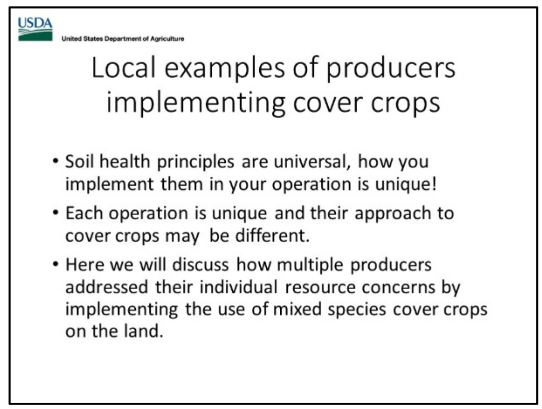
Follow material on presentation slide.



Slide 44

Slide 45

The following slides will show some examples in Tennessee of producers using cover crops.



Slide 45

Slide 46

Ray Jones is a second generation farmer, farming in the Asbury community of Coffee County, TN. His operation encompasses approx. 1000 acres. He grows corn/soybeans on about 700 acres and has about 300 acres of pastureland. Back in the 60's, farming with his dad, they started trying no-till and fully adopted it in the late 80's due to improved equipment, herbicides, and savings on labor, time, and fuel. In the 80's and 90's he began using cover crops but, due to termination issues, they quit using cover crops and transitioned to straight no-till. About 6 years ago he began adding cover crops back in his rotation. To date every cropland acre he farms gets a multi-species cover crop planted on it. He is also integrating livestock onto some of his cropland acres. Ray truly understands why he is planting cover crops and would be the first to tell you that farming nature's way has its own set of challenges. Ray is an outside-the-box thinker and is always willing to share his story with others.

Slide 46

Slide 47

Robert Henley is an agronomist at Security Seed and Chemical and landowner/manager of his farm of 70 acres in Hillsboro, TN in Coffee County. Robert utilizes his farm to try new things to better help his customers reach their farms' yield potential in corn and soybeans. A portion of Robert's farm has not seen tillage in the last 60 years plus. It was in pasture and went straight into no-till production and he has added cover crops in the rotation the last 7 years. The history of this field truly explains why it is functioning the way it is. From this field in 2014, Robert entered a 315 bu/ac dry land corn entry in the NCGA yield contest and won the state. In 1980 Robert rented a different field out to green bean farmers. When it came time to harvest the green beans they rutted the field up badly and the field had to be tilled to smooth it back out. Since then this field has not rebounded from the tillage events and has not been as productive as the other. So, Robert skipped a soybean crop in 2017, planted a summer cover mix that was shown earlier, then planted a cool season cover mix in hopes of rejuvenating its productivity.

Slide 47

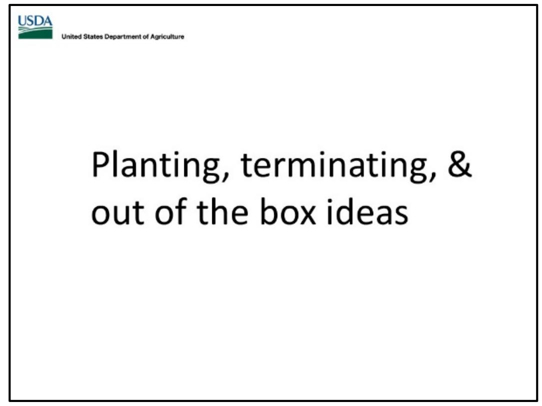
Slide 48

These slides are from Matt Griggs at Griggs Farm in Humboldt, TN.

Slide 48

- In the top left image, he is using a roller crimper on a stand of winter cover crops (cereal rye, ryegrass, crimson clover, hairy vetch, Austrian winter pea, radish, and buckwheat). It was planted on Sept. 20th and terminated on May 10th. It produced 32,000 lbs fresh biomass/acre with 45 lbs N/acre of projected N availability during the growing season.
- In the top right image, corn was planted into 10 lbs/acre cereal rye, 2 lbs/acre annual ryegrass, 10 lbs/acre oats, 10 lbs/acre crimson clover, 10 lbs/acre Austrian winter pea, 6 lbs/acre hairy vetch. The cover crops were planted November 10th and terminated April 20th. The field averaged 202 bushels/acre.
- In the bottom right image, he is using a roller crimper on a stand of summer cover crops (Sudangrass, Millet, Sunn Hemp, Radish, Buckwheat, Mung bean, Clay iron pea, Okra, Teff grass, Sunflower) that were drilled behind winter wheat on June 25th. They were terminated on Sept. 25th and had a winter mix drilled in after.

Slide 49
The next slides will identify some other ideas for planting and terminating cover crops.



Slide 49

Slide 50
The video is of a ZRX Crimper Roller from Dawn Biologic. It is expensive at around $2,000/row!

Slide 50

Slide 51
The image on the left is a culti packer on a front-end loader to roll covers and drill beans in one pass. The covers are then terminated with herbicide.

The video at the top right shows a farmer using a roller/crimper.

The image at the bottom right is a farmer designed and engineered crimper.


Slide 51

Slide 52

Planting into heavy biomass has multiple challenges. Certainly without guidance. This farmer couldn't see where he was going. So he removed a row marker disk and put on a tire. He planted green without GPS (worked great).

Slide 52

Slide 53

The video shows a producer planting corn into a green cover crop. It was hit with herbicide the next day.

Slide 53

Slide 54

This video shows a producer using a single pass roller and crimping 12,000 lbs of biomass and planting soybeans. It was hit with herbicide about a week later.

Slide 54

Slide 55
This video shows a producer laying covers down with light pole from the local utility department.

Slide 55

Slide 56
This video shows a producer using a roller/crimper on 16,000 lbs of biomass. Soybeans were planted after roller/crimper and the cover crops were chemically terminated afterwards.

Slide 56

Slide 57
This video shows a producer planting corn after approx. 9,000 lbs of biomass is rolled down. The cover crops were chemically terminated after planting.

Slide 57

Slide 58

This video shows a producer planting corn into green cover crops. The cover crops were left standing and chemically terminated after planting corn.

Slide 58

Slide 59

Rolling covers to terminate them, some producers also spray a non selective herbicide at the same time. This image is in the southeastern U.S., of an overwintering cover crop.

Slide 59

Slide 60

After rolling, the producer is going to no-till corn into the multi-species mix.

Slide 60

Slide 61

You can see this is rolled and planted with very little soil disturbance.

Slide 61

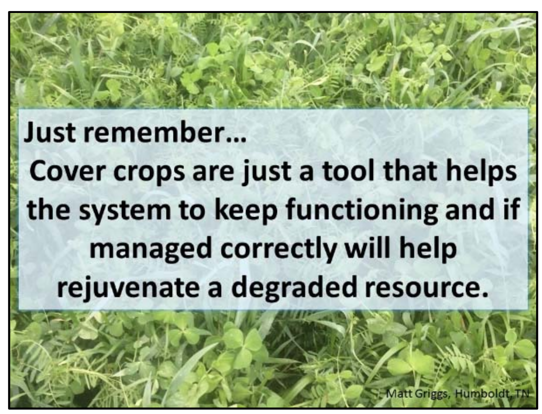
Slide 62

Slice and dice with a disk drill, you could not do this with a hoe drill!

Slide 62

Slide 63

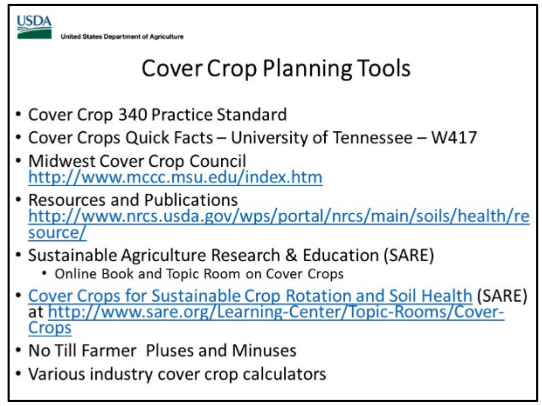
Follow material on presentation slide.



Slide 63

Slide 64

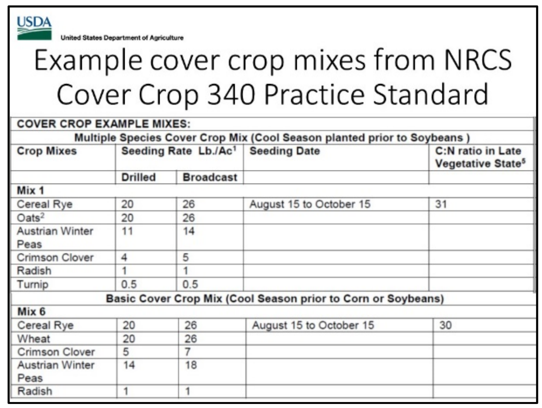
These are some cover crop planning tools that can assist in identifying cover crops and how to make blends.



Slide 64

Slide 65

The first tool on the previous slide is the NRCS Cover Crop 340 Practice Standard. This document can be found in the Appendix of your curriculum and provides some examples of mixes that can be used along with their seeding rate and planting window.



Slide 65

Test their Knowledge - Questions for the audience

Q: What are some of the benefits of cover crops?
A: Supplemental grazing, improved organic matter content, nitrogen capture/cycling, residue/cover, weed suppression, beneficial insects, food source for predators/pollinators, improved soil physical properties, erosion and runoff reduction, soil water management, feed soil biology

Q: What are important things to think about when planning for cover crops?
A: Site preparation, herbicide carryover/restrictions, timing, species, diversity, seeding method, seeding depth, residue management, termination method/timing, management for moisture, weeds, disease, insects, establishment of next cash crop, economics, producer needs and goals

The minimum amount of growth for cover crops in order to achieve most benefits is 6 to 8 weeks .

According to the NRCS, the four functional plant groups are:
1. Warm-season grasses
2. Warm-season broadleaf
3. Cool-season grasses
4. Cool-season broadleaf

Q: How do cover crops help with soil moisture management?
A: Their roots increase infiltration by creating new channels through the soil profile. Their residue helps reduce evaporation. They can remove excess moisture to aid in planting. They can be terminated before peak water use occurs.

Cover crop termination methods can include:
1. roller/crimper
2. cultipacker
3. chemical burndown
4. grazing
5. combination of methods

Soil Health Evaluation

Name of Activity: Cover crop management	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 impacts that cover crops have on soil functions*	①	②	③	④	⑤	①	②	③	④	⑤
2. Management strategies for cover crops	①	②	③	④	⑤	①	②	③	④	⑤
3. Cover crop blends	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!

MODULE 6. GRAZING MANAGEMENT TO IMPROVE SOIL HEALTH

Learning objectives:

Participants will be able to:

- Incorporate soil health principles into grazing systems
- Identify management strategies to integrate soil health into grazing systems
- Discuss the impact that grazing has on soil health and function
- Gain an understanding of stocking density and its importance to soil health
- Understand grazing principles that improve soil health

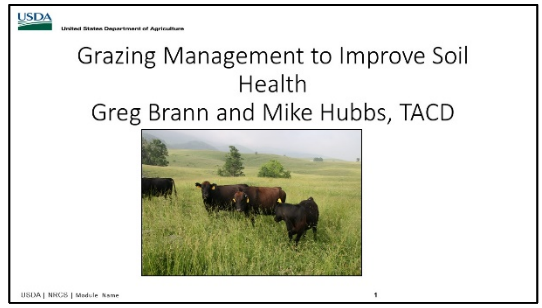
Materials:

- PowerPoint® slides "Module 6: Grazing management to improve soil health"
- 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:

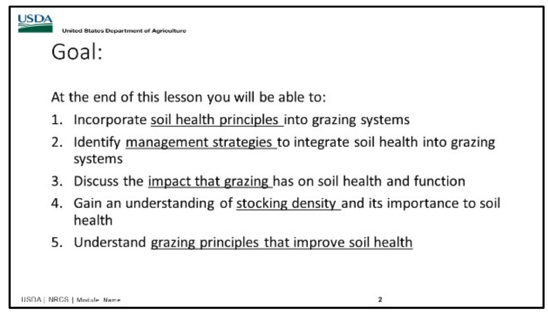
Grazing/cutting height
Stocking rate
Manure
Nutrient cycling
Soil health principles
Plant diversity
Disturbance

Slide 1
This module will focus on identifying grazing management strategies to improve soil health.



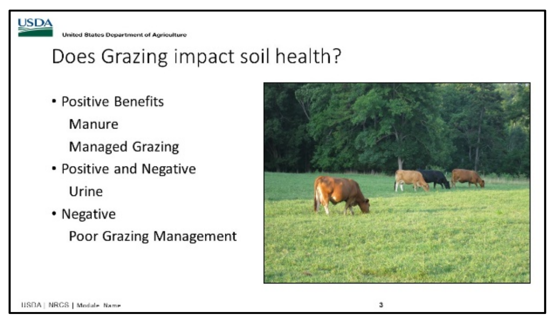
Slide 1

Slide 2
Follow material on presentation slide.



Slide 2

Slide 3
Grazing management has a tremendous impact on the soil health and function necessary for high production. These impacts include:



Slide 3

1. Manure can accelerate the building of organic matter and improve soil health if considered as part of a good grazing system. This begins as residue is broken down in the stomach of livestock.
2. Urine does recycle nutrients but the greater amounts on each "spot" can be a shock to the soil system.
3. Poor grazing management as we might guess leads to overgrazing, poor nutrient distribution, less microbial activity, more runoff, etc…

Grazing management focuses on the hoof and mouth action of the cows…

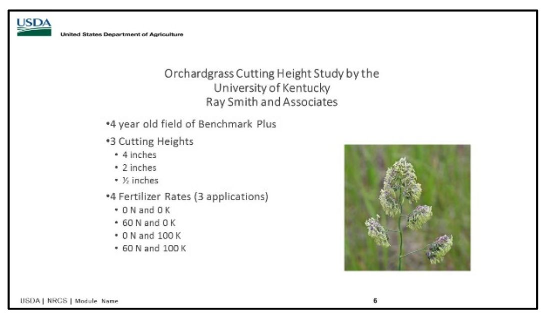
Slide 4
Here is a slide of what we would like to do, turn the livestock in at a certain height. Take half, leave half.

Slide 4

Slide 5
We want to allow for the roots to recover (roots shown above). The photosynthesis collected by the remaining leaf area will produce carbon and some of that carbon is exuded by the roots and helps enhance the soil biology.

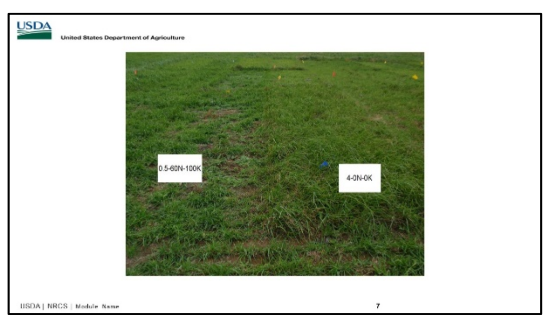
Slide 5

Slide 6
These are some results out of the University of Kentucky looking at different cutting heights and fertilizer rates.



Slide 6

Slide 7
As you can see after 30 days, the half inch cutting height with 60N and 100K is much shorter than the 4 inch cut with no nitrogen or potassium. Therefore, the cutting/grazing height of grass is more important than the nutrients. It takes grass to grow grass.

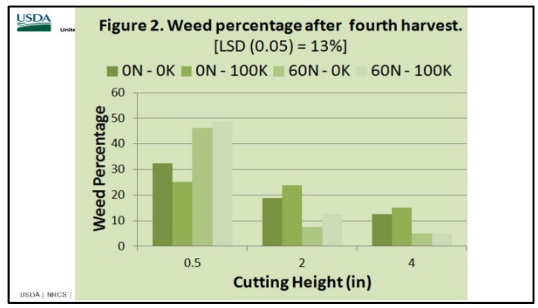


Slide 7

Slide 8
This shows a similar trend where all plots had the same amount of fertilizer but the 4 inch cutting/grazing height had good recovery, the 2 inch cutting height has less recovery and little recovery from the half inch cutting height.

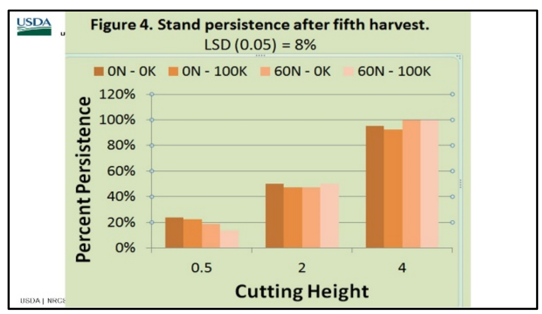
Slide 8

Slide 9
On weed percentage after the fourth harvest, you have a greater number of weeds with the half inch cutting height than the others, particularly with those that have the higher rates of nitrogen. When you overgraze, the ground is more bare, temperatures are higher, leading to greater weed pressure.



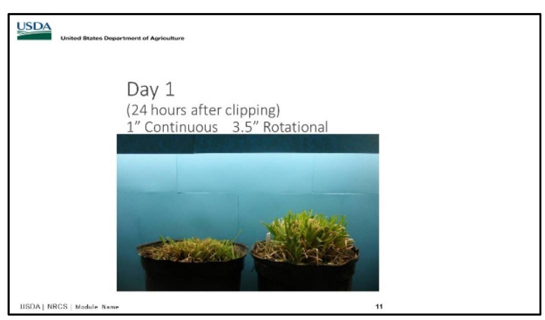
Slide 9

Slide 10
With stand persistence after the fifth harvest, you see greater persistence with higher cutting height and no effect from nitrogen or potassium. If we can stop grazing at 4 inches, particularly with cool season grasses, there's a lot of benefits.



Slide 10

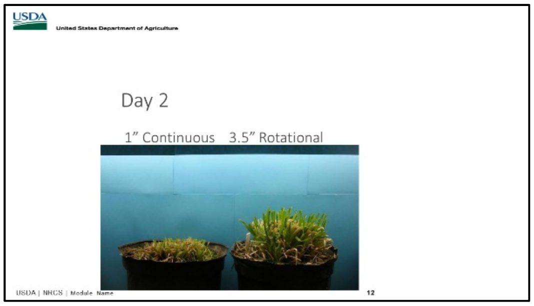
Slide 11
This is another study where in the pot on the left, orchardgrass was clipped down to a 1 inch height on a daily basis for 30 days and with the pot on the right was clipped down to 3.5 inches after a 30 day recovery period. The next few slides show what the daily recovery looked like over time.



Slide 11

Slide 12

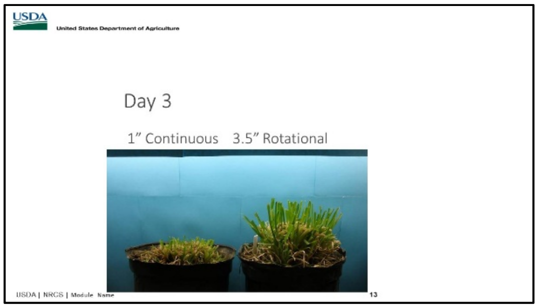
This is Day 2.



Slide 12

Slide 13

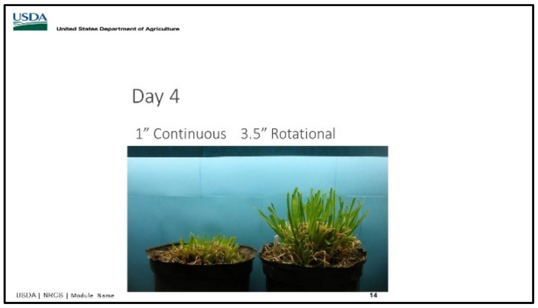
This is Day 3.



Slide 13

Slide 14

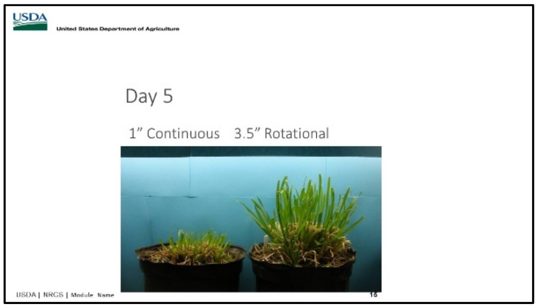
This is Day 4.



Slide 14

Slide 15

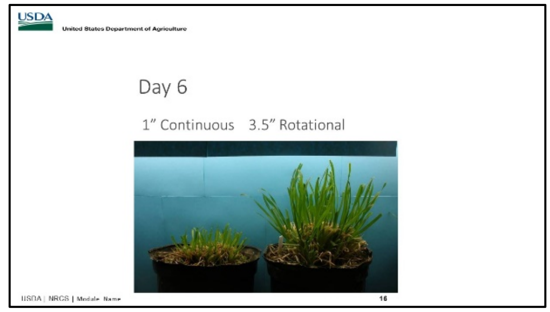
This is Day 5.



Slide 15

Slide 16

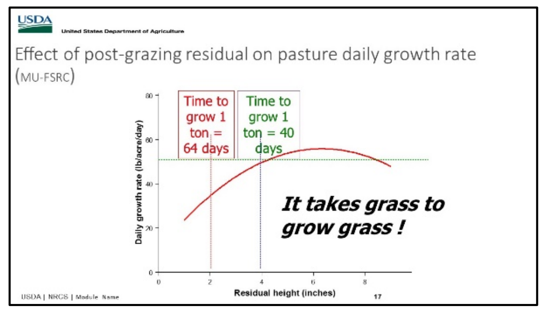
This is Day 6. You can see the 3.5 inch that had a 30 day recovery period prior to the experiment is recovering much quicker than the one inch continuous clipping. It all comes back to photosynthesis and the leaf area that is available for photosynthesis. If we don't have good leaf area, we can't capture sunlight. This is true whether we are talking about cover crops or grazing management. Photosynthesis produces the energy for the plant. Some of the carbon that is produced is released through the roots and feeds the biological organisms in the soil. This is the cycle for grazing management. If we overgraze, this cycle shuts down, the microorganisms in the soil shut down or become dormant until carbon is available again.



Slide 16

Slide 17

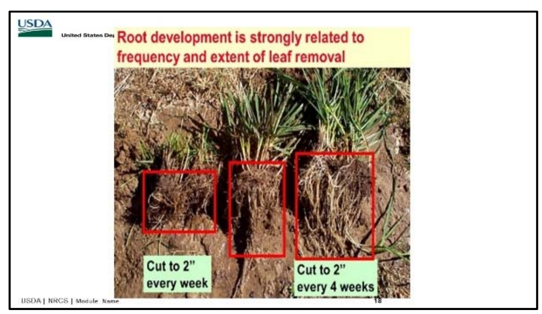
This slide shows it takes about 50% longer to grow a ton of feed if the pasture is grazed down to 2" compared to 4".



Slide 17

Slide 18

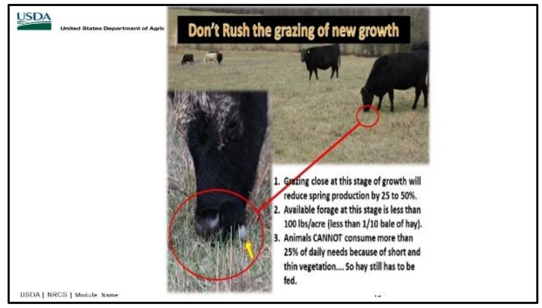
In this study they cut it down to 2 inch height, which is shorter than is normally recommended, and varied the frequency of the cutting. The one on the left is cut every week and you can see the root development is much less than the one on the right that was only cut every four weeks. Therefore, if an area is overgrazed, continuously grazed, the roots will be stunted because there is less carbon ending up in the roots because there is less photosynthesis in the shoots. This is why you can take a rainfall simulator over an overgrazed pasture and see almost as much water erosion as from cropland.



Slide 18

Slide 19

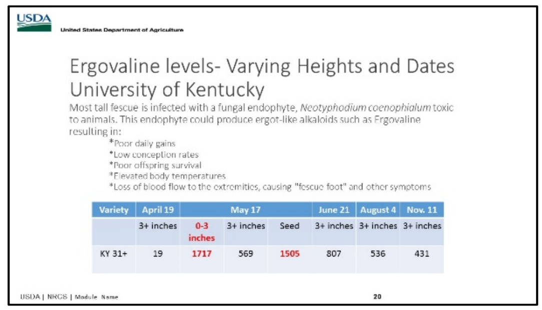
In this slide you can see the points identified where grazing close at this stage can reduce spring production by 25 to 50%. Available forage at this stage is less than 100 lbs per acre, less than one tenth of a bale. Animals cannot consume enough so you might as well feed hay at this stage and rest the pasture. You're not getting any benefits out of it.



Slide 19

Slide 20

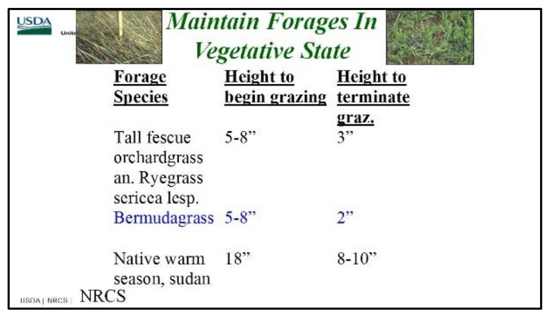
This study shows different ergovaline levels from the fungal endophyte in tall fescue. Basically, managing at 3 inches or higher produces less of this toxin. With endophyte fescue you can also dilute it with legumes or other species.



Slide 20

Slide 21

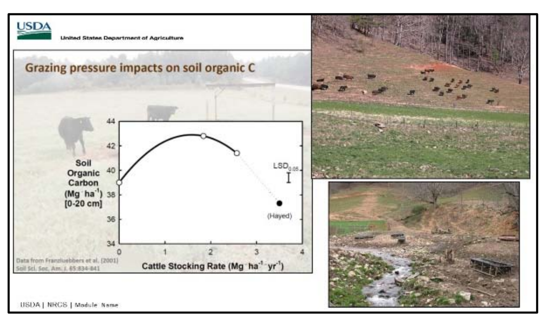
This slide shows the beginning and termination heights for different forage species. Most of the forages have a beginning height of 5 to 8 inches and bermudagrass can be grazed a little lower than the others. With the native warm-seasons you have much higher beginning and termination heights. The growing point on many of the warm-season grasses is at 6 inch height so you don't want to go below that if you are cutting for hay or grazing or you will start to lose your stand.



Slide 21

Slide 22

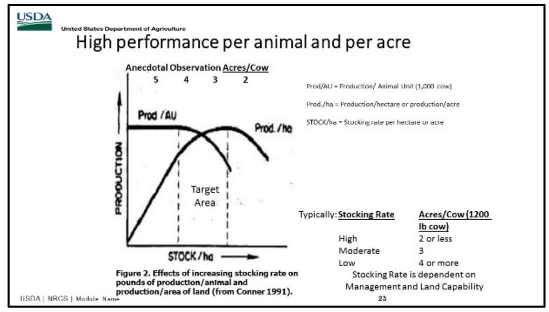
In overgrazing, there are effects below ground as well as the obvious stresses on forages. Negative changes in aggregation, bulk density, and soil carbon. Here we see the increase in SOC as stocking rate increases (positive changes) to a point, then the SOC retreats as it is overstocked. This all relates back to the leaf area and carbon production mentioned in some of the previous slides. Also, note as pastures are hayed and all the carbon is removed, SOC would typically decrease significantly. Research by Alan Franzluebbers. 1 Mg per hectare equals about 892 lbs per acre.



Slide 22

Slide 23

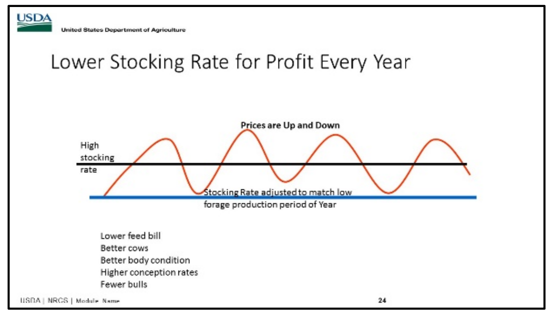
This slide shows the relative production based on stocking rate. The stocking rate is dependent upon productivity, rainfall, the animals and management. As your management increases, you can get more to the right side of the graph. Some producers in Tennessee get up to 2 acres per cow or less but they are moving them on a daily basis or twice daily



Slide 23

Slide 24

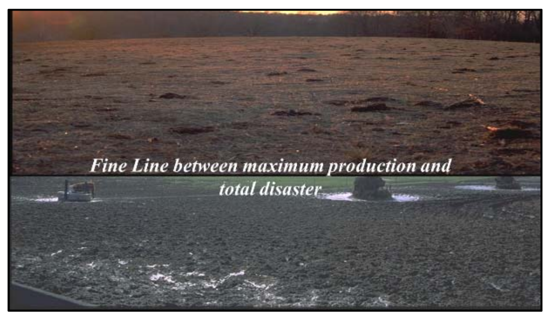
It's a good idea to start out your stocking rate adjusted to match the low forage production period of the year to make sure you have the management skills and a lower feed bill. A lot of the profit margin is based on the feed bill. Anytime we can cut back on hay, we are putting more profit in our pocket.



Slide 24

Slide 25

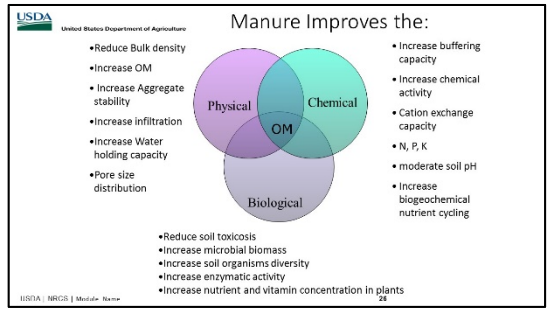
As long as we have time, roots and cover, we avoid disaster. If not, it is a disaster.



Slide 25

Slide 26

Manure can have many positive impacts on the physical, chemical, and biological properties of soils. These are all related to organic matter because manure is organic matter. The soil is less compacted when we have active carbon on the soil. The soil's ability to resist water pressure (aggregate stability) is better when we have organic matter. The nitrogen and carbon in manure becomes available for organisms to build soil organic matter which improves the physical properties described.

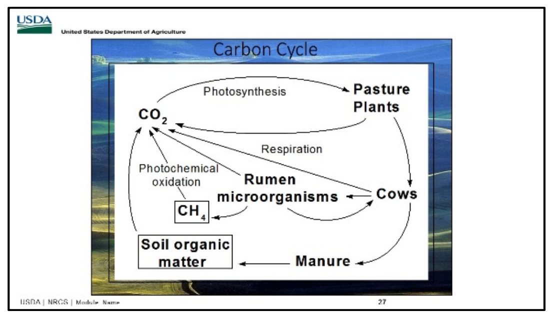


Slide 26

Biological: Manure can increase biological activity, total number and diversity of microorganisms due to nutrient and carbon concentrations. Chemical: Manure contains valuable amounts of nutrients. Manure leads to stable organic matter. This has high cation exchange capacity (CEC) potential which allows for greater nutrient retention and provides increased buffering capacity making soils more resistant to changes in things like pH. Some manures can raise pH due to higher calcium concentrations while manures can reduce acidification compared to inorganic fertilizers due to the stable conversion of nutrients like nitrogen to plant usable forms (organic N to ammonium).

Slide 27

Now look at this carbon cycle. Without animal inputs, the cycle is less complex with Photosynthesis to plants to respiration back to CO_2. With herbivores introduced, soil microorganisms take the carbon in manure which has been altered by processes (including gut microorganisms) in livestock and further decompose to soil organic matter and plant available nutrients. So, livestock convert the forages to forms that soil organisms can use more efficiently (in the right conditions) and into stable organic matter. The process is enhanced.



Slide 27

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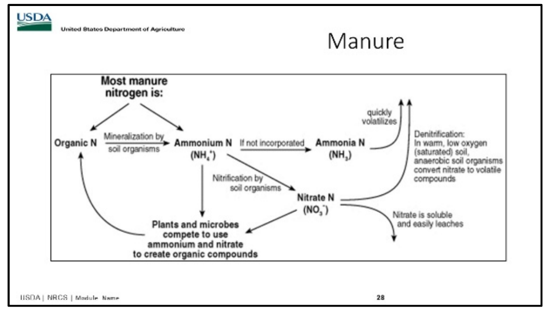
So, nitrogen in the organic state (ON) or as it's mineralized to ammonium (NH_4) state is very stable and does not readily leach. Healthy soil systems are better at recycling N to stable ON due to a healthy, diverse population of microorganisms. Plus: NH_4 is plant available and not as subject to leaching. Converting to nitrate (NO_3) (also plant available) is a natural process but NO_3 is highly leachable. But, again, in healthy forages systems, both microorganisms and plants will use greater amounts of available nitrogen. This is good news! The N stays in the system. <u>Losses to the atmosphere and water can be low compared to urine…</u>

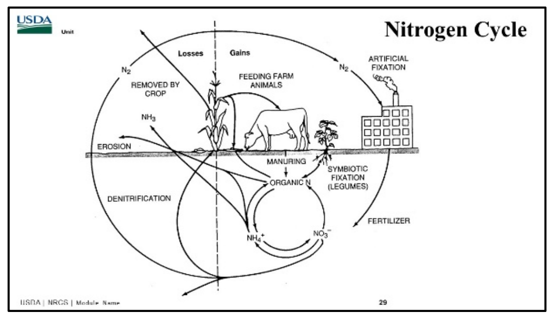


Slide 28

Slide 29

Let's look once more at the nitrogen cycle and the potential for manure to aid in the cycling of N. Nitrogen is broken down in manure from stable organic nitrogen (ON) to ammonium (mineralized), then to nitrates (nitrification). Increases in biological activity from manure organic matter increases uptake of nitrogen into the bodies of microorganisms. This stabilizes N and improves the cycling. So, let's take a look at the way herbivores, plants, and soil biology can work together and mimic nature so all can benefit.

Then we will look at what happens when this breaks down as a result of poor management or when herbivores are not present.

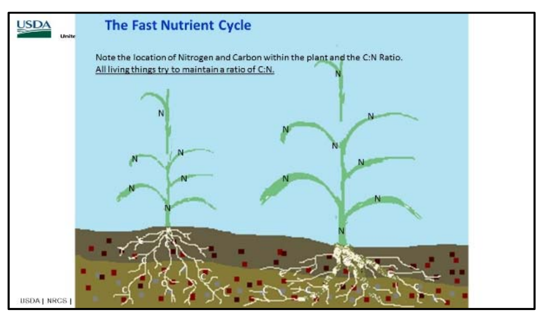


Slide 29

Slide 30

So here is actual footage of the process that is considered the Fast Nutrient Cycle. The grasses here are between the 3rd leaf stage and flower. Notice that the new growth grows on top of the plant. This new growth is high in nitrogen and low in carbon, i.e. high in protein.

Notice the carbon to nitrogen ratio is in balance to what the grass desires. All living things try to maintain a ratio of carbon to nitrogen. If this ratio is changed in any direction the organism will react in some manner to get the ratio back. For example, if you consume more protein than carbon for long periods you will get a craving for carbon. And visa versa. But we are able to walk to the store and get what we need (a bag of chips or French fries from McDonalds, which are high in carbohydrates) to keep our ratio in balance. But a plant can't walk to the store. So what will a plant do if it's C:N ratio is disrupted? Let's see.



Slide 30

Slide 31

Oh no, here comes Gertrude, notice how she is only taking the tops of the plants and then moving to the next plant. Why doesn't she graze the lower portion of the grass plant? Because it is the highest quality forage available, right? The bottom half of the plant is higher in carbon and low in protein and is less digestible than the tops. Gertrude is in high demand of protein, she is milking her calf and is trying to get in condition to reproduce again. She is seeking highly digestible crude protein so see selects the tops and moves to the next plant. This is nothing new to the plants. They evolved under this type of strategy. With large herds of bison grazing through the area, they took the tops and moved on. If the plants put the highest quality feed on the bottom and the top was poor quality what would happen to that plant? It would be overgrazed and doomed to die. Let's watch this actual footage to see if this is really the case.

Slide 31

Slide 32

Notice how Gertrude is taking the top of this plant.   Let's see if she will graze it to the bottom or if she will go to the next plant. What do you think? Why? She will go after the highest nutrition first which is the tops, right. Let take a look and see…

Slide 32

Slide 33

Wow, notice how she took the top and move to the next grass plant.

Slide 33

Slide 34

Notice the auxiliary tiller has been activated. Which is slower growing which is ok because it slows down the plants from going to seed and shutting down for the rest of the year. All living things want to reproduce. Plants have two methods: Their first choice is sexual reproduction, or seed production, but if that is interrupted by grazing or other types or defoliation, then it will go to asexual reproduction….tillering, as we see here. It takes more sun energy to make seed production than leaf production. If we can stop the plant from going to seed we will force it to go to tiller. We will force the plant to grow longer, absorbing more energy from the sun, capturing more carbon from the air. Also note the C:N Ratio. The plant has lost a lot of Nitrogen to the cow. So there is an imbalance of Carbon to nitrogen. More carbon than nitrogen. What's a plant to do????

Slide 34

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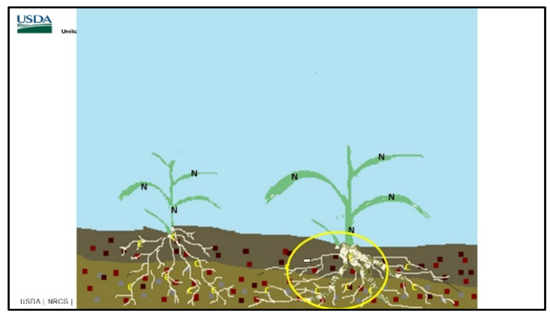
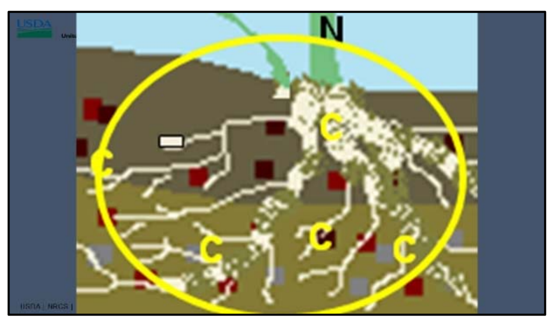
There is also something happening in the root zone. Let's take a look.



Slide 35

Slide 36

Notice all the carbon. Not much nitrogen.. Any thoughts on what the plant can do to get more nitrogen??? Let's get a closer look.



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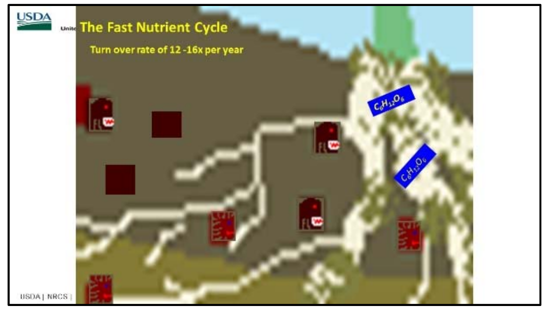
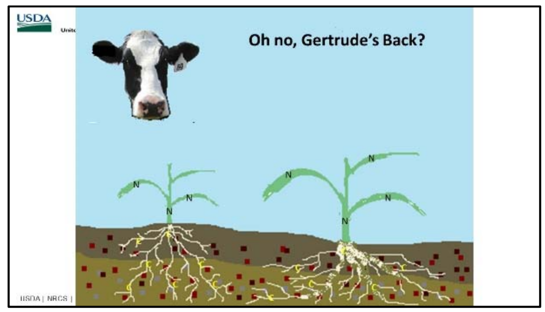
Roots slough off and are broken down by microbes which release N to the plant roots.



Slide 37

Slide 38

Oh no, here comes Gertrude again!! What is the next part of the plant she will eat? Yes, the factory. Let's watch and see.



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Yep, she sure did take the factory off. Now what?

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Slide 40

Oh no, she is now going after all of our factories. There goes take half leave half. What could we have done to avoid this? Yes, we should have moved her to the next pasture before this occurred.

But what is going to happen to the <u>symbiotic relationship between the animal, the plant and the microorganisms</u>? Let see.

Slide 40

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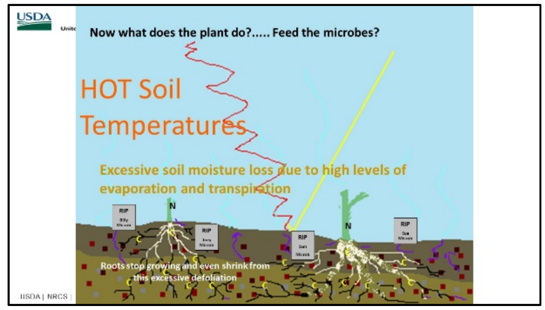
We now have removed the solar panels from the plants, created hot soil temperatures, increased moisture loss, shut down our roots and possibly shortened them. Due to the hot soil temperatures and dry conditions we have caused all of our workers to go dormant and even die. Let's go to live footage and see what actually happens..



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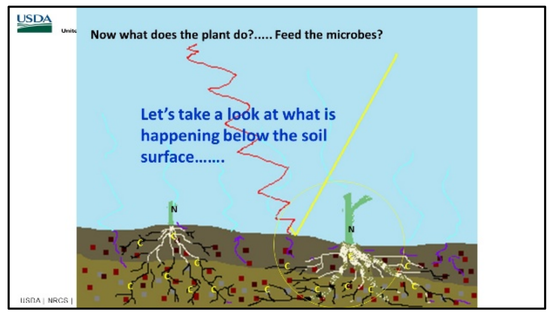
Ask the audience what they think the plant response will be. Will it excrete sugars to the microbe? Once they have explained what they think will happen, go to the next slide to watch and see.



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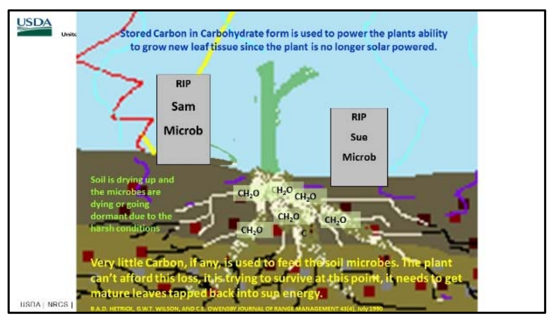
The polysaccharides are used to make new tillers since the plant is no longer solar powered. It is running on stored carbohydrates. It can't afford to give carbon to the microbes that it needs to grow new leaves. It will do this first and hopefully get them to maturity before you know who comes back. If Gertrude does come back what do you think she will be after then? The <u>old growth or this lush new growth?</u> Yes the new growth probably before it becomes mature. That is if there is any moisture left to make new growth.



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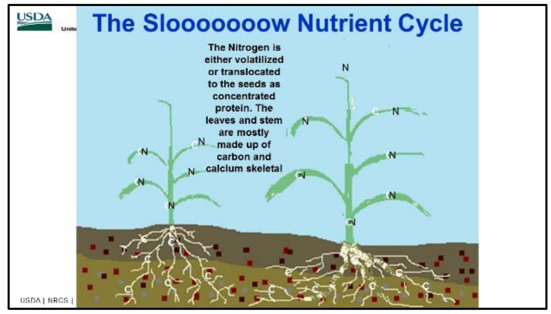
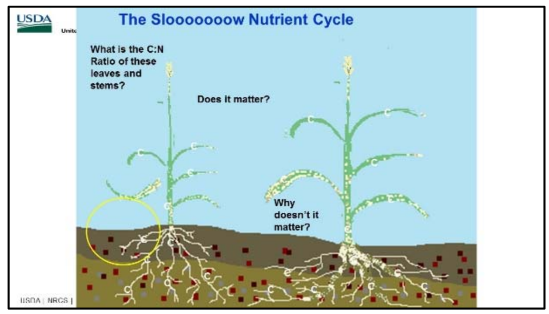


Slide 44

So here is actual footage of the process that is considered the Slow Nutrient Cycle. The grasses here are in the boot to flower stage. Notice that the new growth still grows on top of the plant and is still high in nitrogen and low in carbon (ie. high in protein). But as time goes on the plant goes to seed production robbing the plant of it's protein and concentrating it in the seed. The carbon to nitrogen ratio is still in balance to what the grass desires. There is no need for the plant to trade sugar for nutrients_when it is in a couch potato mode.

Slide 45



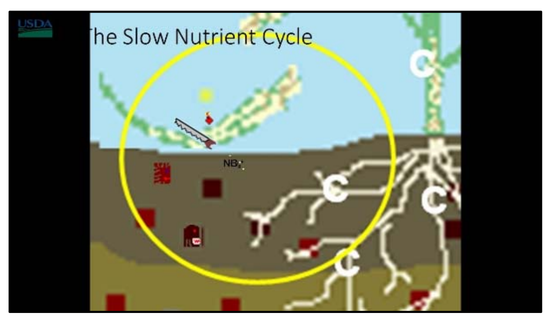
Slide 45

The slow nutrient cycle occurs if grazing occurs after the flower stage if at all. CRP would fall into this cycle, any non-grazed areas of your pastures or pastures that are grazed after the flower stage. Most of the nitrogen leaves the plant either by concentrating protein in the seeds or volatilizes from the leaves and stems.

If grazed at this time, there will be no sugar handouts to the microbes because the plant has produced seed and has shut down. There is no reason for the plant to give up carbohydrates to grow. It has accomplished its mission and is resting for the rest of the growing season. So what will the microbes have to eat? Where can they get their carbon? Let's watch and see.

Slide 46

As leaves fall to the ground, the microbes break them down and it releases nutrients.



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Slide 47

Conclusions: Let's look at how this might look above ground. Under well managed systems, where nutrients are consistently cycled and carbon is effectively added, grazing is a beneficial practice. Here, there is a positive relationship between soil biology, livestock, and plants. After grazing, plants release exudates including sugars. Bacteria feed on these exudates and release nitrogen back to the plant for its use. Forages are meant to be grazed. Look at the ungrazed system on the right. Here processes have slowed down. Higher C/N ratio plant residues are decomposed much slower. No manures are added to assist in the decomposition. Therefore nutrients are cycled much slower.

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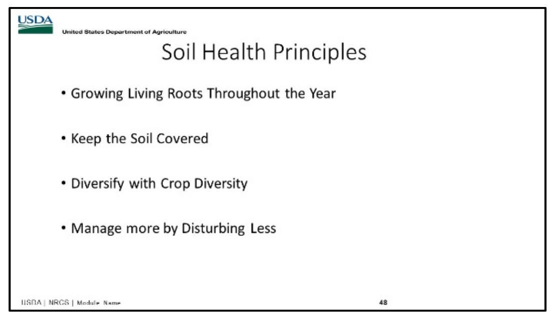

Slide 48

Let's look at our 4 soil health principles as they relate to our perennial grazing systems.
Living roots will keep making carbon for microbes.
Keeping the soil covered will help insulate the microbes from extreme temperatures.
The more diversity we have aboveground, the more diversity we have belowground.
An example of a disturbance in pasture is overgrazing.

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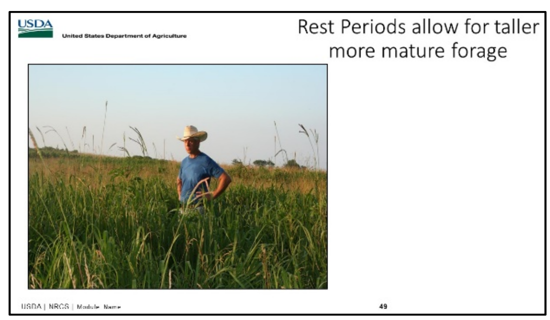
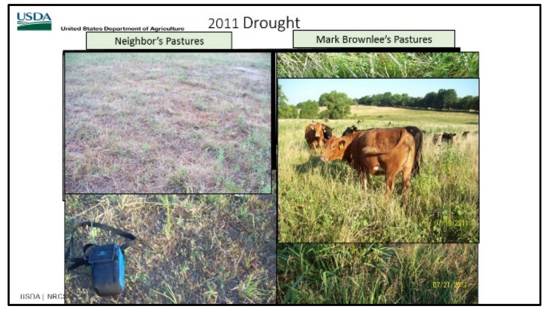


Slide 49

Let's look at Mark Brownlee's operation. He lives in Missouri. Mark had been rotating twice daily at about 100,000 stock density. This is a good example of what having residue can help do. Mark allows forages to grow taller and more mature before using the livestock to trample residue onto the soil surface.
Livestock have eaten weeds that were showing up in Mark's pasture, confining them in a small area makes them less selective, aids in weed control.

Slide 50

This is from the 2011 drought. Compare the neighbor's farm next door. Cooler and moister conditions at the surface and below the soil surface allowed the forages to thrive in stressful conditions.



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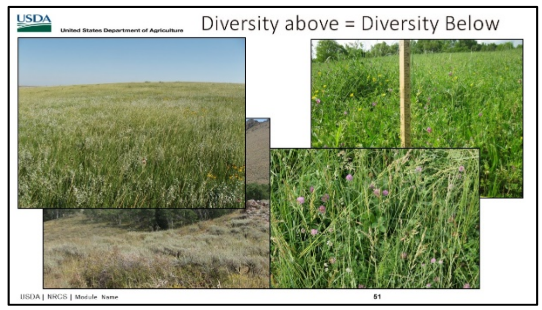
We all know that diversity in our pasture systems is good for livestock, but it also increases biological diversity below ground. More diversity in plants and microorganisms leads to healthier systems that are more resilient and resistant to drought and pest issues while improving nutrient cycling and overall system health. Diversity is not always just about adding annuals into the system. It can mean diversity of perennial species as well. In this photo, there are several examples.

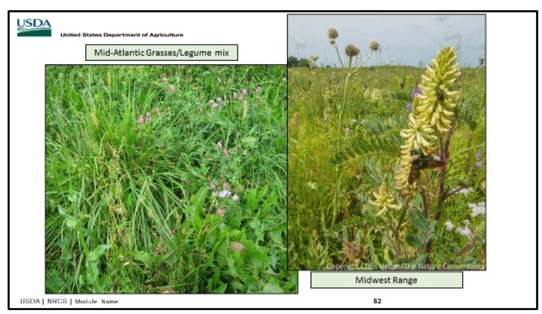


Slide 51

Common introduced cool season mixtures could include several grasses and legumes. In many locations warm season mixtures are more prominent. According to Greg Brann, weeds are opportunities. Opportunities to train cattle to eat weeds through management systems like mob grazing.

Slide 52

Here are a couple of good examples of healthy diverse systems. On the left are mostly introduced grasses and legumes from the mid-Atlantic region of the US, similar to Tennessee. Also in there are some species we might consider weeds but are very nutritious readily grazed. On the right is a range system from the Midwest. These are primarily native species. Both systems can be enhanced and thrive with grazing management. Sometimes new seeding is required but many times there is a healthy seedbank within the soil to provide adequate diversity.



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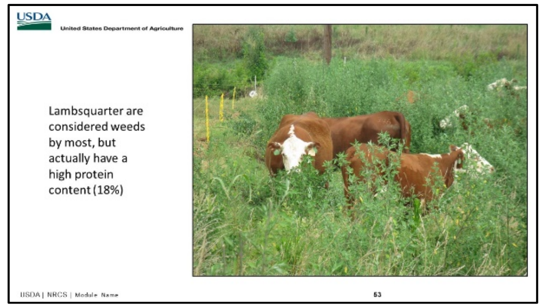
Some things we think of as weeds are actually nutritious and readily eaten by livestock. This is an infestation of lambsquarter. This herd loved it. They were not forced to eat things they didn't want and were readily moved from one temporary paddock to another. The protein content was about 18%



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Slide 54

Here is the before grazing and after grazing photo. On the left, the cattle ate the leaves and left the stems. The weed was controlled through proper management. Again, this is diversity not always considered.

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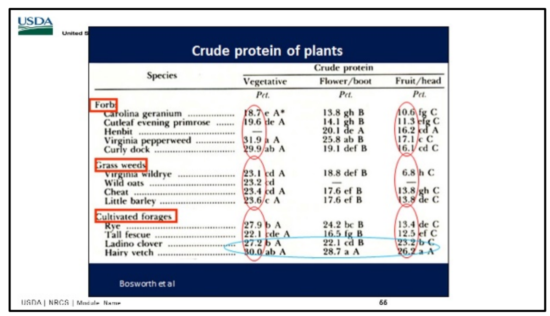
Slide 55

This slide shows other examples of plants and their crude protein contents. You can see some of the weeds can have crude protein contents that are similar to cultivated forages. The point is don't always dismiss a plant as just a weed that must be chemically eradicated when in many cases it is highly nutritious and desired by livestock.



Crude protein of plants

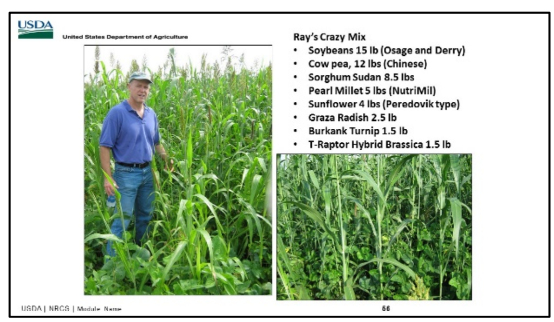
Species	Crude protein: Vegetative	Crude protein: Flower/boot	Crude protein: Fruit/head
	Pct.	Pct.	Pct.
Forbs			
Carolina geranium	18.7 e A*	13.8 gh B	10.6 fg C
Cutleaf evening primrose	19.6 de A	14.1 gh B	11.3 efg C
Henbit	—	20.1 de A	16.2 cd A
Virginia pepperweed	31.9 a A	25.8 ab B	17.1 c C
Curly dock	29.9 ab A	19.1 def B	16.1 cd C
Grass weeds			
Virginia wildrye	23.1 cd A	18.8 def B	6.8 h C
Wild oats	23.2 cd	—	—
Cheat	23.4 cd A	17.6 ef B	13.8 gh C
Little barley	23.6 c A	17.6 ef B	13.8 de C
Cultivated forages			
Rye	27.9 b A	24.2 bc B	13.4 de C
Tall fescue	22.1 cde A	16.5 fg B	12.5 ef C
Ladino clover	27.2 b A	22.1 cd B	23.2 b C
Hairy vetch	30.0 ab A	28.7 a A	26.2 a A

Bosworth et al

Slide 55

Slide 56

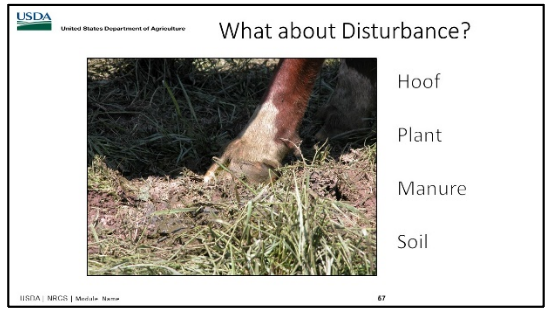
Annuals seeded onto perennial pasture land is popular now as a practice for a variety of reasons. This was an old fescue field. The producer's goal was to renovate it and later put in a perennial warm season grass to offer some good grazing for the summer. In the late spring, the existing stand was terminated, you can even use a disturbance like overgrazing to get rid of the existing stand. The above mix was drilled and growing animals were put on at the stage shown above. Cattle gained over a pound per day which was a lot better than the old fescue during the summer. Much of the residue was trampled. The diversity from these annuals gives the system an instant boost and adds to the biological diversity below ground. After a couple of years of cool and warm season annual mixes, the field will be seeded in perennial forages.



Slide 56

Slide 57

Disturbance in pasture systems is not always bad. It can be beneficial when the hoof, plant, manure, and soil interact. But it must be in a well-managed system to avoid detrimental effects to all the resources. Negative impacts can include compaction, reduced forage quality, increased weed pressure, and decreased water quality due to high concentrations of nutrients coupled with erosion. As mentioned previously, overgrazing can be used as a transition for seeding. Month prior to end of seeding date.



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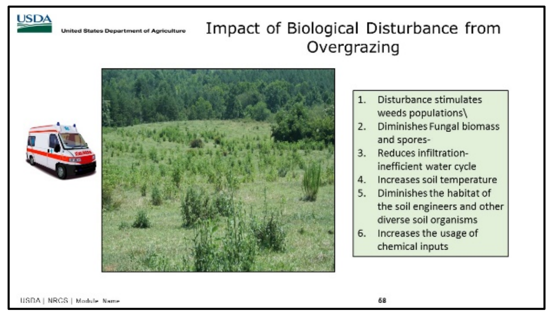
Slide 58

If you overgraze too much though you can get this result. Weeds become the "first responders" (see ambulance) after overgrazing but these weed are not the diversity we want. Discuss any of the outcomes listed.



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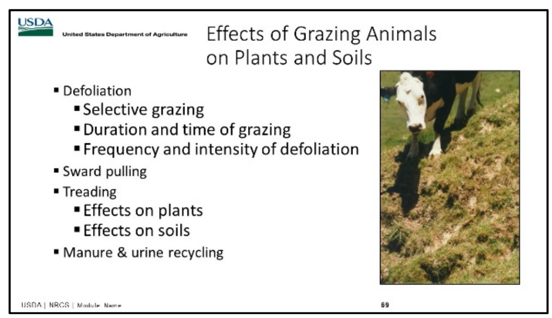
Grazing animals can impact plants and soils. Management can determine if it is good or bad. Here are some of the effects and what to consider. Higher density grazing with shorter duration can reduce selectivity. Again, allowing plants to be repeatedly grazed without restoring energy and leaf area diminishes plant health and thus its collaboration with soil biology. Allowing animals to "tread" on areas of pasture for long periods can cause extensive damage to plants and soil. Pore space can be severely reduced. However, what if the time on an area is short with larger amounts of residue placed on the soil surface by the animal hoof. It could actually be a positive outcome. Let's look at some ways to mimic nature and use livestock in a positive manner.



Slide 59

Slide 60

Slide 60

The bison roamed around eating the grass. Primarily it was warm season grass and forbs but there was a tremendous amount of diversity. There is still discussion about exactly how the bison grazed. There were a lot of factors that came into play. Time of year, growing or dormant grasses, available water, what areas burned, what didn't burn, lots of things. Some writings and accounts say they were in small groups grazing only in the burned areas for the entire year. These burned areas would have been grazed pretty hard while unburned areas were almost ungrazed and then the next year they moved to another burned area. There are also accounts of large herds numbering in the hundreds of thousands. As you can imagine when a large herd like this moved through an area everything probably got grazed and/or trampled pretty hard. In either of these scenarios the grasslands were severely grazed and then rested for a long period of time, severely grazed and then rested. It was this type of management that developed some of the most fertile soils in the world. I think we can use different forms of this type of management to repair our eroded and worn out soils.

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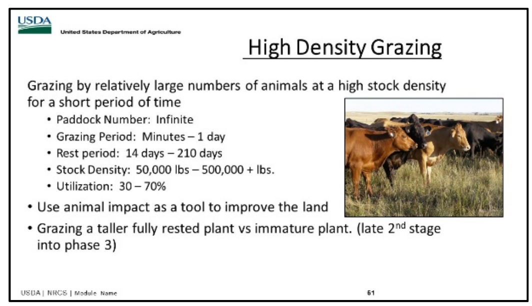


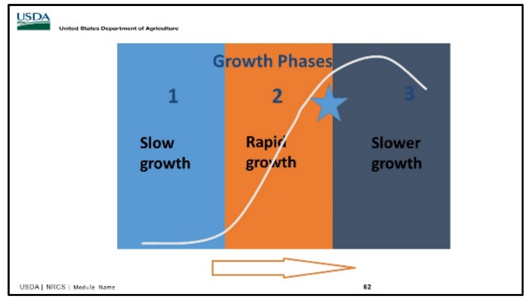
Slide 61

Here's the definition of High Density Grazing that we can use.
Paddock number: can be an infinite number with the size adjusted for the time of the year to account for the amount of forage that is available
Grazing period: short periods require more management to move, but have the potential for higher soil health returns
Rest Period: the longer the better, has benefits beyond the forage, can be used to break pest cycles
Stock density: can be adjusted by how large you make the paddocks
Utilization: need to keep in mind that the "micro herd" needs some forage too

Hoof action (trampling) is what helps to feed the soil microbial community
Grazing taller forage takes a change in paradigm as to how we typically look at forage management

Slide 62

The latter part of stage 2 is the target for high stock density grazing. Earlier stage 2 is what is used in a more traditional system, where C/N ratios are lower. So, with higher C/N ratio material, livestock move thru faster while trampling some of the material flat onto the surface, much like a roller crimper would do on cropland.



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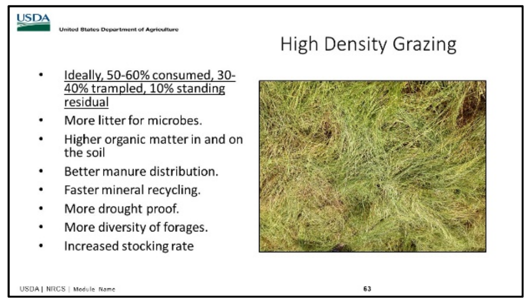
While a larger percentage of the total live biomass is trampled compared to traditional systems, much of this is higher lignin with a high C/N ratio. More of this material is trampled and some farmers might feel that a lot of forage is being wasted. When we have things like recovery time, good soil biology, organic matter, that is building up a bank that pays the dividends shown on the slide. With all these soil health improvements, theoretically stocking rates could be increased due to improved yields.

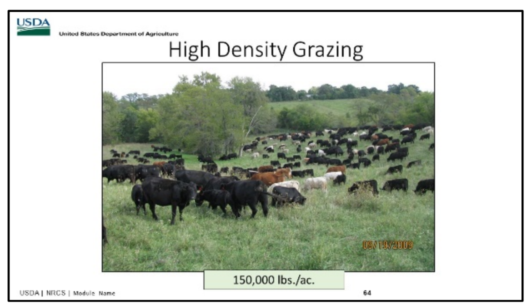


Slide 63

Slide 64

Here is an example from Doug Peterson in Missouri. This is a density of about 150,000 pounds. (density=pounds of animal on a specific area for a specific amount of time) Lots of forage. Utilization was around 50%. Most of what was left was stems.

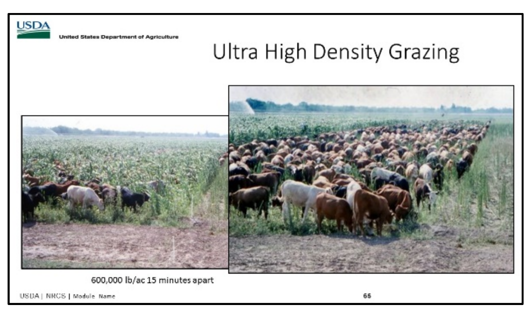
"We DID NOT want to be hard on the cows. We did not want to restrict intake or make them eat something they did not want to. "



Slide 64

Slide 65

Here are a couple of pictures that show Ultra High Density Grazing. This is around 5-7 hundred thousand pounds stock density. The pictures were taken 15 minutes apart. These stockers are moved every 30 minutes.



Slide 65

Slide 66

Here is a field that was allowed to rest from March through Aug in 2008. Then it was grazed/trampled at a stock density of about 150,000 lbs per acre. Not the half a millions pounds like the slide before but significant.

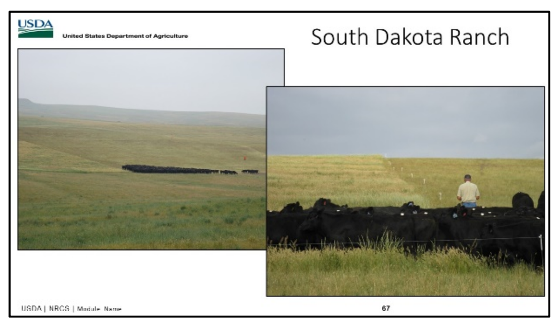
Slide 66

Did the cattle “waste” some grass? Well, they didn’t eat it all but it was all used for a specific purpose. It was trampled onto the surface of the soil creating a layer of mulch, just like the hay pile, that allowed the clover to germinate and grow. In case you are wondering there has not been any clover broadcast on this field, no lime and no fertilizer of any kind for many, many years if ever.. A USDA soil microbiologist said that it typically takes a couple of years for the soil microorganisms to really begin to respond to the increase in decaying plant material. It has been managed for two years in this manner. It is likely that because of the trampling the natural nutrient cycle is starting to really kick in and that is why we are seeing the clover increase. This is closer to the 10 to 20% standing that is recommended.

This is a close up of another field on a different farm. This one has not had any lime or clover added in at least 20 years maybe not ever. It was hayed for 20+ years and now this is the 3rd year for this field to be “mulched” in this manner. What will all this clover do? Besides improving the nutritional value of what the livestock are eating it will let us tap into a free nitrogen source, the air.
There are a couple of things you have to notice. First there is not any bare soil. There is still a lot of green grass. This means the soil stays cooler and they are still able to carry on photosynthesis

Slide 67

This is a rancher in western South Dakota. He is also using some higher density grazing. He uses temporary fencing to more frequently move livestock. The photo on the left gives an idea of the extent of his ranch. Cattle are not really restricted to the small area you see. They are just ready to move to the next paddock as you see being done in the right photo. In just a few years of using this management style, this rancher has noticed improved forages with better diversity of species while the cattle are easier to handle.

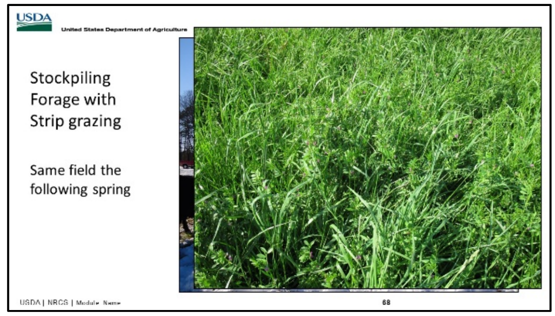


Slide 67

Slide 68

Extending the grazing season by stockpiling forages and strip grazing is a form of high density grazing as livestock "advance" as the fence is moved. Plus the living root is enhanced by the fall/late summer growth (stockpiling).

This is a look at that same stockpiled/stripgrazed pasture the next spring. Diversity has improved. The producer had never seen vetch in this pasture before. The hoof, soil, plant, residue, interaction has stimulated dormant seed to germinate.

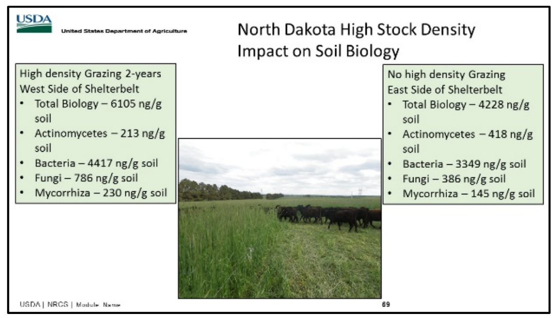


Slide 68

Slide 69

Here is some high density grazing in North Dakota

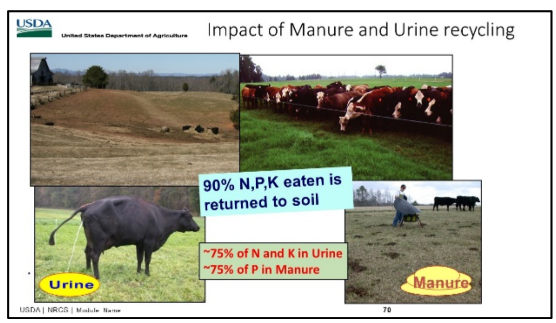
Look at the biological results from a comparison of those systems in ND. There is a greater balance of biology in this higher density grazing. Look at total biology and greater numbers of Fungi….a soil health indicator! In Tennessee, a cropland with no till and cover crops had a total biology value similar to that on the right and when animals were added it got as high as 6000 ng/g for total biology.



Slide 69

Slide 70

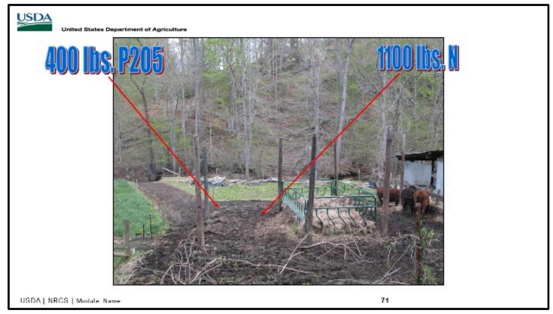
So let's go back and look at manure and urine. Remember that most of what goes in comes out the back end. So we need to make the best use out of it as possible.



Slide 70

Slide 71

In this example 30 head are fed for 120 days. This could easily be about 400 pounds of P2O5 and 1100 pounds of N deposited on one area. So this could be applied to provide nutrients for forages and be properly recycled instead of becoming a water quality problem as shown here (note the stream in the background).

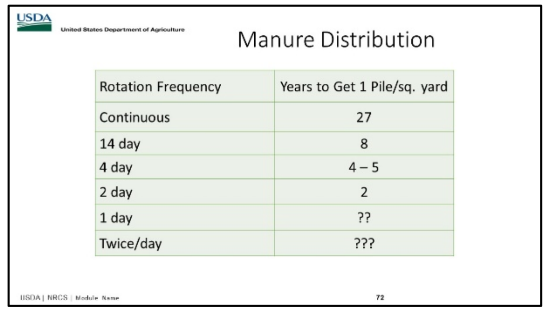


Slide 71

Slide 72

As part of the MU study, they estimated how long portions of the field might go without receiving manure. In continuous grazing, parts of the pasture will only receive manure from the cattle every 27 years. In other words portions of the pasture only receive fertilizer every 27 years. Intensive grazing can reduce this to every 2 years.

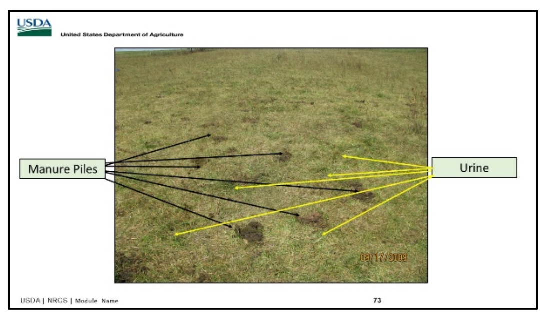
There is no data for once per day or more than once per day.



Slide 72

Slide 73

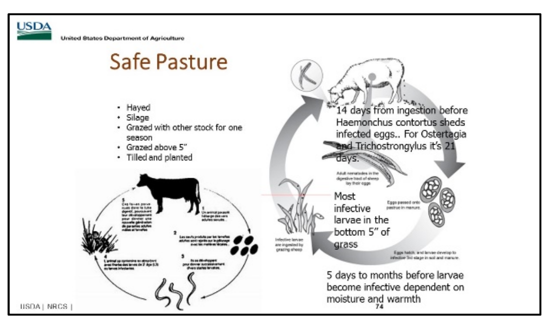
Here is an example of manure that is well distributed. Are there any areas of refusal? It has been over 4 months since anything has been on this field. Previous manure piles are gone, urine smell went away. It can take as long as 90 days for just the urine smell to go away. If we were on a 30-45 day rotation do you think we would have had areas they avoided because of manure and urine? You bet we would have. 45-60 days should be okay, sheep no problem.



Slide 73

Slide 74

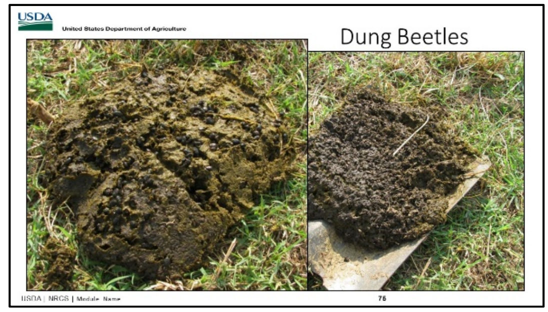
You also want to keep the grazing height higher to reduce disease from things like infective larvae that can be ingested with grass up to 5 inches tall.



Slide 74

Slide 75

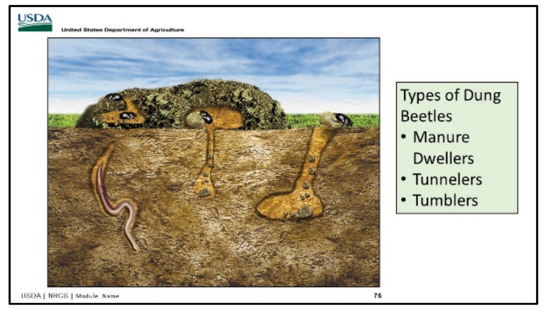
What about dung beetles? They can move and bury organic matter. These are natural tillers in perennial systems. They can persist in grazing systems but certainly thrive better where internal pesticides are absent.



Slide 75

Slide 76

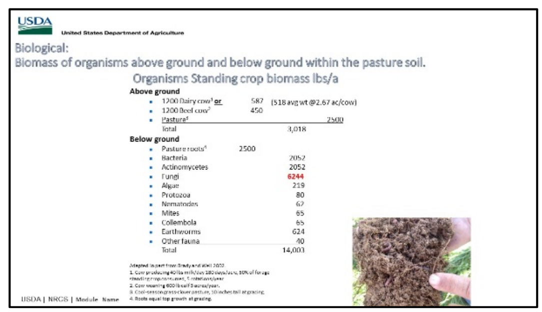
There are three basic kinds of dung beetle. Those that live in the manure, those that move manure directly down and the well-known tumblers.



Slide 76

Slide 77

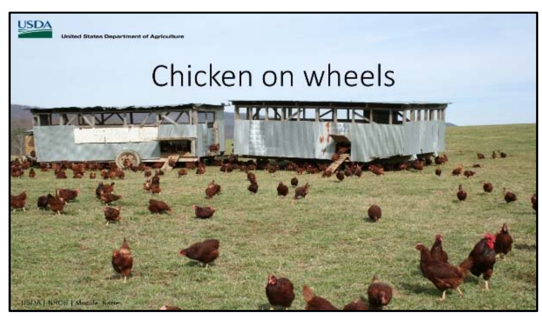
This slide shows the difference in the biomass of animals above ground (3,018 lbs) and below ground (14,003 lbs) for a pasture soil.



Slide 77

Slide 78

Chickens can be great for natural pest control (fly larvae etc) and they can spread manure with their feet. Wait a few days to put chickens out to give dung beetles time to move manure and lay eggs. Otherwise the chickens will eat some of your beetles. 3 days later after beef.



Slide 78

Test their Knowledge - Questions for the audience

Q: Based on the University of Kentucky study, which is more important, cutting height or nutrient rate of application?
A: Cutting height

When you overgraze, the ground is more bare, temperatures are higher, which leads to _greater weed pressure_.

According to the study by the University of Missouri, it takes _50%_ longer to grow a ton of feed if pasture is grazed to 2” compared to 4”.

Q: How can you reduce levels of toxic ergovaline in endophyte fescue?
A: Manage it at 3” or higher or dilute it with legumes or other species.

The form of nitrogen that his highly leachable is _nitrate_.

Q: What is stocking rate dependent upon?
A: It is dependent upon productivity, rainfall, the animals and management.

Q: For grazing, what determines whether fast nutrient cycling or slow nutrient cycling occurs?
A: The age of the plant when it is grazed. As long as a plant is not overgrazed, when it is grazed in the vegetative stage it will slough off roots that are quickly broken down and nutrients are released. If grazed after the flowering stage, any leaves remaining that fall to the ground are higher in carbon and less quickly digested by microbes. Roots no longer need to provide carbohydrates to microbes because the plant is no longer growing and does not need the nutrients.

Q: Under high density grazing, what is the ideal proportions for the amount consumed, trampled, and left standing?
A: 50-60% consumed, 30-40% trampled, 10% standing residual

Soil Health Evaluation

Name of Activity: Grazing management to improve 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 impact that grazing has on soil health	①	②	③	④	⑤	①	②	③	④	⑤
2. Stocking density and its importance for soil health	①	②	③	④	⑤	①	②	③	④	⑤
3. The impact that manure has on soil health	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!

MODULE 7. ECONOMIC BENEFITS OF IMPROVING SOIL HEALTH

Learning objectives:

Participants will be able to:

- Determine and evaluate the benefits of improving soil health based on economic impacts, reduced risk, increased production efficiencies, and more resilient soils.

Materials:

- PowerPoint® slides "Module 7: Economic benefits of improving soil health"
- 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:

Erosion/runoff
Value of organic matter
Nitrogen loss and efficiency
Drainage and water storage
Weed suppression
Insect pests and disease
Grazing economics

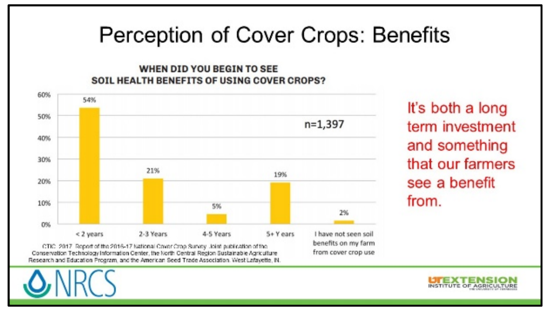
Slide 1

This module will focus on identifying the economic benefits involved in improving soil health.

Slide 1

Slide 2

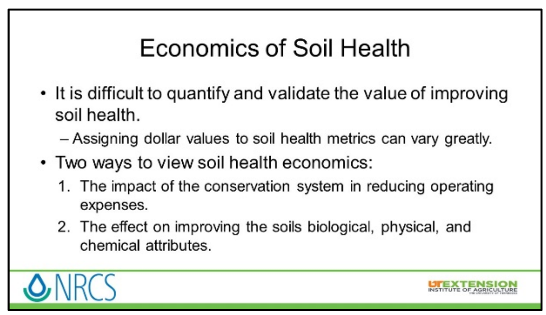
The survey shown on the screen comes from the latest National Cover Crop Survey. The results of this survey were likely the largest effort to obtain feedback from producers on their experiences with cover crops. The question above is an important one to have answered by farmers. It helps us to understand the farming community's perception of the use of cover crops. It also points to the fact that cover crop use is a long-term investment.



Slide 2

Slide 3

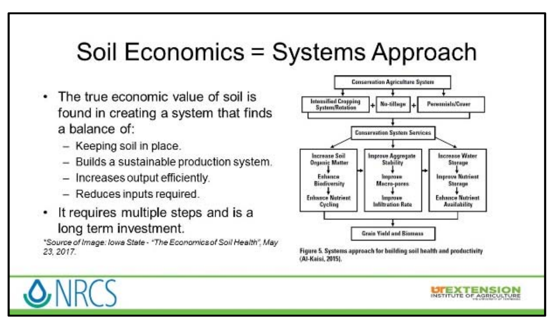
The above two points need to be made when discussing the economics of soil health. The economic return from a healthy soil is very difficult to measure. The reason is how do you place a value on an asset that is not easily sold or bought. The best method in valuing soil health is to measure the impact it has on the farming operation's bottom line. In agriculture, we tend to measure the economic impact of a production practice by asking how it increases yield and/or how much it costs.



Slide 3

Slide 4

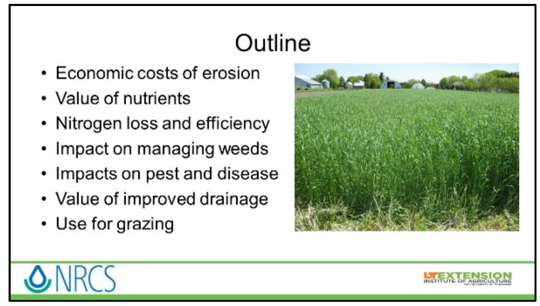
Like the figure above shows, the systems approach has many moving parts that are reliant on one another. Soil health is impacted by tillage practices, crop rotation, and the presences of vegetation in all seasons. The benefit of these production practices is multifaceted. However, the benefits are not seen overnight and will vary greatly from year to year.



Slide 4

Slide 5

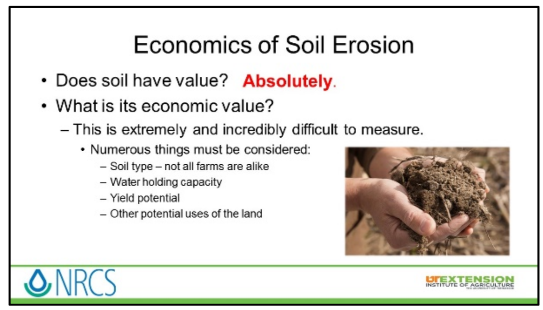
We will cover each of these in greater detail in a few minutes. Some of these have a greater impact on a producer's decision to implement cover crops.



Slide 5

Slide 6

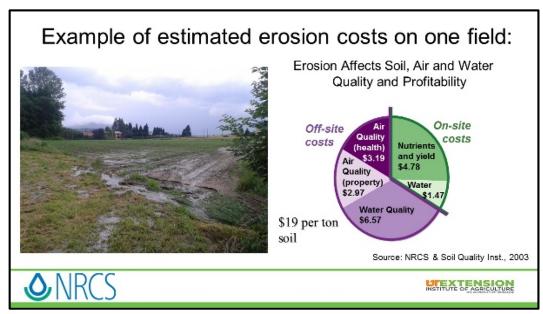
The value of soil erosion is difficult to quantify. What is not difficult to do is understand the value of a highly productive soil. When trying to determine the value of a soil, you have to consider the location of the land, the productivity of the soil, drainage of the soil, and the other possible uses for the land.



Slide 6

Slide 7

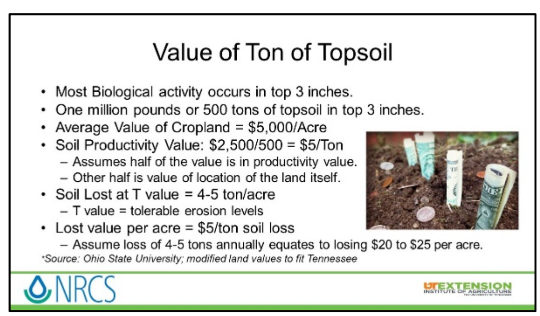
Erosion costs can come in various forms. Erosion increases costs by requiring landowners, or farmers, to excavate or create conservation structures. Also, productivity of the soil is reduced due to lost topsoil. NRCS research in 2003 estimated that the cost of erosion was approximately $19 per ton.



Slide 7

Slide 8

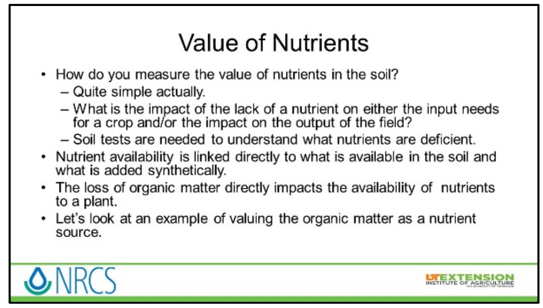
This example shows how you can calculate the value of topsoil. This study was conducted by the Ohio State University to show the value of topsoil based on the value of the land. I have adjusted the values to fit the values of land here in Tennessee. The T Value means tolerable erosion levels and was developed by NRCS. The example assumes that half of the land's value is in its productivity. Based on all of the assumptions made for this example, the loss of topsoil on this farm equates to $20-$25 per acre on an annual basis.



Slide 8

Slide 9

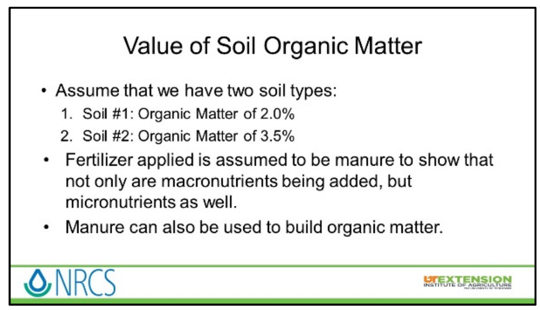
Nutrients play such a vital role in both row crop and forage production. In fact, the nutrients found in the soil are part of the discussion on soil health. Cover crops can improve the nutrients found in the soil over time. As organic matter increases, we tend to see the nutrients found in the soil increases. A glaring question that needs to be addressed is: How do you measure the value of the nutrients in the soil? The easiest way to measure the impact of nutrients in a soil is to quantify the reduction of output.



Slide 9

Slide 10

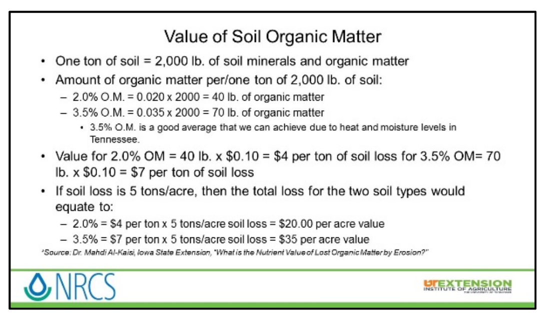
We are going to look at an example of the value of having more nutrients in the soil. We are going to focus on the soil organic matter levels of two different soil types.



Slide 10

Slide 11

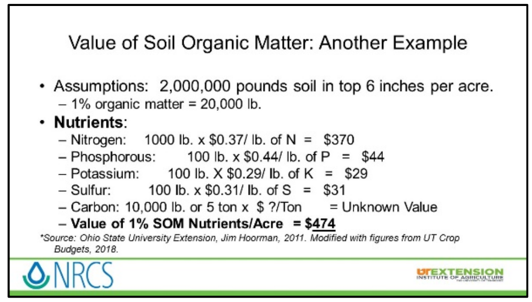
This example assumes that there is an actual value assigned to organic matter. As mentioned earlier in the presentation, it is hard to place a tangible value on soil and the contents therein. I would like to stress again the likely best way to quantify the value of organic matter is through its direct impact on reducing operating expenses and crop output. This valuation is a long-term process and one must keep that in mind.



Slide 11

Slide 12

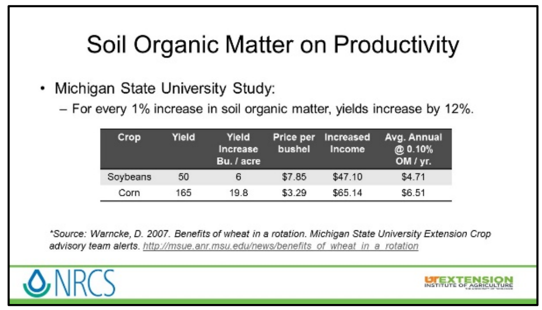
In this example, we assume that there are 2,000,000 pounds of soil in the top six inches. For every 1% of organic matter, the total weight would equate to 20,000 lbs. of organic matter per acre. Ohio State University developed a method of quantifying the value of nutrients per acre. If we assume that 1,000 lbs. of N, 100 lbs. of potassium, phosphorus, and sulfur, and use the respective values from the UT Crop Budgets, we derive a value of $474/acre for every 1% of soil organic matter.



Slide 12

Slide 13

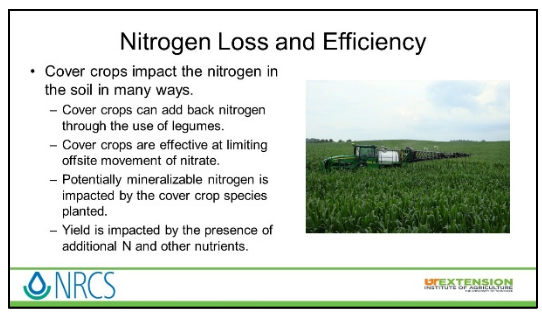
This study from Michigan State shows that for every 1% increase in soil organic matter, yield will increase by 12%. If that assumption is indeed correct, the 12% increase in yield for a soybean field with an average yield of 50 bu./acre would result in a $47.10 increase in income.



Slide 13

Slide 14

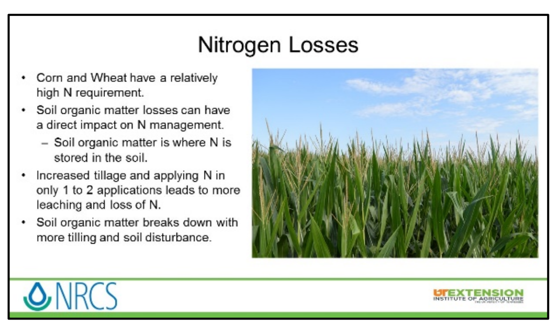
Cover crops can increase the nitrogen in the soil. Legumes can be used to fix nitrogen in the soil. Also, soil organic matter influences leaching and denitrification. Of course, yield potential is directly impacted by the availability of nitrogen to the plant.



Slide 14

Slide 15

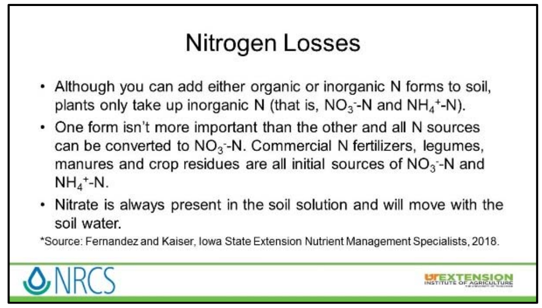
Nitrogen loss can be managed by altering production practices. Conservation tillage practices such as no-till and use of cover crops can reduce nitrogen loss. Since organic matter is one place where N in the soil is housed, any production practice that can increase soil organic matter can partially reduce N loss.



Slide 15

Slide 16

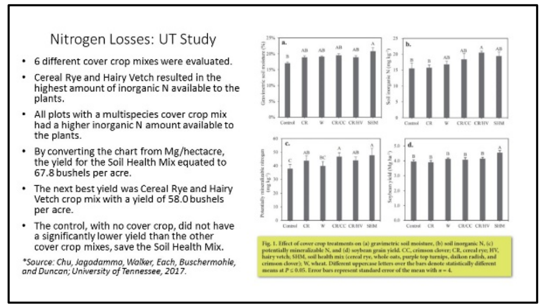
Follow material on presentation slide.



Slide 16

Slide 17

A study conducted by the University of Tennessee compared different cover crop mixes to determine which had a higher amount of N available to plants. The study showed that the multispecies cover crop mix provided more inorganic N to the soybeans. Also, the multispecies cover crop mixes increased yields in the soybean trials in comparison to the single species cover crops.

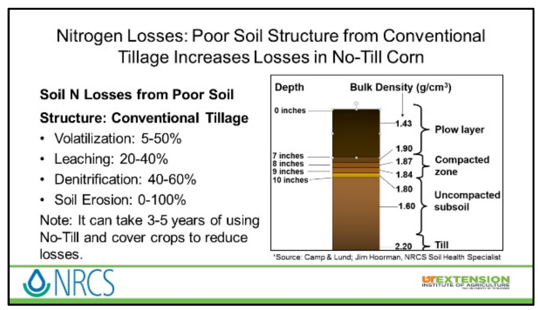


Slide 17

Slide 18

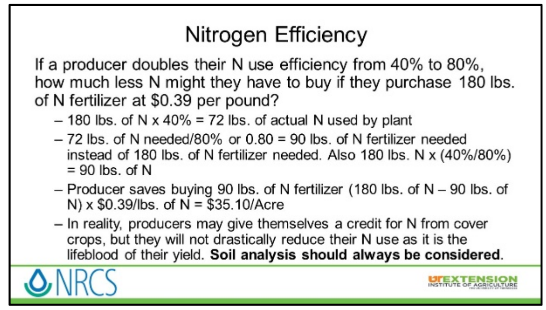
When farmers convert to no-till from conventional tillage, did they start with good soil structure? Do they still have soil compaction problems?

Generally the answer is yes, they have multiple problems in the soil, especially with poor soil structure. Due to poor soil structure, water runs off due to poor water infiltration and a lack of SOM. This causes soil erosion, a huge loss in SOM (floats with the water), and a large N investment (1000# for every 1% SOM). Due to poor soil structure, denitrification losses of N can be 40-60% due to standing water and the loss of N to the atmosphere. In sandy soils without much SOM, leaching losses can be 20-40%. On the soil surface, volatilization losses can be 5 to 50% because there is no residue to cool the soil and no residue on the soil surface initially to absorb and tie up N in the soil profile. It may take 3 to 5 years to improve soil structure with NT and cover crops before these losses are reduced. Our N efficiency in conventional tilled soils is only 30 to 40%. (Source: NRCS, Economic Benefits of Soil Health)



Slide 18

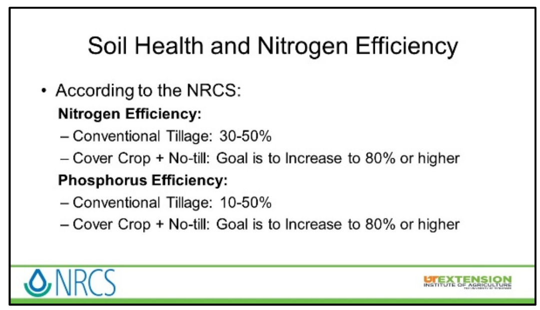
Slide 19



Slide 19

As mentioned earlier, one goal of cover crops is to increase the amount of soil organic matter in the soil. With more organic matter in the soil, nitrogen efficiency is purported to increase. In this example, if we increase nitrogen efficiency from 40% to 80%, doubling the amount of nitrogen being utilized, the producer can save 50% on their nitrogen costs and reduce the amount of applied N by 90 pounds per acre. By valuing nitrogen at $0.39 per elemental pound, we show a total savings of $35.10 per acre.

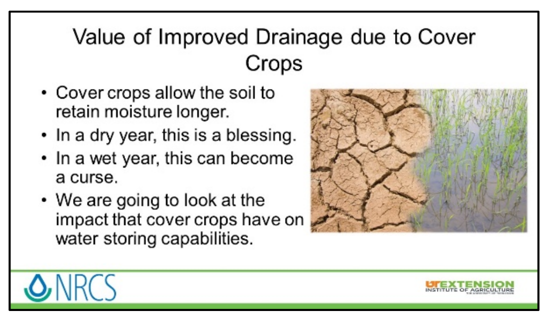
Slide 20



Slide 20

Nitrogen efficiency is drastically reduced when conventional tillage practices are used. Producers are encouraged to use a no-till system and utilize a cover crop that increases the amount of organic matter found in the soil. Also, phosphorus efficiency is impacted by tillage practices and organic matter levels. Therefore, it is important to consider tillage practices, crop residue, and perform soil tests to know the nutrients present in the soil before making an application. You may be leaving money on the table by either over applying fertilizer or not adopting cover crops.

Slide 21

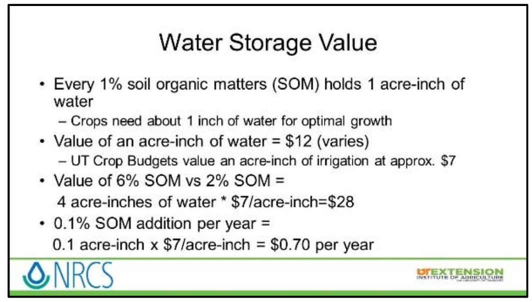


Slide 21

Soil drainage impacts the movement of nutrients through the soil. Soils that do not drain properly tend to have a negative impact on production. A producer can do a few things to address drainage such as installing tile or delaying planting during wet months. However, our focus is on how cover crops can be used to improve drainage. The benefit of cover crops will vary from a dry year to a wet year. In a wet year, cover crops can provide an added challenge. Like most things in agriculture, the benefit of a production practice or product choice depends on growing conditions, which makes results very, very subjective. But, we do want to look at the benefits of cover crops in regard to water storing capabilities.

Slide 22

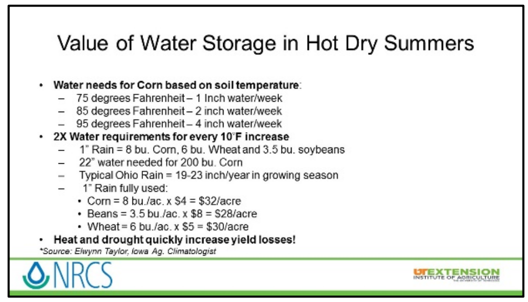
With higher amounts of soil organic matter, we tend to see an increase in water retention. The increase in soil organic matter will aid in keeping more moisture in the soil longer. This example shows the savings from not having to irrigate as much. Of course, these costs savings only hold water if we are talking about irrigated land. Yes, the pun was intentional.



Slide 22

Slide 23

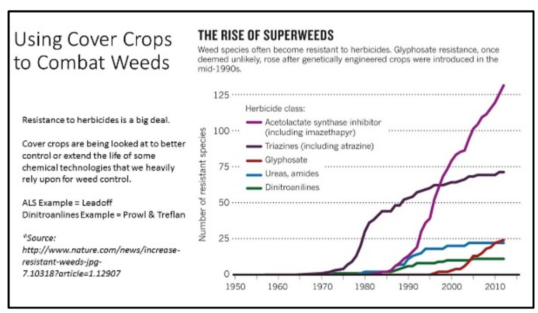
The water needs for crops are affected by temperature. As the temperature rises, the amount of water needed increases as well. The water needed essentially doubles for every 10 degree increase in temperature once the temperature hits 75°F. In this example, we can see that 22" of water is needed to produce a 200 bu. corn crop. By using the assumption that 1" rain increases corn yields by 8 bushels, the value of a fully utilized inch of rain is $8 per acre, assuming a price of $4 per bushel. If we use the same methodology on the soybean and wheat example, we show that the decrease in stress on the plant equate to a savings of $28 per acre for soybean and $30 per acre for wheat.



Slide 23

Slide 24

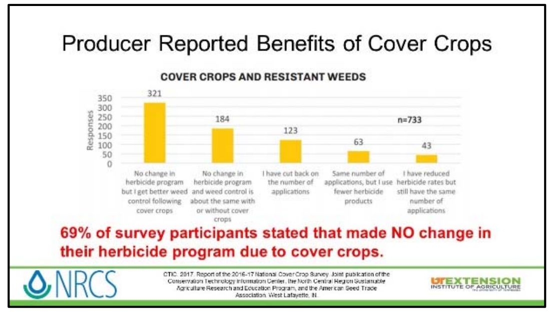
Cover crops can also be used to combat weeds. The increase in weed resistance has led us to become reliant upon only a few families of herbicides. As we increase the reliance upon only a select few chemistries, we increase the chance of creating a level of resistance that we cannot overcome with a solution poured from a jug. This chart shows how some species of plants have become resistant to common classes of herbicides. The number continues to increase. Cover crops are being looked at to try to be part of the solution to controlling resistant weeds.



Slide 24

Slide 25

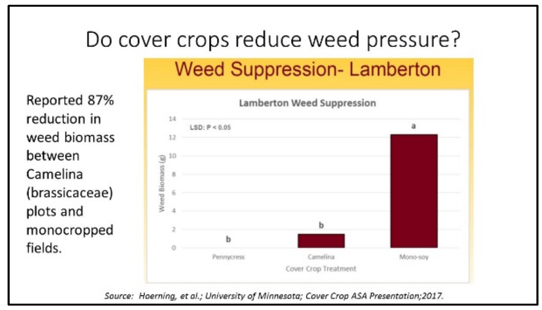
I would like to reference the 2016-2017 National Cover Crop Survey again. The question was posed to the farmers that participated in the survey whether cover crops had changed their herbicide program. 43.7% of the respondents said that there has been no change in their program but that they have better weed control following cover crops. 25.1% of respondents reported that there was no change in their herbicide program and that weed pressure was unchanged following cover crops. 31.2% of respondents did state that their total use of herbicides was reduced in some manner.



Slide 25

Slide 26

The University of Minnesota conducted research between two different locations. In each of the locations, a field of soybeans, planted in a monocrop, were compared to a field planted with either Pennycress or Camelina, which are a harvestable oilseeds. The plots with the Camelina had less weed biomass in comparison to the monocropped soybeans.

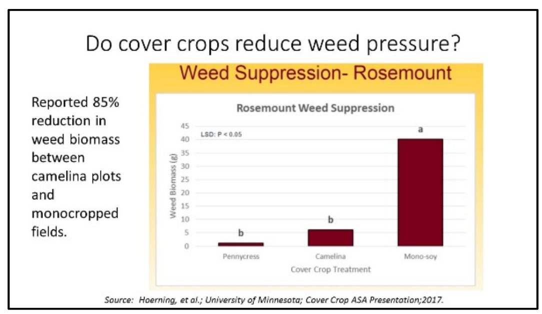


Slide 26

Location #1 Results.

Slide 27

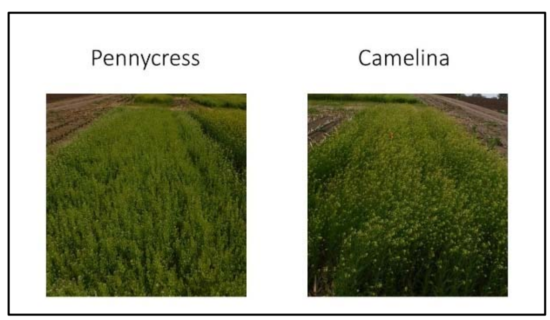
Location #2 results from the University of Minnesota field study.



Slide 27

Slide 28

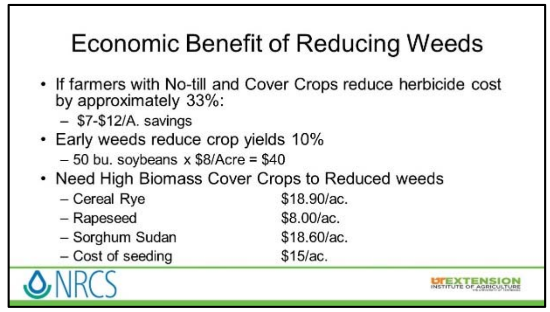
Images of cover crops used in the previous two slides. Pennycress on left and Camelina on the right are both an oilseed grown in colder climates such as MN and Canada.



Slide 28

Slide 29

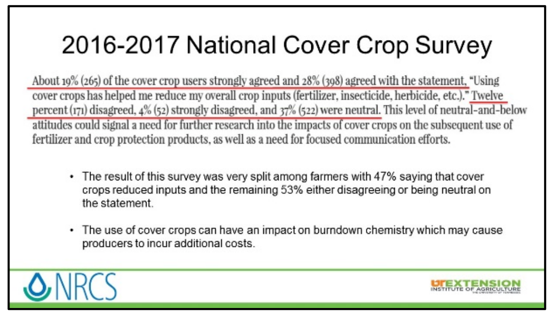
Let's look at an example of the economic benefit of reducing weeds. The NRCS suggests that with the use of no-till and cover crops that herbicide use can be reduced by 33% (Source: NRCS, Economics Benefits of Improved Soil Function), which results in an average savings of $7-$12 per acre. They also show that early weeds can reduce crop yields by 10%, which directly impacts a farmer's overall profitability. In order to reduce weeds, a high biomass cover crop needs to be planted.



Slide 29

Slide 30

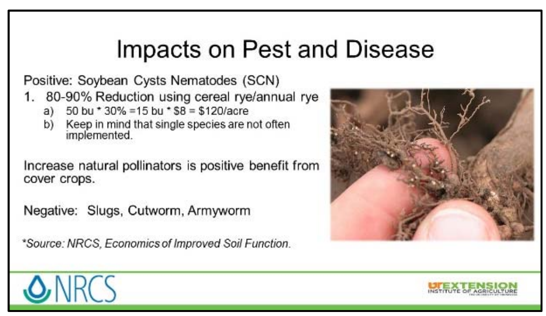
A relevant quote from the narrative of the 2017 National Cover Crop Survey.



Slide 30

Slide 31

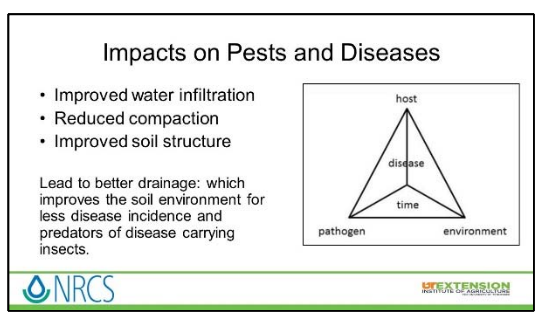
Example of the impact cover crops have on pests and diseases. The reduction in pests such as the soybean cyst nematode has a positive impact on yield. The presence of cover crops does attract additional pests such as vole, slugs, and other insects. These added pests can come with added costs and reduced yields, but the issues will likely vary from field to field.



Slide 31

Slide 32

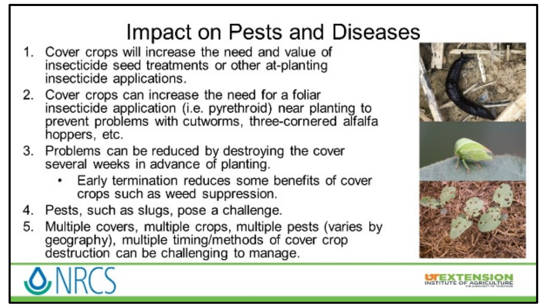
Cover crops help to improve water infiltration, reduce compaction, and improve soil structure. All of which lead to better drainage which can create an environment that is habituated by predators that remove harmful diseases.



Slide 32

Slide 33

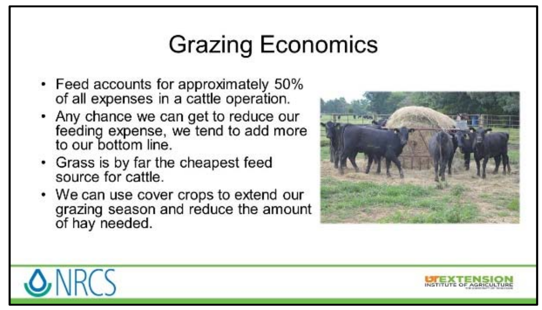
A few things to consider when using cover crops. The impact on pests and diseases can be very beneficial, but can as easily be problematic. Comments were gathered from input provided by Dr. Scott Stewart, University of Tennessee, IPM Coordinator and Professor Entomology and Plant Pathology.



Slide 33

Slide 34

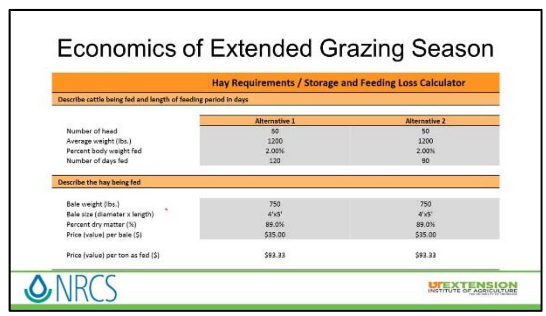
Cover crops can also be used to graze. This helps to reduce feed costs for producers. Grass is the cheapest feed source for livestock. Therefore, any extension of the grazing season will lower the overall feed bill for the herd.



Slide 34

Slide 35

Example of the impact of a longer grazing season. The above example is taken from the UT Extension Hay Calculator. We assume that the use of cover crops reduces the producer's hay requirements by 25%, or 30 days.

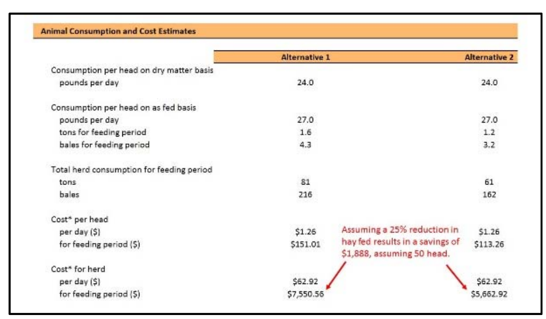


Hay Requirements / Storage and Feeding Loss Calculator		
Describe cattle being fed and length of feeding period in days		
	Alternative 1	Alternative 2
Number of head	50	50
Average weight (lbs.)	1200	1200
Percent body weight fed	2.00%	2.00%
Number of days fed	120	90
Describe the hay being fed		
Bale weight (lbs.)	750	750
Bale size (diameter x length)	4'x5'	4'x5'
Percent dry matter (%)	89.0%	89.0%
Price (value) per bale ($)	$35.00	$35.00
Price (value) per ton as fed ($)	$93.33	$93.33

Slide 35

Slide 36

The total savings from having a longer grazing season is $1,888 (25% savings).



Animal Consumption and Cost Estimates		
	Alternative 1	Alternative 2
Consumption per head on dry matter basis		
pounds per day	24.0	24.0
Consumption per head on as fed basis		
pounds per day	27.0	27.0
tons for feeding period	1.6	1.2
bales for feeding period	4.3	3.2
Total herd consumption for feeding period		
tons	81	61
bales	216	162
Cost* per head		
per day ($)	$1.26	$1.26
for feeding period ($)	$151.01	$113.26
Cost* for herd		
per day ($)	$62.92	$62.92
for feeding period ($)	$7,550.56	$5,662.92

Slide 36

Slide 37

Total cost of a cover crop mix planted before corn was $49,

Cost of fence and water was $120.69/acre

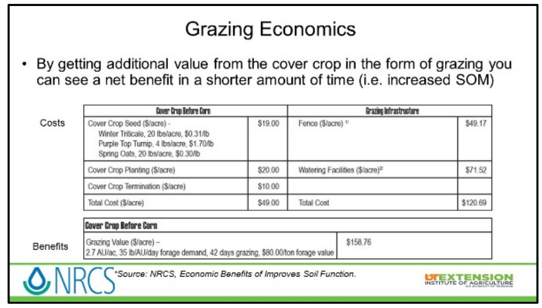
Benefit of grazing

Cover crop produced approx. 4,000 lbs. of forage

Allowed 2.7 AU/acre to be grazed for 42 days

To have purchased this forage would have cost $80/ton total $158.76

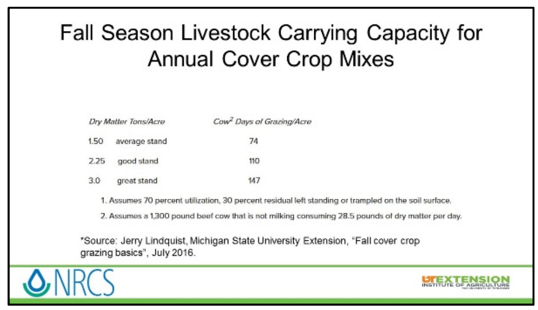
This doesn't include the value of the nutrients returned through the cows



Slide 37

Slide 38

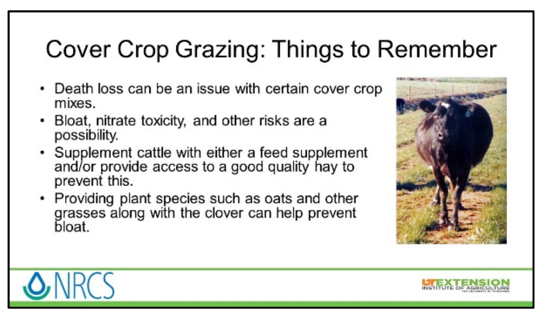
This information comes from Michigan State University Extension. Their study shows that a good stand of cover crops can be an excellent source of grazing. The better the stand of grass results in a longer period of grazing. With a good stand, the cows had an average grazing time of 110 days. In this study, cover crops could potentially replace the need for hay as the primary feed source in winter months.



Slide 38

Slide 39

Cover crops present some challenges that cattle producers need to keep in mind. Address all of the bullet points to show they can impact the health of the herd.



Slide 39

Slide 40

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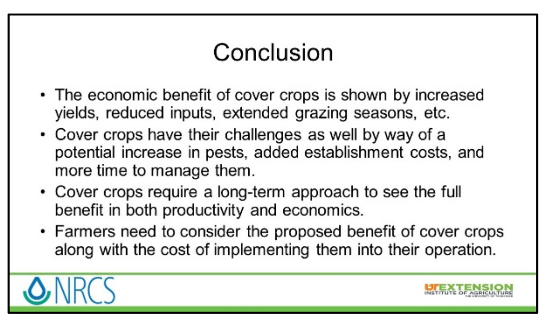
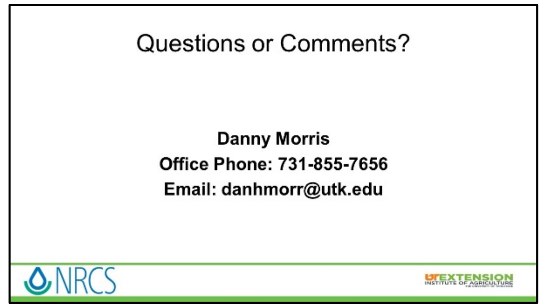


Slide 40

Slide 41

For more information, contact Danny Morris, UT Area Farm Management Specialist



Slide 41

Test their Knowledge - Questions for the audience

Q: What is the estimated cost of erosion?
A: $20-25/acre/year

The estimated value of the nutrients present in 1% organic matter is _474_ $/acre.

According to a study by Michigan State University, for every 1% increase in organic matter, there was a _12%_ increase in yield of corn and soybean.

Q: On the soil surface, how much nitrogen can be lost under conventional tillage due to volatilization?
A: 5-50%

Every 1% organic matter can hold about _1_ acre-inch of water.

Q: How do cover crops help reduce the potential for plant disease?
A: They reduce the potential for saturated soils by increasing water infiltration, reducing compaction, and improving soil structure. Some cover crops can even promote predators that consume certain disease organisms.

Q: How can you control the potential for insect problems when using cover crops once cover crops have been planted?
A: Apply foliar insecticides at planting (cash crop) or terminate cover crops several weeks before planting.

Q: If a producer is able to graze an extra 30 days using cover crops, what will their savings be?
A: 25%

Soil Health Evaluation

Name of Activity: Economic benefits of improving 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 economic impacts of erosion*	①	②	③	④	⑤	①	②	③	④	⑤
2. *The economic impacts of soil organic matter*	①	②	③	④	⑤	①	②	③	④	⑤
3. *The effect of good soil management on nitrogen efficiency*	①	②	③	④	⑤	①	②	③	④	⑤
4. *The impacts cover crops can have on grazing economics*	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!

MODULE 8. FINANCIAL BENEFITS OF COVER CROPS

Learning objectives:

Participants will be able to:

- Describe cover crop establishment costs.
- Utilize the USDA Cover Crop Economics Decision Support Tool
- Identify financial assistance for farmers planting cover crops

Materials:

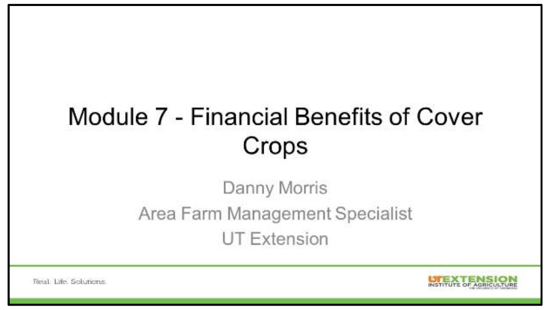
- PowerPoint® slides "Module 8: Financial benefits of cover crops"
- Lesson guide: Use the notes in this lesson guide to present information for each presentation slide.
- Questions found at the end of this lesson guide can be used to test participants' knowledge at the end of the presentation. This 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:

USDA Cover Crop Economics Decision Support Tool
Costs related to cover crops
Direct nutrient credit
Pesticide reduction
Yield increase
Erosion reduction
Additional benefits
Financial assistance

Slide 1

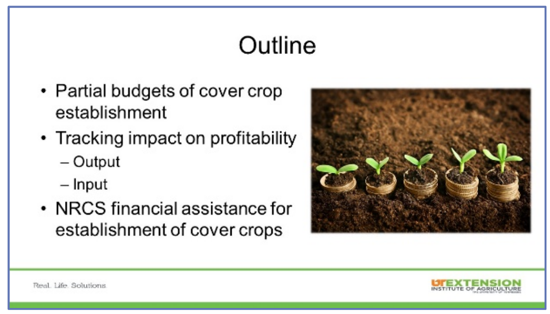
This module covers the financial benefits of cover crops.



Slide 1

Slide 2

This is an outline of the different topics that will be discussed within this module.



Slide 2

Slide 3

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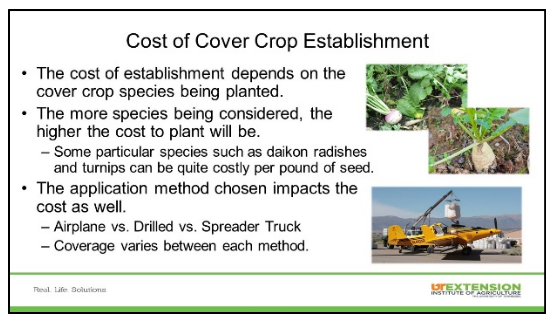

Slide 3

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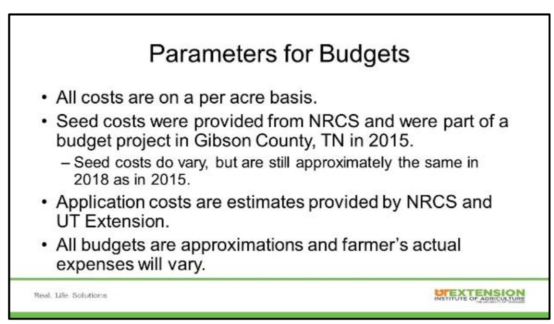
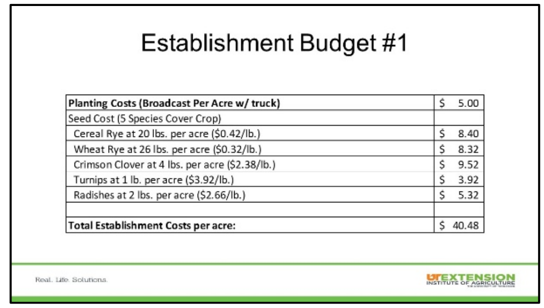


Slide 4

Slide 5

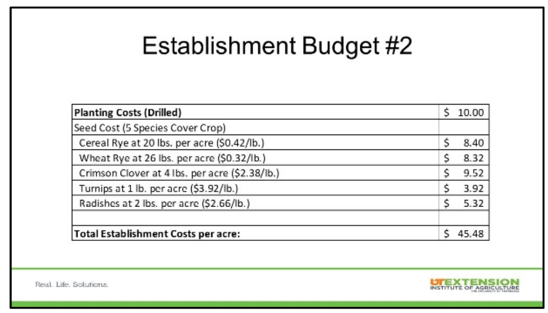
The largest difference between budgets will be the cost of application. On these first few slides, the species being planted will be the 5-way species. The only difference will be the application method. Each of the application methods has its own benefits and drawbacks.



Slide 5

Slide 6

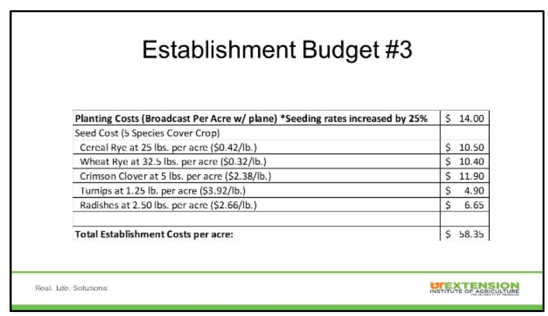
The only difference between Budget #1 and Budget #2 is the seeding method. The difference between drilling and using a spreader truck is estimated to be $5.00 per acre. Another difference in production will be the stand coverage of the cover crop. The stand coverage from drilling tends to be better than simply broadcasting in crops such as wheat. However, the variance in seed sizes can be an issue with drilling. Producers will need to keep this in mind when drilling multispecies cover crops.



Slide 6

Slide 7

Again, the primary difference between establishment budgets is the seeding cost. However, with an airplane application, farmers have to increase seeding rates by roughly 25% to receive the same stand from either drilling or broadcasting with a truck. With the added cost of the plane, which can vary between $9-$14 per acre, and the increase in seeding rates, the choice to fly on a 5 species cover crop is $23-$28 higher than the other options.



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Slide 8

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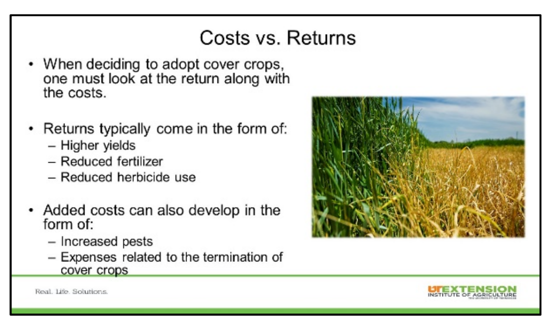

Slide 8

Slide 9

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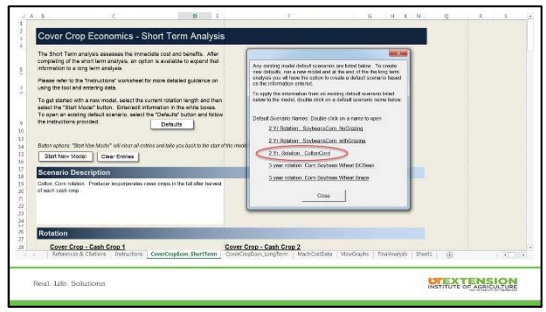
Slide 9

Slide 10

We are going to look at the impact of cover crops on a corn and cotton rotation. Given where corn and cotton prices are, this rotation will likely be widespread across West Tennessee in 2019.



Slide 10

Slide 11

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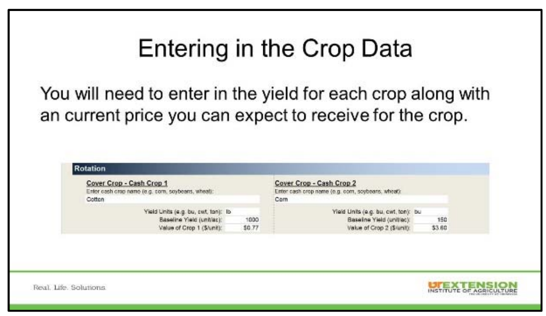
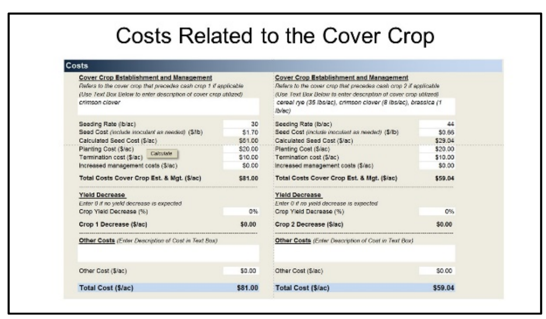


Slide 11

Slide 12

This is an example of the total cost of a cover crop system over 2 years. The first year cover crop is crimson clover, which was planted before a cotton crop. Costs include all establishment expenses at the required rate. The right column shows a three species cover crop mix of cereal rye, crimson clover, and brassica. The three species mix was planted in the fall prior to planting a corn crop.



Slide 12

Slide 13

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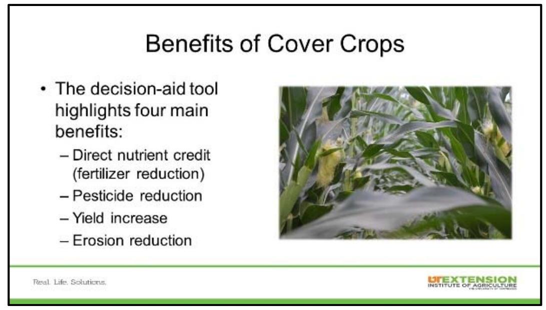

Slide 13

Slide 14

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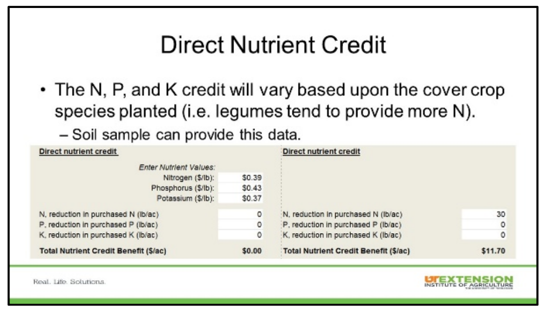
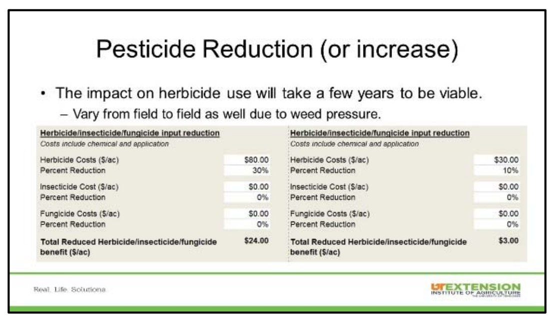


Slide 14

Slide 15

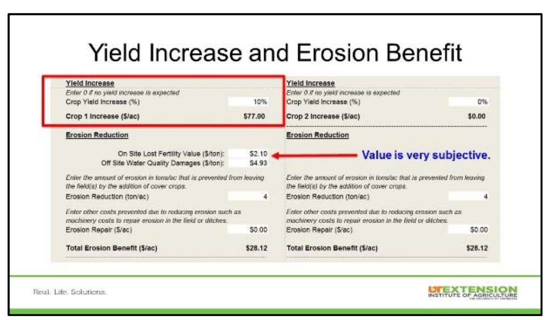
The next section of the calculator is the influence on pesticides. You may find that your use of herbicides is reduced in a few years due to the cover crops providing a window of opportunity to suppress weeds. However, in some years and in some fields with extremely high weed populations, you may see that cover crops increase your herbicide use due to termination of the crop and persistent weeds.



Slide 15

Slide 16

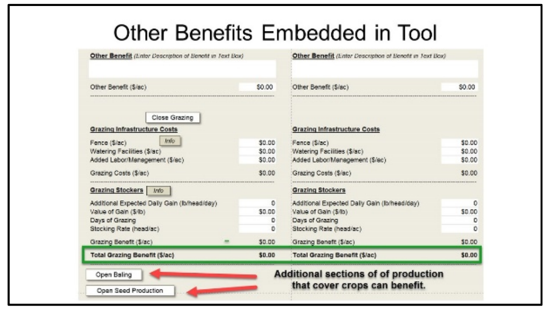
The stated yield increase should be based on your actual production records. The yield increase brings in the stated price that you input at the top of the spreadsheet. Also, keep in mind, that the value for soil loss is very subjective based on the price you place on the soil.



Slide 16

Slide 17

You can also use the grazing, baling, and seed production section to add the additional benefits provided from using cover crops. Some producers that graze the cover crops would benefit from adding in the expense of fencing off the areas being grazed, installing waterers, and any increase in labor expenses. However, the added poundage from feeding the cover crops needs to be accounted for as well.

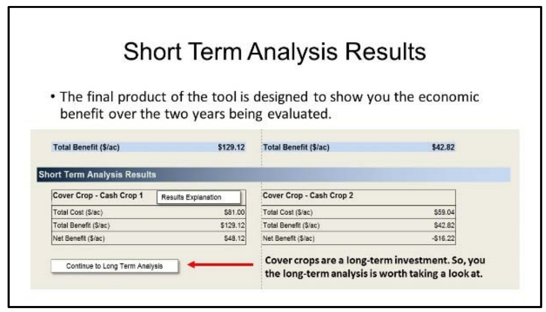


Slide 17

If a farmer is baling or raising cover crop seed, there are sections for that as well built into the spreadsheet.

Slide 18

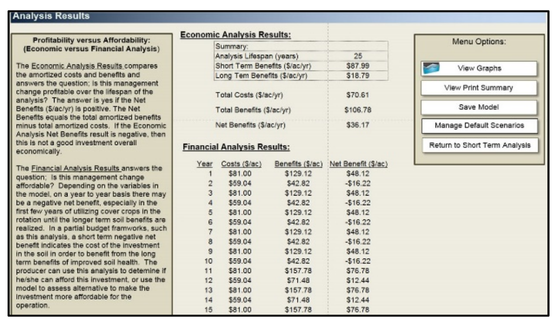
The short term analysis results provide the most immediate economic benefit of using cover crops. This information is sufficient to make a planting decision. However, many adopters of cover crops are in it for the long haul. So, the long-term analysis is worth looking at.



Slide 18

Slide 19

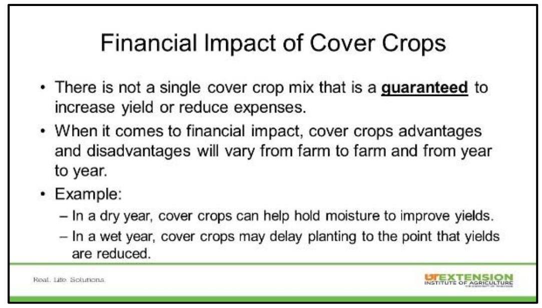
The economic analysis shows the results in the short term and long term. Also, the financial analysis shows the results of the cover crops by year. You can look at multiple years to track the long term impacts of cover crops over a long period of time, up to 50 years. In this example, I have only entered in two years of data and the model shows that 2 year crop rotation repeating every other year.



Slide 19

Slide 20

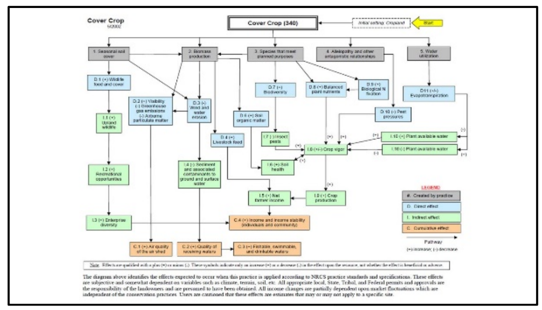
Follow material on presentation slide.



Slide 20

Slide 21

This chart shows the complexity of cover crops. This is shown to highlight the many factors that go into evaluating cover crops and why it can be hard to determine financial impact.



Slide 21

Slide 22

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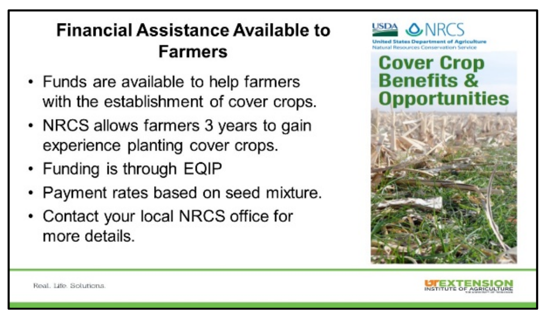
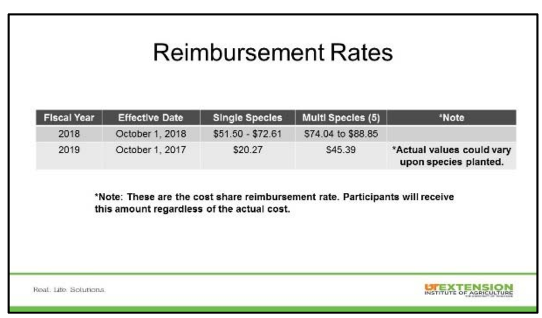


Slide 22

Slide 23

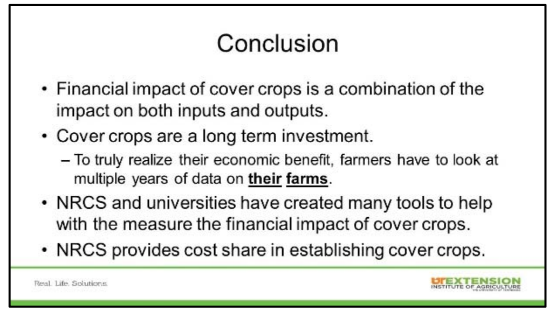
This is the cost share reimbursement rate. Participants will receive this amount regardless of the actual cost. Farmers should contact their local NRCS office for the latest information regarding funding for cover crop cost share.



Slide 23

Slide 24

Follow material on presentation slide.



Slide 24

Slide 25

For more information, contact Danny Morris, UT Area Farm Management Specialist.

Slide 25

Test their Knowledge - Questions for the audience

Cover crop establishment costs are largely based on _the species planted_ and _the method of establishment__.

Q: What financial returns might be expected from using cover crops?
A: Higher yields, reduced fertilizer application, reduced herbicide use, erosion reduction

Q: What tool can be used to determine the costs and benefits of using cover crops?
A: The Cover Crop Economics Decision Support Tool by the USDA/NRCS

Q: How long does the NRCS offer cost share funding for cover crop establishment?
A: 3 years

Q: What NRCS program offers cost share funding for cover crop establishment?
A: EQIP

Soil Health Evaluation

Name of Activity: Financial benefits of cover crops	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 USDA/NRCS Cover Crop Economics Decision Support Tool*	①	②	③	④	⑤	①	②	③	④	⑤
2. How to calculate financial costs and returns from cover crops	①	②	③	④	⑤	①	②	③	④	⑤
3. USDA/NRCS cost share available for cover crop establishment	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!

Appendix

Cover Crop 340 Practice Standard (NRCS)

Cover Crop 340 Requirements in Tennessee (NRCS)

Cover Crop Tips (NRCS)

Earthworm Test (NRCS)

Electrical Conductivity (EC) Test (NRCS)

Infiltration Test (NRCS)

pH Test (NRCS)

Soil Physical Observations and Estimations (NRCS)

Tennessee Soil Health Score Card (NRCS)

Indicator Plants

Some Options for Mitigating Resource Concerns

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

COVER CROP

Code 340

(Ac)

DEFINITION

Grasses, legumes, and forbs planted for seasonal vegetative cover.

PURPOSE

This practice is applied to support general criteria and one or more of the following purposes:

- Reduce erosion from wind and water.
- Maintain or increase soil health and organic matter content.
- Reduce water quality degradation by utilizing excessive soil nutrients.
- Suppress excessive weed pressures and break pest cycles.
- Improve soil moisture use efficiency.
- Minimize soil compaction.

CONDITIONS WHERE PRACTICE APPLIES

All lands requiring seasonal vegetative cover for natural resource protection or improvement.

CRITERIA

General Criteria Applicable to All Purposes

Plant species, seedbed preparation, seeding rates, seeding dates, seeding depths, fertility requirements, and planting methods will be consistent with applicable local criteria and soil/site conditions. (See Appendix – Table 1, Recommended Cover Crop Mixes or refer to SARE's publication:

http://www.sare.org/Learning-Center/Books/Managing-Cover-Crops-Profitably-3rd-Edition.)

Select species that are compatible with other components of the cropping system.

Ensure herbicides used with crops are compatible with cover crop selections and purpose(s).

Cover crops may be established between successive production crops, or companion-planted or relay-planted into production crops. Select species and planting dates that will not compete with the production crop yield or harvest.

Do not burn cover crop residue.

Determine the method and timing of termination to meet the grower's objective and the current NRCS Cover Crop Termination Guidelines.

When a cover crop will be grazed or hayed, ensure that crop selection(s) comply with pesticide label rotational crop restrictions and that the planned management will not compromise the selected conservation purpose(s).

When grazing cover crops, the combined canopy and surface residue will be 90% or greater at all times. The cover crop should reach a minimum height of 10 inches before grazing and grazed no lower than 5 inches. An area must be provided to remove livestock from the cover crop when the cover crop is vulnerable to overgrazing or excessive trampling. The area must be a pasture or a designated sacrifice area away from sensitive areas. See the livestock feeding assessment tool in the TN Graze program to size and site the sacrifice area.

Cover crops will not be managed as a harvested crop.

If the specific rhizobium bacteria for the selected legume are not present in the soil, treat the seed with the appropriate inoculum at the time of planting.

The cover crop will be a minimum of 10" tall or have a biomass of 3000 lb. (300 lb. /ac. In.) at termination.

Additional Criteria to Reduce Erosion from Wind and Water

Time the cover crop establishment in conjunction with other practices to adequately protect the soil during the critical erosion period(s).

Select cover crops that will have the physical characteristics necessary to provide adequate erosion protection.

Use the current NRCS-approved erosion prediction technology to determine the amount of surface and/or canopy cover needed from the cover crop to achieve the erosion objective.

Combined canopy and surface residue cover will be 90 percent or greater during the period of potentially erosive wind or rainfall.

Additional Criteria to Maintain or Increase Soil Health and Organic Matter Content

Cover crop species will be selected on the basis of producing higher volumes of organic material and root mass to maintain or increase soil organic matter. Plant mixtures of legumes with grasses, crucifers, and/or other forbs. A minimum of 5 species will be planted with a total seeding rate of 100% or higher of the full rate. The full seeding rate in the mix should include (1) 10% or more of small grains and legume species components; (2) 5 to 15% brassica or crucifers (for cotton, no brassicas other than optional radish); and, (3) no more than 1.5 lbs. of brassicas are recommended in any mix. If planting after October 1, do not plant radish in the mix.

Species that will terminate by frost or heat (e.g. buckwheat) can make up to 20% of the total seeding rate for the mix.

Cover crops and the following cash crop will be planted no-till. EXCEPTION: Cash crops that have not been traditionally planted no-till (ONLY tobacco, green beans and vegetable crops) may be strip tilled at planting when meeting a STIR value of $\leq$ 20 for each crop in the rotation.

Target a C:N ratio prior to a high residue crop of 30:1 or less.

Target a C:N ratio prior to a low residue crop of 31:1 or higher.

C:N ratio effects nutrient cycling and soil residue cover. If the residue covering the soil is lacking, increase the C:N ratio by increasing the grass component and terminating the cover crop later. If residue is building up, lower C:N ratio by increasing the legume and or brassicas and terminate earlier.

Full width soil tillage is not permitted for any crop.

The planned crop rotation including the cover crop and associated management activities will score a Soil Conditioning Index (SCI) value > 0, as determined using the current approved NRCS Soil Conditioning

Index (SCI) procedure, with appropriate adjustments for additions to and or subtractions from plant biomass.

The cover crop shall be planted as early as possible and be terminated as late as practical for the producer's cropping system to maximize plant biomass production, considering crop insurance criteria, the time needed to prepare the field for planting the next crop, and soil moisture depletion.

Additional Criteria Reduce Water Quality Degradation by Utilizing Excessive Soil Nutrients

Establish cover crops as soon as practical prior to or after harvest of the production crop. (i.e. before or after harvest)

Select cover crop species for their ability to effectively utilize nutrients.

Terminate the cover crop as late as practical to maximize plant biomass production and nutrient uptake. Practical considerations for termination date may include crop insurance criteria, the amount of time needed to prepare the field for planting the next crop, weather conditions, and cover crop effects on soil moisture and nutrient availability to the following crop.

If the cover crop will be harvested for feed (hay/balage/etc.), choose species that are suitable for the planned livestock, and capable of removing the excess nutrients present. When a cover crop will be grazed or hayed, ensure that crop selection(s) comply with pesticide label rotational crop restrictions and that the planned management will not compromise the selected conservation purpose(s).

Additional Criteria to Suppress Excessive Weed Pressures and Break Pest Cycles

Select cover crop species for their life cycles, growth habits, and other biological, chemical and or physical characteristics to provide one or more of the following:

- To suppress weeds, or compete with weeds.
- Break pest life cycles or suppress of plant pests or pathogens.
- Provide food or habitat for natural enemies of pests.
- Release compounds such as glucosinolates (brassicas) that suppress soil borne pathogens or pests.

Select cover crop species that do not harbor pests or diseases of subsequent crops in the rotation.

Additional Criteria to Improve Soil Moisture Use Efficiency

In areas of limited soil moisture, terminate growth of the cover crop sufficiently early to conserve soil moisture for the subsequent crop. Cover crops established for moisture conservation shall be left on the soil surface.

In areas of potential excess soil moisture, allow the cover crop to grow as long as possible to maximize soil moisture removal.

Additional Criteria to Minimize Soil Compaction

Select cover crop species that have the ability to root deeply and the capacity to penetrate or prevent compacted layers. A mixture of fibrous roots (e.g. grass) and tap roots (e.g. radish, turnip, clover) improve soil structure.

CONSIDERATIONS

Plant cover crops in a timely matter and when there is adequate moisture to establish a good stand.

When applicable, ensure cover crops are managed and are compatible with the client's crop insurance criteria.

Maintain an actively growing cover crop as late as feasible to maximize plant growth, allowing time to prepare the field for the next crop and to optimize soil moisture.

Select cover crops that are compatible with the production system, well adapted to the region's climate and soils, and resistant to prevalent pests, weeds, and diseases. Avoid cover crop species that harbor or carry over potentially damaging diseases or insects.

To improve fertility for the cover crop, phosphorus, potassium and lime can be applied to the cover crop for the following cash crop. Use Land Grant University's recommended nitrogen credits from the legume and reduce nitrogen applications to the subsequent crop accordingly. "Reduce N rate by 60 to 80 pounds per acre following a well-established single-species winter cover crop of crimson clover or hairy vetch that has reached early bloom stage." This will apply for all mixes that are 75% or more legume. For all others cover crop mixes, do not reduce N rate unless biomass is analyzed for N credit value.

Cover crops may be used to improve site conditions for establishment of perennial species.

When cover crops are used for grazing, select species that will have desired forage traits, be palatable to livestock, and not interfere with the production of the subsequent crop.

Use plant species that enhance forage opportunities for pollinators by using diverse legumes and other forbs.

Cover crops may be selected to provide food or habitat for natural enemies of production crop pests.

Cover crops residues should be left on the soil surface to maximize allelopathic (chemical) and mulching (physical) effects.

Seed a higher density cover crop stand to promote rapid canopy closure and greater weed suppression. Increased seeding rates (1.5 to 2 times normal) can improve weed-competitiveness.

Cover crops may be selected that release biofumigation compounds that inhibit soil-borne plant pests and pathogens.

Species can be selected to serve as trap crops to divert pests from production crops.

Select a mixture of two or more cover crop species from different plant families to achieve one or more of the following: (1) species mix with different maturity dates, (2) attract beneficial insects, (3) attract pollinators, (4) increase soil biological diversity, (5) serve as a trap crop for insect pests, or (6) provide food and cover for wildlife habitat management.

Plant legumes or mixtures of legumes with grasses, crucifers, and/or other forbs to achieve biological nitrogen fixation. Select cover crop species or mixture, and timing and method of termination that will maximize efficiency of nitrogen utilization by the following crop, considering soil type and conditions, season and weather conditions, cropping system, C:N ratio of the cover crop at termination, and anticipated nitrogen needs and residue cover for the subsequent crop.

Time the termination of cover crops to meet nutrient release goals. Termination at early vegetative stages may cause a more rapid release compared to termination at a more mature stage.

Legumes add the most plant-available N if terminated when about 30% of the crop is in bloom.

Both residue decomposition rates and soil fertility can affect nutrient availability following termination of cover crops

Allelopathic effects to the subsequent crop should be evaluated when selecting the appropriate cover crop.

For nursery production, grass cover crops may be used as opposed to legumes since grass cover crops do not build up as much damping-off fungi as legume crops.

Do not plant high biomass cover on soils that are somewhat poorly drained or wetter, unless planting can be delayed allowing the cover crop to wick out moisture. High biomass cover can be planted when soil temperatures are optimum and soils are not wet. Good slot closure is important.

Do not harvest cover crops for seed other than that needed to seed the following year's cover crop.

CAUTION:
Brassicas are not recommended in a cover crop mix prior to cotton because of the sensitivity of the cotton seedlings.

Austrian winter peas can cause issues when planting cotton. A mid-morning soil temperature of 68°F at proper planting depth for three consecutive days and a favorable five-day forecast following the planting of cotton are best.

Slugs can be an issue in soybean fields when climatic conditions are cool, overcast and wet. When heavy residue is present, delay planting until growing conditions are good. Soybeans will germinate at 55 °F but ideal soil temperature is 77 °F.

Additional Considerations to Reduce Water Quality Degradation by Utilizing Excessive Soil Nutrients

Use deep-rooted species to maximize nutrient recovery.

When appropriate for the crop production system, mowing certain grass cover crops (e.g., sorghum-sudangrass, pearl millet) prior to heading and allowing the cover crop to regrow can enhance rooting depth and density, thereby increasing their subsoiling and nutrient-recycling efficacy.

Additional Considerations to Increase Soil Health and Organic Matter Content

Aerial seeding is a no-till planting method. Consider aerial seeding only during moist conditions when rain is forecasted.

Consider leaving brassicas out of the cover crop mix every other year.

For optimum soil health benefits, land managers are strongly encouraged to only graze the cover crops just prior to termination.

Rotating species in the cover crop mix can improve diversity.

Increase the diversity of cover crops (e.g., mixtures of several plant species) to promote a wider diversity of soil organisms, and thereby promote increased soil organic matter.

Plant legumes or mixtures of legumes with grasses, crucifers, and/or other forbs to provide nitrogen through biological nitrogen fixation.

Legumes add the most plant-available N if terminated when about 30% of the crop is in bloom.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for each field or treatment unit according to the planning criteria and operation and maintenance requirements of this standard. Specifications shall describe the requirements to apply the practice to achieve the intended purpose for the practice site. Plans for the establishment of cover crops shall, as a minimum, include the following specification components in an approved Cover Crop, 340, Implementation Requirements document:

- Field number and acres
- Species of plant(s) to be established.
- Seeding rates.
- Seeding dates.
- Establishment procedure.
- Rates, timing, and forms of nutrient application (if needed).
- Dates and method to terminate the cover crop.
- Other information pertinent to establishing and managing the cover crop e.g., if haying or grazing is planned specify the planned management for haying or grazing.

OPERATION AND MAINTENANCE

Evaluate the cover crop to determine if the cover crop is meeting the planned purpose(s). If the cover crop is not meeting the purpose(s) adjust the management, change the species of cover crop, or choose a different technology.

REFERENCES

A. Clark (ed.). 2007. Managing cover crops profitably. 3rd ed. Sustainable Agriculture Network Handbook Series; bk 9.

Hargrove, W.L., ed. Cover crops for clean water. SWCS, 1991.

Magdoff, F. and H. van Es. Cover Crops. 2000. p. 87-96 *In* Building soils for better crops. 2nd ed. Sustainable Agriculture Network Handbook Series; bk 4. National Agriculture Library. Beltsville, MD.

Reeves, D.W. 1994. Cover crops and erosion. p. 125-172 *In* J.L. Hatfield and B.A. Stewart (eds.) Crops Residue Management. CRC Press, Boca Raton, FL.

NRCS Cover Crop Termination Guidelines:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/climatechange/?cid=stelprdb1077238

Revised Universal Soil Loss Equation Version 2 (RUSLE2) website:
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/rusle2/

Wind Erosion Prediction System (WEPS) website:
http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/weps/

USDA, Natural Resources Conservation Service, National Agronomy Manual, 4th Edition, Feb. 2011. Website: http://directives.sc.egov.usda.gov/ Under Manuals and Title 190.

APPENDIX

Table 1: Recommended Cover Crop Mixes

COVER CROP EXAMPLE MIXES:				
Multiple Species Cover Crop Mix (Cool Season planted prior to Soybeans)				
Crop Mixes	**Seeding Rate Lb./Ac[1]**		**Seeding Date**	**C:N ratio in Late Vegetative State[5]**
	Drilled	**Broadcast**		
Mix 1				
Cereal Rye	20	26	August 15 to October 15	31
Oats[2]	20	26		
Austrian Winter Peas	11	14		
Crimson Clover	4	5		
Radish	1	1		
Turnip	0.5	0.5		
or				
Mix 2				
Cereal Rye	20	26	August 15 to October 15	32
Wheat	15	20		
Crimson Clover	4	5		
Radish	1.5	1.5		
Hairy Vetch	4	5		
or				
Mix3				
Cereal Rye	28	36		35
Wheat	28	36		
Crimson Clover	4	5		
Radish	1	1		
Turnip	O.5	0.5		
Multiple Species Cover Crop Mix (Cool Season drilled only after double crop soybeans or cotton and up to 20% of land in full season soybeans.)				
Mix 4				
Cereal Rye	20	-	Drilled only up to November 1	33
Triticale	20	-		
Turnip	0.5	-		
Crimson Clover or Hairy Vetch	5	-		
Austrian Winter Peas[3]	13	-		
or				
Mix 5				
Black oats	20	-	Drilled only up to November 1	26
Barley	20	-		
Annual ryegrass[4]	10	-		
Crimson Clover or Hairy Vetch	5	-		
Turnip	0.5	-		
Basic Cover Crop Mix (Cool Season prior to Corn or Soybeans)				
Mix 6				
Cereal Rye	20	26	August 15 to October 15	30
Wheat	20	26		
Crimson Clover	5	7		
Austrian Winter Peas	14	18		
Radish	1	1		

Basic Cover Crop Mix (Cool Season prior to Corn)				
Mix 7				
Wheat	25	32	August 15 to October 15	25
Crimson Clover	5	7		
Austrian Winter Peas	14	18		
Hairy Vetch	5	7		
Radish	1	1		
Multiple Species Cover Crop Mix (Warm Season) Double crop soybean producers could plan a warm season cover crop to achieve 3 consecutive years of cover crops. This option is available to all producers.				
Mix 8				
Buckwheat (optional)	1	1	April 20 to July 1	21
Sunflowers (optional)	1	1		
Sudangrass	10	13		
Millet (any)	4	5		
Cowpeas	11	14		
Soybeans (optional)	11	14		
Turnips	1.5	1.5		
Sunhemp	5	7		
Multiple Species Cover Crop Mix (Self-Terminating) Must be approved by local District Conservationist.				
Mix 9				
Spring Oats	90	117	August 1 – Sept. 10	27
German Millet	20	26		
Spring Pea	15	20		
Radish	1.5	1.5		
Buckwheat	4	5		
Sunflower	2	3		

[1] If grazing is planned increase small grain seeding rate up to 100lb./ac.
[2] Black oats may be substituted for Winter Oats, although in the northern and high elevation areas black oats may freeze out in colder winters. Spring oats provide quick cover but may smother other species so rate should not be increased above 20 lb/ac.
[3] Austrian Winter Peas can be an issue to plant cotton into.
[4] Annual ryegrass, especially Italian ryegrass can be difficult to kill and if it goes to seed it could volunteer later. Best to use a variety with annual ryegrass to improve control of termination. Use a cold tolerant variety if planting late. Annual ryegrass is easier to control when it is terminated at 10”. Only recommended for producers with experience controlling it. Not recommended if you plan to grow wheat in the future.
[5] The Carbon: Nitrogen (C:N) ratio is recommended to be 30:1 or higher prior to low residue crops and below 30:1 prior to high residue crops.

- All mixes are only examples of mixes that can be used. Other mixes can be approved for use.
- Buckwheat and sunflower at a 1 lb/ac rate can be added to any mix as long as it is 30 or more days till the date of the average killing frost. These would add to diversity but at this rate they would not count as one of the five species in a mix
- Seed needs to meet the state seed law. It can be variety not stated (VNS), a Variety, certified seed or seed harvested from the producer’s farm. Ideal is to be a Variety due to uniformity, Branded seed can be VNS seed.
- Seeding rate can be increased on all species but be aware that early production species can shade and reduce the stand of slower growing species. E.g. radish and or turnip could reduce the stand of other species.
- Some producers have reported a corn yield drag after cereal rye. If it is a concern other small grains can be substituted. Most likely the issue is too much carbon in mixture causing a higher C:N ratio.
- Recommend not using brassicas preceding cotton and caution using Austrian winter peas prior to cotton.
- Brassicas are heavy feeders and caution needs to be taken when using them. Maintain good fertility for the following crop.
- Mixes can be developed using the “smart mix 5_20_17 KB slim version.xlsx” calculator. No more than 1.5 lb. of brassicas is typically recommended in a mixture. Turnip and more so rape (canola) can be difficult to kill.
- Mixes can be developed using the “smart mix 5_20_17 KB slim version.xlsx” calculator. No more than 1.5 lb. of brassicas is typically recommended in a mixture. Turnip and more so rape (canola) can be difficult to kill.

- Cover crop species that have worked well in suppressing herbicide resistant weeds such as palmer amaranth and horseweed (marestail) are cereal rye, annual ryegrass, rape and black oats. Sorghums, warm season annuals are also reported to have some allelopathic nature.
- Legumes are typically coated and pre-inoculated if not order fresh inoculant and inoculate seed at seeding.

Full Rates of Single Species (not a complete list)					
Plant Species	Peak Bloom Period	Seeding Rate lb./Ac		Seeding Date	Note
		Drilled	Broadcast		
Barley (CSA)	May	90	112	Aug. 15 to Nov. 1	Can be planted later than most cereals
Buckwheat (WSA)	21 days after planting	35	42	June 1 to Aug. 15	Quick warm season cover, can be added as 1 lb/ac to any mix between the last frost and 30 days prior to the first frost
Clover, Crimson (CSA) (ss)	Late April or May	17	21	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Tap root, late spring growth
Clover, Berseem (CSA) (ss)	June	11	14	Feb. 20 to Ap. 1	
Clover, Red (CSP) (ss)	July	8	10	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	
Cowpea	July	56	70	May 20 to June 20	High N producer
Millet, Browntop (WSA)	August	17	21	May 1 to July 1	Quick cover
Oats (CSA)	May	100	140	Sept. 1 to Oct. 1 Feb. 20 to Ap. 1	Spring oats can give quick cover in the fall but will winter kill and may smother other species. Black oats, not as cold tolerant as winter oats but may help weed control.
Phacelia	6 wks. after germ.	15	20	May 1 to June20	Good for beneficial organisms
Radish, forage (CSA)	-	8	10	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	May freeze out. 1.5 lb/ac is enough in a mix
Rye, cereal (CSA)	May	90	112	Aug. 15 to Nov. 1	Highest biomass, most cold tolerant, may increase weed control. Tolerant of somewhat poorly drained soils
Ryegrass, annual	June	20	30	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Can be invasive particularly in wheat. Deep rooted and tolerant of poorly drained soils
Sudangrass (WSA)	July	28	35	May 1 to June20	Deep strong roots, can help in weed control
Sunflower (WSA)	July-Aug.	9	11	April 15 to May 15	Can be added as 1 lb/ac in a mix as late as 40 days prior to first frost
Sunhemp (WSA)	-	20	25	May 1 to July 20	Need 60 days minimum growth, N producer
Sweet clover (CSB)	July	13	17	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Could be added as 1 lb/ac in a mix
Turnips (CSA)	-	3	4	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	No more than 1.5 lb/ac in a mix
Vetch, hairy (CSA)	May	22	28	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Can be invasive particularly in wheat, tolerant of low fertility and somewhat poorly drained soils
Wheat (CSA)	June	90	112	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Low cost, reduced vigor following sorghums
Winter Peas, Austrian	May	40	50	Aug. 15 to Oct. 15 Feb. 20 to Ap. 1	Somewhat slow to establish, produce a lot of biomass in spring

Note: CSA = Cool Season Annual, CSP= Cool Season Perennial, WSA= Warm Season Annual, ss = subsoiler crop or tap rooted, Ideal seeding depth is 8x the width of the seed. Typically in mixed species seeding depth should be 0.50” to 0.75”.

COVER CROP (340) REQUIREMENTS IN TENNESSEE
2017 Environmental Quality Incentives Program (EQIP)

Purpose: To improve soil health function by controlling erosion, building organic matter, increasing available water holding capacity, and promoting nutrient retention and recycling.

Objective: To continue the growth of the cover crops for the production of biomass above and below the ground for as long as possible before the following crop is planted. Producers are encouraged to plant early maturing crops and cover crops.

Eligible Land: Cropland where annual crops are grown.

Soil Testing: Using the Soil Health Test (Haney test) is recommended for selecting the best cover crop mixes to increase soil biology. Results can also be used to determine when fertilizer inputs can be reduced. Soil samples taken at the same time (either fall or spring) and location will best document soil health trends over time. If historic yields, management and soils are similar acreage up to 50 total acres can be sampled as one.

Planting Requirements (for all cover crops):

- Cover crops and the following crop will be planted no-till. Exception: crops that have not been traditionally planted no-till (ONLY tobacco, green beans and vegetable crops) may be strip tilled at planting when meeting a STIR value $\leq$20 for each crop in the rotation. Full width tillage is not permitted for any crop. Consider using a crop roller when planting. **NOTE:** Aerial seeding is a no-till method (aerial seeding during moist conditions with follow up rain is best).
- Currently tilled cropland can convert to a no-till residue management system.
- Planting dates are to be strictly adhered to and producer is locked into a planned crop rotation.
- Cover crops are **not** to be managed as a harvested crop. P and K can be applied to cover crop for the crop following the cover crop.

Termination Requirements (for all cover crops):

- In order to benefit from nitrogen fixation by legume cover crops, allow legumes to reach early to mid-bloom stage prior to being killed.
- For pollinator crops, allow plants to reach full bloom.
- **Do not allow cover crop to go to seed,** however, in mixed species stands allowing some species to go to seed is acceptable, but realize the potential impacts on future wheat crops.
- Cover crops will serve as cover for a **minimum of 90 days**.
- At termination, the cover crop should have 90% or better ground cover and a **minimum height of 10 inches**.
- Terminate cover crops 7 to 14 days prior to planting to reduce allelopathic (toxic) activity toward the primary crop. Sorghum and cereal rye are plants that have strong allelopathic activity which may be beneficial for weed control. Typically terminate with Glyphosate at bloom stage or early head stage wait 14 days and spray gramoxone. If brassicas are in the mix spray broadleaf spray 2,4-D or Banvel 30 to 45 days prior to planting broadleaf crops like cotton, soybeans and tobacco. Always follow directions on the label and/or Univ. of TN herbicide recommendations. https://extension.tennessee.edu/publications/Documents/PB1580.pdf

Grazing Cover Crop Requirements:

- Only producers with a commitment to manage grazing heights are allowed to graze cover crops.
- Management technique will be to take half-leave half; allowing cover to reach 8" height then graze to 4" minimum height, maintaining 70% ground cover. To realize optimum benefits producers are strongly encouraged to only graze the cover crops just prior to termination.
- Producer must have an area to remove livestock from the cover crop when the cover crop is vulnerable to overgrazing or excessive trampling.
- Cover crop can be grazed to a 4" minimum height prior to termination.
- No mechanical harvest (e.g. silage, balage, hay etc.) allowed.
- Base sacrifice area on feeding site assessment tool. Sacrifice area will not receive payment.

Leave an untreated area (for all cover crops):

- For all cover crops, leave a portion of the field or similar field to compare results.
- Area should be wide and large enough to get a reliable yield monitor reading.
- Only planted cover crop acres will receive payment.

Planting Options (for all cover crops):

- When planting with a drill use the lower recommended seeding rate. For broadcast (aerial) seeding, seed a minimum of 1.3 times the low rate.
- In developing mixes, seed a minimum of 70% of legume full rate in Nitrogen fixing cover or develop mix based on C: N ratio.
- Total seeding rate will equal 100% or higher. Up to 20% of mix can be a species that will be terminated by frost or heat (e.g. buckwheat with cool season mix planted in August.)
- 10% or more of the recommended full rate is required to count as a species in the 5 species mix, no more than 1.5 lb of total brassicas are recommended in a mix. If planting after Oct. 1 don't plant radish in the mix.

Select Cover Crop: Small grain and legume will make up 10% or more of the full seeding rate in the mix, brassica 5% to 15% (0.5 to 1.5 lb) of the full seeding rate in the mix. Consider leaving brassicas out of the cover crop every other year.

- **Basic (up to 3 yr):** Five species minimum (e.g. Rye, oats, wheat, radish, and turnips). Target the C:N ratio to be 24:1 but less than 31:1.
- **Multiple Species (3 yr):** (small grain, legume and brassica mix 5 species minimum): see planting options.
    - Target C:N ratio prior to a high residue crop to be 30:1 or less.
    - Target C:N ratio prior to a low residue crop to be 31:1 or higher.

C:N Ratio: The C:N ratio effects residue cover and nutrient cycling. For early soil health conditions (beginning stages), the target C:N ratio is 24-30:1. After soil health is more developed, the target C:N ratio will increase to 31-50:1. Look at the soil surface, if the residue is lacking increase the C:N ratio by increasing the grass component and terminating the cover crop later. If residue is building up on the soil surface, decrease the C:N ratio of the cover crop.

Cover Crop Example Mixes

Crop Mixtures	Seeding Rate Seeding lb/ac Drilled	Broadcast (Option: If grazing is planned increase small grain seeding rate up to 100 lb/ac)		C:N rate at Vegetative Stage
Multiple Species Cover Crop Mix (Cool Season planted after corn)				
Cereal Rye	20	26	Aug. 15 to Oct. 15	31
Oats	20	26		
Austrian W	11	14		
Crimson Clover	4	5		
Radish	1	1		
Turnip	0.5	0.5		
Multiple Species Cover Crop Mix (Cool Season planted after corn)				
Cereal Rye	20	26	Aug. 15 to Oct. 15	32
Wheat	15	20		
Crimson Clover	4	5		
Radish	1.5	1.5		
Hairy Vetch	4	5		
Multiple Species Cover Crop Mix (Cool Season planted after corn)				
Cereal Rye	28	36	Aug. 15 to Oct. 15	35
Wheat	28	36		
Crimson Clover	4	5		
Radish	1	1		
Turnip	0.5	0.5		
Multiple Species Cover Crop Mix (Cool Season drilled only after double crop soybeans or cotton and up to 20% of land in full season soybeans can be drilled till Nov. 1 in this mix).				
Cereal Rye	20	Drilled only, up to Nov. 1		33
Triticale	20			
Turnip	0.5			
Crimson clover or hairy vetch	5			
Austrian winter peas	13			
Multiple Species Cover Crop Mix (Warm Season) Double crop soybean producers could plant a warm season cover crop to achieve 3 consecutive years of cover crops. This option is available for all producers.				
Buckwheat (optional)	1	1	April 20 to July 1	21
Sunflowers (optional)	1	1		
Sudangrass	10	13		
Millet	4	5		
Cowpeas	11	14		
Soybeans	11	14		
Turnips	1.5	1.5		
Sunhemp	5	7		

Basic Cover Crop Mix 1				
Cereal Rye	20	26	Aug. 15 to Oct. 15	30
Wheat	20	26		
Crimson Clover	5	7		
Austrian Winter Pea	14	18		
Radish	1	1		
Basic Cover Crop Mix 2				
Wheat	25	32	Aug. 15 to Oct. 15	25
Crimson Clover	5	7		
Austrian Winter Pea	14	18		
Hairy Vetch	5	7		
Radish	1	1		

- All mixes are only examples of mixes that can be used. Other mixes can be approved for use.
- Seed needs to meet the state seed law. It can be variety not stated (VNS) or certified seed or seed harvested from producer's farm.
- Seeding rate can be increased on all species but be aware that early production species can shade and reduce the stand of slower growing species. E.g. radish or turnips could reduce the stand of other species.
- Some producers have reported a corn yield drag after cereal rye. If it is a concern, other small grains can be substituted. Most likely the issue is too much carbon in mixture causing a higher C:N ratio.
- Recommend not use brassicas preceding cotton.
- Brassicas are heavy feeders and caution needs to be taken when using them. Maintain good fertility for the following crop.
- Mixes can be developed using the Green Cover Seed Smart mix calculator. No more than 1 ½ lbs of brassicas is typically recommended in a mixture. Turnips and more so rape (canola) can be difficult to kill. http://www.greencoverseed.com/smartmix_web/smartmix_web.htm
- High biomass cover crops, like cereal rye, have worked best in control of palmer amaranth.
- Annual Ryegrass has allelopathic (toxic) nature too but is only recommended for those who have experience using it. Annual ryegrass especially Italian ryegrass can be hard to kill and become a weed.
- Sorghums are warm season annuals with some reported allelopathic nature.
- Buckwheat is a succulent fast growing annual that winter kills very easy; it or other warm season cover crop species can make up 20% of the mix. Buckwheat is a very good attractant of beneficial insects.
- Legumes are typically coated and pre-inoculated if not order fresh inoculant and inoculate seed at seeding.

______________________________	______________________________
Producer	District Conservationist

Additional seeding options (full rates listed)				
Plant Species	**Peak Bloom Period**	**Seeding Rate Lb/Ac <u>Drilled</u> Broadcast**	**Seeding Date**	**Note**
Buckwheat (WSA)	21 day after planting	35 42 1 lb/ac for mix	June 1 to Aug 15	Quick warm season cover, can be added as a minor component of fall cool season mix
Clover, crimson (CSA) (ss)	May	17 21	Aug 15 to Oct 15 Feb 20 to April 1	Tap root, late spring growth
Clover, berseem (CSA) (ss)	June	11 14	Feb 20 to April 1	Tap root
Clover, red (CSP) (ss)	July	8 10	Aug 15 to Oct 15 Feb 20 to April 1	Tap root
Cowpea (WSA) (ss)	July	56 70	May 20 to June 20	Tap root, High N producer
Millet, Browntop (WSA)	August	17 21	May 1 to July 1	Quick cover
Oats (CSA)	May	100 140	Sept 1 to Oct 1 Feb 20 to April 1	May freeze out
Radish, forage (CSA) (ss)	-	8 10 No more than 1.5 lb/ac of brassicas	Aug 15 to Oct 15 best sown before Sept 15 Feb 20 to April 1	may freeze out at 25 degrees F, tap root, 1.5 lb/ac is enough
Rye, cereal (CSA)	May	90 112	Aug 15 to Nov 20	Allelopathic to palmer amaranth, plant small seeded crops 2 wk after rye termination
Sudangrass (WSA) (ss)	July	28 35	May 1 to June 20	Strong roots
Sunflower (WSA)	July - Aug	9 11 1 lb/ac for mix	April 15 to May 15	Fast establishment
Sun hemp, (WSA) Tropical (ss)	-	20 25	May 1 to July 20	Need 60 days minimum growth high biomass and N producer
Sweet clover (CS Biennial) (ss)	July	13 17	Aug 15 to Oct 15 Feb 20 to April 1	Allelopathic to thistle and green foxtail, 1 lb/ac
Turnips (CSA) (ss)	-	3 4 No more than 1.5 lb/ac of brassicas	Aug 15 to Oct 15 Feb 20 to April 1	Very small seed (electric seeder or carrier like pelletized lime or crimson clover, 1.5 lb/ac
Vetch, hairy (CSA) (ss)	May	22 28	Aug 15 to Oct 15 Feb 20 to April 1	Can be invasive, late spring growth, tolerant of low fertility, High N producer
Wheat (CSA)	June	90 112	Sept 15 to Nov 10 Feb 20 to April 1	Low cost quick cover, reduced vigor following sorghums
Winter Peas, Austrian (CSA)(ss)	May	40 50	Aug 15 to Oct 15 Feb 20 to April 1	Slow to establish

Note: CSA = Cool Season Annual, CSP = Cool Season Perennial, WSA = Warm Season Annual, WSB = Warm Season Biennial, ss = subsoiler crop

USDA
United States Department of Agriculture

Cover Crop Tips

Natural Resources Conservation Service
Montana

1 Let your goals and resource concerns guide your cover crop design.

For example, a cover crop designed for grazing should be different than a cover crop designed for maximum nitrogen fixation. Plan accordingly.

4 The overall crop rotation is more important than a single cover crop for adding diversity.

Use the cover crop to fill gaps in the rotation. A cover crop mix does not need to have all four plant functional groups (cool-season broadleaf, cool-season grass, warm-season broadleaf, warm-season grass) to be successful.

2 Tailor the cover crop species mix to the planting window.

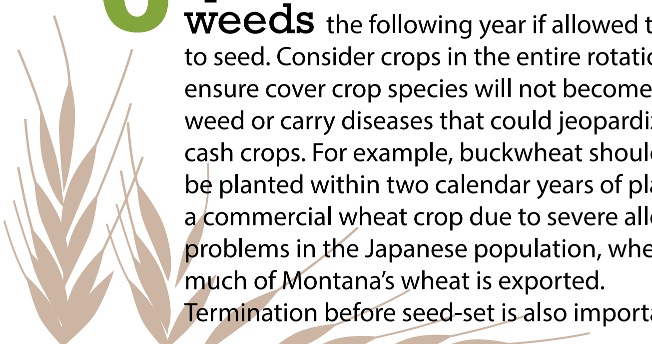
Mixes are most successful when they are mostly cool-season species or mostly warm-season species. **One exception to this may be the brassica species.** Turnips, radishes, forage kale, and collards seem to do well regardless of planting window. Our cool-season planting window is usually April to mid-May and mid-August to early September. Our warm-season window is mid- May to mid-June (shallow soil temps 70 degrees F or warmer and adequate soil moisture). Planting cool and warm season species in mixes together is generally not recommended unless a mid-season planting date is used when chance of frost is over. Some areas may not have a warm season due to high elevation and/or short growing season.

5 Plan for adequate weed control,

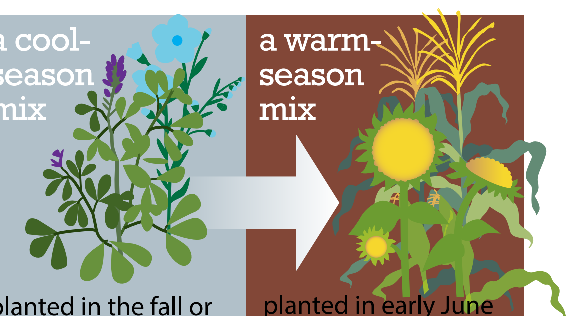
especially prior to seeding a mixed cover crop. Allow time for a flush of weeds and adequate weed kill prior to seeding. Once the cover crop is planted, few weed control strategies are available if something gets out of control.

6 Likewise, certain cover crop species can become weeds

the following year if allowed to go to seed. Consider crops in the entire rotation and ensure cover crop species will not become a weed or carry diseases that could jeopardize cash crops. For example, buckwheat should not be planted within two calendar years of planting a commercial wheat crop due to severe allergy problems in the Japanese population, where much of Montana's wheat is exported. Termination before seed-set is also important.



3 If you want cover over an entire growing season, you may need to plant two cover crops:



a cool-season mix

planted in the fall or early spring and terminated at the end of May followed by

a warm-season mix

planted in early June and terminated with fall frost followed by grazing.

7 More cover crop species are not always better than fewer

species for biomass production. There seems to be a biomass threshold for each site, and the addition of more species may only dilute the effects of the strongest competitors.

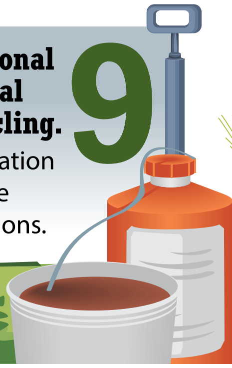
there's more

Cover Crop Tips

8

Even in small amounts, certain cover crop species can provide flowers that are **beneficial to pollinators and beneficial insects.**

9



A small amount of additional fertilizer may be beneficial to encourage nutrient cycling. A soil test can provide information that can be used to determine species and nutrient applications.

10

Soil moisture conservation is critical for dryland cover crops. Be mindful that our peak precipitation window is April through early June, with a very dry period from June 15th onward. In dryland situations where soil moisture is critical, plan a cool-season cover crop to be planted in late fall or early spring and terminated by June 15th. Be particularly mindful of this in annual precipitation zones of 13 inches or less.

11

Using cover crops in dryland prior to winter wheat seeding may be one of our most challenging cover crop scenarios, as there is no time for soil moisture recharge prior to wheat seeding. In addition, the threats of diseases such as rhizoctonia or wheat streak mosaic virus needs to be addressed by breaking the "green bridge." Breaking the "green bridge" means having a period of several weeks prior to seeding with no growing plants. For a partial fallow replacement in a winter-wheat rotation, plant a spring-seeded, cool-season cover crop and terminate based on soil moisture, weeds and cover crop maturity. When considering a warm-season cover crop for fallow replacement, it may be best to follow the cover crop with a spring-seeded cash crop.

12

Be aware that the Risk Management Agency (RMA) requires 35 days of no crop growth between cover crop termination and winter wheat seeding for crop insurance purposes. If a crop, or a cover crop, is planted on summerfallow acreage in a fallow year, the following planted crop will not meet the RMA Summerfallow Practice definition until the acres lie fallow for a full crop year. However, the acreage may be insured under the "Continuous Cropping Practice". Check with your crop insurance agent or RMA before planting cover crops to understand the implications on crop insurance.

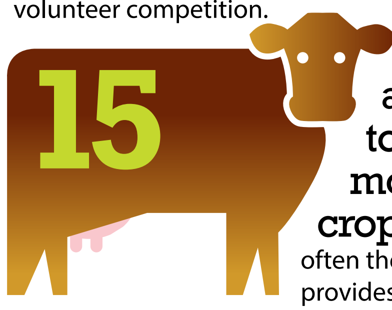
13

When cover crops follow small grains especially barley, under irrigated or high moisture conditions spray after small grain harvest to decrease volunteer competition.

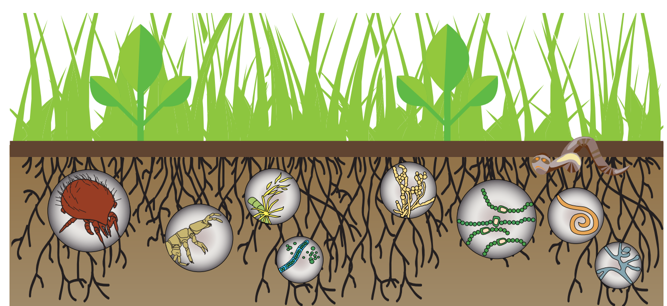
14

Annual cover crops are only one tool to build soil health. Perennial crops and diverse rotations also provide positive soil health benefits.

15



Grazing can be an excellent way to re-coup the money in a cover crop investment. Fall is often the best time for grazing, as it provides supplemental forage at a necessary time of the year, and the combination of frost and grazing makes it easy to terminate the crop. Ensure species planted are not poisonous to livestock and send forage samples to a certified lab for nitrate and other toxicity tests as needed, and a forage quality analysis prior to grazing.



16

Improving soil health is a long-term commitment. It can take 10 to 15 years to noticeably build soil organic matter in dryland crop systems. Be patient.

17

Cover crops require good management. Growers new to the technique are advised to **start small** (5 –10 acres) and build on lessons learned.

10. Earthworms

Earthworms are most active during the spring and fall, which are the best times to observe their activity.

Did You Know?
Earthworm burrowing improves infiltration and their casts improve aggregation. Earthworms also break down larger bits of residue for use by other soil organisms.

Materials needed to measure the number of earthworms:

- **tap water (2 L)**
- **hand trowel or shovel**
- **large jar or container for worm collection and cleaning**
- **mustard solution (2 tablespoons mustard powder in 2 liters of tap water)**

Considerations: When examining the soil for earthworms, avoid places where their populations might be affected, such as near mulch or compost piles. The abundance of earthworms is usually patchy within a field and varies with season. Therefore, count earthworms several times during a season and use the average to gauge changes from year to year.

① **Dig Plot**

Measure a square-foot plot and dig down 12 inches with the hand trowel or shovel (**Figure 10.1**). Try to minimize the number of cuts with the shovel to avoid damage to the earthworms. **Dig the hole first, then sort for earthworms.**

Figure 10.1

② **Count the Number of Earthworms**

Sort the soil samples against a pale-colored background to help locate the earthworms. Separate and count the number of earthworms.

③ **Add Mustard Solution (optional)**

To facilitate extraction of deep burrowing earthworms, add two liters of mustard solution to the hole. **First**, make sure the bottom of the hole is level. The deep burrowing worms should appear within five minutes (**Figure 10.2**). Count the number of worms.

Figure 10.2

④ **Record Total Number of Earthworms**

Record the total number of earthworms (those found in the hole and after adding the mustard solution) on the Soil Data worksheet. **[The mustard solution should not harm the worms. Rinse them in water before returning them to the soil.]**

5. Electrical Conductivity Test

Soil samples for the electrical conductivity (EC) test are taken from the 0- to 3-inch depth. Bulked soil samples from across the field can be collected, and two subsamples can be taken for analysis (See Chapter 1, Sampling Guidelines). **Electrical conductivity, pH, and soil nitrate are all measured from the same soil subsample.**

Materials needed to measure electrical conductivity (EC):

- **1/8-cup (30 mL) measuring scoop**
- **120-mL plastic containers with lid**
- **EC pocket meter (blue with black cap)**
- **squirt bottle**
- **calibration solution (0.01 M KCl)**
- **distilled water**

> **Did You Know?**
> Excess salts in soil can be a detriment to plant health. Salts can also hamper water movement into the soil and increase the occurrence of surface compaction.

① **Extract Subsample**

The soil sample should be thoroughly mixed before taking a subsample. Measure a 1/8-cup level scoop subsample of soil and place it in the plastic container. If soil nitrates will be measured on this subsample (Chapter 7), weigh the subsample for a more accurate estimate of soil nitrates. Enter the subsample weight on the Soil Data worksheet.

② **Add Water to Subsample and Mix**

- Add 1/8-cup (30 mL) of distilled water to the container with the subsample. The resulting soil/water mixture equates to a 1:1 soil to water ratio on a volume basis.
- Put the lid on the container and shake vigorously about 25 times.

> **Calibration Tip**: Make sure the EC meter is calibrated before making a measurement. See Appendix C for calibration instructions.

③ **Measure and Record EC (See Calibration Tip)**

- Open the container and insert the EC pocket meter into the soil-water mixture. Take the reading while the soil particles are still suspended in solution. To keep the soil particles from settling, stir gently with the EC pocket meter. Do not immerse the meter above the immersion level (See Appendix C, Figure 1c). Allow the reading to stabilize (stays the same for about 10 seconds).
- Enter the EC reading on the Soil Data worksheet in decisiemens per meter (dS/m). The DiST WP 4 meter gives readings directly in dS/m. For the Microsensor 4 meter, divide the reading by 10, and for the Microsensor 3 meter, divide the reading by 100 to get readings in dS/m.
- Save the soil-water mixture for the pH measurement (Chapter 6).

④ **Turn the meter off. Thoroughly rinse meter with distilled water and replace cap.**

3. Infiltration Test

The infiltration test is generally performed after the **first** respiration measurement. The same 6-inch diameter ring left in place from the soil respiration test can be used for the infiltration test. If soil respiration was not determined, follow the instructions in Step 1 of the soil respiration procedure (Chapter 2) for inserting the 6-inch diameter ring.

Materials needed to measure infiltration:

- **6-inch diameter ring (left in soil from respiration test)**
- **plastic wrap**
- **500 mL plastic bottle or graduated cylinder**
- **distilled water**
- **stopwatch or timer**

Did You Know?
Infiltration rate is a measure of how fast water enters the soil. Water entering too slowly may lead to ponding on level fields or to erosion from surface runoff on sloping fields.

Considerations: If the soil is saturated, infiltration will not occur. Wait for one or two days to allow for some drying. Also, if the respiration test is not performed, make sure the sampling area is free of residue and weeds or that vegetation is trimmed to the soil surface before inserting the ring.

① **Firm Soil**

With the 6-inch diameter ring in place, use your finger to gently firm the soil surface **only** around the **inside edges** of the ring to prevent extra seepage. Minimize disturbance to the rest of the soil surface inside the ring.

② **Line Ring with Plastic Wrap**

Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring as shown in **Figure 3.1.** This procedure prevents disturbance to the soil surface when adding water.

Figure 3.1

③ **Add Water**

- Fill the plastic bottle or graduated cylinder to the 444 mL mark with distilled water.
- Pour the 444 mL of water (1" of water) into the ring lined with plastic wrap as shown in **Figure 3.1.**

4 Remove Wrap and Record Time

Figure 3.2

- Remove the plastic wrap by gently pulling it out, leaving the water in the ring **(Figure 3.2)**. **Note the time.**
- Record the amount of time (in minutes) it takes for the 1" of water to infiltrate the soil. Stop timing when the surface is just glistening.

Figure 3.3

- If the soil surface is uneven inside the ring, count the time until half of the surface is exposed and just glistening **(Figure 3.3)**.
- Enter the amount of time in minutes on the Soil Data worksheet.

5 Repeat Infiltration Test

In the same ring, perform Steps 2, 3, & 4 with a second inch of water. On the Soil Data worksheet, enter the number of minutes elapsed for the second infiltration measurement. If soil moisture is at or near field capacity, the second test is not necessary.

[The moisture content of the soil will affect the rate of infiltration; therefore, two infiltration tests are usually performed (if soil is dry). The first inch of water wets the soil, and the second inch gives a better estimate of the infiltration rate of the soil.]

6 Replace Lid

If a second respiration measurement will be performed, set the lid loosely on the ring and leave it covered for preferably 16 to 24 hours (6-hour minimum) before beginning the second test (Chapter 2). (Remove lid and replace it before beginning the second soil respiration measurement).

> **!** **Reminder**: If you still need to perform the second respiration measurement, remember to loosely place the lid back on the ring before leaving the field.

6. Soil pH Test

Use the same soil-water mixture prepared in the EC test to conduct the pH Test. **If you are starting with a fresh soil sample, read the introduction and follow Steps 1-3 in the EC Test Chapter on preparing the sample.**

Materials needed to measure pH:

- **1/8-cup (30 mL) measuring scoop**
- **plastic specimen bottle**
- **calibration buffer solutions**
- **squirt bottle**
- **pH pocket meter (red with black cap)**
- **distilled water**

Did You Know?
Soil acidification can also be an indication of excessive N fertilizer applications and N leaching loss.

Considerations: If the soil sample is saturated or very wet, a 1:1 ratio, on a volume basis, of soil to water will not be obtained in the soil-water mixture (See Step 2, Chapter 5). Let the soil dry before proceeding with Step 1 in Chapter 5. Also, a small amount of salts diffuse out of the pocket pH meter; therefore, **EC measurements should always be taken first when measuring both EC and pH on the same sample**.

(1) **Measure and Record pH**

- Make sure to periodically calibrate your pH meter (See Appendix C for instructions). If the meter has not been used in a while, place the meter in tap water for about 5 minutes before calibrating or taking a reading.

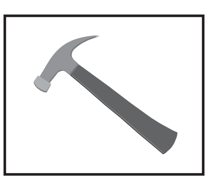
- Wait about 10 to 15 minutes after the EC measurement before measuring the pH. This gives the soil particles time to settle. Insert the pH pocket meter into the topmost portion of the solution and turn the meter on. Wait until the reading stabilizes (0-30 seconds), and record the digital reading on the Soil Data worksheet.

(2) **Rinse Pocket Meter**

- Thoroughly rinse the electrode with distilled water.

- Store the electrode with a few drops of the **pH 7** buffer solution and replace the cap. (See Appendix C on storage of pH meter)

Maintenance Tips: Check the batteries and calibrate the EC and pH meters periodically. Be sure to clean the meters thoroughly to keep them working properly.



11. Soil Physical Observations and Estimations

Materials needed in observing the soil physical properties:

- **tape measure**
- **sharpshooter spade or shovel**
- **18-inch metal rod**
- **tap water**

① Dig hole

Dig a hole to a depth of 1 foot. Make it wide enough to cut out a slice of soil.

② Cut Slice of Soil

Using the shovel, cut a slice of soil from a wall of the hole and lay it on the ground.

Figure 11.1

③ Measure Depth of Topsoil

- Measure the depth of the topsoil. Look for color changes from the soil surface downward through the soil profile. The topsoil is usually distinguished by a darker color than the underlying material **(See Figure 11.1)**.

- Record the depth of topsoil on the Soil Data worksheet.

④ Observe Plant Roots

- Observe plant roots in the hole and the slice of soil. To get a better look at the roots, dig down along a plant stem. The roots should be well branched with lots of fine root hairs.

- Things to look for are balled up roots or roots growing sideways. A lack of fine root hairs indicates oxygen deprivation in the root zone. Lateral root growth indicates a hardpan, or compacted layer.

⑤ Determine Resistance

- Use the metal rod to probe one of the side walls, starting from the soil surface to the bottom of the hole. Determine changes or differences in penetration resistance as you probe the side wall **(See Figure 11.2)**.

- Look for compacted layers that may restrict root growth and water movement.

Figure 11.2

6 Examine Soil Structure

Observe soil structure in the slice of soil to a depth of about 12 inches. Measure and mark, starting at the surface and moving downward; depth increments of 0 to 4 inches, 4 to 8 inches, and 8 to 12 inches. Note and record the type, size, and grade of the soil structural units or aggregates for each depth increment.

Note: Soil structure is how particles of soil are grouped together in stable collections or aggregates.

6a Note the type of soil structure at each of the three depth increments.

- The three general types of soil structure are granular (**Figure 11.3**), blocky (**Figure 11.4**), and platy (**Figure 11.5**).

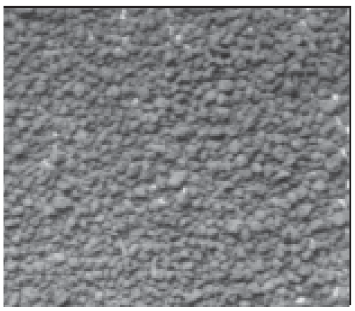


Figure 11.3 Granular: imperfect spheres, usually sand-size.

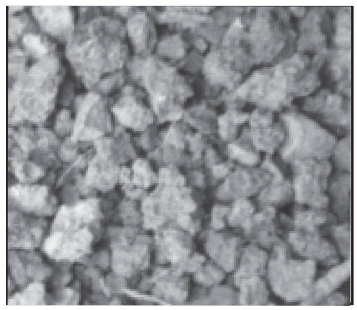


Figure 11.4 Blocky: imperfect cubes with angular or rounded edges.

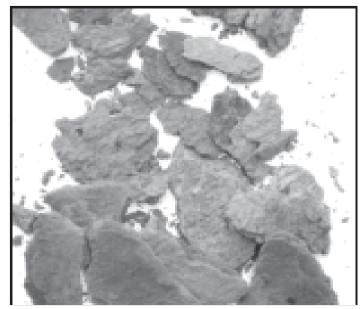


Figure 11.5 Platy: a flattened or compressed appearance.

- If there are no noticeable aggregates or peds, the soil has no structure. It is either single grained (**Figure 11.6**) or massive (**Figure 11.7**).

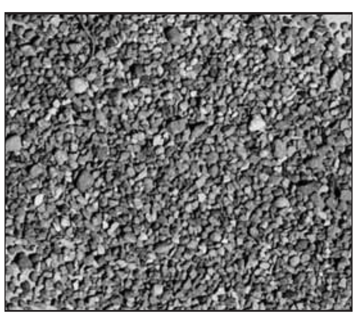


Figure 11.6 Single grain: unconsolidated mass such as loose sand.

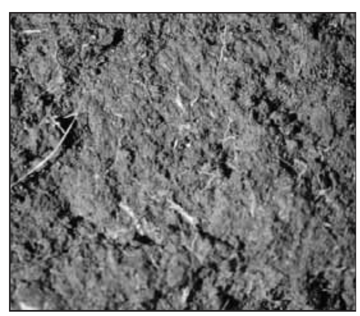


Figure 11.7 Massive: cohesive mass.

- Record on the Soil Data worksheet the type of structure observed for each depth increment.

6b **Note the size of the aggregates or peds at the different depths**.

- Estimate the general size of the aggregates or peds. If the structure is granular, choose from fine (**Figure 11.8**), medium (**Figure 11.9**) and coarse (**Figure 11.10**) granule sizes.

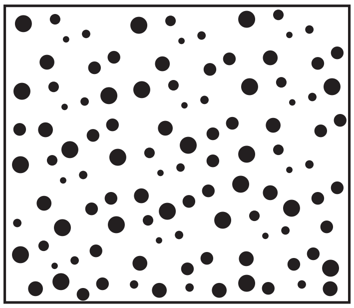


Figure 11.8
Fine: < 2 mm.

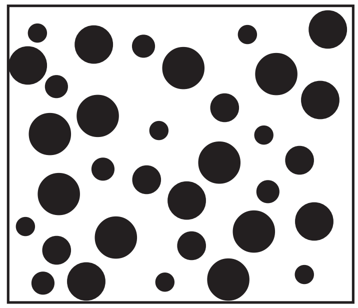


Figure 11.9
Medium: 2 to 5 mm.

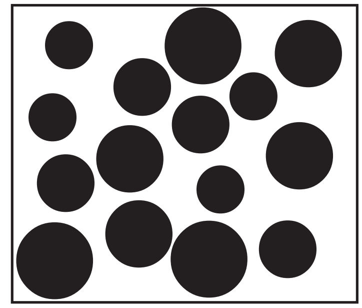


Figure 11.10
Coarse: 5 to 10 mm.

- If the structure is blocky, choose from very fine (**Figure 11.11**), fine (**Figure 11.12**), and medium (**Figure 11.13**) block sizes.

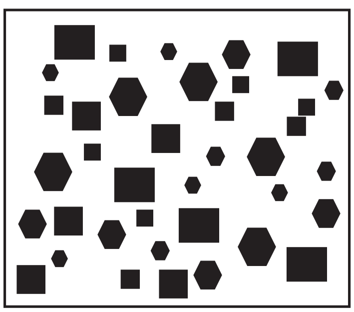


Figure 11.11
Very fine: < 5 mm.

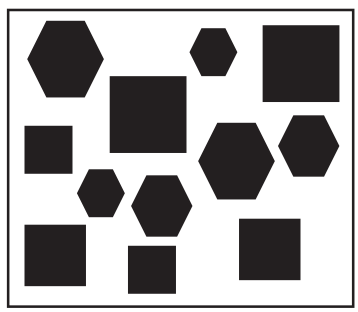


Figure 11.12
Fine: 5 to 10 mm.

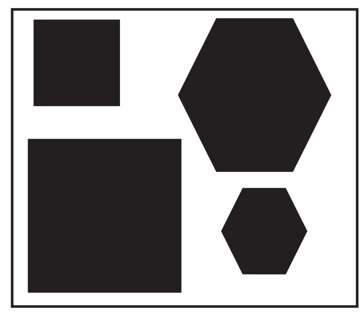


Figure 11.13
Medium: 10 to 20 mm.

- If structure is platy, choose from thin (**Figure 11.14**), medium (**Figure 11.15**), and thick (**Figure 11.16**) plate sizes.

Figure 11.14
Thin: < 2 mm.

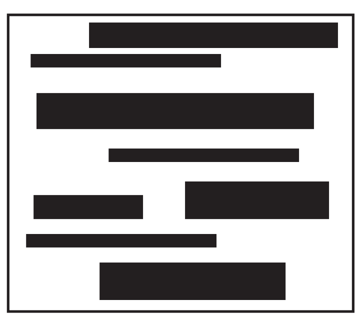


Figure 11.15
Medium: 2 to 5 mm.

Figure 11.16
Thick: 5 to 10 mm.

- Record on the Soil Data worksheet the size of the aggregates or peds observed for each depth increment.

6c **Note the distinctness (grade) of the aggregates in place and when removed from the slice of soil.**

The distinctness of the aggregates is either weak, moderate, or strong.

Weak structure:

- Aggregates or peds are barely observable in place in moist soil.
- When removed, the structure breaks into a few observable aggregates or peds **(Figure 11.17)**.

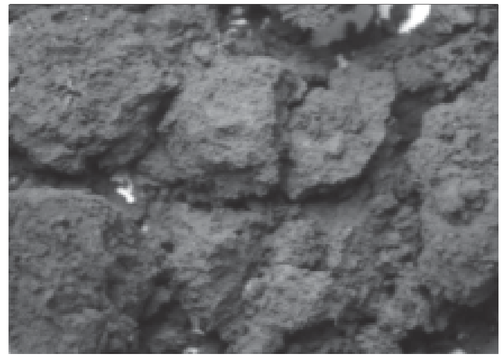


Figure 11.17

Moderate structure:

- Aggregates or peds are moderately well-formed and distinct in place.
- When removed, many well-formed aggregates are observable **(Figure 11.18)**.

Figure 11.18

Strong structure:

- Aggregates or peds are well-formed and very evident in place.
- When disturbed, the structure breaks into quite evident aggregates or peds **(Figure 11.19)**.

Record on the Soil Data worksheet the grade of the aggregates or peds observed for each depth increment.

Figure 11.19

7 **Determine soil textural class**

- Perform the Texture by Feel procedure **(See page 27)** on the top three inches of soil.
- Record on the Soil Data worksheet the soil textural class.

TEXTURE BY FEEL PROCEDURE

Making a Ribbon

Place approximately 25 grams in palm. Add water dropwise and knead the soil to break down all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.
Add dry soil to soak up water
Yes
Yes
Does soil remain in a ball when squeezed?
No
Is the soil too dry?
No
Is the soil too wet?
No
Sand
Yes
Place ball of soil between thumb and forefinger, gently push the soil with the thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over the forefinger, breaking from its own weight.
Does the soil form a ribbon?
No
Loamy Sand
Yes
Does soil make a weak ribbon less than 1 inch long before breaking?
No
Does soil make a ribbon 1 inch long before breaking?
No
Does soil make a strong ribbon two inches or longer before breaking?
Yes
Yes
Yes
Excessively wet a small pinch of soil in palm and rub with forefinger.
Sandy Loam
Yes
Does soil feel very gritty?
No
Silt Loam
Yes
Does soil feel very smooth?
No
Loam
Yes
Neither gritty nor smooth?
Sandy Clay Loam
Yes
Does soil feel very gritty?
No
Silty Clay Loam
Yes
Does soil feel very smooth?
No
Clay Loam
Yes
Neither gritty nor smooth?
Sandy Clay
Yes
Does soil feel very gritty?
No
Silty Clay
Yes
Does soil feel very smooth?
No
Clay
Yes
Neither gritty nor smooth?

Recommendations

- Evaluate soil health periodically (about every 3 years) to document changes.
- Consider looking at the soil health in the fence row relative to the field
- Periodic assessments in a field should be done by the same person, during the same season and under similar soil moisture conditions.
- For better assessments, base sampling on variability in the field such as soil, soil moisture and yield.
- Examine the distribution of indicator values. Even if most of the indicators are scored 10 (healthy), the soil may still have serious problems.
- Careful consideration should be used to identify the cause of the problem(s).
- Impaired properties may need immediate action and should be closely monitored.
- Keep completed soil health cards on file for future reference.
- For more information on soil health, contact your local USDA Natural Resources Conservation Service (NRCS) office, county agent, agribusiness or the NRCS Soil Health website

http://www.nrcs.usda.gov/wps/portal/nrcs/site/tn/home/

Soil Health Card for Tennessee Producers

A Locally Adapted Tool Designed by Producers for Producers

United States Department of Agriculture
Natural Resources Conservation Service

What is Soil Health?

The terms "soil quality" and "soil health" are used interchangeably. However, soil health refers to the function of the soil as a living ecosystem to support plants and animals. Humans also benefit from improved soil function.

Soil health is very important to all people. Healthy soil absorbs and holds more water, and has better physical, chemical, and biological properties. If we have good soil health, we will have productive land, good air and water quality as well as a healthy environment.

How to Improve Soil Health

Management greatly affects soil health. Farmers throughout Tennessee are increasing the amount of soil organic matter in their land and improving the soil's health and function by following these basic principles of soil health:

1. Minimize disturbance due to tillage, overgrazing and traffic
2. Diversify the soil microbes that support plant growth by increasing plant diversity through crop rotation and multispecies cover crops and forage plantings
3. Keep living roots growing throughout the year to provide food for soil microbes and reap the benefits of their presence
4. Keep the soil covered as much as possilbe to conserve soil moisture, reduce soil temperature, prevent soil erosion and suppress weed growth.
5. Consider adding livestock, in a managed grazing system, to a row crop system in order to increase the cycling of plant nutrients
6. Talk with farmers using conservation tillage or managed grazing systems. They can give you some ideas about how they are changing the health of their row crop or grazing land.

About this Card

The soil health card was designed and adapted for local use. Originally, it was developed by farmers in partnership with the Georgia Conservation Tillage Alliance. It has been modified for use on all landuses in Tennessee.

It was developed by and for producers to identify where improvements could be made and to evaluate the effect of changes in management on soil health. Assessments are about quality and not absolute measures.

Note the before and after conditions in the field to record long-term improvements in soil health.

In addition to farmers, the card can also be used by soil conservationists, educators, students and garden clubs

How to Use the Tennessee Soil Health Card

Tools Required: A shovel and a soil probe, or wire flag

- Turn over a shovel full of soil (about 6-8" deep) and rate each indicator by making an **"X"** or shading out the box that best represents the value for that indicator.
- Determine soil compaction by simply pushing the probe or wire flag into undisturbed soil and noting the resistance.

Date: _________ **Evaluation by:** ___________________ **County:** _______________ **Farm:** _______________ **Field:** __________

Soil Moisture Level (check one): Good for planting: ____; **Too wet for planting:** _____; **Too dry for planting** _____.

Goal and Management: ____

Landuse Rotation for: Crops: Tillage and crop rotation; Pasture: Begin and end height and average rotation; Hay: Cutting height and number of cuttings/year; Forest: grazed or not, last harvest

Enter "Landuse Rotation" information: ____

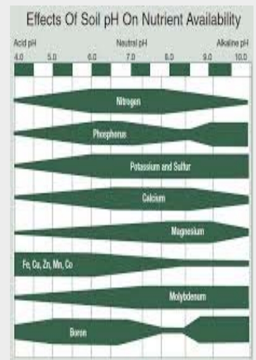
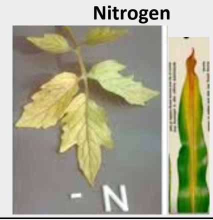
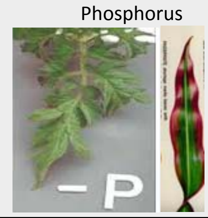
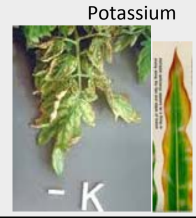
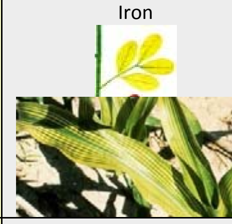
	Indicator	*Is the soil Functioning?*	→ Preferred 1/										Indicator Values		
			1	2	3	4	5	6	7	8	9	10	1	5	10
1	**Cover** or Forage greater than 2"												No living or dead cover on the soil surface	50-90% of soil surface covered with living or dead cover	>90% of soil surface covered with living or dead cover
2	**Plant Vigor** (Crop Growth)												Uneven stand; stunted crop growth; discoloring common	Some uneven stand; stunted growth; slight discoloring	Even stand; vigorous & uniform crop growth
3	**Soil Erosion** (look for terracettes & pedestal erosion) 2/												Excessive soil movement by water	Some visible soil movement by water	Little or no soil erosion by water
4	**Disturbance:**												0-30% of soil surface is covered with residue	50-70% of soil surface is covered with residue or grass over rested: brown leaves shading green leaves	>70% soil surface covered with residue
5	**Plant Diversity** Crop rotation/Forage diversity												Two crops or less in rotation or one dominant forage species	3 to 4 crops with no cover crop or three forage species from 1 group	4 crops with cover crop or 4 or more forage sp. 3 groups
6	**Surface Soil Color**												White, light gray, or red	Dark gray or light brown	Dark brown or black
7	**Soil Structure** (Tilth)												Hard (cloddy, hard or crusty)	Some visible crumbly structure	Friable (crumbly)
8	**Water Infiltration** and Water Holding Capacity												Excessive runoff or ponding; Very low water holding capacity	Some runoff or ponding; Poor water holding capacity	Very little runoff/ponding; Good water holding
9	**Living Roots**/Biological Activity												Roots turning and or stunted. Little or no sign of soil life	Some living organisms or signs of soil life	Numerous signs of soil life
10	**Compaction**/Crusting (check relative to a non-traffic area)												Can **Not** push probe or wire flag into soil; crusting is prevalent	Can push probe or wire flag in soil with force; some soil crusting	Probe or flag enters soil easily; no soil crusting
11	**Soil pH** 3/												pH 1.0 lower than needed	pH 0.5 lower than needed	Proper pH for the crops(s)
12	**Soil Fertility** 3/												More than 2 elements not within UT recommendations	Two elements not within UT recommendations	All elements within UT recommendations
13	**Soil Organic Matter** 3/												<1% in a soil sample	1-2% in soil sample	>4% in a soil sample
14	**Other Indicator**(s) Chemical, Physical or Biological														

1/Ratings 1 to 10 are user determined. 2/Terracette: small drift of soil and residue; Pedestal erosion: soil standing up under residue or a rock. 3/Lab analysis needed. Soil sample depth of 6". 07/06/2015

INDICATOR PLANTS

Greg Brann, Grazing Soil Health Specialist

Indicator Plants are plants that by their presence or abundance, provide an assessment of the quality of the site. Past soil management has a dramatic effect on the plant community and the plant community doesn't change quickly so some indicator plants may persist after management has improved. Indicator plants provide insight to what is occurring below the surface but there are many factors that come into play such as previous land use or management. These can dramatically influence seed availability on the site (e.g. – a low fertility site may still have broomsedge or rabbit tobacco on it even though fertility has improved). Soil testing, rest and recovery, more cover, increased diversity, seeding or other soil management methods may be required to alter the site to the desired state. The best weed control is out-competing undesirable plants. "Manage for what you want, not for what you don't want. It takes grass to grow grass."

COMPACTED SOIL	OVER GRAZED LAND	WET OR FLOODED SOIL	LOW FERTILITY SOIL	DEFICIENCY
Low Oxygen soils: Platy layers in soil, high bulk density (poor infiltration, increased runoff)	**Lack of cover:** effects similar to compacted land – High weed population	**Low Oxygen soils:** Pore spaces become saturated or not present negatively affecting soil structure, decomposition, and chemical and biological processes	**Unbalanced Fertility:** pH below 5.1 (frequent) or above 7.3 (high pH is uncommon in TN). Often Phosphorous is limiting factor. Potassium is typically limiting on hay land	**Severe deficiency of a nutrient or pH is low and infrequently too high in TN** 
Prostrate knotweed: ***Polygonum arenastrum or aviculare*** 	**Horsenettle:** *Solanum carolinense* 	**Sedges:** ***Carex spp*.** **Sedges have edges, triangular stem** 	**Rabbit tobacco:** *Pseudognaphalium obtusifolium* 	
Rushes: *Juncus spp.* 	**Bitter sneezeweed**: *Helenium amarum* 	**Rushes**: Juncus spp. Segmented hollow stem 	**Red sorrel:** *Rumex acetosella* 	**Nitrogen** 
Goosegrass: *Eleusine indica* 	**Spiny amaranth:** *Amaranthus spinosus* 	**Spikerush:** *Eleocharis spp.* 	**Poor Joe:** *Diodia virginiana* 	Phosphorus 
Bitter sneezeweed: *Helenium amarum* 	**Bermudagrass:** *Cynodon dactylon* 	**Flatsedge:** *Cyperus spp.* 	**Broomsedge:** *Andropogon virginicus* 	Potassium 
Dog fennel: *Eupatorium capillifolium* 	**Annual bluegrass:** *Poa annua* 	**Bulrush:** *Scirpus spp.* 	**Sweet vernalgrass:** *Anthoxanthum odoratum* 	Calcium 
Buttercup: *Ranunculus* 	**Kentucky bluegrass:** *Poa pratensis* 	**Virginia buttonweed:** *Diodaia Virginiana* 	**Oxeye Daisy:** *Leucanthemum vulgare* 	Magnesium 
Curly dock: *Rumex crispus* 	**Crabgrass:** *Digitaria ischaemum* 	**Smartweed:** *Persicaria spp.* 	**Panicums:** *Panicum spp.* 	Iron 
Chicory: *Cichorium spp.* 	**Ironweed:** *Vernonia gigantea* 	**Reed canarygrass:** *Phalaris arundinacea* 	**Yarrow:** *Achillea millefolium* 	Zinc 

Some Options for Mitigating Resource Concerns

The plants that grew naturally on the site are nature's way of healing the site some of them are very palatable and others are not. If these are undesirable plants you may want to terminate existing plants and plant a more desirable plant community that is adapted to the site.

Compacted Soil: More roots are needed fibrous and tap roots. Maintaining living roots all year helps. Allowing plants to recover longer between grazing and mowing improves root system. More residue helps. Resting plants during their active growing season strengthens plants. All plants help reduce issues with compaction but the following plants are renowned for improving soil Compaction. Cool season annual plants are: Forage radish and Cereal rye; perennial cool season plants: alfalfa, chicory, red clover and sweet clover. Warm season annual plants are: sorghums and warm season perennial plants: Native warm season grasses like: big bluestem, little bluestem, indiangrass, switchgrass and eastern gamagrass. Bermudagrass is tolerant of overgrazing and rather drought tolerant but doesn't have as deep a root system as natives and needs nutrients for production.

Overgrazed Land: Longer recovery between grazing improves vigor of plants. If grazing skip a paddock resting a paddock for up to 90 days in the growing season and up to 210 days in the winter. Lowering stocking rate will remove stress on the the grass, soil, livestock and you. Increasing inputs such as fertilizing, feeding, number of paddocks and rotating more often leaving minimum heights of grass for soil protection, improved infiltration, lower soil temperature and improved water management. All of these inputs reduce the impacts of overgrazing and shallow root systems. When minimum grazing heights are reached confine livestock to 20% or less of the land and feed hay till other paddocks reach a minimum height of 8" then resume grazing. It is ideal to graze a paddock for 3 days or less, not allowing livestock to take a second bite of the same plant. In general the minimum recovery time or rest period between grazings is 14 days but base the rotation on height don't graze below 4" (minimum of 4 layers of leaves).

Minimum Grazing Heights

Species	Minimum Starting Height (Layers of leaves)	Minimum Ending Height (Layers of leaves)	Notes
Tall fescue, orchardgrass, bromegrass, ryegrass and small grains	8" (8)	4" (4)	Tall fescue and annual ryegrass are tolerant of lower grazing but will produce more and regrow faster at these heights.
Bermudagrass, Crabgrass, Dallisgrass	5" (4)	2" (2)	Plants tolerant of lower grazing
Tall Upright grasses like: sorghums, millets, johnsongrass	18" (7)	8" (3 to 4)	If you graze lower they will likely not die but production will be compromised
Flat leaf plants like clovers	5" (5)	3" (3)	White clover is tolerant of close grazing and will actually increase when close grazed

Wet or Flooded: NRCS does not encourage draining land, wetlands are very important ecosystems and aquifer recharge areas. Before draining land check with your local NRCS office you could lose USDA benefits or be fined by other agencies. Don't graze or travel on wet or saturated soil. Drive only in designated areas controlling traffic. If you must enter a field when it is wet walk or use an atv also wide tires compact less that narrow tires. Forage species that are adapted to wet and flooded land are: cereal rye, hairy vetch, alsike clover, red top, alsike clover, switchgrass and eastern gamagrass.

Low Fertility Soil: A plant tissue test may be in order to determine the deficiency contact the lab prior to sending in the sample. Feeding hay on low fertility relocates nutrients to the feeding site. Move or unroll hay in a new location each time you feed. High density short duration grazing improves manure distribution which improves fertility. Adjust pH to the desired level prior to applying deficient nutrients. You can move fertility in the animal as well by grazing a fertile field then rotating to one less fertile the manure dropped will be from the more fertile field. Plants, cover and roots aid in making more nutrients actively available to plants. Plants adapted to low fertility include: Cereal rye, lespedezas and native grasses.