SOIL SMaRTS

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

TRAINING CURRICULUM

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Southern SARE Sustainable Agriculture Research & Education

UT Extension Institute of Agriculture The University of Tennessee

USDA United States Department of Agriculture

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

Soil Smarts Training Curriculum

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MODULE 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

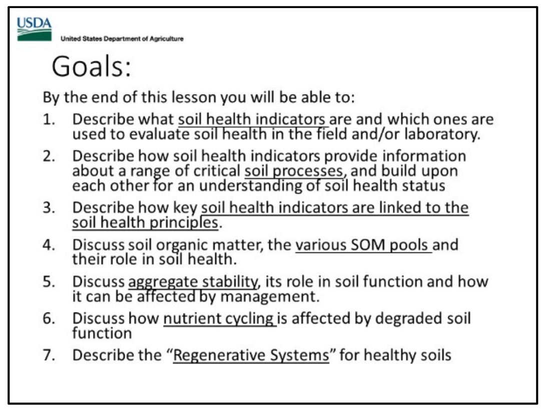
Slide 1

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

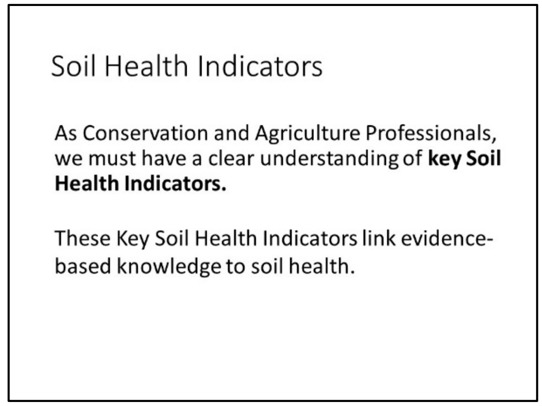
There are many indicators of soil health and soil quality. Most of these can be measured and quantified in a lab or a field assessment. For example, indicators like organic matter content and water stable aggregates need to be measured in a lab but soil morphological features that relate to soil health 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

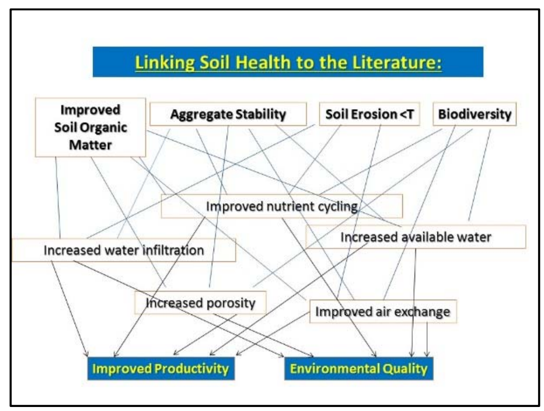
Slide 7

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.

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.

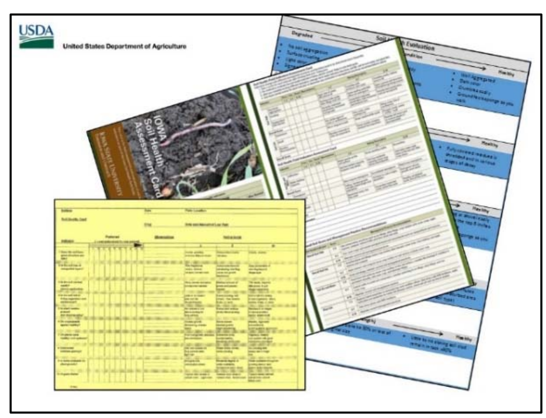
Slide 8



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 9

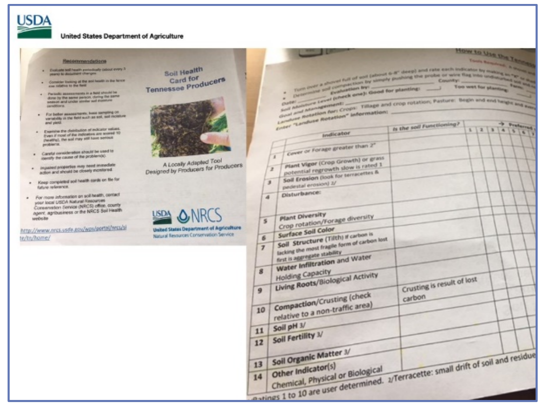


Slide 9

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 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

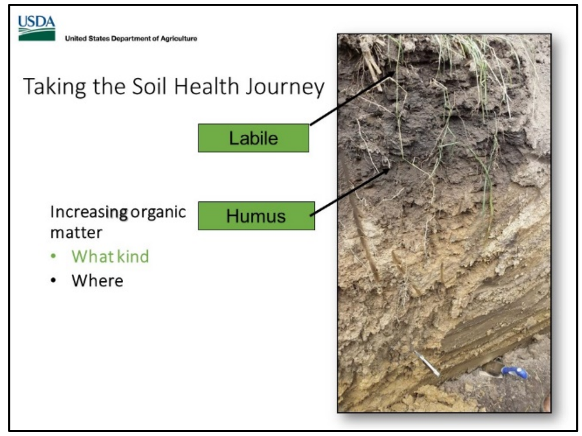
Slide 12

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

Slide 12

Slide 13

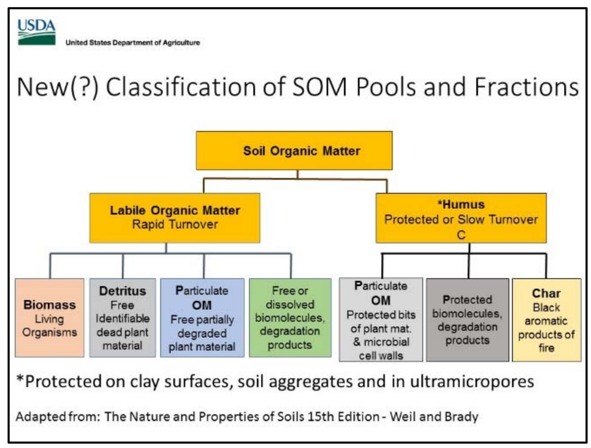
Increasing organic matter (OM) is the foundation of improved soil health. All OM isn't the same, however. Newer, more reactive carbon is referred to as labile and older, more stable is referred to as humus. Labile OM is closer to the surface while humus is distributed throughout the profile more evenly.



Slide 13

Slide 14

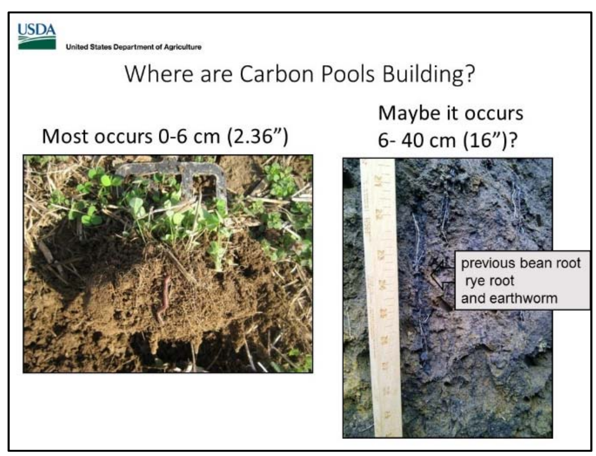
This slide depicts the different types of organic matter related to labile OM and humus. Labile OM is the most readily available for use by soil microbes. It is the first to be lost and is affected more by management, e.g. tillage.
Humus is more protected.
Some of these pools do not show up in standard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



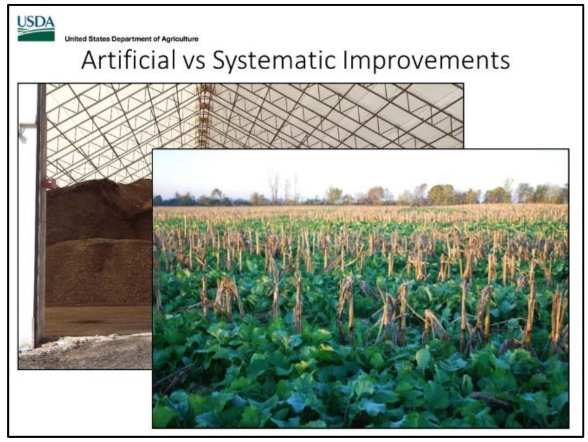
Slide 15

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

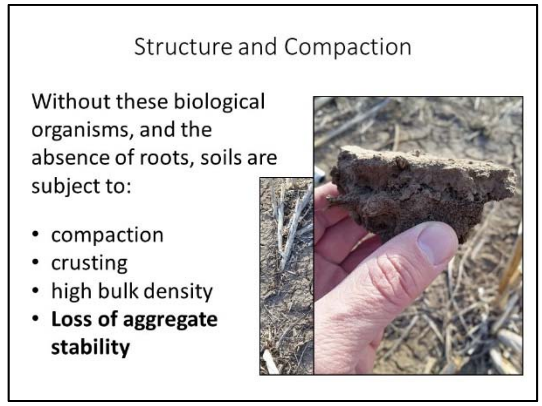
Slide 18

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

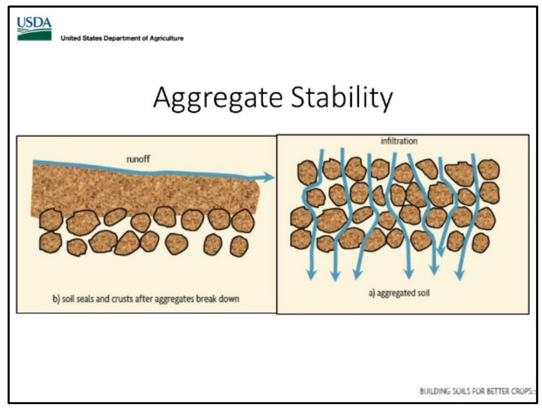
Fields saturated for long periods lose soil structure, especially at the surface. No-till by itself doesn't increase aggregate stability, you need the roots and biological organisms to achieve water stable aggregates. Stable aggregates can withstand the impact of a raindrop and individual soil particles (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

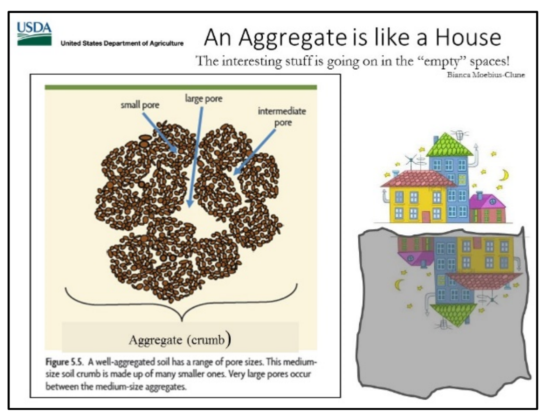
This slide shows how much more easily water can infiltrate into the soil when there is good aggregate stability (right). When there is not, the aggregates fall apart and plug pore spaces, leading to runoff under rain events where any kind of slope occurs (left).



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.

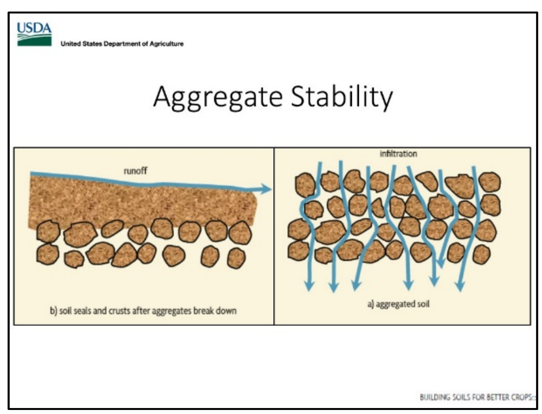
Slide 23

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

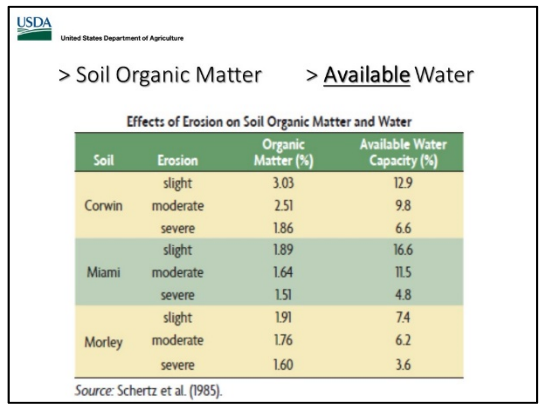
Slide 25

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.

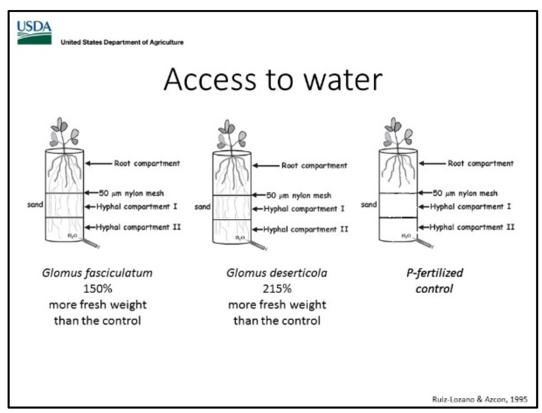


Soil	Erosion	Organic Matter (%)	Available Water Capacity (%)
	slight	3.03	12.9
Corwin	moderate	2.51	9.8
	severe	1.86	6.6
	slight	1.89	16.6
Miami	moderate	1.64	11.5
	severe	1.51	4.8
	slight	1.91	7.4
Morley	moderate	1.76	6.2
	severe	1.60	3.6

Slide 26

Slide 27

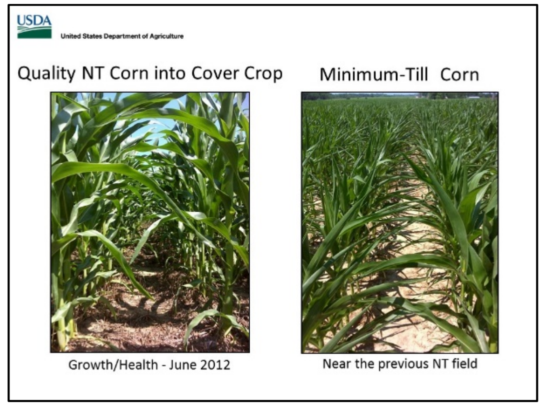
Soil fungi can also help to increase the amount of water available to plant roots. On the slide, the fungi that were added in the first two containers could access water that the plant roots couldn't, thereby bringing water up the soil profile. This lead to greater water availability and greater fresh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



Slide 27

Slide 28

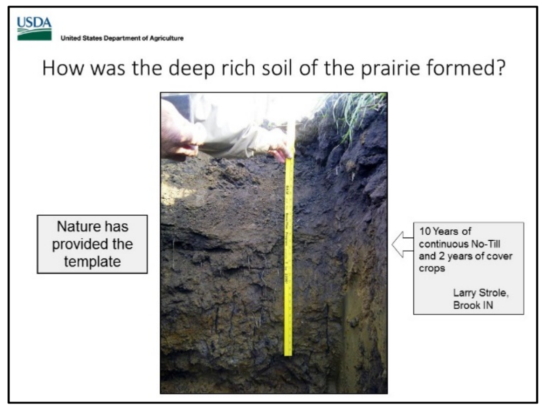
Example: The minimum-till field on the right actually looked better early in the growing season but lacked the resilience to make it to the end. 2012 was the worst drought on record in Indiana (this drought also occurred here in Tennessee). In the end, the field on the left out-yielded the minimum-till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

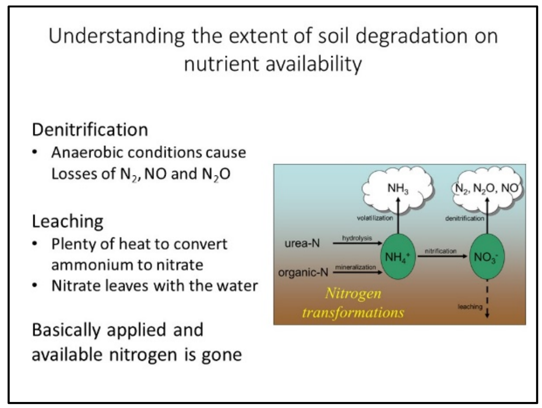
Slide 31

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

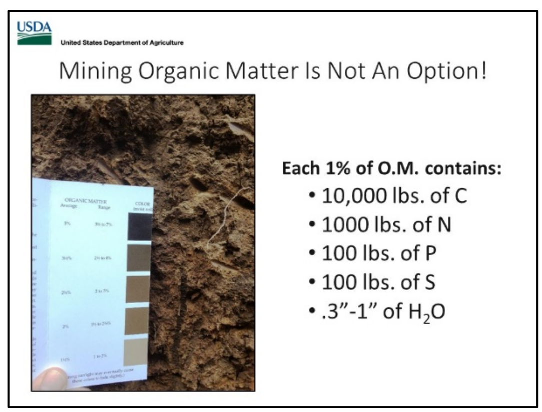
Let's take a look at the important soil functions/processes that are affected by these saturated conditions. We can have losses of N from the field when they are saturated through the processes of denitrification and leaching. Under denitrification, N is lost as a gas whereas with leaching it is lost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



Slide 32

Slide 33

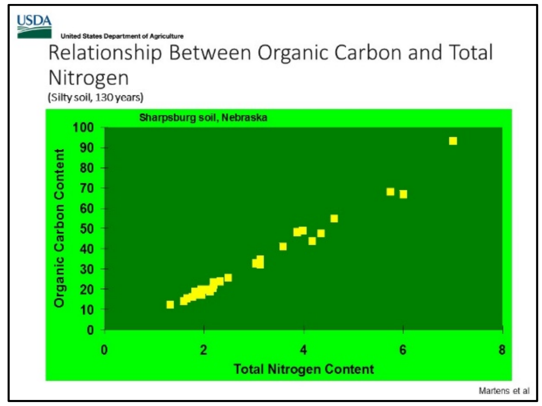
Over much of our cropland, we have been living off the annual withdrawal of nutrients from SOM. We cannot afford to burn off our organic soil carbon if we intend to be sustainable. This is our production bank account. It is also our water bank due to its ability to retain moisture in the soil. When SOM 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

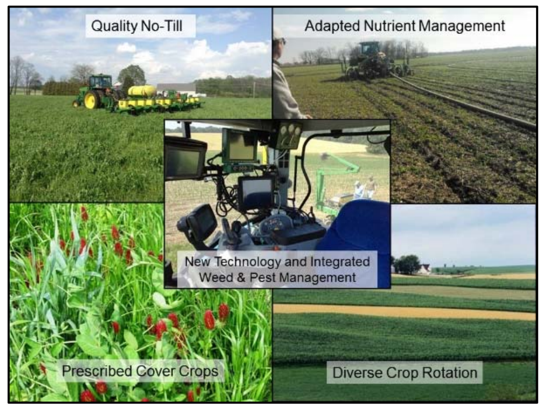
As organic carbon increases in the soil, total soil nitrogen content also increases. Bottom line, it takes protein to increase life in the soil. Consider this your nitrogen bank account where every pound saved is quite literally one that didn't get lost through erosion. There's no better contamination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



Slide 34

Slide 35

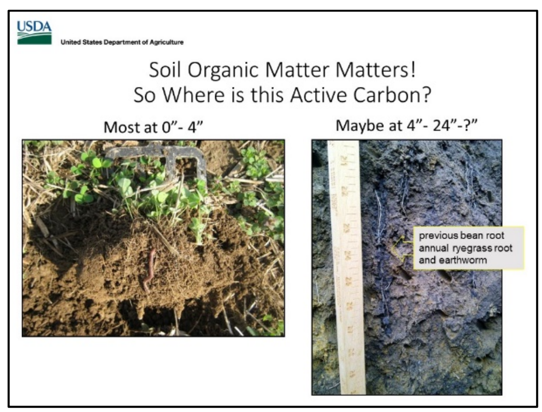
As depicted in the slide, improving soil function is about optimizing and understanding all aspects of the conservation cropping system such that soil health is the central focus with every operation. Each practice should complement and enhance the others of the system.



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

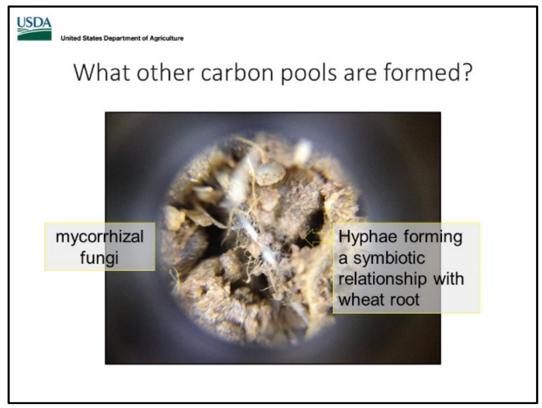
Slide 37

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

Slide 37

Slide 38

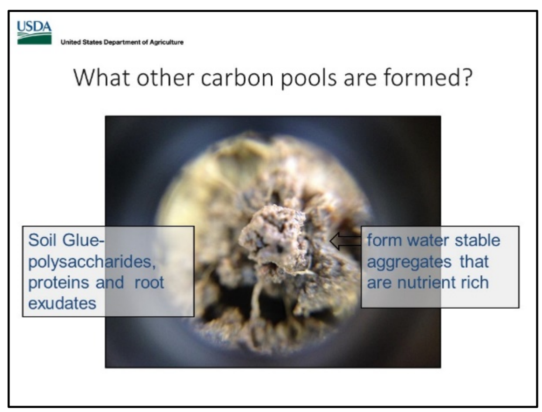
As we've already mentioned, soil biology is greatly important for creating/maintaining stable soil aggregates and increasing available water which provide important soil health functions. The slide shows a hyphae involved in "rhizo-engineering" at the sublevel through its symbiotic relationship with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

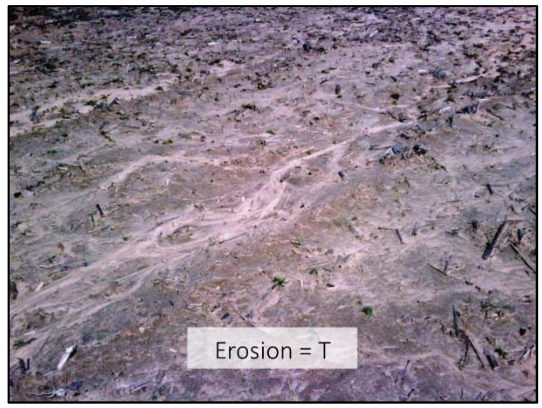
Slide 40

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

Slide 40

Slide 41

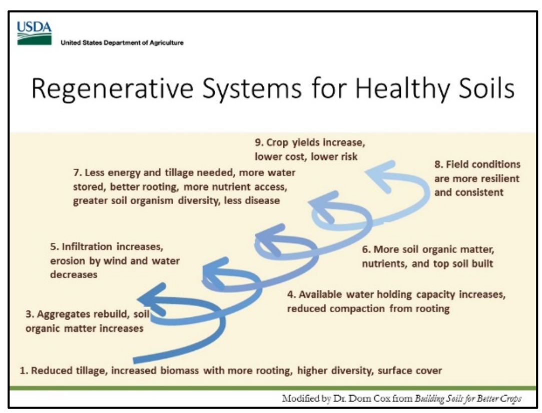
T refers to the soil loss tolerance rate which is the maximum rate of annual soil loss that will still allow sustainable crop productivity now and in the future. In the minds of many soil health producers there is no "tolerable" soil loss, they have moved beyond this. Identification of erosion in the 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

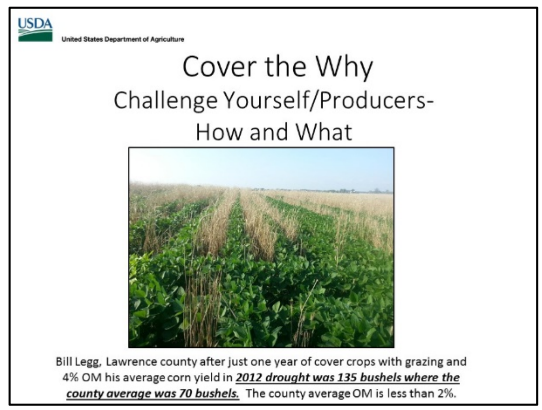
Slide 43

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

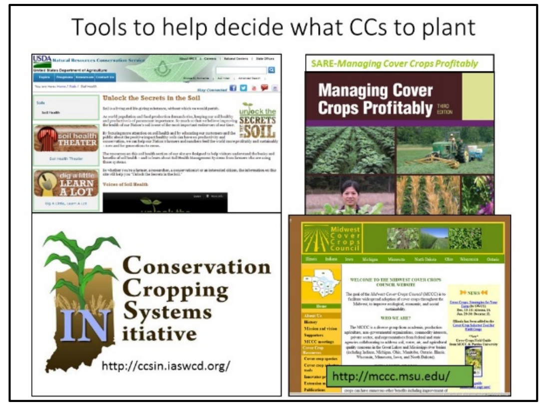
Slide 45

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!