Soil Health Workshop

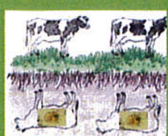
Wednesday, November 14, 2012

Biesiot Activity Center, 398 State Avenue, Dickinson, ND

8:30 – 9:00	Registration – Coffee and Donuts
9:00 – 9:15	Welcome and Introductions
9:15 – 9:45	**Jon Stika,** NRCS Area Resource Soil Scientist • *Soil Stability and Soil Biology*
9:45 – 10:15	**Derrick Dukart**, Manning, ND • *Grazing Cover Crops*
10:15 – 10:30	Break
10:30 – 11:00	**Dirk O'Connor**, Plevna, MT • *Crop Diversity in 'Semi-Tropic' Plevna, MT*
11:00 – 11:30	**James Zielsdorf**, Beach, ND • *Hay Today, Cover Tomorrow*
11:30 – 12:00	**Panel A**: Dukart, O'Connor, Zielsdorf
12:00 – 12:45	LUNCH - Dunn, Western & Central Stark SCD
12:45 – 1:45	**Panel B**: SARE Cover Crop Participants
1:45 – 2:30	**Dan Forgey**, Gettysburg, SD • *Soil Health: The Driving Force*
2:30 – 2:45	Break
2:45 – 3:30	**Ann-Marie Fortuna**, NDSU Soil Scientist • *The Microbes Behind Soil Health*
3:30 – 4:00	**Jon Stika**, NRCS Area Resource Soil Scientist • *Managing for Soil Health*
4:00 – 4:30	**Toby Stroh**, Dickinson, ND • *Soil Health Demonstration Wrap-Up*

"It's not about the amount of precipitation, but how we use it."
Dirk O'Connor

"The longer we are in No Till with good crop diversity, the more benefits we see."
Dan Forgey



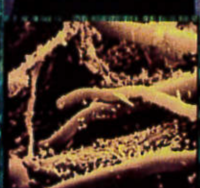
*"We need to feed the **underground herd**."*
Jon Stika

"Hay Today, Cover Tomorrow"
James Zielsdorf

Grazing full-season cover crops at Derrick Dukart's

<u>Ann-Marie Fortuna, PhD</u>

Soil: A Living System

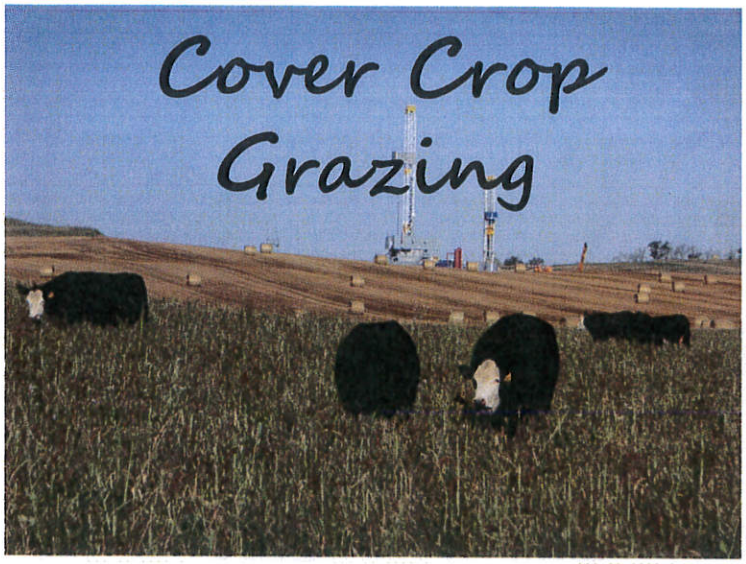


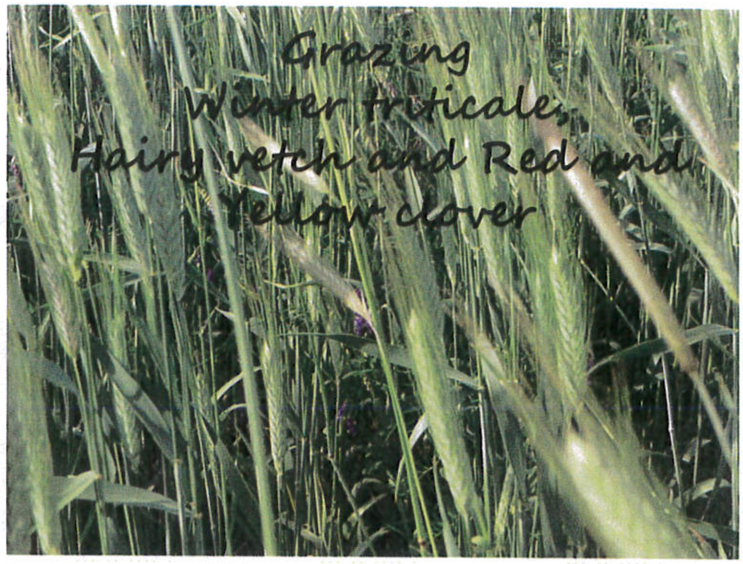
Resource Conservation & Development – Making Things Happen!

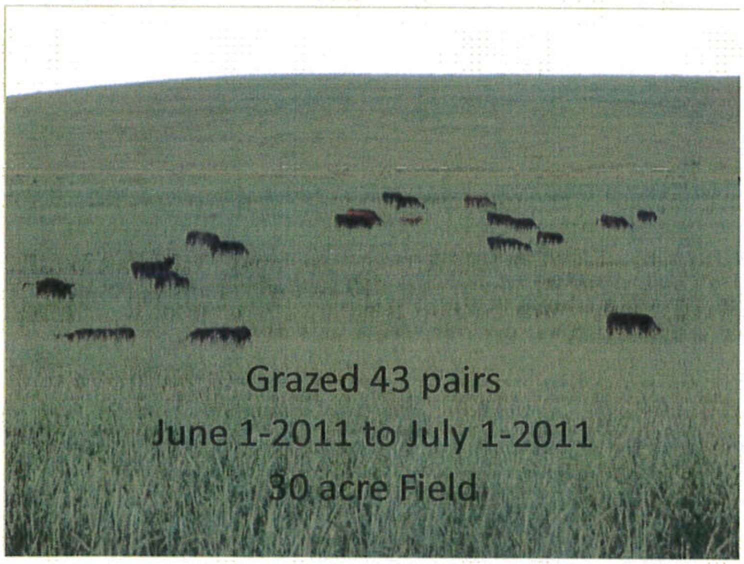
SARE Sustainable Agriculture Research & Education

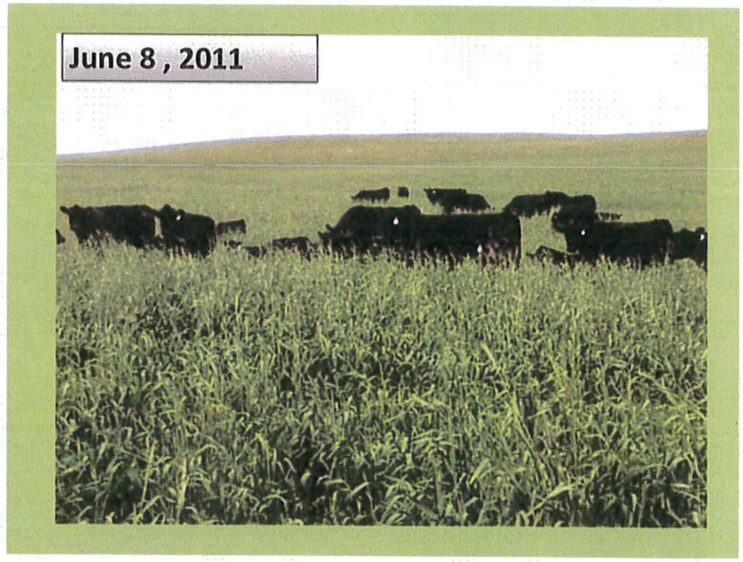
Southwest ND SOIL HEALTH DEMONSTRATION
www.swndsoilhealth.mandakzerotill.org
NRCS | Dunn County, Central Stark, Western SCD | NDSU Dickinson Research Extension Center

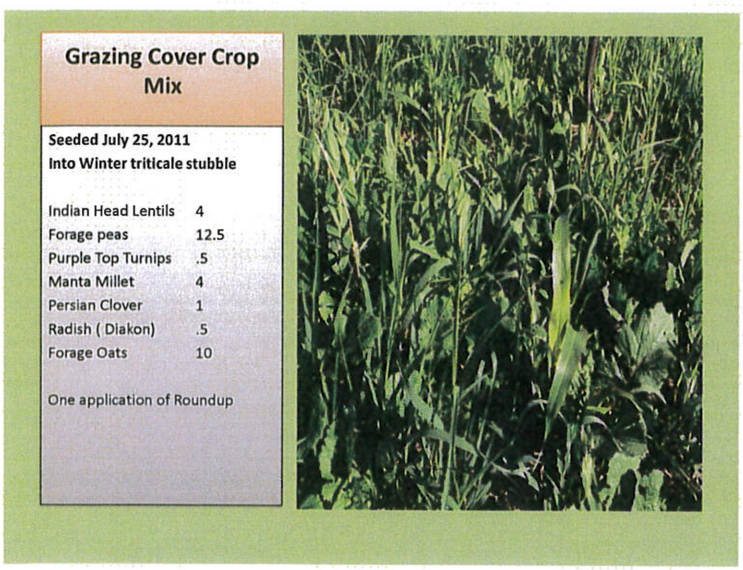
Please RSVP for meal count by November 7
701-390-3222 or
heidihintz@hotmail.com


Cover Crop
Grazing


Grazing
Winter triticale,
Hairy vetch and Red and
Yellow clover


Grazed 43 pairs
June 1-2011 to July 1-2011
30 acre Field

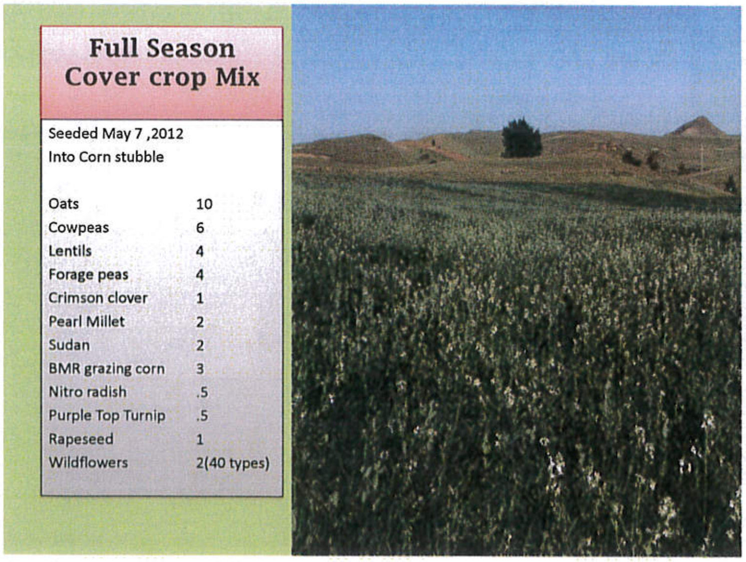

June 8 , 2011

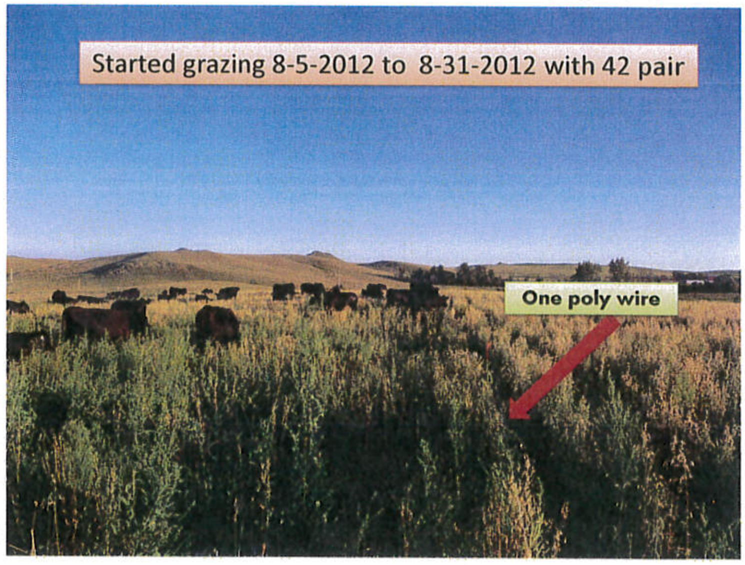

Grazing Cover Crop
Mix
Seeded July 25, 2011
Into Winter triticale stubble
Indian Head Lentils 4
Forage peas 12.5
Purple Top Turnips .5
Manta Millet 4
Persian Clover 1
Radish (Diakon) .5
Forage Oats 10
One application of Roundup


10-23-2011

Turned 10 yearling heifers 10/16/11 thru 11/7/11
Then added 30 cows on grazed till 12/4/11

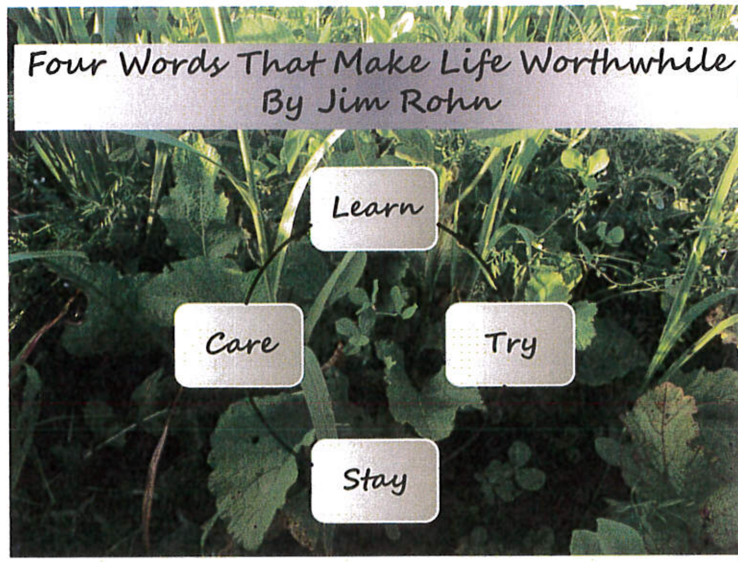
August 5, 2012


Full Season
Cover crop Mix
Seeded May 7 ,2012
Into Corn stubble
Oats 10
Cowpeas 6
Lentils 4
Forage peas 4
Crimson clover 1
Pearl Millet 2
Sudan 2
BMR grazing corn 3
Nitro radish .5
Purple Top Turnip .5
Rapeseed 1
Wildflowers 2(40 types)


Started grazing 8-5-2012 to 8-31-2012 with 42 pair
One poly wire


8-17-2012
RESIDUE


Wildflowers


Four Words That Make Life Worthwhile
By Jim Rohn
Learn
Care
Try
Stay

WHY I GROW COVER CROPS

I have been growing them for years anyway,

and besides I'm an old man and I don't have enough time left to do a series of 5 year rotations. So I might just as well plant cover crop cocktails so I can reap at least some of the benefits the good farmers get from their rotation.

Cover Crops Between Seeded Rows

- Like I said I have been growing cover crops for years anyway, hay mixes and for establishing alfalfa.
- The other kinds of cover crops were less desirable
- winter annual   cheat grass
- N savaging   kochia, wild oats, volunteer grain
- Brasica   wild yellow mustard
- Legume N fixing   black medic and sweet clover
- Compaction fighting   wild sunflowers and sweet clover among others
- These were grown mostly between rows in my seeded crops

What do I need and what does it cost

- Pretty much what I already have but now I decide what grows where and when
- My saline prone soils tend to have extra water from who knows where but it's mixed with salts and other dissolved minerals
- Seeds which I don't raise and some I do raise
- A trusting heart to listen to our fantastic researchers.

Cover Crops Between the Rows Before

Cover Crops Between the Rows After

A Better Cover Crop Between the Rows

Warning!!

- I tell people if they want to be successful watch what I do and do the opposite
- That's where the trusting heart comes in
- Don't listen to me but listen to the researchers
- We do the things we think are right but there are still lots of lessons to learn
- Having said that I will tell you some of the things I have observed

A Cover Crop Cocktail On Saline Soil

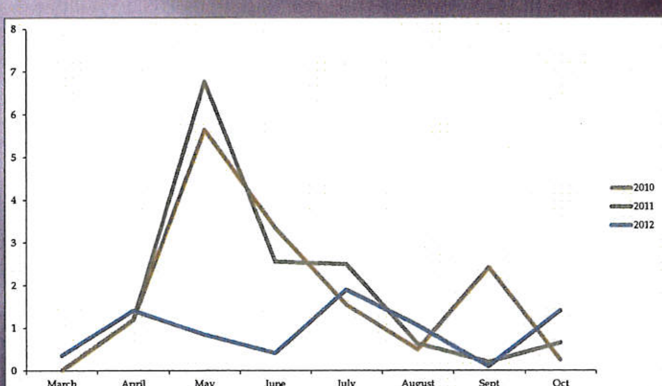
Choices of Objectives

Reduce Erosion / Particulates
Crop Abrasion / Blow-out
Biological Nitrogen Fixation
Pest Suppression
Increase Soil Organic Matter
Enhance Biodiversity
Provide Supplemental Hay
Provide Supplemental Grazing
Soil Moisture (Conservation or Utilization)
Attract Beneficial Insects
Minimize and Reduce Soil Compaction
Capture, Recycle, and Redistribute Nutrients

Chosen Objectives For SE ¼ S2 140-106

Provide Supplemental Grazing
Soil Moisture (Conservation or Utilization)
Attract Beneficial Insects
Minimize and Reduce Soil Compaction
Capture, Recycle, and Redistribute Nutrients
Biological Nitrogen Fixation
Pest Suppression
Increase Soil Organic Matter
Enhance Biodiversity

Rain Fall 20190 2011 2012



Seed Mix For SE ¼ S2 140-106

- **Crops in seed mix**
- 1 sudangrass, sudan-sorghum hybrid
- 2 Indian Head Lentil
- 3 Flax
- 4 Turnips
- 5 Pod Radish
- 6 Safflower
- 7 Snail Medic
- 8 Sweet clover
- 9 Pinto beans
- 10 Corn
- 11 Russian Wild Rye Grass
- 12 Alfalfa

Crop Attributes of Main Species

- 1 sudangrass, sudan-sorghum hybrid
- Compaction fighter, N scavenger, Supplemental Grazing, Forms VAM,adds organic matter and cover, warm season grass rotation, shades ground to prevent evaporation
- 2 Indian Head Lentil
- Great supplemental grazing, N fixing Legume, cool season broad leaf, good C to N ratio, full season crop
- 3 Flax
- Forms VAM, full season crop, attracts beneficial insects
- 4 Turnips
- Excellent grazing, Scavenge nutrients, good C to N ratio, Compaction fighter
- 5 Pod Radish
- Excellent grazing, Scavenge nutrients, good C to N ratio, Compaction fighter
- 6 Safflower
- Compaction fighter, Deep cycling of nutrients, forms VAM, Good grazing, attracts beneficial insects
- 8 Sweet clover
- Fixes N, forms VAM, Winter broad leaf, full season crop

Cover Crop Functions

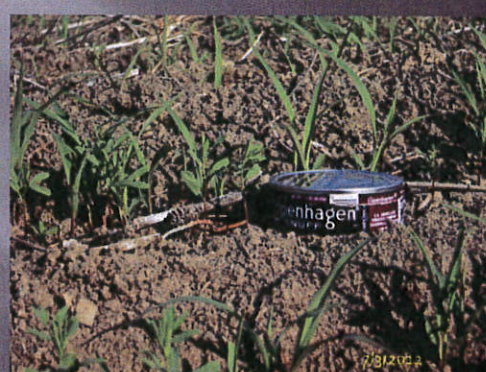
- 1. vesicular-arbuscular mycorrhizae (VAM)
- 4 species
- Sorgum sudan, flax, sweet clover, safflower
- 2. Fixes N -5 species Indian Head Lentil, sweet clover, snail medic, alfalfa
- 3. Cycle Nutrients All
- Deep cycle nutrients 7 species safflower, sorgum sudan, radish, turnip, sweet clover, corn, alfalfa
- Additional benefits not listed. Some crops were present in small quanities

How I Planted the Mix

Planting Day 6/18/2012

Watching It Grow

Watching It Grow



Watching It Grow

Watching It Grow

Ready to Graze 8/8/2012

A Cover Crop Cocktail On Saline Soil

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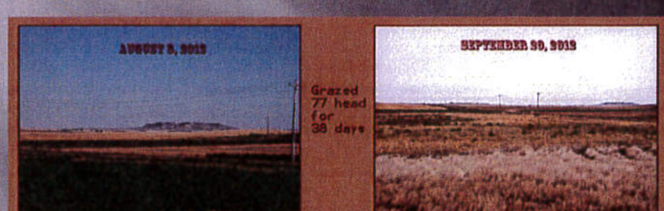
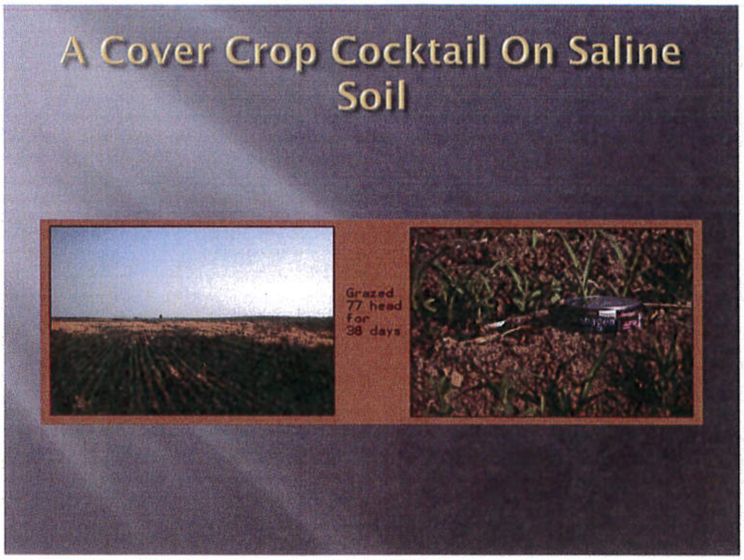
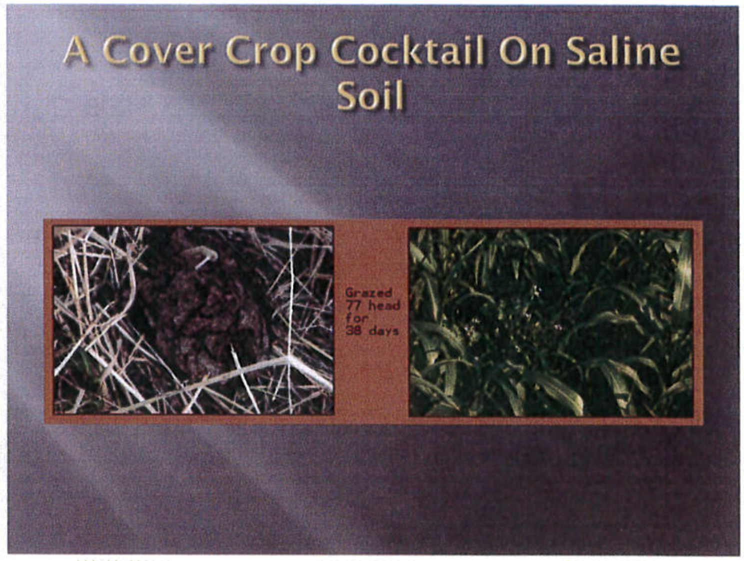
A Cover Crop Cocktail On Saline Soil




A Cover Crop Cocktail On Saline Soil
Grazed 77 head for 38 days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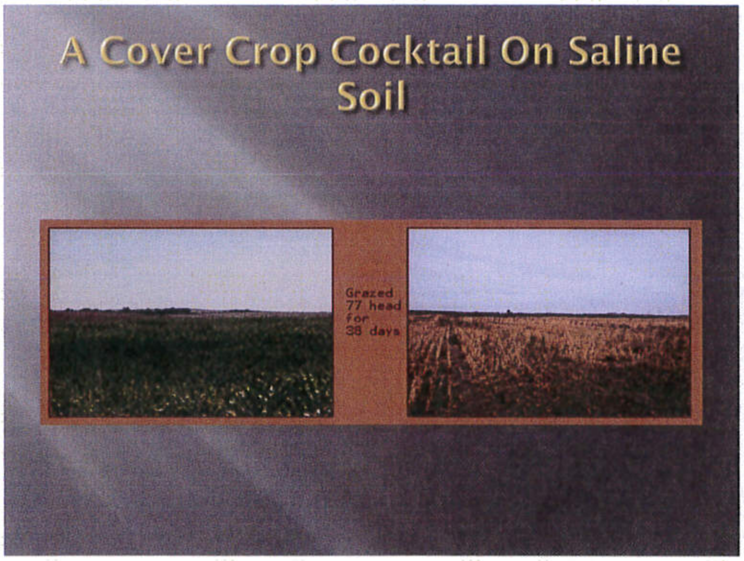
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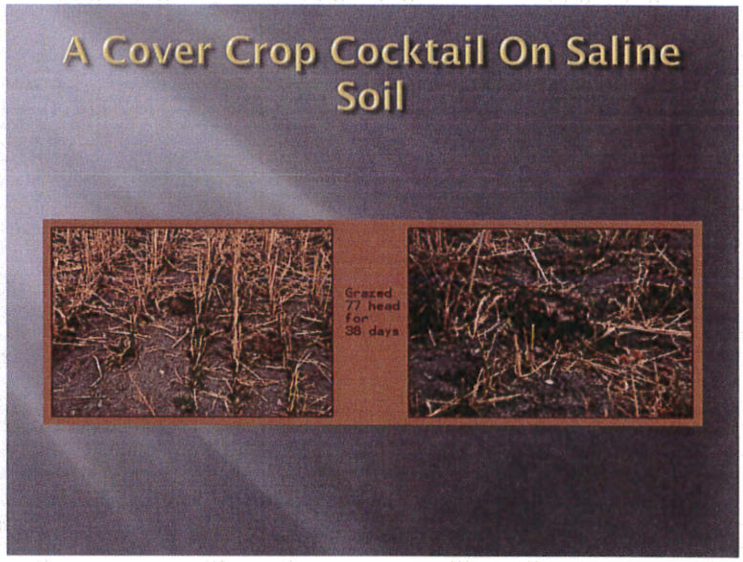

A Cover Crop Cocktail On Saline Soil
Grazed 77 head for 38 days


Winter Wheat Seeded 8/13/12
Winter Wheat Seeded 10/13/2013


Winter Wheat Seeded 8/13/12
seed germinating

Cool, But Why Did I Do It

- Donnie needed supplemental grazing and I wanted cattle for hoof action and manure
- I am in CSP program and I have contracted to grow cover crops on all my acres once in 5 years
- That field was hurting from the stresses of the last 3 years of extreme weather conditions
- It has been very productive in the past and I wanted to make money with it in the future
- I wanted to keep the seep areas covered to reduce evaporation which results in mineral deposits on or near surface
- I wanted to scavenge any N and other nutrients I could that has leached from other fields and moved to mine
- I wanted food for the earth worms I have attracted by planting safflower and no-till farming

What Did It Cost?

- RT3 and Vida burn down$ 4.30
- Spray Operation $ 7.50
- Seed Mix $ 26.00
- Mowing PreSeed 5ac $ 2.00
- Total input $ 39.80
- Total for field 40acres $ 1592.00
- Total rainfall from 3/29/12 6.05 inches
- Hot July, August and September

What Did It Yield

- Charged $ 1.00 head per day
- Aug 6-11 32 head $ 192.00
- Aug 12-21 79 head $ 790.00
- Aug 22-Sept 8 77 head $ 1386 .00
  - Total $ 2368.00
  - Inputs $ 1592.00
  - Net $ 776.00
  - Per Acre $ 19.40

What Did It Yield

- Per Acre $ 19.40 cash
- N scavenged ?
- Ground protected from evaporation ?
- Manure spread on field ?
- Food for Micro organisms ?
- Mycorizal Fungi and earth worms ?

? = "priceless!"

Cover Crop NE ¼ S2 140-106 39 Acres

Planted 6/30/2012

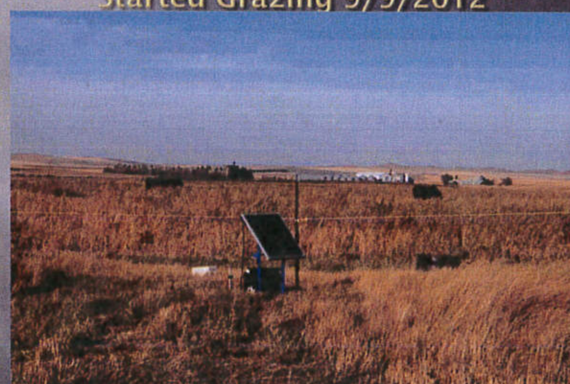
Cover Crop NE ¼ S2 140-106 39 Acres

Cover Crop NE ¼ S2 140-106 39 Acres

Cover Crop NE ¼ S2 140-106 39 Acres

Cover Crop NE ¼ S2 140-106 39 Acres

Started Grazing 9/9/2012



Cover Crop NE ¼ S2 140-106 39 Acres

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Cover Crop NE ¼ S2 140-106 39 Acres

Seeded Winter Wheat 10/13/2012

Cover Crop NE ¼ S2 140-106 39 Acres

Seeded Winter Wheat 10/13/2012

What Did It Cost?

- RT3 and Vida burn down$ 4.30
- Spray Operation $ 7.50
- Seed Mix $ 26.00
- Mowing Weed Control $ 12.00
- Total input $ 49.80
- Total for field 35acres $ 1743.00
- Total rainfall from 3/29/12 6.05 inches
- Hot July, August and September

What Did It Yield

- Charged $ 1.00 head per day
- Sept 9-18 117 head $ 2106.00
  - Total $ 2106.00
  - Inputs $ 1743.00
  - Net $ 363.00
  - Per Acre $ 10.38

What Did It Yield

- Per Acre $ 10.38 cash
- N scavenged ?
- Ground protected from evaporation ?
- Manure spread on field ?
- Food for Micro organisms ?
- Mycorizal Fungi and earth worms ?

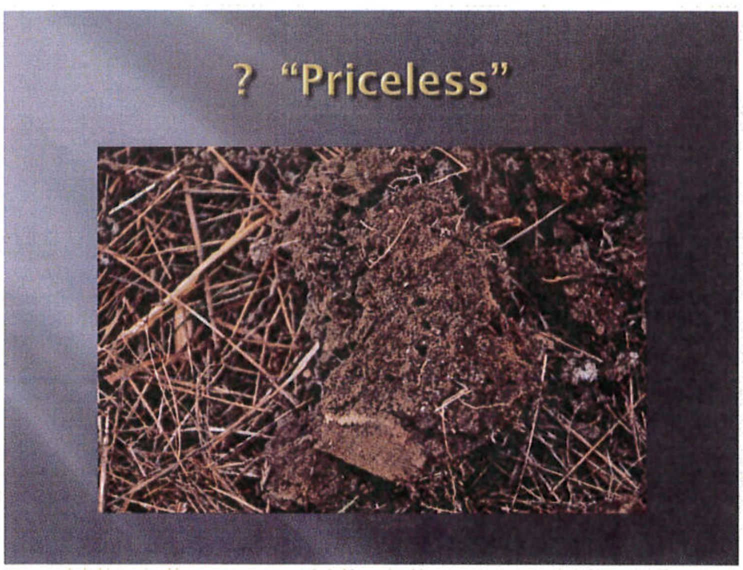
? = "priceless!"

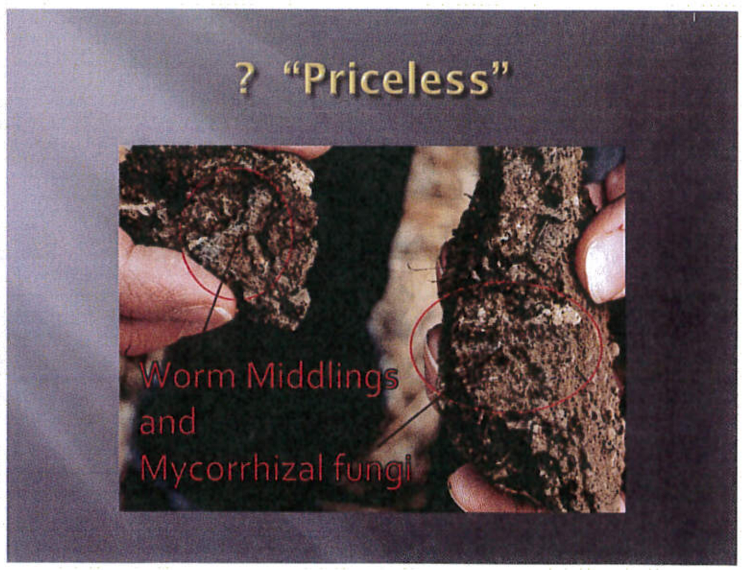

? "Priceless"

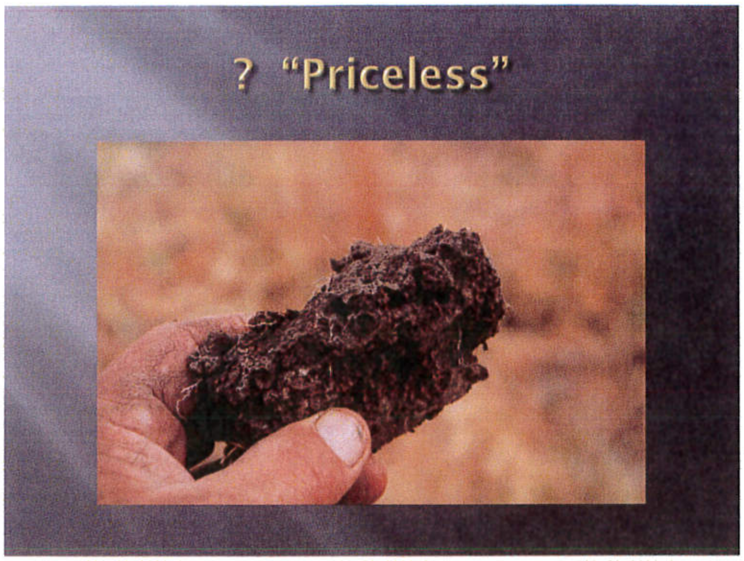

? "Priceless"


? "Priceless"


? "Priceless"


? "Priceless"


? "Priceless"
Worm Middlings
and
Mycorrhizal fungi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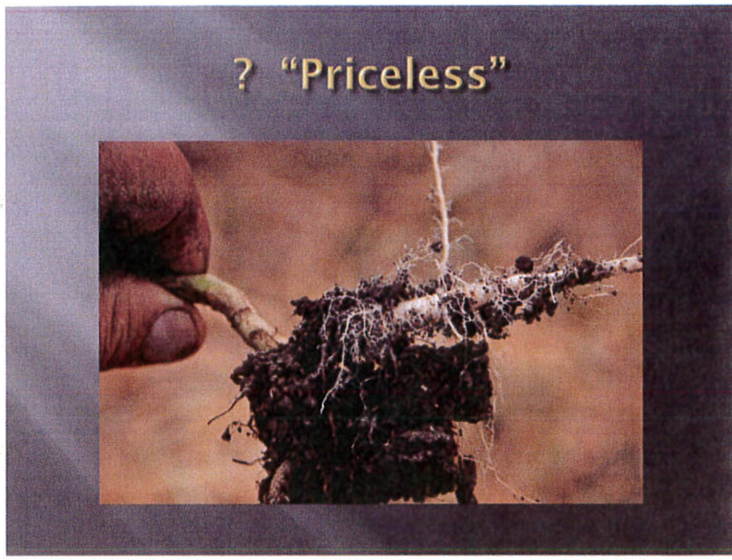
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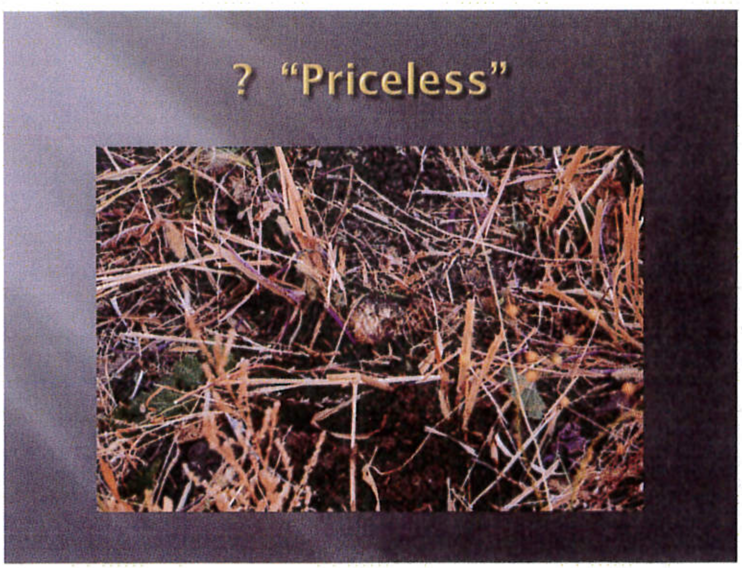
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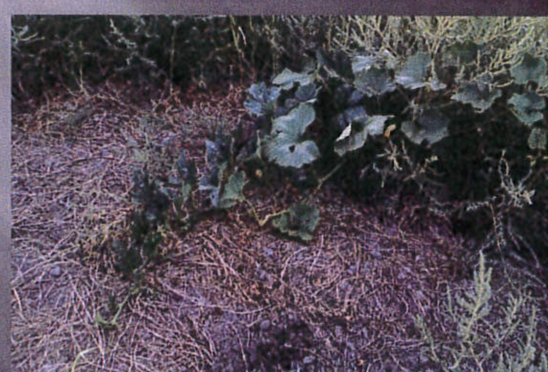
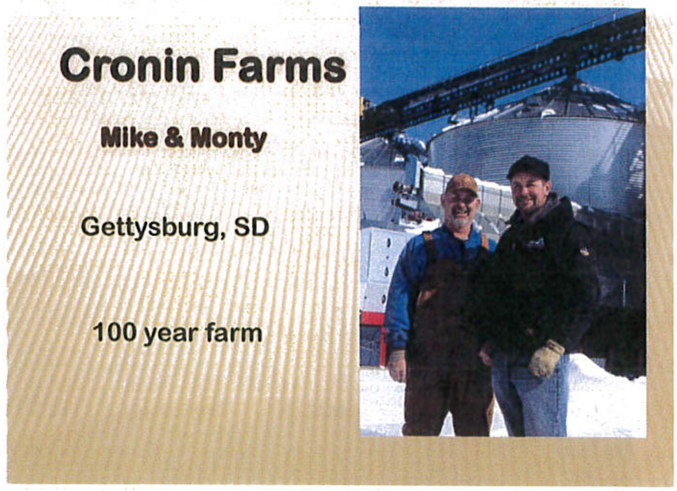


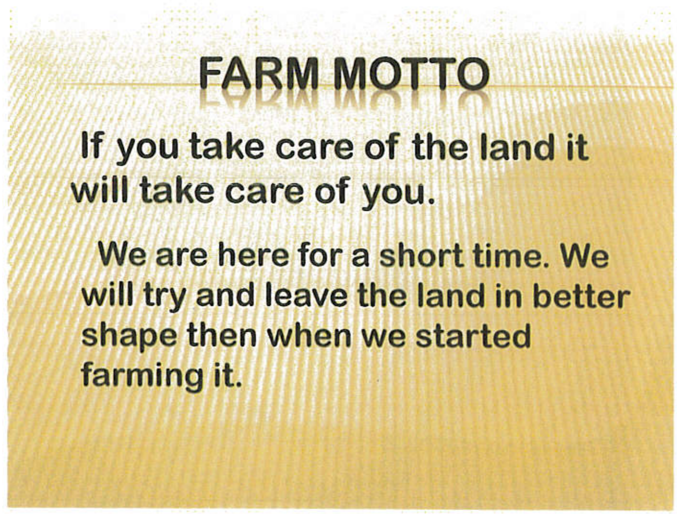
? “Priceless”

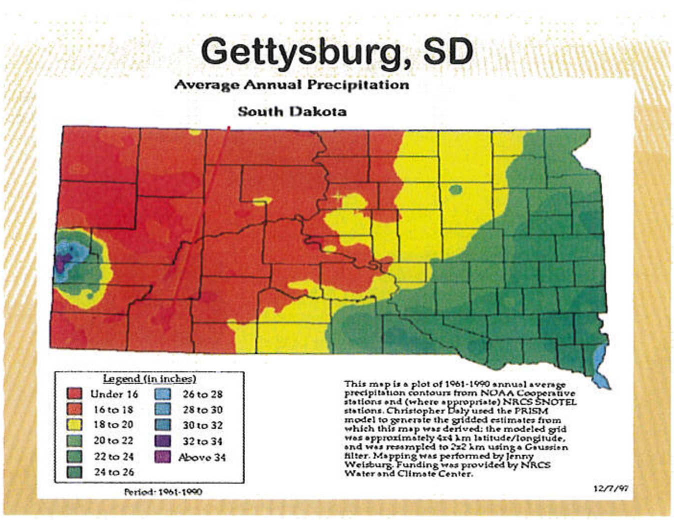
? “Priceless”

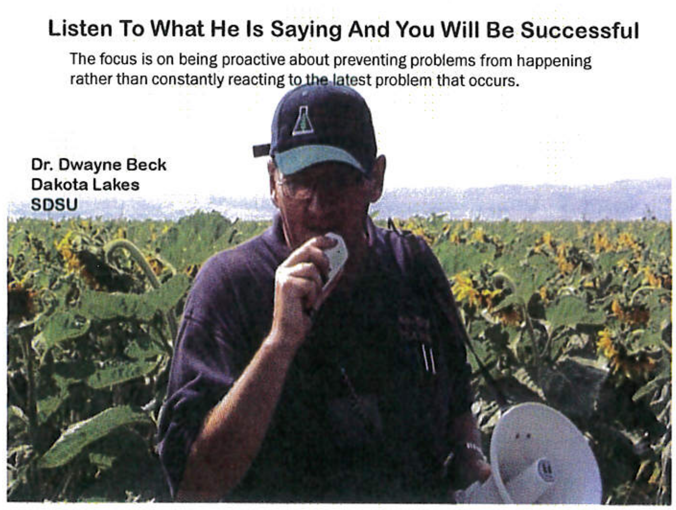

Using Crop Diversity To Improve Soil Health
Dan Forgey


Cronin Farms
Mike & Monty
Gettysburg, SD
100 year farm


Farm Ground 2012 8,300 Acres
320 of that is irrigated
8,500 Grass Which is On The Missouri River Breaks


FARM MOTTO
If you take care of the land it will take care of you.
We are here for a short time. We will try and leave the land in better shape then when we started farming it.

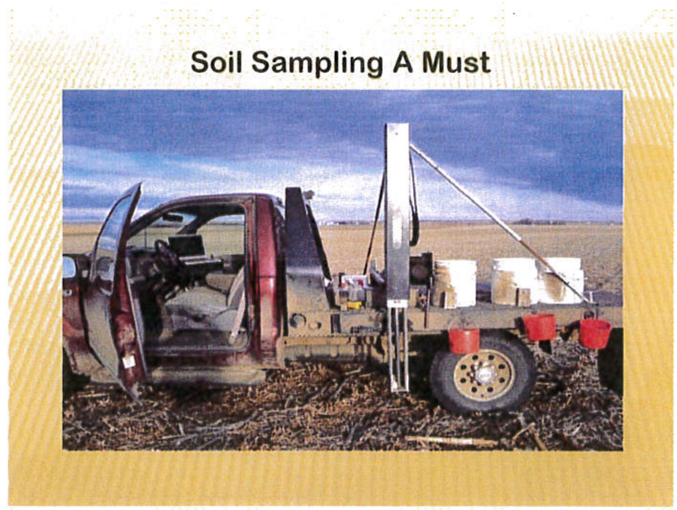

Gettysburg, SD
Average Annual Precipitation
South Dakota
Legend (in inches)
Under 16
16 to 18
18 to 20
20 to 22
22 to 24
24 to 26
26 to 28
28 to 30
30 to 32
32 to 34
Above 34
Period: 1961-1990
This map is a plot of 1961-1990 annual average precipitation contours from NOAA Cooperative stations and (where appropriate) NRCS SNOTEL stations. Christopher Daly used the PRISM model to generate the gridded estimates from which this map was derived; the modeled grid was approximately 4x4 km latitude/longitude, and was resampled to 2x2 km using a Gaussian filter. Mapping was performed by Jenny Weisburg. Funding was provided by NRCS Water and Climate Center.
12/7/97


Listen To What He Is Saying And You Will Be Successful
The focus is on being proactive about preventing problems from happening rather than constantly reacting to the latest problem that occurs.
Dr. Dwayne Beck
Dakota Lakes
SDSU

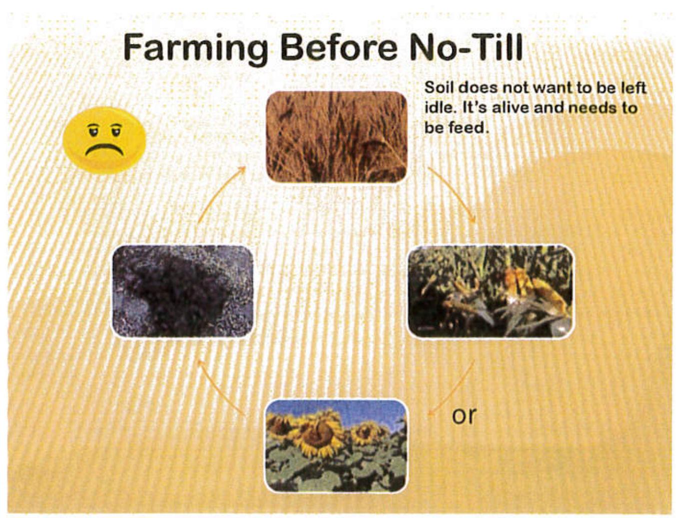

Low
Disturbance
No-Till
09/12/2008 1:08 am


We have no excuse. We have the tools and the knowledge to stop this.
Sully County Spring 2007


We need to learn from their mistakes.
No-Till Natures Way
09/10/2009


Soil Sampling A Must


Taking Step Two
Diversified
Rotations
Low
Disturbance
No-Till
09/12/2008 1:08 am


Farming Before No-Till
Soil does not want to be left idle. It's alive and needs to be feed.
or

How It All Started In 1992

   Or 

Spring Wheat → Winter Wheat → Corn → Sunflowers →

In 2002 We Felt It Was Time To Change

Spring Wheat → Winter Wheat → Cover Crops → Corn → Corn → Soybeans

Is this the complete answer? NO

Does it help?

We added cover crops In 2006

Spring Wheat → Winter Wheat → Field Peas → Cover Crops → Corn → Sunflowers

Rotations 2012

1. Forage Sorghum – Corn – Sunflowers - SW – WW – Cover Crop - Corn
2. Corn – Soybeans – Soybeans – SW – WW
3. Field Peas – Corn – Sunflowers - SW
4. WW – Corn – Field Peas – Cover Crop - Corn
5. Corn – Soybeans – SW – Corn - Sunflowers
6. WW – Soybeans – Soybeans – Corn – Oats
7. WW – German Millet – Corn – Soybeans – Field Peas
8. Sunflowers – SW – WW – Field Peas - Corn
9. Sunflowers - SW – WW – Cover Crop - Corn – Soybeans
10. Corn – Sunflowers – SW – WW – Cover Crop
11. Corn – Sunflowers – SW – WW – Soybeans - Lentils
12. Field Peas – WW – Corn
13. SW – Oats (Forage) – Alfalfa - Alfalfa

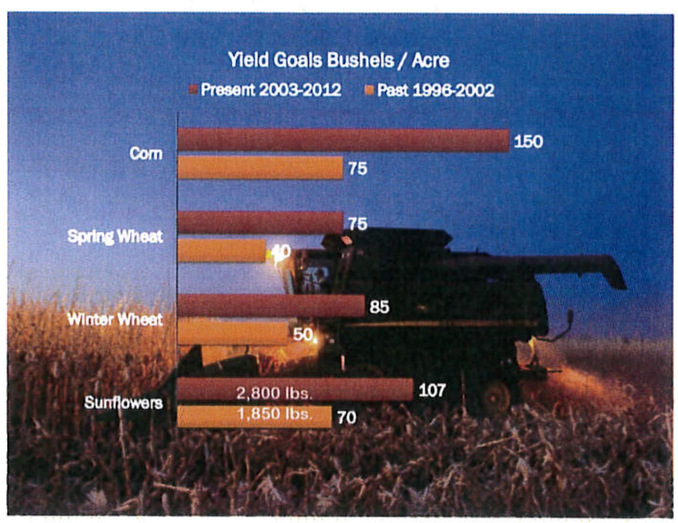
   

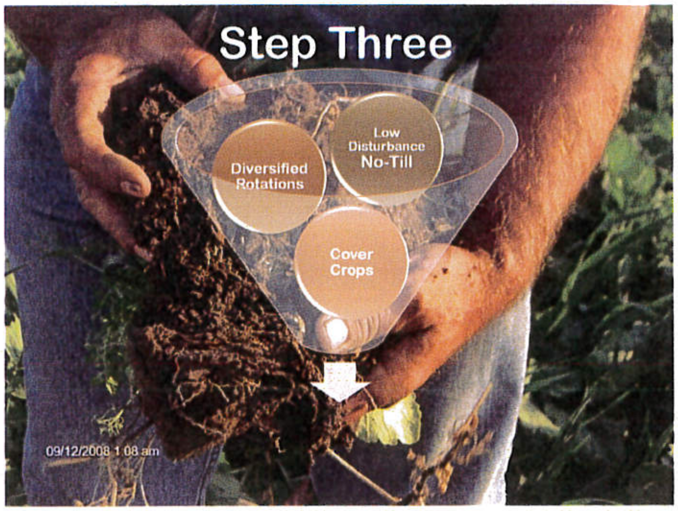
Letting Rotations Work For You

1. Feed the soil food web to promote soil health and gain OM
2. Help with weed control without the use of chemicals
3. Allows you to use different chemicals to stop resistance
4. Help manage our fertility by planting legume crops and taking N credits on past legume crops
5. Manage your residue

Crops Raised In 2012

- Spring Wheat
- Winter Wheat
- Corn
- Sunflowers
- Soybeans
- Field Peas
- Lentils
- Alfalfa
- Millet (forage)
- Oats (forage)
- Sudan Grass
- Cowpeas
- Turnips
- Radish
- Canola
- Common Vetch
- Rye (fall grazing – forage)





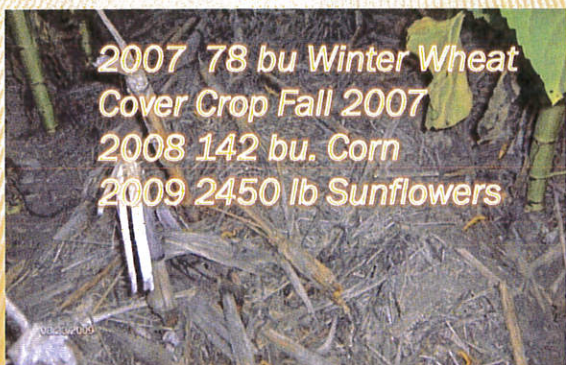
Carbon And Soil Organic Matter

Carbon is a key ingredient in soil organic matter (57% by weight).

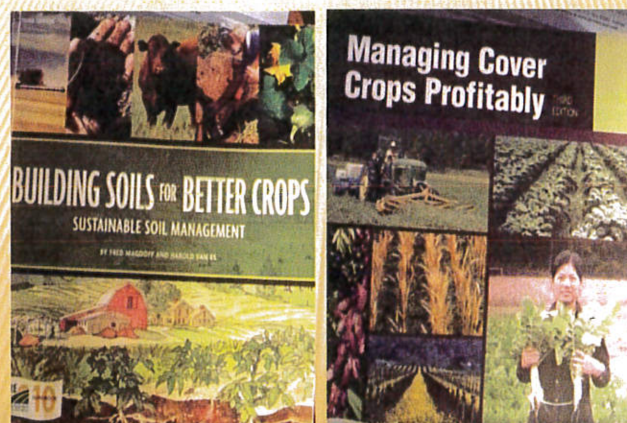
Plants produce organic compounds by using sunlight energy and combining carbon dioxide from the atmosphere with water from the soil.

Soil organic matter is created by cycling of these organic compounds in plants, animals and microorganisms into the soil.

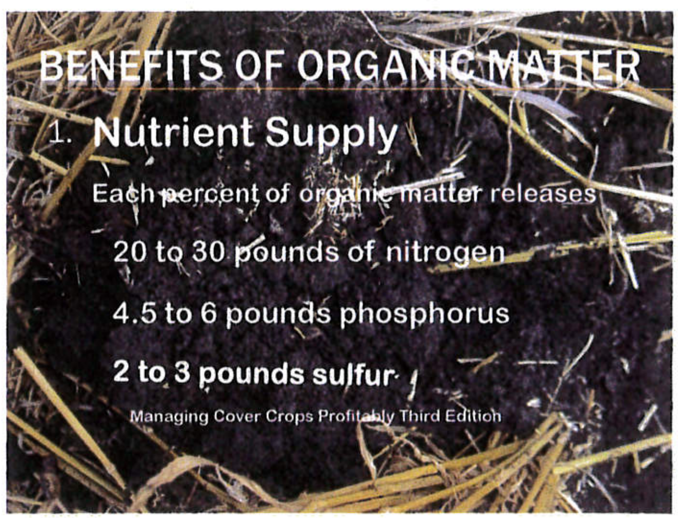
Residue Is Not A Problem On Our Farm



Two Very Good Books



We Like The Flax And Oats



2. Water Holding Capacity

Organic matter acts like a sponge. It will hold up to 90% of its weight in water.

3. Soil Structure Aggregation

Organic matter causes soil to form aggregates which helps with water infiltration.

4. Erosion Prevention

Increasing soil organic matter from 1 to 3 percent can reduce erosion by 20 to 30 percent because of water infiltration.

08/23/2009

FINDING THE RIGHT COVER CROP

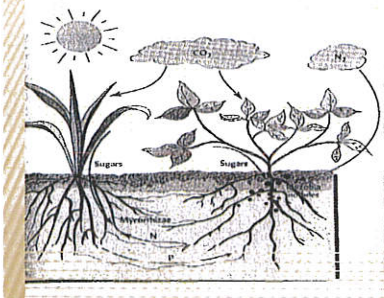
- **What C/N do I want?**
- **Do I want to have a legume to help fix N?**
- **Do I need a cool season cover crop or warm season cover crop?**
- **What crop will I be planting next year?**
- **What is safe to graze?**
- **What herbicides did I use last year?**
- **How much do I want to spend?**

Working With Cover Crops In 2011 With Limited Moisture

Field Peas	**21 lbs**	**$2.71**
Canola	**.3 lb.**	**$0.23**
Flax	**8 lbs**	**$2.40**
Radish	**1 lbs**	**$1.45**
Oats	**12 lbs**	**$1.31**

Seed Cost $8.10

Mycorrhizal Fungi



Assists with P uptake from the soil.

Moves P from the non-legume plant to the legume plant.

Moves N from the legume plant to the non-legume plant.

The Nature and Property of Soils, Brady and Weil

Mycorrhizal fungi increase the surface area absorbing area of roots 100 to a 1,000 times, thereby greatly improving the ability of the plant to access soil resources.

	Increase OM	Fix N	Grazing	Seed rate	C/N Ratio	Mycorrhizal	% of mix	Lbs/Acre
Flax	F	N	P	20	H	H	**18%**	**3.6 lbs**
Oats	G	N	F	70	M	L	**20%**	**14 lbs**
Radish	P	N	G	8	L	N/A	**10%**	**.8 lbs**
Peas	P	Y	F	90	L	M	**30%**	**27 lbs**
Sudan	G	N	G	25	M	H	**22%**	**5.5 lbs**
							100%	**50.9 lbs**

60% Higher Carbon Crops
30% N Fixer Cover Crop
10% Low Carbon Cover Crop

Understanding C/N Ratio

If you want to slow down the residue breakdown you want more carbon.

If you want to fix N you plant more legumes.

If you are trying to breakdown residue use more brassica and legumes.

This Is Where The Cocktail Mix Comes In.

Canola Radish

Learning To Work With Cover Crops

Finding the right C/N ratio

Radishes – Peas – Oats
Turnips - Canola

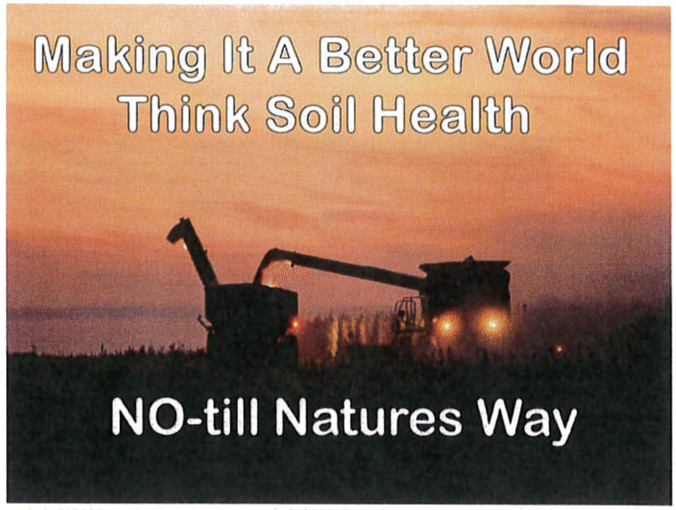
Forage Sorghum - Cow Peas

Rye For Cover Crop And Fall Grazing

Cattle Grazing Rye The Winter Of 2006

Lessons Learned

1. If you take care of the land it will take care of you.
2. You will make mistakes. Just try and learn from them.
3. When trying something new start on a small scale.
4. Heavy residue is your friend. Learn to work with it.
5. We are feeding the soil food web. This is like adding to your savings account.
6. The more you learn, the more questions you will have.
7. Learn from the mistakes of others, you can't live long enough to make them all yourself.



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Soil Health & Land Management Team

Mission: Help guide & prioritize soil health research & extension efforts directed by NDSU; to provide networking opportunities among NDSU, state & federal agencies, retail partners, & commodity-grower groups; & to help increase the awareness & importance of soils to North Dakota's vitality. By providing the public and scientific communities evidence for adaption to changing soil environments, North Dakota's land managers will be better suited to adapt to changes in climate, cropping systems, & environmental situations.

NDSU

Dr. Ann-Marie Fortuna | Research Soil Health Assistant Professor
NDSU Soil Science Department, Fargo
Starting July 15, 2012

Dr. Fortuna received her PhD (2001) in Soil Science from Michigan State, and has been an assistant professor at Washington State for the past four years. She has been awarded over $6.8 million in grants and published 16 peer-reviewed journal articles.

Her research at WSU integrated soil health, nutrient cycling, long-term ecosystems management, and microbiology; improving soil quality and managing nutrient efficiency.

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Soil Health

The capacity of a soil to sustain biological production, maintain environmental health, and promote plant and animal health.

- Soil health is a function of various soil attributes (physical, chemical, and biological) which respond to land management and vary in space and time

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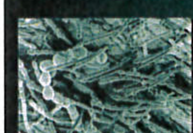
Soil a Living System

Soil organisms (biota) carry out a wide range of processes that are important for soil health and fertility in agricultural. Soil contains all forms of life and elements on earth!



NDSU

Soil Biota

- consist of micro-organisms (bacteria, fungi, archaea and algae), soil animals (protozoa, nematodes, mites, springtails, spiders, insects, and earthworms) and plants (Soil Quality Institute 2001) living all or part of their lives in or on the **soil** or ***pedosphere***.

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Soil Biota

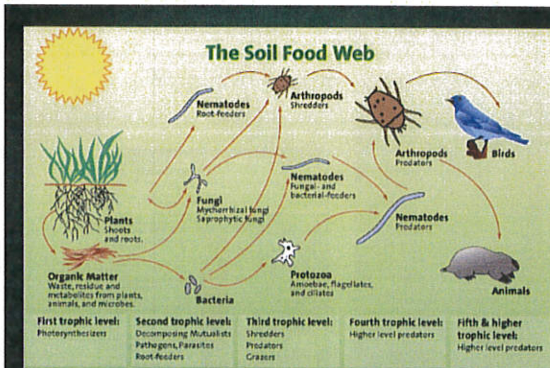
- Soil organisms range in size from microscopic, bacteria to centimeters, earthworms
- Activity of soil biota is concentrated in the top 10 cm of soil
- Millions of organisms exist of which only a fraction have been identified
- 80 - 90% of soil biological activity is carried out by bacteria and fungi

Soil Food Web

- The community of organisms living all or part of their lives in the soil
- A series of conversions of energy and nutrients occurs as one organism and or substance is consumed by other organisms

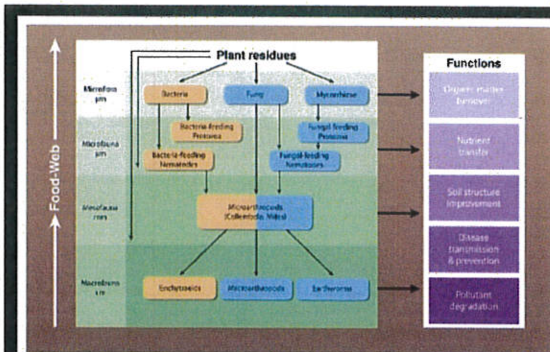
Soil Food Web

- In natural and managed environments a complex food web exists
- These 'predator-prey' relationships help control the balance of species present
- The Food Web includes microflora, microfauna, mesofauna & macrofauna



Plant, Animal & Soil Organic Matter Turnover & Nutrient Transformations

- Carbon constitutes the chemical backbone of all matter and is the energy source for most soil biota
- Microbial decomposition of plant, animal and soil organic matter provides access to carbon & nutrients like nitrogen & phosphorus needed by soil biota & plants



µm to thousands of inches, mm = 0.04 in, cm = 0.39 in

Figure 2. Trophic levels in a soil food web

Soil Testing & Measures of Soil Health

- Soil texture
- Aggregate stability
- Available water capacity
- Field penetration resistance
- Organic matter
- Active carbon
- Potentially mineralizable nitrogen
- Root health assessment
- Chemical analyses

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- Commercial & university run soil testing labs offer soil analyses based on indicators of soil health
- Interpretation challenging, requires standardization across regions, cropping systems & managements
- Standard biological indicators of soil health relate to turnover of nutrients in the food web
- Some labs use specific biota to represent the resilience & fertility of an agroecosystem

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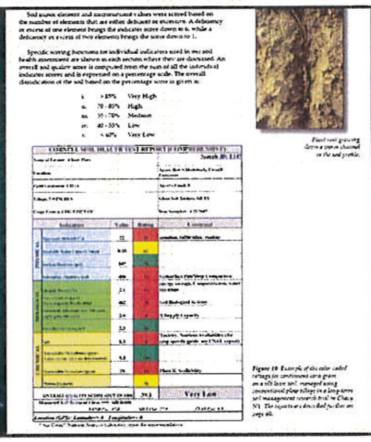

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Soil Resilience an Index of Soil Health

- Soil resilience is a function of soil quality, land use & management
- Soil resilience = *f*(water capacity x soil structure x rooting depth x cation exchange capacity x nutrient supplying capacity x soil biodiversity) (Bezdicek et al., 1996)

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Southwest North Dakota Soil Health Demonstration

- Illustrate the effect of no tillage and diverse crop rotations integrating cover crops improve soil health
- Soil health measured using soil quality indicators covered in John Stika's talk will discuss interpret of food web analysis during this workshop

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Arenas of Activity Control Nutrient Cycling

- Soils contain limited resources & many environments ranging in size from: a no-till field, crop rhizosphere, aggregate, & a single aggregate pore each of which contain areas of biological activity rich in soil biota as well as plant & animal material & soil organic matter, ~ 10% of the soil volume.

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Soil Aggregate – Arenas of Soil Biological Activity

- An aggregate represents a soil on a microscale (Fig. 1)
- made up of sand, silt, clay, organic matter, root hairs, microorganisms and their "glue" like secretions mucilages, extracellular polysaccharides, & hyphae (filaments) of fungi as well as pores

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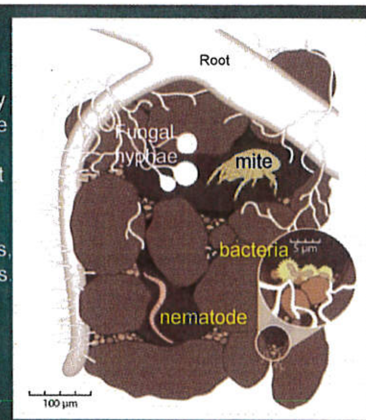
Figure 1: A soil aggregate or ped is a naturally formed assemblage of sand, silt, clay, organic matter, root hairs, microorganisms and their secretions, and resulting pores.



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- Temporary binding agents (hyphae & polysaccharides) made by soil organisms aid in formation of macroaggregates contained within microaggregates.
- These macroaggregates function as "ecosystems or arenas of activity" (Beare *et al.* 1997, Coleman *et al.* 2004).

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- Describe the soil system in terms of the biogeochemical processes that soil organisms (biota) control at an aggregate and field scale
- Discuss the influence of best management practices on these biological processes

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Critical or Break Even C:N Ratio

The critical C:N ratio is the C:N ratio at which net ammonium production results. Releasing plant available N

Organic amendments with C:N ratios below 20:1 typically result in net ammonium production

Organic amendments with C:N ratios greater than 30:1 typically result in net immobilization

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Michigan State University Extension Bulletin E-2646

Typical nitrogen content of manures from selected animals

Animal type	lb N/ft³ manure
Dairy cattle	0.30
Beef cattle	0.35
Swine	0.42
Sheep	0.73
Horse	0.36
Poultry	0.83

Nitrogen fixed in root nodules of common legumes

Legume species	N fixed (lb/A)
Alfalfa	50 - 150
Red clover	60 - 70
White clover	60 - 100
Hairy vetch	60 - 180
Soybean	30

Nitrogen credits for soil nitrogen

Soil organic matter	Nitrogen credit
(percent)	(lb N/A/yr)
0 - 4	0
4 - 8	20 - 40
organic soils (>8)	40 - 80

C:N ratios of common crop residues

Residue	C:N ratio
Young legumes	12 - 20:1
Young grasses	20 - 40:1
Corn stalks	60:1
Small grain straw	80:1
Woody materials	400:1

Yield and nitrogen content of common crops

Crop	bu or ton/A	lb/A	Nitrogen content
Alfalfa hay	6 ton	12,000	270
Corn, grain	150 bu	8,400	135
Corn, stover	4.5 ton	9,000	101
Soybean, seed	50 bu	3,000	188
Soybean, straw	2.5 ton	5,000	127
Wheat, grain	60 bu	3,600	75
Wheat, straw	2.5 ton	4,500	30

Nitrogen credits for previous crops when followed by corn

Previous crop	Nitrogen credit (lb N/A)
Corn and most other crops	0
Soybeans	30
Grass sod/pastures	40
Annual legume cover crop	40 - 80*
Perennial forage legume	60 - 140*

*Nitrogen credits can vary considerably based on plant species, stand density, growing conditions and harvest date. Values are calculated using 40 + 20x, where x is plants/sq ft.

Critical or Break Even C:N Ratio

Fungi & bacteria convert C substrate into microbial biomass at different rates or yield coefficients. What is not converted to g of microbial biomass is evolved as CO_2.

If the N requirement of the fungi plus bacteria is less than the amount of inorganic N available in the soil, net N mineralization will occur.

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Critical or Break Even C:N Ratio

The C/N of bacteria 4, 1/3 of microbial biomass. Yield coefficient (Y) is 0.32

The C/N of fungi 10, 2/3 of microbial biomass. Yield coefficient (Y) is 0.44

Average C/N of biomass = 4(1/3) + 10(2/3) = 8

Average microbial yield coefficient (Y) = 0.32(1/3) + 0.44(2/3) = 0.4

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Critical or Break Even C:N Ratio

So for every 100 g of C substrate - 40 g becomes microbial biomass & 60 g is evolved as CO_2

If the amount of available inorganic N is greater than 5 g net mineralization will occur.

8/1 = 40 g/X X = 40/8 =5 g

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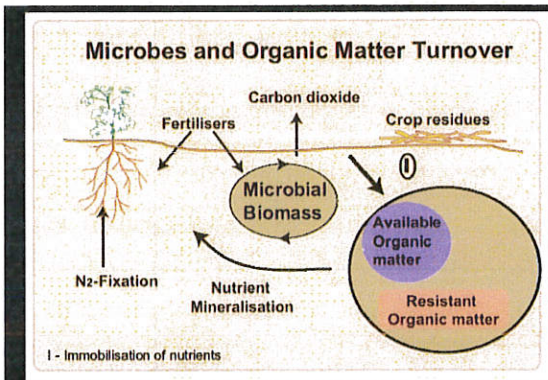

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Gupta, V. V. S. R. *et al. Life in the Soil.* Adelaide, Australia: Cooperative Research Centre for Soil & Land Management, CSIRO, The University of Adelaide, 1997.

Organic Matter (OM) and Soil Health

OM maintains soil health improving: aggregate stability, soil structure, reduces erosion, provides energy for microorganisms, is important to nutrient cycling, improves infiltration, water holding capacity, cation exchange capacity, & the breakdown of pesticides.

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Soil Organic Matter Turnover & Nutrient Transformations

- Soils with high levels of OM support a greater number and a more diverse range of soil biota
- The rate of OM breakdown relates to the soil environment, the number and type of organisms present and the chemical structure of organic inputs

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Table 2. Typical Numbers of Soil Organisms in Healthy Ecosystems

	Ag Land	Prairie	Forest
	Organisms per gram (teaspoon) of soil		
Bacteria	100 million - 1 billion	100 million - 1 billion	100 million - 1 billion
Fungi	Several meters	10s – 100's of meters	1-60 kilometers (in conifers)
Protozoa	1000's	1000's	100,000's
Nematodes	10-20	10's – 100's	100's
	Organisms per square meter		
Arthropods	< 10	45-200	900-2,300
Earthworms	4-25	8-42	8-42 (0 in conifers)

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- Describe the soil system in terms of the biogeochemical processes soil organisms (biota) control at an aggregate and field scale
- Discuss the influence of best management practices on these biological processes

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Best ways to manage organic matter in a cropping sequence

- Reduce tillage,
- Plant cover crops,
- Practice crop rotations to increase organic inputs as root biomass

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- Long-term experiments have shown that addition of manure, adequate fertilization, and crop rotations can increase soil C and N
- But, manure and crop rotations in agricultural systems often result in a decline of soil C & N relative to native conditions
- The rate and magnitude of additions will be affected by cropping sequence, tillage system, soils, climate, and temperature

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'Bio Strip-Till' Boosts Corn Yields – No-till Farmer

Forage radishes and field peas grow in fall on a "bio strip-till" experiment at the Conservation Cropping Systems Project (CCSP) in ND. Corn planted in these plots in 2010 were 5th and 6th highest yielding of 53 plots. (Photo CCSP)

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Intercropping Green Manures & Catch Crops Improves Water & N Use Efficiency

- Green manures like field pea & vetch, fix atmospheric N via a symbiotic relationship with rhizobium, bacteria
- Legumes can potentially provide ~100 lb N/ A
- Catch crops like radishes can retain over 100 lb N/ A & reduce excess water & compaction
- Catch crops taking up residual soil N & biologically fixed N force legumes to fix N more efficiently, biodiversity improves soil health and nitrogen use efficiency

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NDSU NORTH DAKOTA STATE UNIVERSITY http://www.sare.org/publications/covercrops.htm

Conservation Tillage

- Facilitates moisture retention & reduces erosion increasing the number & diversity of soil fauna
- Moisture retention in sandy & clay soils under conservation tillage can be reduced with catch crops
- Residue management & decomposition of residues by soil biota aid in planting, crop emergence & may reduce disease pressure

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Arenas of Activity Conservation Tillage & Cover Crops

- Conservation tillage management stratifies nutrients at the surface creating an environment that benefits fungi, microarthropods (soil insects), and worms
- Constant ground cover & live roots stimulate soil biota to transform nutrients
- Soil Biota release & translocate nutrients through their activity and movement

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- Best management practices create conditions in which energy & nutrients are supplied to soil biota that turnover these inputs, improving soil health and fertility

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Summary

"Through their biochemical and physical effects, living organisms and plant roots have altered the soil, a product of destructive (microbial decay) and creative (synthetic) processes" (Brady and Weil, 2002).

These forces link biological, chemical & physical soil processes at a micro & macro-scale defining soil health.

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Managing for Soil Health

Think small in size and **big** in numbers...

Credit and thanks to
- Dr. Kristine Nichols – ARS Mandan, ND
- Dr. Elaine Ingham – Oregon State University
- Dr. Rebecca Phillips – ARS Mandan, ND
- Dr. James Nardi – University of Illinois

SOIL QUALITY/HEALTH:

The continued capacity of the soil to function as a vital living system that sustains plant, animal, and human health.

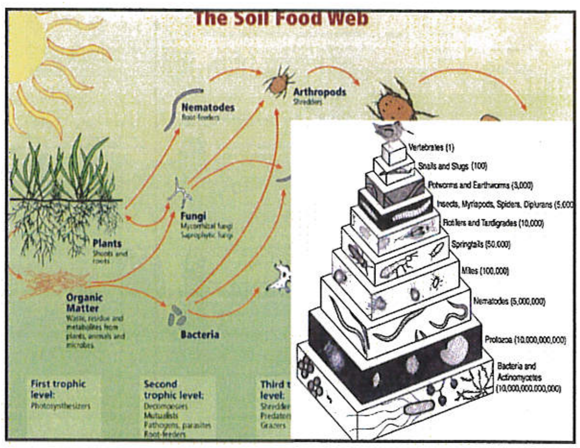
What Functions Do You Expect Your Soil to Perform?

- Grow Crops
  - –Infiltrate Water
  - –Supply Nutrients
    - How does soil perform these functions?

Soil Aggregate stability

Glue-makers

- It's all about the Food
- Bacteria – stick it to me.
  - – microaggregation
- Fungi – seal the pipes.
  - – Macroaggregation
- Aggregates are habitat
- Microbes must be fat to make good aggregates.



What the Soil Foodweb Does

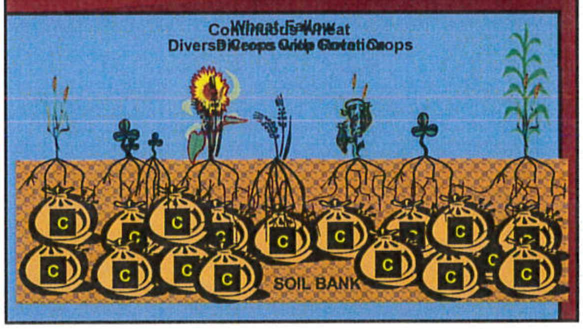
- Plant nutrient immobilization / cycling
- Creates stable soil aggregates
  - Water infiltration / retention
  - Habitat for soil foodweb
  - Root movement
  - Nematode, microarthropod movement
  - Air movement
- Less than .1% of the organisms that live in the soil have been identified and described.

Rhizosphere...where roots meet soil

Zone of concentrated biological activity adjacent to the root...

- Bacteria
- Fungi
- Protozoa
- Nematodes
- Microarthropods
- Earthworms

Managing for Soil Health



Managing for Soil Biology & Soil Health

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

Soil Health Toolbox

- No Tillage
- Crop Rotation Diversity
- Cover Crops
- Reduce Fertilizer use
- Reduce Pesticide use
- Livestock
- Compost

No Tillage

- Tillage is physical soil disturbance
  - Destroys aggregates
  - Exposes organic matter to decomposition
  - Causes compaction
  - Damages soil fungi
  - Reduces habitat for all members of SFW
  - Disrupts soil pore continuity
  - Increases salinity at the soil surface

Crop Rotation Diversity

- Crop diversity = Soil Food Web diversity
- Diversity
  - Balanced diet to Soil Food Web
  - Reduces pest pressure
  - Increases crop nutrient cycling
  - Reduces risk
  - Spreads workload

Cover Crops

- Increased influence of living roots
  - Feeds Soil Food Web
  - Increase soil aggregation and porosity to increase available water holding capacity
  - Use excess water to address salinity
- Opportunity for additional diversity
  - Stimulate SFW into increased activity
- Opportunity for increased income
  - Grazing, nitrogen fixation/recovery

Reduce Fertilizer Use

- Excessive nitrogen fertilizer…
  - Short-circuits the rhizosphere
  - Depresses activity of natural N fixers
  - Stimulates bacterial decomposition of SOM
  - N at risk for leaching or denitrification
  - Synthetic fertilizers are salts (salinity)

Reduce Pesticide Use

- Impact of pesticides on non-target organisms not well understood.
- Pesticides simplify, not diversify
- Crop rotation restrictions
- Cover crop diversity restrictions

Livestock

- Add and distribute biology to soil
- Cycle residues, reduce C:N ratios
- Put plant residues in contact with soil
- Opportunity for increased income

Compost

- Aerobic compost is a biologic army
- Increase SFW diversity
- Low application rate
- Can be applied as a "tea"

Benefits of Managing for Soil Health

- Improved Nutrient Cycling
  - NDSU 50#/ac N credit for long term no-till
  - Fungi increase P and water supply to plants
- Improved soil aggregation
  - Increased water movement and storage
  - Better root growth into more soil
  - Better habitat for the Soil Food Web
- Fewer weeds and diseases
  - A balanced Food Web suppresses pests
  - Less soil disturbance plants fewer weed seeds

How do we know if soil health is improving?

- Soil aggregate stability increases
- Water infiltration increases
- Organic matter increases
- Crop response
- Reduced input costs
- Soil Food Web analysis

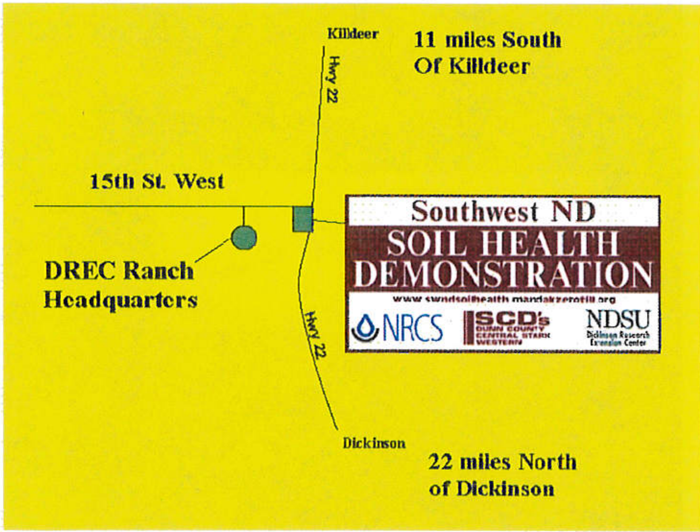
Questions / Discussion

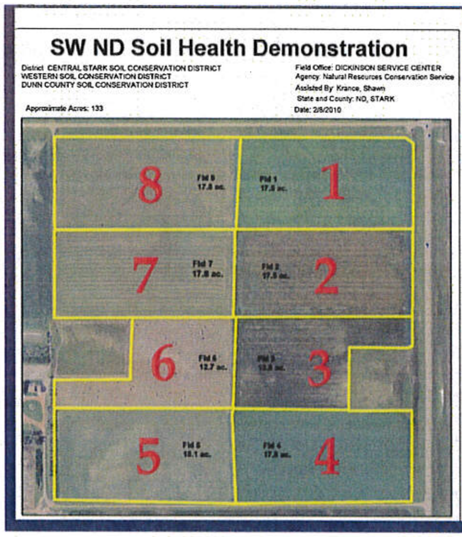
Southwest ND
SOIL HEALTH DEMONSTRATION
www.swndsoilhealth.mandakzerotill.org
NRCS | Dunn County, Central Stark, Western SCD | NDSU Dickinson Research Extension Center

Objectives:

A. How is Soil Health effected by:
  - no tillage
  - a diverse crop rotation with cover crops

B. Enhance awareness of Soil Health





NE ¼ Sec. 24
T143N R96 W

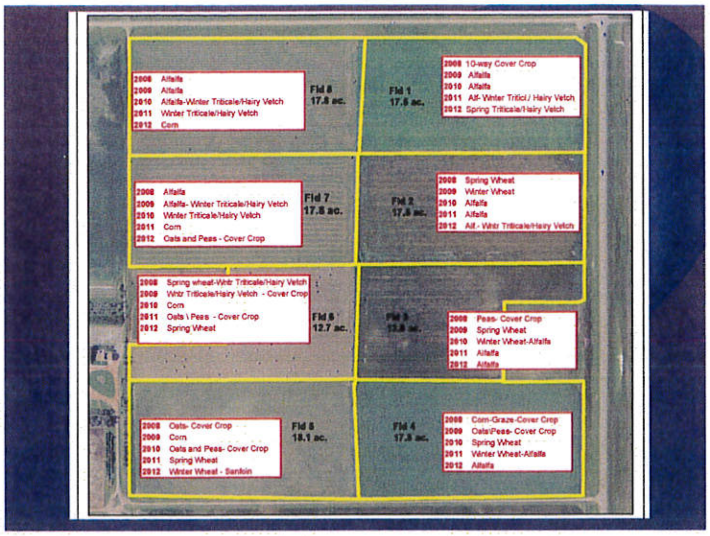
Dunn County, ND
8 Fields
Approx. 12 – 18 ac.

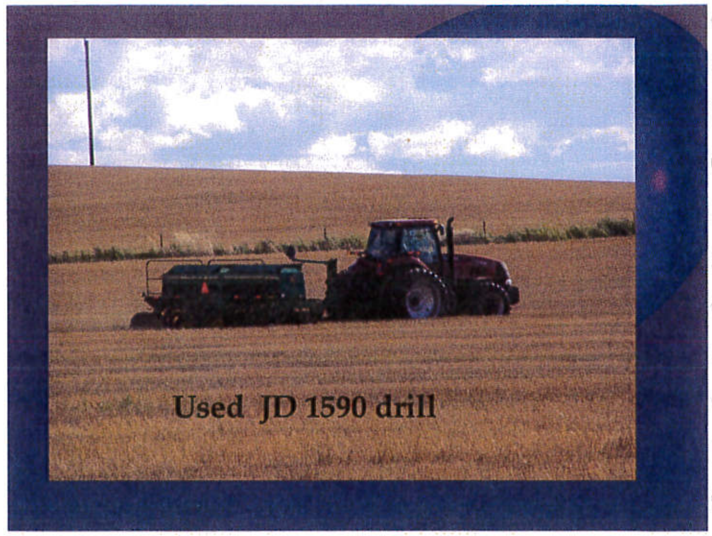
Diverse Crop Rotation

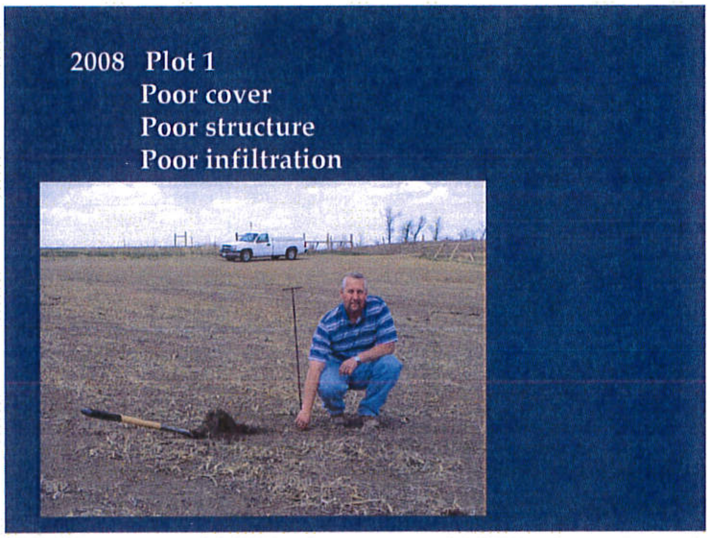
Alfalfa	
Alfalfa	
Alfalfa	
Winter Triticale / Hairy Vetch	7 - 10 Cover Crop
Corn	
Oats/Peas	7 – 10 Cover Crop
Spring Wheat	
Winter Wheat	

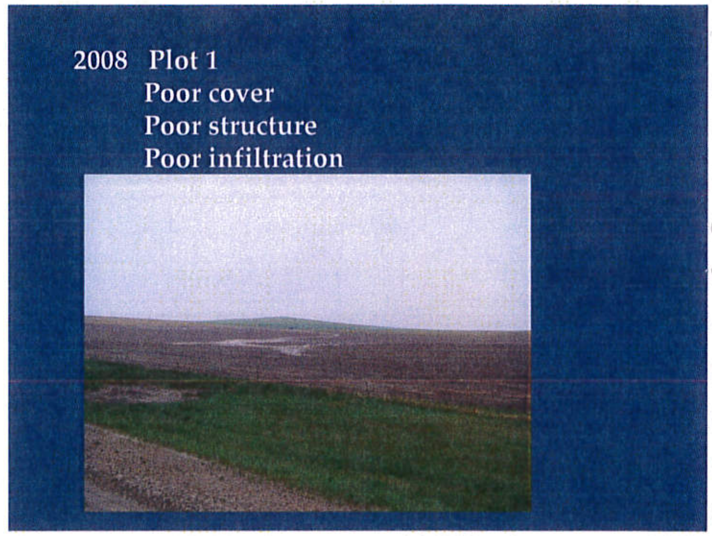
2012 Cover Crop Mix

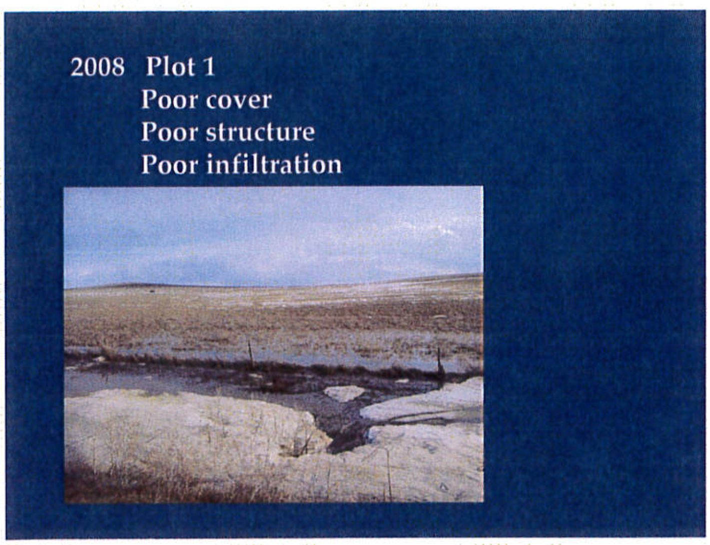
	lb/ac
Millet	5
Sorghum	7
Sunflower	.6
Safflower	4.5
Hunter Brassica	.5
Graza Brassica	1.5
Soybeans	4.5
Total	23.6 lb/ac

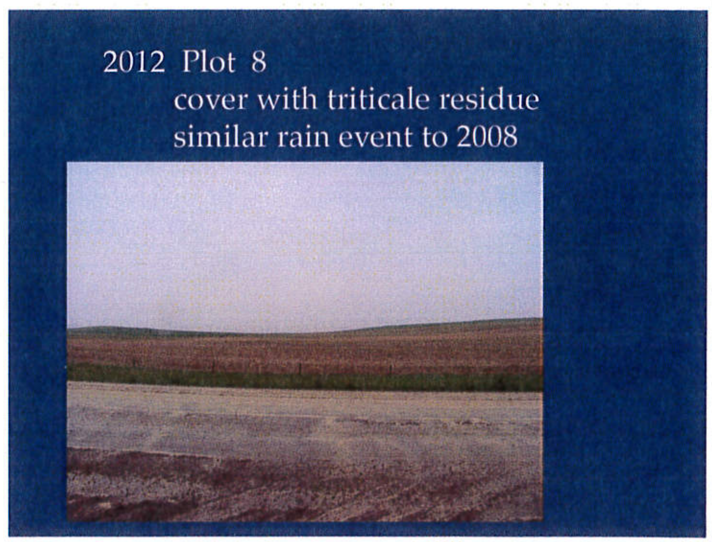

2008 Alfalfa
2009 Alfalfa
2010 Alfalfa-Winter Triticale/Hairy Vetch
2011 Winter Triticale/Hairy Vetch
2012 Corn
Fld 8
17.8 ac.
Fld 1
2008 10-way Cover Crop
2009 Alfalfa
2010 Alfalfa
2011 Alf- Winter Triticl / Hairy Vetch
2012 Spring Triticale/Hairy Vetch
2008 Alfalfa
2009 Alfalfa- Winter Triticale/Hairy Vetch
2010 Winter Triticale/Hairy Vetch
2011 Corn
2012 Oats and Peas - Cover Crop
Fld 7
17.8 ac.
Fld 2
2008 Spring Wheat
2009 Winter Wheat
2010 Alfalfa
2011 Alfalfa
2012 Alf.- Wntr Triticale/Hairy Vetch
2008 Spring wheat-Wntr Triticale/Hairy Vetch
2009 Wntr Triticale/Hairy Vetch - Cover Crop
2010 Corn
2011 Oats \ Peas - Cover Crop
2012 Spring Wheat
Fld 6
12.7 ac.
2008 Peas- Cover Crop
2009 Spring Wheat
2010 Winter Wheat-Alfalfa
2011 Alfalfa
2012 Alfalfa
2008 Oats- Cover Crop
2009 Corn
2010 Oats and Peas- Cover Crop
2011 Spring Wheat
2012 Winter Wheat - Sanfoin
Fld 5
18.1 ac.
Fld 4
2008 Corn-Graze-Cover Crop
2009 Oats\Peas- Cover Crop
2010 Spring Wheat
2011 Winter Wheat-Alfalfa
2012 Alfalfa


Used JD 1590 drill


2008 Plot 1
Poor cover
Poor structure
Poor infiltration


2008 Plot 1
Poor cover
Poor structure
Poor infiltration


2008 Plot 1
Poor cover
Poor structure
Poor infiltration

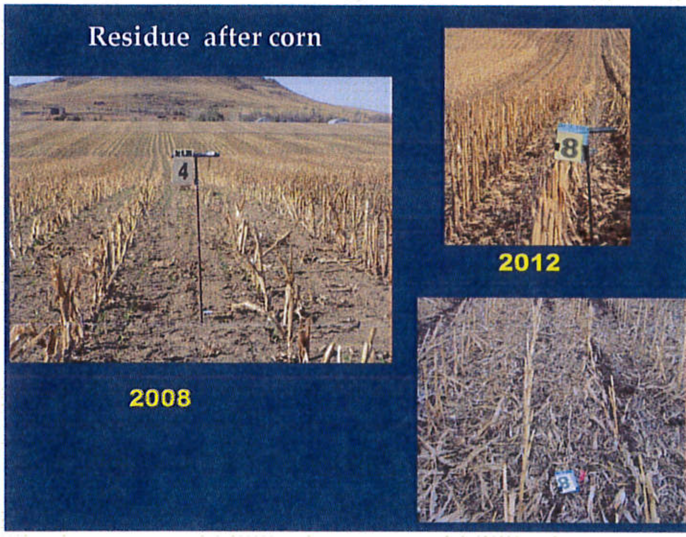

2012 Plot 8
cover with triticale residue
similar rain event to 2008

2009 Plot 8 Alfalfa - poor stand in 2008

2008

2012 Corn planted
in triticale residue

Residue after corn



2012

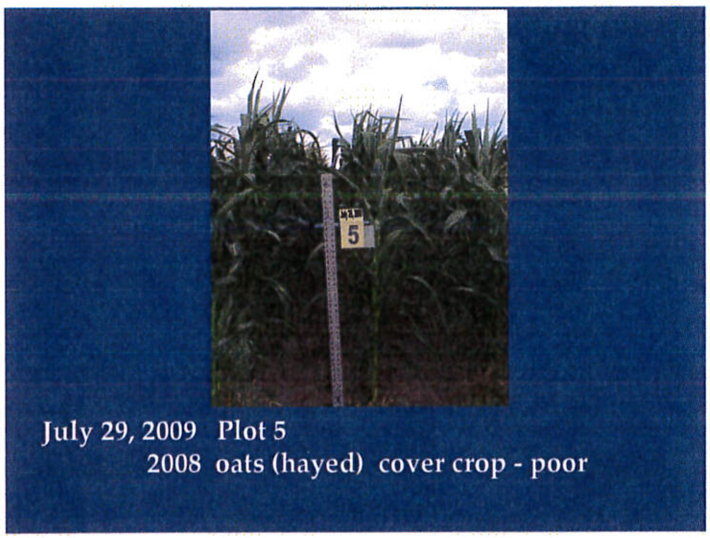
2008

2008 Field 1
plow pan
poor aggregation

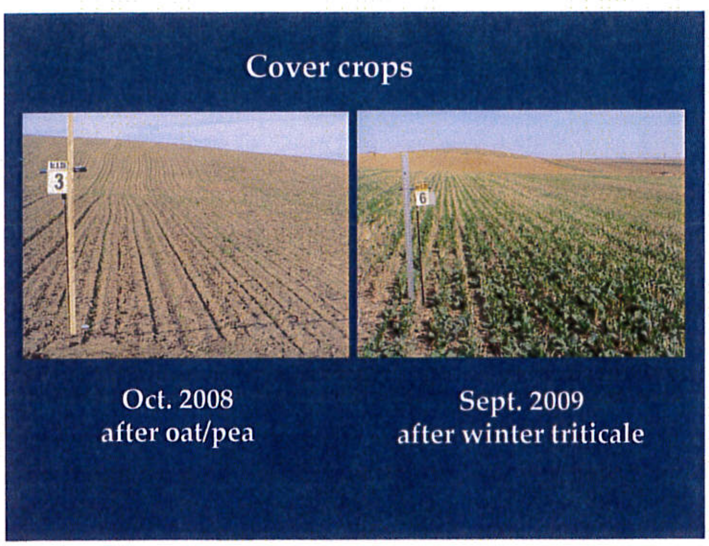
2012 Field 1
after 1 year 10 way cover crop and
3 years of alfalfa
more improvement needed

2012 Field 1
Spring Triticale


2008
No cover
cover crop attempted
after Pea/Oat
2012
Second year alfalfa

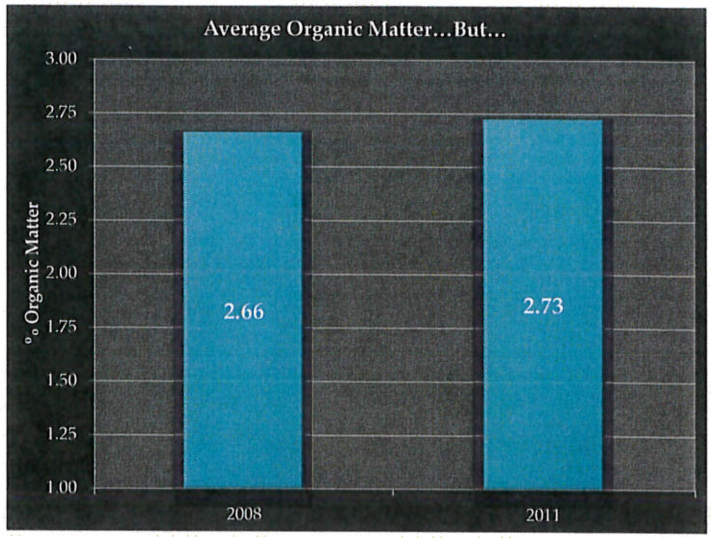

July 29, 2009 Plot 5
2008 oats (hayed) cover crop - poor

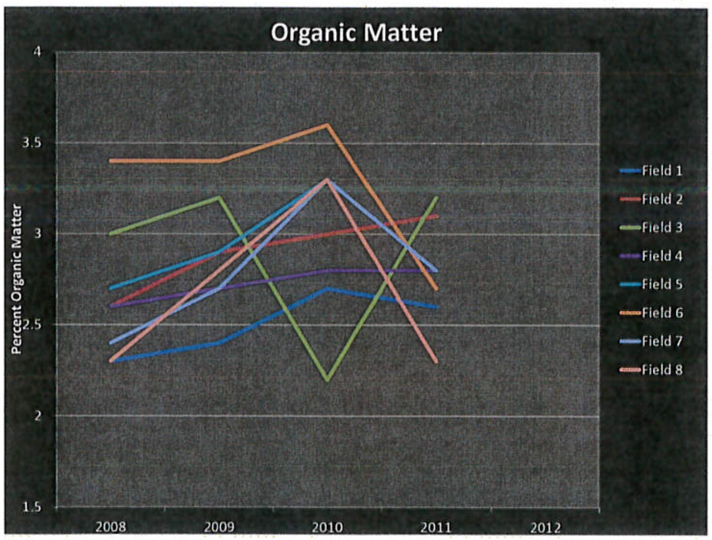

Winter wheat residue
Sanfoin seeded 8-21-12

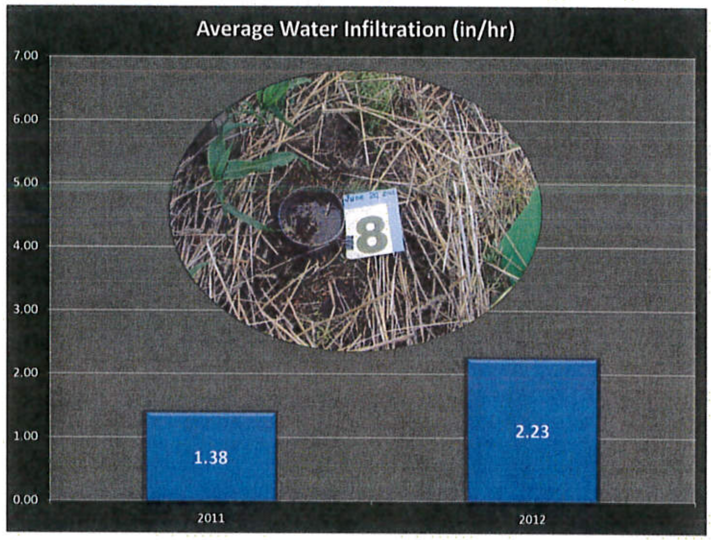

Cover crops
Oct. 2008
after oat/pea
Sept. 2009
after winter triticale

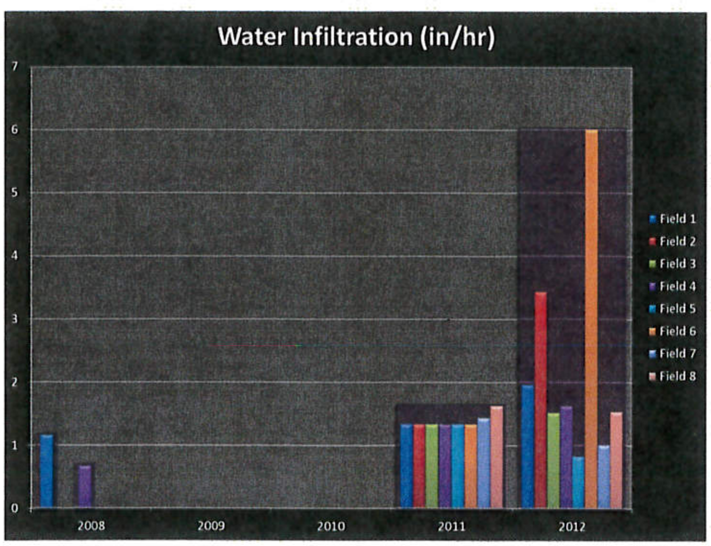

Cover crops
Sept. 2012
after oat/pea
Seeded 7-20-12
Sept. 2012
after winter triticale
DREC 6 miles west of demo.
Seeded 6-30-12

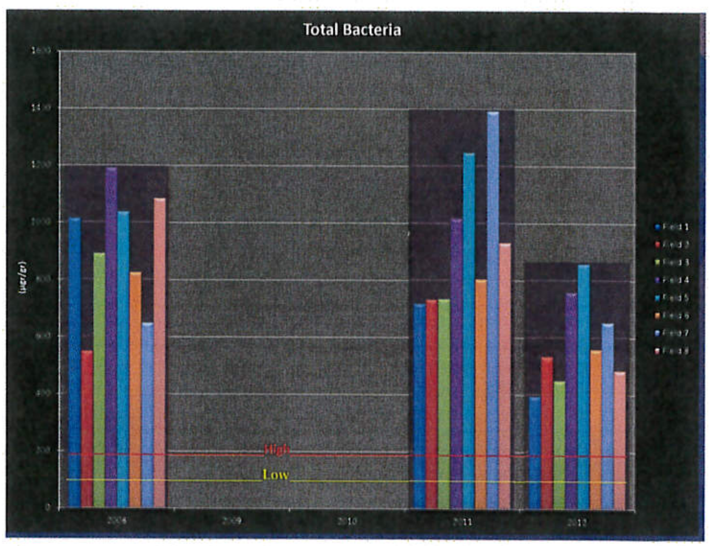

Cover crops
Nov. 8, 2012
after oat/pea
Nov. 8 2012
after winter triticale
DREC 6 miles west of demo.

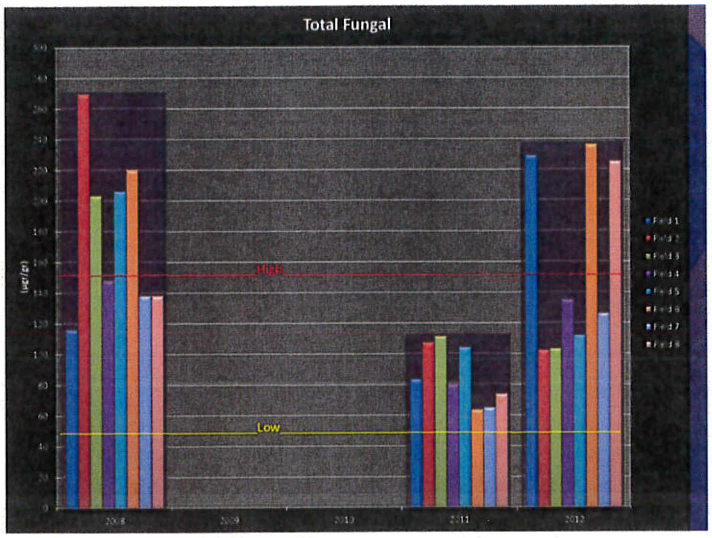

Average Organic Matter…But…
% Organic Matter
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
2.66
2.73
2008
2011

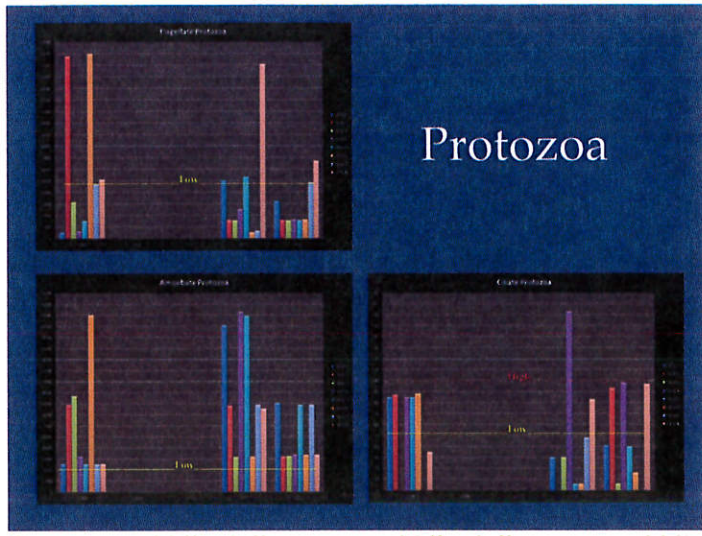

Organic Matter
Percent Organic Matter
4
3.5
3
2.5
2
1.5
2008
2009
2010
2011
2012
Field 1
Field 2
Field 3
Field 4
Field 5
Field 6
Field 7
Field 8

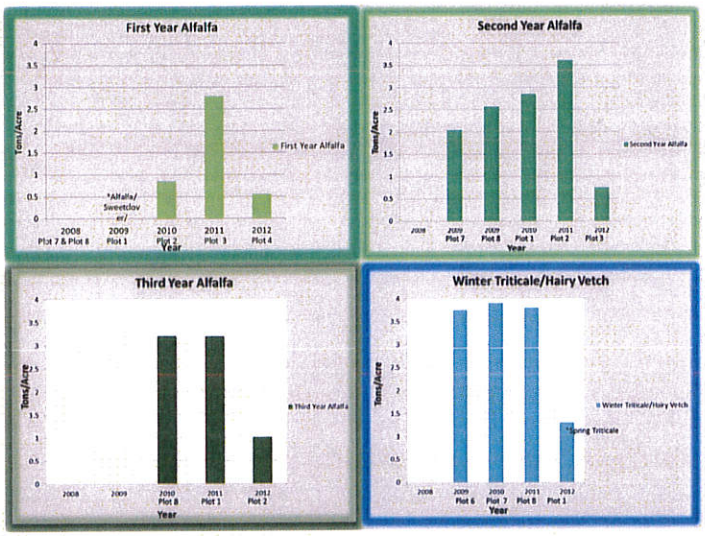

Average Water Infiltration (in/hr)
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1.38
2.23
2011
2012
8

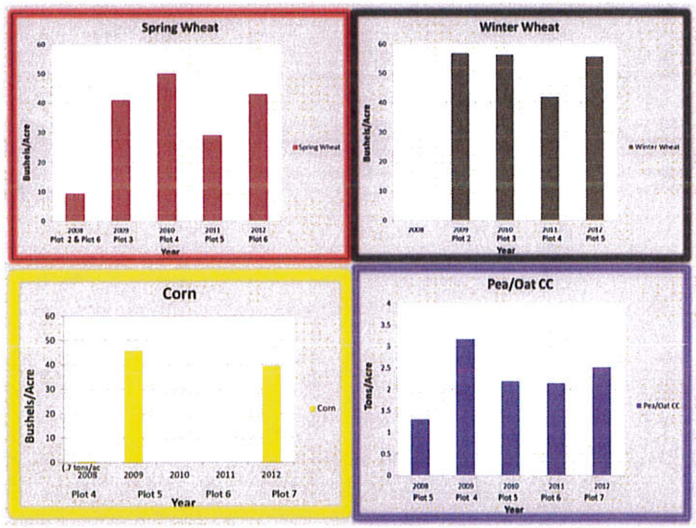

Water Infiltration (in/hr)
7
6
5
4
3
2
1
0
2008
2009
2010
2011
2012
Field 1
Field 2
Field 3
Field 4
Field 5
Field 6
Field 7
Field 8


Total Bacteria
High
Low









Thoughts:

- -Demonstration was successful
- -Armor Up....cover, cover, cover – 1st thing
- -Seeding cover crop after winter annual harvested or grazed in June
- -Results are variable – research would help

USDA Natural Resources Conservation Service

Indicator	Test	Function
P	L/O	S

Soil Quality Indicators

Aggregate Stability

Soil aggregates are groups of soil particles that bind to each other more strongly than to adjacent particles. Aggregate stability refers to the ability of soil aggregates to resist disintegration when disruptive forces associated with tillage and water or wind erosion are applied. Wet aggregate stability suggests how well a soil can resist raindrop impact and water erosion, while size distribution of dry aggregates can be used to predict resistance to abrasion and wind erosion.

Long-term use of a conservation tillage system (no-till) and cover crops resulted in increased soil organic matter and improved soil structure and aggregate stability of this north Georgia (Cecil) soil. Photo courtesy James E. Dean, USDA NRCS (retired).

Factors Affecting

Inherent - Aggregation and stability of soil aggregates are affected by predominant type and amount of clay, adsorbed cations, such as calcium and sodium, and iron oxide content. Expansion and contraction of clay particles as they become moist and then dry can shift and crack the soil mass and create aggregates or break them apart. Calcium, magnesium, iron, and aluminum stabilize aggregates via the formation of organic matter – clay bridges. In contrast, aggregate stability decreases with increasing amounts of exchangeable sodium. Dispersion is promoted when too many sodium ions accumulate between soil particles.

Dynamic - Aggregate stability is highly dependent on organic matter and biological activity in soil, and it generally increases as they increase. Fungal hyphae, thread-like structures used to gather resources, bind soil particles to form aggregates. Other soil organisms, like earthworms, secrete binding materials. Soil particles are also aggregated and stabilized by organic "glues" resulting from biological decomposition of organic matter. Physical disturbance, e.g. tillage, accelerates organic matter decomposition rates, and destroys fungal hyphae and soil aggregates. Soil biota help create aggregates and use them as habitat or refugia to escape predation.

Relationship to Soil Function

Changes in aggregate stability may serve as early indicators of recovery or degradation of soils. Aggregate stability is an indicator of organic matter content, biological activity, and nutrient cycling in soil. Generally, the particles in small aggregates (<0.25 mm) are bound by older and more stable forms of organic matter. Microbial decomposition of fresh organic matter releases products (that are less stable) that bind small aggregates into large aggregates (>2-5 mm). These large aggregates are more sensitive to management effects on organic matter, serving as a better indicator of changes in soil quality. Greater amounts of stable aggregates suggest better soil quality. When the proportion of large to small aggregates increases, soil quality generally increases.

Stable aggregates can also provide a large range in pore space, including small pores within and large pores between aggregates. Pore space is essential for air and water entry into soil, and for air, water, nutrient, and biota movement within soil. Large pores associated with large, stable aggregates favor high infiltration rates and appropriate aeration for plant growth. Pore space also provides zones of weakness for root growth and penetration.

Problems with Poor Function

Aggregate stability is critical for infiltration, root growth, and resistance to water and wind erosion. Unstable aggregates disintegrate during rainstorms. Dispersed soil particles fill surface pores and a hard physical crust can develop when the soil dries. Infiltration is reduced, which can result in increased runoff and water erosion, and reduced water available in the soil for plant growth. A physical crust can also restrict seedling emergence.

Wind normally detaches only loosely held particles on the soil surface, but as blowing soil particles are accelerated by the wind they hit bare soil with sufficient energy to break additional particles loose from weakly aggregated soil. This action increases the number of particles that can be picked up by the wind and abrade a physically-unprotected soil surface.

Practices that lead to poor aggregate stability include:

- Tillage methods and soil disturbance activities that breakdown plant organic matter, prevent accumulation of soil organic matter, and disrupt existing aggregates,
- Cropping, grazing, or other production systems that leave soil bare and expose it to the physical impact of raindrops or wind-blown soil particles,
- Removing sources of organic matter and surface roughness by burning, harvesting or otherwise removing crop residues,
- Using pesticides harmful to beneficial soil microorganisms.

Improving Aggregate Stability

Practices that keep soil covered physically protect it from erosive forces that disrupt aggregation, while also building organic matter. Any practice that increases soil organic matter, and consequently biological activity, improves aggregate stability. However, it can take several growing seasons or years for significant organic matter gains. In contrast, management activities that disturb soil and leave it bare can result in a rapid decline in soil organic matter, biological activity and aggregate stability.

Aggregates form readily in soil receiving organic amendments, such as manure. They also form readily where cover and green manure crops and pasture and forage crops are grown, and where residue management and/or reduced tillage methods are used.

Improving aggregate stability on cropland typically involves cover and green manure crops, residue management, sod-based rotations, and decreased tillage and soil disturbance. Aggregate stability declines rapidly in soil planted to a clean-tilled crop.

Pasture and forage plants have dense, fibrous root systems that contribute organic matter and encourage microbial activity. However, grazing and fertility must be managed to maintain stands and prevent development of bare areas or sparse vegetation.

Conservation tillage systems, such as no-till with cover crops, reduce soil disturbance, and provide and manage residue for increased soil organic matter and improved aggregate stability. Additionally, surface roughness provided by crop residues protects soil from wind erosion.

Conservation practices resulting in aggregate stability favorable to soil function include:

- Conservation Crop Rotation
- Cover Crop
- Pest Management
- Prescribed Grazing
- Residue and Tillage Management
- Salinity and Sodic Soil Management
- Surface Roughening

Measuring Aggregate Stability

Measuring Water Stable Aggregates is described in the Soil Quality Test Kit Guide, Section I, Chapter 8, pp. 18 - 19. See Section II, Chapter 7, pp. 69 - 71 for interpretation of results.

Arshad MA, Lowery B, and Grossman B. 1996. Physical Tests for Monitoring Soil Quality. In: Doran JW, Jones AJ, editors. Methods for assessing soil quality. Madison, WI. p 123-41.

Kemper WD, Rosenau RC. 1986. Aggregate Stability and Size Distribution. In: Klute A, editor. Methods of soil analysis. Part 1. Physical and mineralogical methods. Madison, WI. p 425-42.

Specialized equipment, shortcuts, tips:

Determine for the top three inches of soil. However, in rangeland conditions determine for the top ¼ to ½ inch of soil as it is most likely to be removed by erosion. A 400-watt hairdryer and drying chamber are required to conduct the wet aggregate stability test.

Time needed: 2 hours

United States Department of Agriculture
Natural Resources Conservation Service

Farming in the 21st Century
a practical approach to improve Soil Health

What is Soil Health? Why Should I Care?

Soil health is *the capacity of a soil to function*. How well is your soil functioning to infiltrate water and cycle nutrients to water and feed growing plants?

Soil is a living factory of macroscopic and microscopic workers who need food to eat and places to live to do their work.

There are more individual organisms in a teaspoon of soil than there are people on earth; thus, the soil is controlled by these organisms.

Tillage, fertilizer, livestock, pesticides, and other management tools can be used to improve soil health, or they can significantly damage soil health if not applied correctly.

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.

Managing for soil health 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.

Manage More by Disturbing Soil Less

Tilling the soil is the equivalent of an earthquake, hurricane, tornado, and forest fire occurring simultaneously to the world of soil organisms. Simply stated, tillage is bad for the soil.

Physical soil disturbance, such as tillage with a plow, disk, or chisel plow, that results in bare or compacted soil is destructive and disruptive to soil microbes and creates a hostile, instead of hospitable, place for them to live and work.

The soil may also be disturbed chemically or biologically through the misuse of inputs, such as fertilizers and pesticides. This disrupts the symbiotic relationship between fungi, microorganisms and crop roots.

By reducing nutrient inputs, we can take advantage of the nutrient cycles in the soil to supply crop nutrients and allow plants to make essential associations with soil organisms.

Diversify with Crop Diversity

Sugars made by plants are released from their roots into the soil and traded to soil microbes for nutrients to support plant growth.

The key to improving soil health is assuring that the food and energy chains and webs includes as many different plants or animals as practical.

Biodiversity is ultimately the key to success of any agricultural system. Lack of biodiversity severely limits the potential of any cropping system and disease and pest problems are increased.

A diverse and fully functioning soil food web provides for nutrient, energy, and water cycling that allows a soil to express its full potential.

Above ground diversity (plants) = Below ground diversity (soil food web)

Grow Living Roots Throughout the Year

There are many sources of food in the soil that feed the soil food web, but there is no better food than the sugars exuded by living roots.

Soil organisms feed on sugar from living plant roots first. Next, they feed on dead plant roots, followed by above-ground crop residues, such as straw, chaff, husks, stalks, flowers, and leaves. Lastly, they feed on the humic organic matter in the soil.

Healthy soil is dependent upon how well the soil food web is fed. Providing plenty of easily accessible food to soil microbes helps them cycle nutrients that plants need to grow.

Keep the Soil Covered as Much as Possible

Soil should always be covered by growing plants and/or their residues, and soil should rarely be visible from above. This is true regardless of land use (cropland, hayland, pasture, or range).

Soil cover protects soil aggregates from 'taking a beating' from the force of falling raindrops. Even a healthy soil with water-stable aggregates (held together by biological glues) that can withstand wetting by the rain may not be able to withstand a 'pounding' from raindrops.

A mulch of crop residues on the soil surface suppresses weeds early in the growing season giving the intended crop an advantage. They also keep the soil cool and moist which provides favorable habitat for many organisms that begin residue decomposition by shredding residues into smaller pieces.

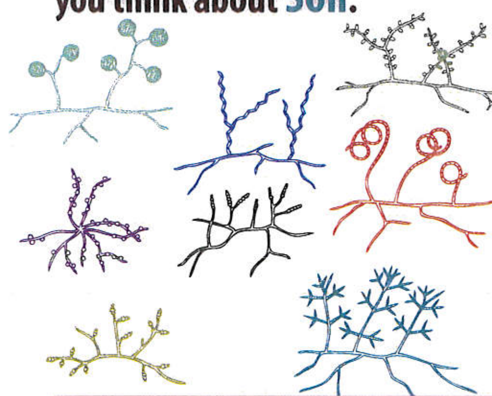
Soil Health for Your Farm, Ranch... for You!

Soil health is improved by disturbing the soil less, growing the greatest diversity of crops (in rotation and as diverse mixtures of cover crops), maintaining living roots in the soil as much as possible (with crops and cover crops), and keeping the soil covered with residue at all times.

Drills, planters, seed, fertilizer, pesticides, livestock, fences, water, farm implements, etc. are all tools that can be used to manage the soil habitat for the benefit of living members of the soil food web.

Many soils have a water infiltration problem that causes a water runoff problem. If soil health is improved, the structure of the soil results in greater water infiltration, less runoff, less or no erosion, and reduced incidence of flooding and sedimentation.

Managing for Soil Health must begin by changing the way you think about Soil.



Illustrations courtesy of Dr. James Nardi, University of Illinois at Urbana-Champaign

September 2010

Developed by the Soil Quality National Technology Development Team with contributions from North Dakota NRCS

Soil Health Resources

Books	Author
Managing Cover Crops Profitability: 3rd Edition	SARE Outreach & Andy Clark
Soil Biology Primer	Elaine Ingham
The Nature & Properties of Soils: 14th Edition	Ray Weil & Nyle Brady
Stubble over the Soil	Carlos Crovetto Lamarca
No Tillage	Carlos Crovetto Lamarca
Buffalo Bird Woman's Garden	Maxi'diwiac & Gilbert Wilson
Teaming with Microbes	Jeff Lowenfels & Wayne Lewis
Holistic Management	Allan Savory & Jody Butterfield
For the Love of Land	Jim Howell
Pollinator Conservation Handbook	M. Shepherd, S. Buchmann, M. Vaughan, S. Black
Kick the Hay Habit	Jim Gerrish
The One-Straw Revolution	Masanobu Fukuoka
Grassland Plants of SD & the Northern Great Plains	James R. Johnson & Gary E. Larson

Websites	Description
www.bcscd.com	Burleigh County Soil Conservation District
www.nd.nrcs.usda.gov	North Dakota Natural Resources Conservation Service
www.mandan.ars.usda.gov	North Great Plains Research Laboratory
www.dakotalakes.com	Dakota Lakes Research Farm
www.notill.org	No-Till on the Plains
www.mandakzerotill.org	Manitoba – North Dakota Zero Tillage Farmer's Association
www.notillcovercrops.com	Providence Farms, LLC
www.websoilsurvey.nrcs.usda.gov	Web Soil Survey
www.attra.ncat.org/video/#notill	Burleigh County Soil Health Webinar
http://connect.extension.iastate.edu/p63586080/	Enhancing Soil Health with Cover Crops & Livestock Webinar