UNIVERSITY OF VERMONT EXTENSION
CULTIVATING HEALTHY COMMUNITIES

Event Summary – UVM Extension Champlain Valley Crop, Soil & Pasture Team

EVENT TITLE:	**Spring Soil Health Workshop & Field Day**
EVENT DATE:	April 21st, 2015
EVENT TIME:	9:00 am – 3:00 pm (6 hours)
EVENT LOCATION:	Vergennes American Legion *(Vergennes)* & VanDerWey's Nea-Tocht Farm *(Ferrisburgh)*
AUDIENCE:	55 total attendees (38 farmers, 10 ag service providers, 7 agency/gov't/university) *+ 6 CV Crops Team Members*

SUMMARY:
The UVM Extension Champlain Valley Crop, Soil & Pasture Team hosted a soil health workshop and field day. The day was started with presentations by Jim Hoorman, Ohio State University Extension at the Vergennes American Legion. Lunch was served, and then a short soil health demonstration (a slake test) was done before heading out the VanDerWey's farm in Ferrisburgh to look at soil up close and see what Howard, Raymond and Sid VanDerWey are doing to avoid compaction and use cover crops to protect soil health on their dairy farm that has a mixture of both loamy and heavy clay soils.

The presenter, Jim Hoorman, is an Assistant Professor with Ohio State University Extension specializing in Cover Crops and Water Quality in Putnam County, Ohio. Jim has a Bachelor's degree in Agriculture, a Masters of Arts degree in Business, and a Master of Science degree in Agricultural Economics from Ohio State University. He is currently working on a PHD in Environmental Sciences at Ohio State University. Jim owns a 40 acre farm with his wife Marlene and son Jonathan where he is conducting cover crop research trials. Mr. Hoorman presented three topics: The Biology of Soil Compaction, Using Cover Crops the Keep Phosphorus out of Water, and The Economics of Cover Crops and Weed Suppression.

The event was a very successful. We had good attendance, with more than half attendees being local farmers (mostly from Addison and Chittenden counties) and had lots of good discussions about how to make no-till and cover cropping work on heavier soil. In addition, there was lots of good networking between farmers, and between farmers and service providers. One New York farmer shared his experience visiting no-till dairy farms recently in Pennsylvania and was very inspired to take his soil health practices up a notch. This conversation led to a great discussion about creating a future opportunity for Vermont farmers to take a similar trip.

SPONSORS:
Vermont Agency of Agriculture, Food & Markets (FAP Education & Outreach Grant)
Ben & Jerry's Caring Dairy
Dairy One
Champlain Valley Farmer Coalition

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The Biology of Soil Compaction

James J. Hoorman hoorman.1@osu.edu
Randall Reeder reeder.1@osu.edu
www.mccc@msu.edu

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Healthy Soil versus Sick Soil

Healthy soils have these things in common:

1) Live plants growing year round to absorb energy.
2) Healthy microbial populations. Microbes process 90% of the energy in soils.

Sick soils have these things in common:

1) Compacted soils, high bulk density, poor water infiltration, poor water holding capacity and bare soils.
2) Low SOM and Nutrient Imbalances

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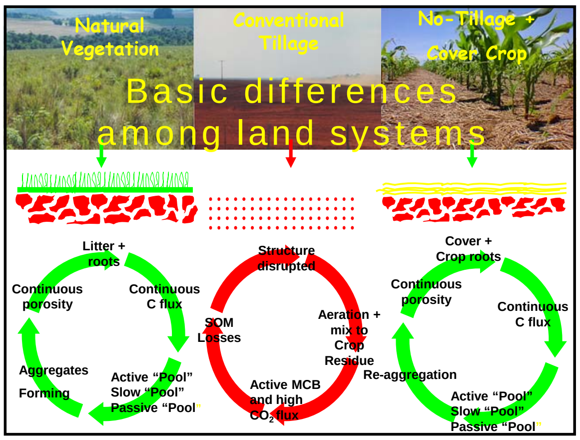

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ECO Farming

- **E**cological Farming with **E**ternal No-till
- **C**ontinuous Living Cover
- **O**ther Best Management Practices

- Economical for Farmer
- Ecologically Viable
- Environmentally Sound

ECO Farming Mimics Natural Cycles!

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Soil Energy Comes from Plants

Conventional Tillage

No-till +Cover Crops "ECO Farming"

Plants 4 months out of 12 months
Fuel & Energy = 1/3 of time

Plants 12 months out of the year
Fuel & Energy = 100% of time

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

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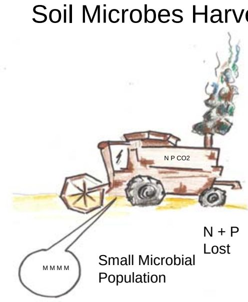
Soil Microbes Harvest & Recycle Nutrients

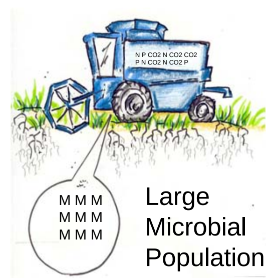
ECO Farming



N + P Lost

Small Microbial Population

Conventional tillage

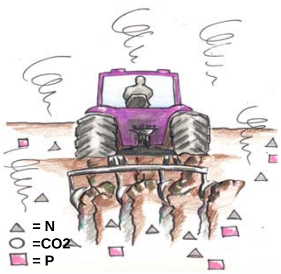


Large Microbial Population

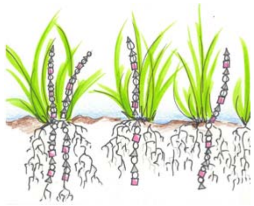
Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Tillage Burns Soil Organic Matter

Conventional Tillage



ECO Farming

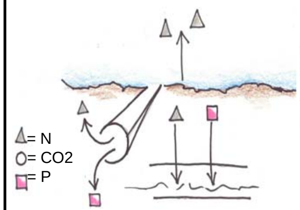


Nutrients (CO2, N, P) tied up in Plants.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

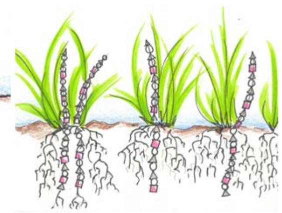
Nutrient Fate in Winter and Spring

Conventional Tillage



Nutrients lost to air and water because no plant roots to absorb nutrients (N, P).

ECO Farming



Nutrients recycled in winter & spring & carried forward to next crop.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

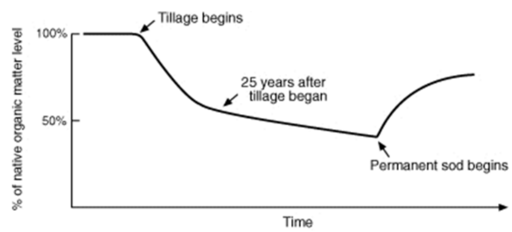
Five Factors of Soil Formation

- Parent material
- Vegetation
- Climate
- Topography
- Time

- Is their a Sixth Factor?

Soil Organic Matter Loss

Recent research



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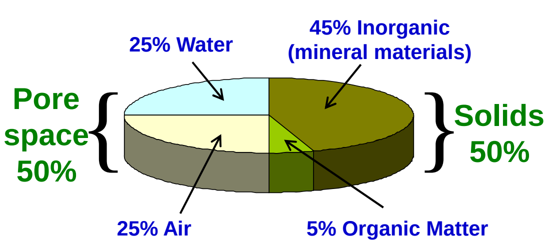
Ideal Soil Composition



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Some Common Bulk Densities

- **Uncultivated/undisturbed woodlots**
  - **1.0 to 1.2 g/cm³**
- **Cultivated clay and silt loams**
  - **1.5 to 1.7 g/cm³**
- **Cultivated sandy loams**
  - **1.3 to 1.7 g/cm³**
- **Compacted glacial till**
  - **1.9 to 2.2 g/cm³**
- **Concrete**
  - **2.4 g/cm³**

1.6 g/cm³ = Root Limiting
1.8 g/cm³ = Roots Restricted

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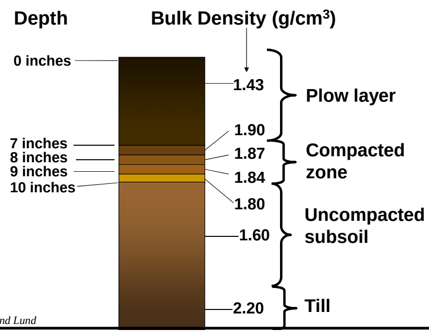
Bulk Density and Compaction



Data from Camp and Lund

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Soil Organic Matter Characteristics

*Density of SOM: .6 g/cm^3 vs 1.45 g/cm^3 soil
Bulk density =Mass (grams)/Volume (cm^3)

SOM has less density than soil so it has more space for air and water storage.

*Every Pound SOM holds 18-20# of Water!

*SOM acts like a Sponge!

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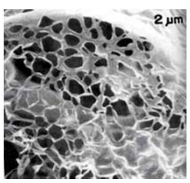
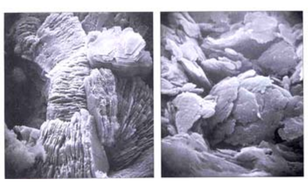
Physical properties and nature of SOM

Color and shape ~ light to dark brown and amorphous
Size ~ Large to colloidal (0.1 - 2 μm)
Surface area ~ Variable (20 – 800 m2 g-1)
Adsorption ~ like sieve to hold cations, anions & water



Soil Organic Matter
From Brady & Weil



Electron Microscope of Clay Particles

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Compacted Soil Characteristics

*Density 1.6 to 1.8 g/cm^3 vs 1.45 g/cm^3 regular soil.

*Compacted soil has higher density than regular soil so it has less space for air and water storage.

*Dense soils acts like a road or pavement!
Result in Flash floods!

*Dense soils have less microbes/biological life.

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Three Soil Compaction Factors

1) Heavy Equipment (Weight)

2) Rain (Precipitation)

3) Gravity

What is a visual way to measure soil compaction?

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Increased Water Storage Capacity Equals less Flooding

1) 6-9 inch Elevation Difference

2) 50% Void Space Equals 3-4.5 inches of additional water storage capacity.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

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SOM and Available Water Capacity
Inches of Water/Per one foot of Soil

Berman Hudson Journal of Soil & Water Conservation 49(2) 189-194 March-April 1994

Percent SOM	Sand	Silt Loam	Silt Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

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Dynamic Properties: Infiltration

- If rainwater runs off field…. It is not available to the crop
  - Dynamic Soil Property greatly influenced by management

Tillage System	Water Infiltration Rate after 1 Hour (in/hour)
Plowed, disked, cultivated, bare surface	.26
No-tillage, bare surface	.11
No-tillage, 40% cover	.46
No-tillage, 80% cover	1.04

Bare Soil
Low Residue Cover
High Residue Cover

- Residue cover prevents soil crusts

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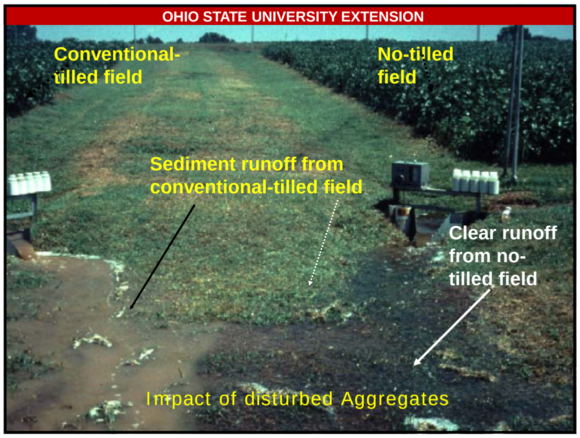

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Saving Nutrients in the Soil

…is related to the speed of Water!

If the velocity of water is doubled how many more nutrients travel in a stream with the water?

2^6 = 64 times more nutrients lost!

1 to 2 mph	64x	
2 to 4 mph	128x	
4 to 8 mph	256x	
8 to 16 mph	512x	
16 to 32 mph	1,024x	

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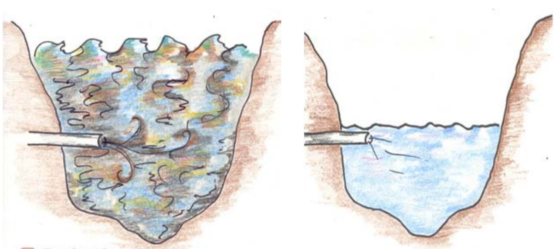
Agricultural Flooding

Conventional Tillage ECO Farming



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Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

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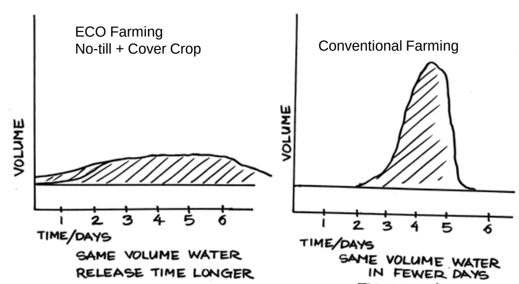
Flooding Hydrographs



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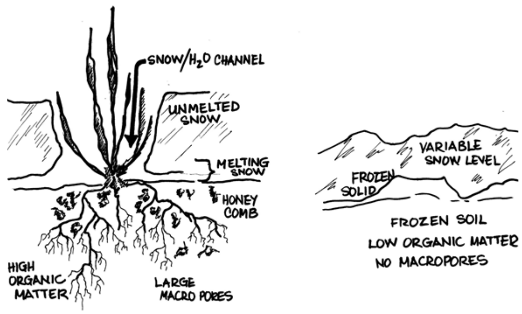
Impact of Crops on Frozen Soil



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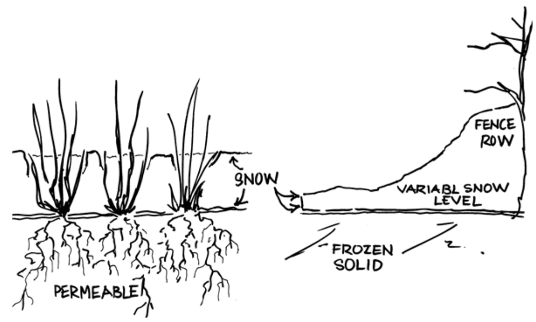
Snow accumulation



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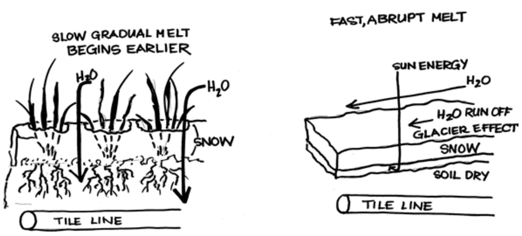
How snow melts



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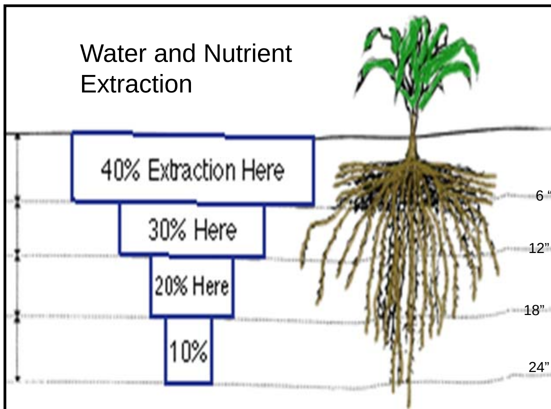
Water and Nutrient Extraction



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For Hot Dry Summers??

- For Corn Production:

75 degrees Fahrenheit – 1 Inch water/week
85 degrees Fahrenheit – 2 inch water/week
95 degrees Fahrenheit – 4 inch water/week

Water requirements double for every 10 degree increase in temperature!

Heat and drought linked together quickly increase yield losses. By Elwynn Taylor, Iowa Ag. Climatologist

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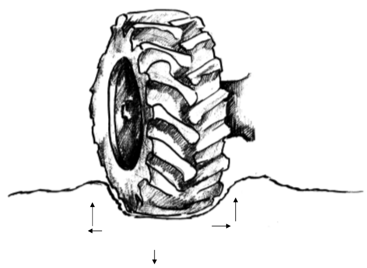
Tire Rut Soil Compaction



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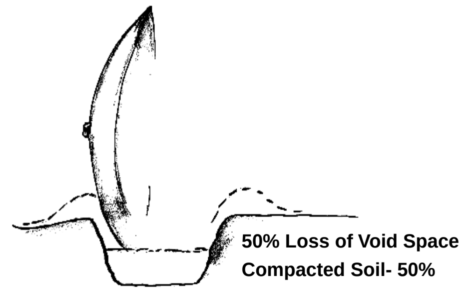
Loss of Void Space



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Roots expanding the soil

Roots reducing soil compaction

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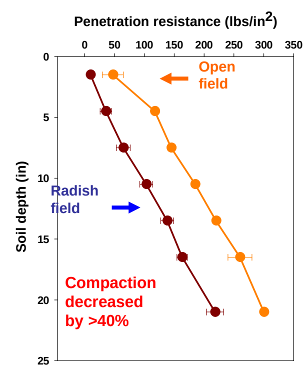

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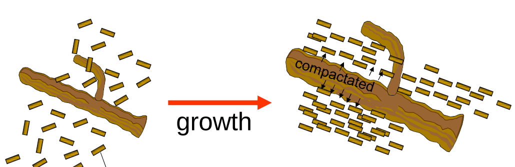
Roots and fungi hyphae

Fine roots goes through the soil pores and drying the soil and compress clay particles to form the aggregates that will be stabilized by polysaccharides excreted by microorganisms (Allison, 1968)



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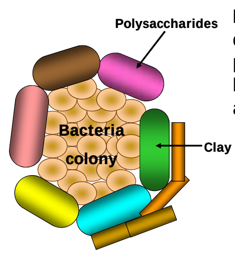
Microaggregates formation



Foster, 1983 - cells and bacteria colonies are enclosed in polysaccharides capsules, aligned by clay particles, forming an aggregate.

40 to 60% of the soil microbial biomass associated with microaggregates

90% of the bacteria linked to clay

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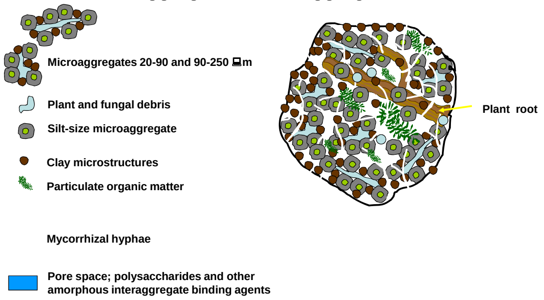
Microaggregates-macroaggregates model



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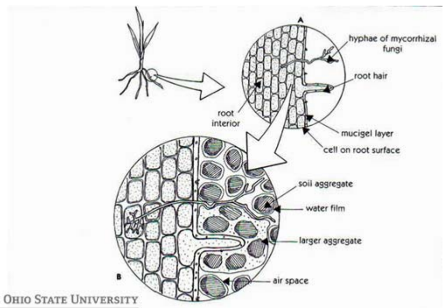
Mycorrhizal Fungus



Source: Better Soils for Better Crops

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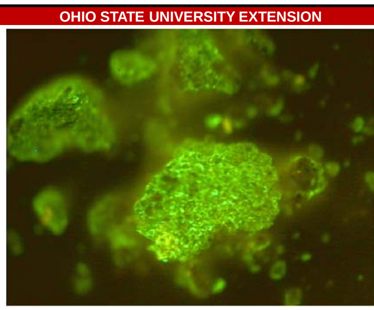

Sticky substance, glomalin, surrounding soil aggregates, water soluble. Photo by Sara Wright

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Building Soil Structure is like Building a House

Architecture	Mother Nature
Carpenter	Plants
Foundation/Cement	Sand Silt Clay (K+, Ca++)
Frame for House	Roots
Nails/Lag Screws	Humus & P
Braces	N & S
Insulation/Glue	Polysaccharides
House wrap	Glomalin
Roof	Surface Residues

Developed by Jim Hoorman (2010)

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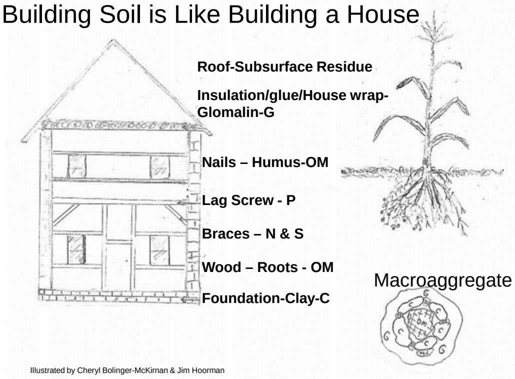
Building Soil is Like Building a House



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Oxygen and Carbon Dioxide

Carbon dioxide (CO_2) is heavier than O_2

CO_2 and O_2 are inversely related in the soil. If one increases the other decreases.

Too much O_2 in the soil causes CO_2 to be lost from the soil to the atmosphere.

Roots act like a **Biological Valve** to control O_2.

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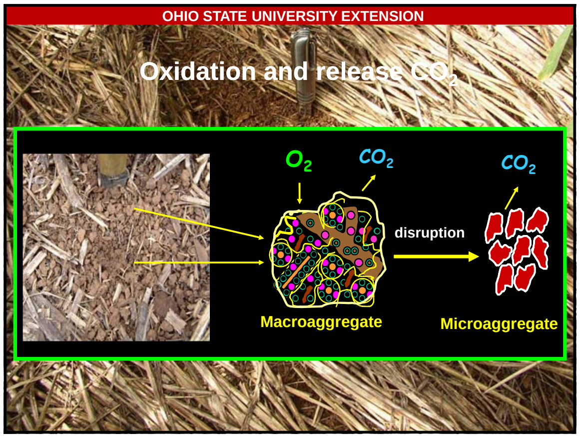

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Cold No-till Soils

- Probably due to Compaction.
- Compacted soil hold moisture and heat (cold).

No-till with a Cover Crop

- Aerated soils warm up faster
- Black residue absorbs heat
- Thick residue at surface has biological activity and gives off heat.

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Why do our Soils Compact?

- Look at your Crop Rotation
  Drilled Soybeans have poor root system
  Corn has thick roots limited by plow layer
- What percentage of time do we have live roots?
  Corn-Soybean rotation 4/12 months = 1/3 of time
- Does No-till have more Live Roots than Conventional tillage? NO
- What is missing in No-till? Live Roots

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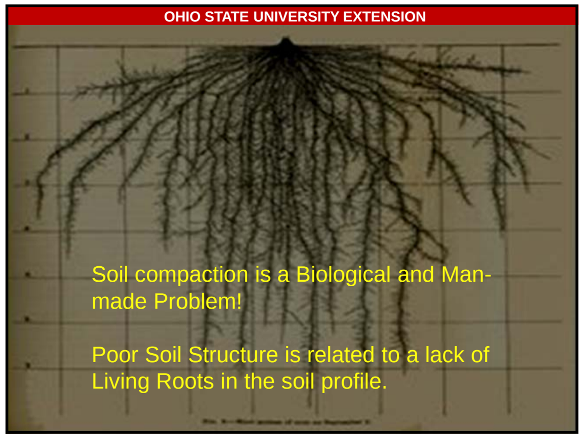

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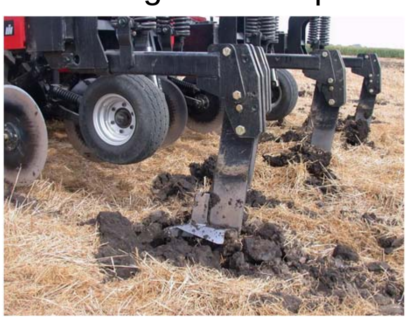
Subsoiling and Compaction



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Subsoiling Yield Gains (Losses)

- Conventional tillage with subsoiling
  Corn Yield gain 1-3 bu or 3%
  Soybean Yield Gain 2-5 bu or 10%
- No-till and subsoiling
  Corn Yield loss 1-3 bu or 3%
  Soybean Yield loss 2-5 bu or 10%

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Subsoiling vs. Cover Crops

What can a subsoiler do?

Immediate change in soil structure, 18 inches deep

Increase infiltration

Leaves soil susceptible to compaction later

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Subsoiling vs. Cover Crops

What can cover crops do?

Slow change in soil structure, 3 ft deep or deeper.
Increase infiltration, over time
Protect soil from erosion
Add nutrients and organic matter
Fit into a continuous no-till system
Help protect against soil compaction

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Soil Resistance to Compaction Ranked

Continuous No-till, controlled traffic, cover crop
Continuous No-till with growing cover crop
Continuous No-till, heavy residue, no cover crop
Continuous No-till, light residue or bare ground
Intermittent No-till
Shallow tillage (Aer-Way, Phoenix harrow…)
Strip-till
Subsoiled, wide spaced shanks
Moldboard or chisel plow, finely tilled seedbed
Subsoiled, deep ripped, full surface tillage

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Best Cover Crops to Fight Soil Compaction

- Grasses: Fibrous Roots
  Sorghum Sudan>Annual Rye> Cereal Rye/Oats
- Brassicas: Large Taproot (Fine root hairs)
  Oilseed Radish > Turnips (Shallow rooted)
- Legumes: Large Root Network
  H. Vetch>Cowpeas>Red Clover>Winter peas
- For Surface Compaction? For Deep Compaction?
  Buckwheat>Phacelia Sunflowers

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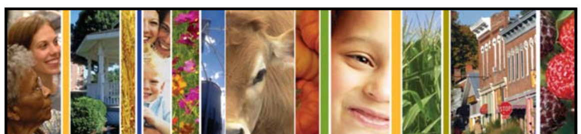
Summary

- Soil Compaction is related to the Biology of the Soil & How the Soil was Managed.
- Organic Matter and Microbes influence Soil Compaction.
- Cold No-till Soils result from Soil Compaction and poor Soil Structure.
- Active Living Roots and Microbes work together to Improve Soil Structure.
- Equals No-till plus Cover Crops or a new system called ECO Farming!



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James J. Hoorman hoorman.1@osu.edu
Randall Reeder reeder.1@osu.edu
www.mccc@msu.edu

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Economics of Cover Crops

James J. Hoorman
Ohio State University
hoorman.1@osu.edu
www.mccc.msu.edu

Cost of Tillage Operations/Acre

- Chisel Plow $14/A
- Disk Tandem $13/A
- Field Cultivate $11/A
- Plow $17/A
- Soil Finishing Tools $11/A
- Subsoil $18/A

Ohio Farm Custom Rates 2010
Barry Ward, OSU Economist

Legume Cover Crop Seed Cost

Cover Crop	Seed Price/lb	Pound	Planting	Kill	Total Cost/A.
Cowpeas	$.80	40-50	$14	$0	$46-54
Winter peas	$1.00	30-40	$14	$0-15	$34-$69
Red Clover	$2.00	10-12	$6	$15	$41-$45
Chickling vetch	$1.00	30-70	$14	$15	$59-$99
Sweet Clover	$1.50	10-20	$6	$10	$31-$46
Hairy Vetch	$1.25	15-20	$14	$15	$49-$54

Grass Cover Crop Seed Cost

Cover Crop	Seed Price/lb	Pound	Planting	Kill	Total Cost/A.
Cereal Rye	$.20 $12/bu	60 1 bu	$14	$15	$41
Annual rye	$.80	15-25	$14	$15	$41-$49
Wheat	$.10 $6/bu	60 1 bu	$14	$15	$35
Oats	$.15 $6/Bu	42-63 1-1.5 bu	$14	$0	$20-$23
Brassicas					
Oilseed Radish	$3.00	1-10	$14	$0	$17-$44

Value of Soil Organic Matter

Assumptions: 2,000,000 pounds soil in top 6 inches
1% organic matter = 20,000#

Nutrients:

Nitrogen:	1000# * $0.50/#N	=	$500
Phosphorous:	100# * $0.70/#P	=	$ 70
Potassium:	100# * $0.50/#K	=	$ 50
Sulfur:	100# * $0.50/#S	=	$ 50
Carbon:	10,000# or 5 ton * $?/Ton	=	$ 0

Value of 1% SOM Nutrients/Acre = $670

Original Jim Kinsella/Terry Taylor(2006)/revised Jim Hoorman (2011)

Soil Organic Matter Accumulation

- Takes 10 tons of Decomposed Organic Matter to equal 1% SOM
- If start with 40 tons Organic Matter and lose 75% to get 10 tons decomposed SOM
- Accumulate 4-6 tons and lose 75% equals 1-1.5 tons Decomposed SOM or .1-.15% SOM * $670/Acre or $67 to $100/Acre

You are Building Your Soil Fertility with SOM!

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Crop Residue along Ditch from Bare Cropland, Chiseled Wheat Stubble

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Value of Ton of Topsoil

- Most Biological activity occurs in top 3 inches.
- One million pounds or 500 ton of topsoil in top 3 inches.
- Average Value of Cropland = $10,000/Acre
- Soil Lost at T value = 4-5 ton/acre
- Soil Productivity Value: $5,000/500 = $10/Ton
- Lost value per acre = $10/ton soil loss * 4-5 tons

Losing $40 to $50 per acre.

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8” Rain in Iowa in 2012

Photo courtesy of RM

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Productivity of SOM

- Michigan study: Every 1% SOM =12% increase in crop yields.
- Baseline Yields: 170 bu corn, 50 bu soybeans

Starting SOM = 2.5% and add 1% SOM

Soybeans 50 bu * 12% = 6 bu * $10 = $60/A.
.1 to.15% SOM increase/year = $6-$9/yr.

Corn 170 bu * 12% = 20.4 bu * $4 = $81/A
.1 to.15% SOM increase/year = $8.10-$12.30/yr.

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Lime Costs/acre

- 1 to 2 tons of lime per acre * $15/Ton
- Plus spreading cost $6/Acre
- Total lime cost: $36/Acre over 3-5 years
- Cost /Acre/Year: $7-$12
- No-till and Cover Crops need less lime because they keep Ca^{2+} circulating

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Legume Cover Crop N Economics

Cover Crop	Total Cost/A.	Pound Of N	Value of N	Total N $	Net Gain
Cowpeas	$46-54	120-150	$.50	$60-75	$6-$29
Winter peas	$34-$69	120-150	$.50	$60-75	($9) - $41
Red Clover	$41-$45	100-120	$.50	$50-60	$5-$19
Sweet clover	$30-45	100-200	$.50	$50-$100	$5-$70
Crimson Clover	$18-25	100-150	$.50	$50-$75	$25-$50
Hairy Vetch	$49-$54	100-200	$.50	$50-$100	($4)-$51

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Drainage

- $800 to $1000/acre for subsurface drainage.
- Farmers say you pay for drainage every 20 years whether you pay for it or not. Poor drainage costs you in reduced yields.

  Keep $1000 in Bank, Collect 2-3% interest

  Spend Interest on Cover Crops: $20-30/A.

  Still have principal at end of 20 years.

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Annual Ryegrass Cover Crop

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No-till Cropland No cover

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Annual Ryegrass Cover Crop

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SOM and Available Water Capacity
Inches of Water/Per one foot of Soil

Berman Hudson Journal of Soil & Water Conservation 49(2) 189-194 March-April 1994

Percent SOM	Sand	Silt Loam	Silt Clay Loam
1	1.0	1.9	1.4
2	1.4	2.4	1.8
3	1.7	2.9	2.2
4	2.1	3.5	2.6
5	2.5	4.0	3.0

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Soil Temperature Differences

Conventional /No-till??

No-till + Cover Crops & Live Plants

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For Hot Dry Summers

For Corn Production:

75 degrees Fahrenheit – 1 Inch water/week
85 degrees Fahrenheit – 2 inch water/week
95 degrees Fahrenheit – 4 inch water/week

2X Water requirements for every 10F increase

1" Rain = 8 bu. corn, 22" needed for 200 bu. Corn
Rain = 19-23 inch/year in growing season
1" Rain fully used = 8 bu/A * $4 = $32/A

Heat and drought quickly increase yield losses!

By Elwynn Taylor, Iowa Ag. Climatologist

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SOM Buffers Soil Temperatures

- Early frost 1/20 years
- Value to replant soybeans $120/acre
- Value of frost protection over 20 years = $6/acre/year

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Soil Compaction costs

Conventional tillage vs No-till and Cover Crops
Corn 3% yield gain
170 bushel corn * 3% = 5.1 bu * $4 = $20.40/A

Soybeans 10% yield gain
50 bushels soybeans * 10% = 5 bu * $10 =$50/A

Cover crops improve soil structure, water infiltration, and decrease runoff.

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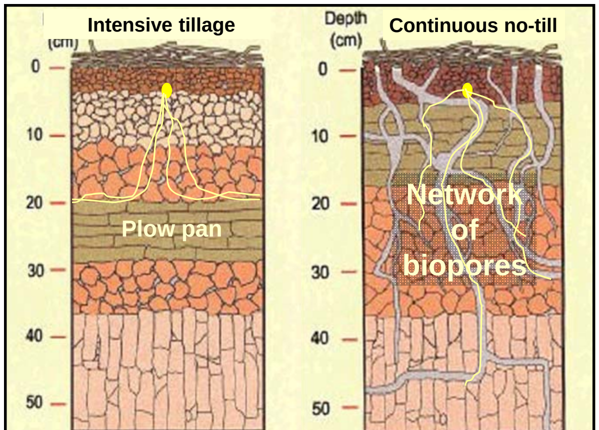

Ontario Ministry of Ag and Food

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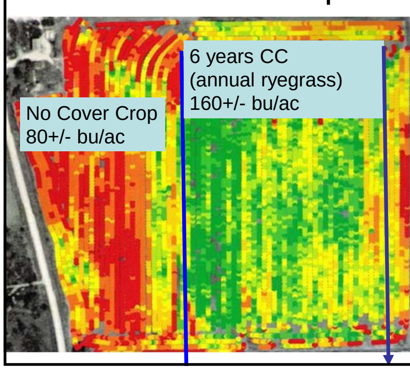
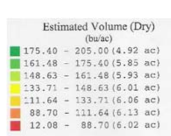
Cover Crop Effects





Mike Plumer's long-term no till with ryegrass cover crops on heavy clay soil.

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2005 Illinois Demonstration Results

Tillage/cover crop	Yield bu./A.
Conventional tillage	82
No cover crop no-till	124
Ryegrass 1 year no-till	137
Ryegrass 6 years –claypan	165
Ryegrass 6 years no claypan	215

Rain fall .... May- Sept. 2.3"

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Cover Crop Benefits in Drought

2005 Illinois Corn Data (2.3 inches rain)
Conventional tillage 82bu.
No-till 124-82=42 bushels * $4.00/Bu = $168
No-till + Annual Rye 137-82=55*$4.00 = $220
$220/20 years = $11/Acre/Year

Negative Effects:
Cover crops may excessively dry the soil through respiration in a dry spring. Solution is to kill the cover crop early if the soil is getting too dry.

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CTIC Survey: Cover Crops & Yields

In 2012 (Drought)

Corn plus cover crops yielded 11 bushels more than conventional @ $7/bu. Or $**77**/Acre.

Soybean plus cover crops yielded 5 bushels more than conventional @ 15/bu. Or $**75**/Acre.

In 2013 (Good Moisture)

Corn plus cover crops yielded 5 bushels more than conventional @ $4/bu. Or $**20**/Acre.

Soybean plus cover crops yielded 2 bushels more than conventional @ 10/bu. Or $**20**/Acre.

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Robison Farms Corn Yields w/wo Cover Crops - 2012

Plot	Yield
check (no cover crop on No-till, replicated 3 times)	**105.24**
Annual Ryegrass + Crimson Clover + Radish	**120.31**
Winter Cereal Rye	**126.86**
Oats + Radish	**138.79**
Annual Ryegrass Blend	**134.27**
Annual Ryegrass + Crimson Clover	**136.41**
Crimson Clover + Radish	**153.99**
Oats + Rye + Appin Turnips	**164.37**
Austrian Winter Peas + Radish	**164.82**

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The NET PROFIT from Cover Crops 2012

Robison Farms Cover Crop Research Plot	Revenue	(Revenue less Seed and application cost)	Net Advantage (extra profit)
check (no cover crop)	$ 605.13	$605.13	**$0.00**
Annual Ryegrass + Crimson Clover + Radish	$ 691.78	$646.91	**$41.78**
Winter Cereal Rye	$ 729.45	$696.97	**$91.84**
Oats + Radish	$ 798.04	$733.29	**$128.16**
Annual Ryegrass Blend	$ 772.05	$743.05	**$137.92**
Annual Ryegrass + Crimson Clover	$ 784.36	$750.76	**$145.63**
Crimson Clover + Radish	$ 885.44	$829.44	**$224.31**
Oats + Rye + Appin Turnips	$ 945.13	$870.23	**$265.10**
Austrian Winter Peas + Radish	$ 947.72	$892.07	**$286.94**

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Dave Brandt Farm 2012

30 Years No-Till and 15 years Cover Crops
Corn: 149.9 Bu/A Soybeans: 49.5 Bu/A

Neighbors: Conventional Tillage
Corn: 80-95 Bu/A Soybeans: 32-35 Bu/A

Corn = $7.50/Bu. Soybeans = $15/Bu.
$7.50 * 55-70 = $412-$525/A $15 * 15-18 = $225-$270/A.

Rain makes Grain! Increased moisture equals higher yields.

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2012 Putnam County Soybeans Replicated 4 times

Conventional Soybeans: 55 Bu/A ---
Cereal Rye/Soybeans: 60 Bu/A $75
Oil Seed Radish/Soybeans: 68 Bu/A $195
Soybeans = $15/Bu
Weeds
Conventional: Highest Level = Moderate
Cereal Rye: Medium Level = Few
Oilseed Radish: Lowest Level = Scattered

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Mimic Mother Nature

60 Million Bison in USA in early 1800's

Did they stop eating or pooping in winter?

Water Quality?

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Holding Nitrogen from Manure... Effects from Annual Ryegrass

Manure w/o cover crop

Manure w/ cover crop

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Holding Nutrients from Manure

3 kernels = 1 bushel corn on 30,000 corn pop.
18 rows * 4-5 kernels =75-90 kernels more per ear
25-30 bushel yield difference * $4 = $100-$120/A.

Manure w/o cover crop
Ave. 5 ½ -6"

Manure w/ cover crop
Ave. 7 ½"

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Manure Value of Cover Crops

Swine Manure: 95% Water 5% solids
Manure Nutrient Analysis:18-16-14/1000 gallons
Uptake: At 5,000 gallons/A =90-80-70 $80
At 10,000 gallons/A =180-160-140 $147

Dairy Manure: 98% water 2% solids
Manure Nutrient Analysis: 20-15-15
Uptake: At 5,000 gallons/A =100-75-75 $87
At 10,000 gallons/A =200-150-150 $122

*Absorb 70% N, maximum 20# P
Crops absorb about 0.5% N Maximum and 0.2% P

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Ecological Concepts

- Weeds, Insects and Diseases Cost Farmers 30% of their Crop every year since 1940's.
- Native undisturbed soils have diverse species (predators, prey, parasites). Keep pests in check.
- 100% Pest Control not Achievable!
- New ECO Goal: Keep pests at acceptable levels using all Ecological strategies: Safe, durable, $$$
- Keep Insecticides, Fungicides, Herbicides around for major outbreaks.

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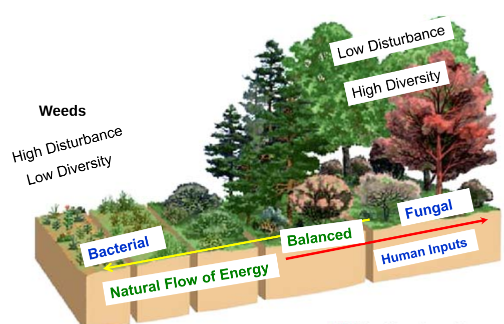
Natural Succession of Plants & Soil



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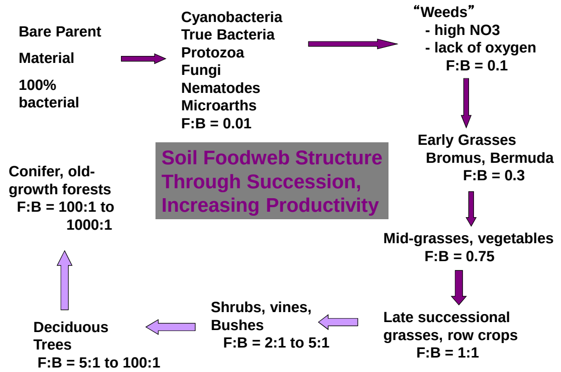
What does your plant need?



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Weeds

- Farmers promote weed seed by tilling the soil.
- Ways to fight weeds
  1) Hoe or pull them out
  2) Kill with herbicides
  3) Compete for sunlight and nutrients by growing cover crops and reduce weed seed production.
- Farmers with No-till and Cover Crops reduce herbicide cost by 1/3 = $7-$12/A.
- Early weeds reduce crop yields 10% * 50 bu soybeans * $10/Acre = $50
- Reduced weeds: cereal rye, oilseed radish, etc.

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Insects

Positive: Soybean Cysts Nematodes (SCN)
1) 80-90% Reduction using cereal rye/annual rye
50 bu * 30% =15 bu * $10 =$150/A

Natural Pollinators:$5 Billion/350 million =$14/A

Negative: Slugs, Cutworm, Armyworm

1) Carabidae beetles/ground beetles and lightning bugs are natural predators of soft body insects.
2) Cover crops may be an alternative food source for slugs and may protect corn from damage.

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Five Steps to Fighting Insect Pests

- Small Fields surrounded by natural vegetation. These areas offer refuge and extra food.
- Diverse crops with diverse flowers. Small flowers with open flowers promote predators.
- Minimize use of insecticides and fungicides.
- Keep soils high in SOM (mulch) and biological activity. Winter refuge and food for predators.
- Use multiple natural tactics. Plant cover crops and mow every other row or raise mowing height.

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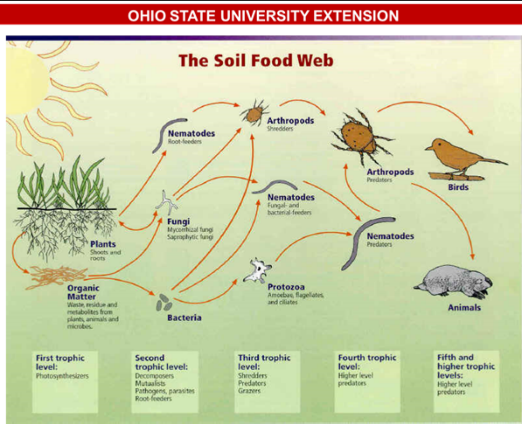

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Promote Predator Friendly Plants

- Promote nectar early spring, mid-summer, and late fall.
- Early spring: Dandelions, Henbit
- Mid summer: Buckwheat, Sunflower, Flowering Legumes: crimson clover, sweet clover, hairy vetch, red clover
- Late Fall: Wild carrot (Queen Ann's Lace), Goldenrod
- Ecosystems with more diversity are more stable and *Resistant* to change and are more *Resilent!*

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Diseases

Diseases that thrive under excess water
- Phytophthora: 20% loss*50 bu=10 bu * $10= $100/A
- Phythium: 5-10% *50 bu=2.5-5 bu*$10= $25-$50/A
- Fusarium: 10% * 50 bu= 5 bu. * $10 = $50
- Rhizoctonia 2-5%*50 bu=1-2.5bu*$10= $10-$25/A

Thrive with less biological activity (tillage)
- Sclertina/White Mold (Bury seed with tillage)

2 to 4 bushel per acre * $10 = $20-40/A

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Seed Production

Cereal rye:
30-60 bushels * $12 =
$360-$720/A minus $49 seed, plant, kill it plus $30 for harvesting = $280 - $640

Cowpeas: 30-35 bushels per acre or 1500 to 1750 pounds times $.80/lb = $1200 -$1400/A minus seed, planting, harvesting costs

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Forage Value of Cover Crops

- Oats, cereal rye, annual ryegrass
- 4 tons cereal rye at $100/ton =$400 Income
- Costs $60 (2 bu/Acre for seed) per acre for seed, plant, kill it.
- Harvest Costs: $40
- Net Income: $300

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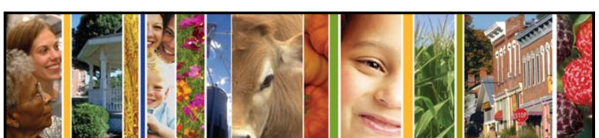
Summary

- No-till is an important first step in keeping soils healthy. Cover crops or live plants is the second step.
- Farmers can reduce their input costs by planting cover crops.
- How we manage the soil impacts soil temperature, water storage, & crop yields.
- Soil health also impacts weeds, insects, diseases, weather and climate.



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Economics of Cover Crops

James J. Hoorman
Ohio State University
hoorman.1@osu.edu
www.mccc.msu.edu

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Bringing Knowledge to Life

Keeping Phosphorus Out of Surface Water

Tying Up Soluble Reactive Phosphorus (SRP)

Jim Hoorman, Assistant Professor, Agriculture and Natural Resources
hoorman.1@osu.edu

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Agriculture in Lake Erie Basin

- 4.2 Million Acres Maumee Watershed
- 4.9 Million Total
- 59.1% cropland
- 72% cropland in Western

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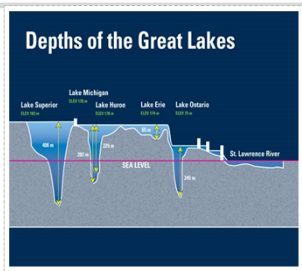
Interesting Lake Erie Facts

- 50/2 Rule
- $10.7 billion economic activity
- Employing 119,100 Ohio residents and generating $750 million in tax dollars
- Drinking water: 10-11 Million



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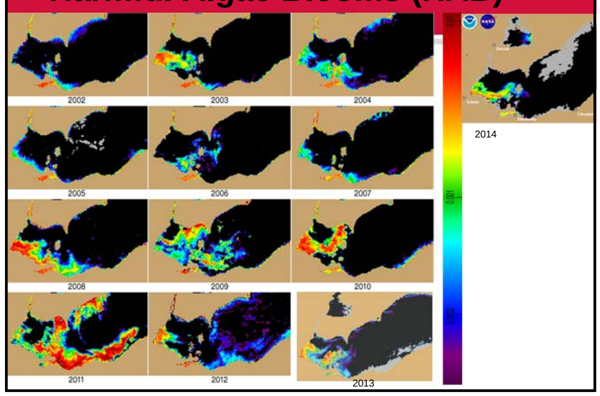
Harmful Algae Blooms (HAB)



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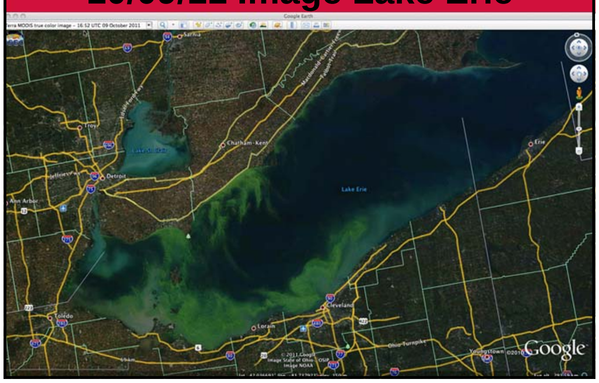
10/09/11 Image Lake Erie



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SRP in Surface Water

Two Key factors:
a) Soil P concentration
b) Transport Factor

Soil P concentration
* Transport Factor
= Pounds of P Lost to Surface Water

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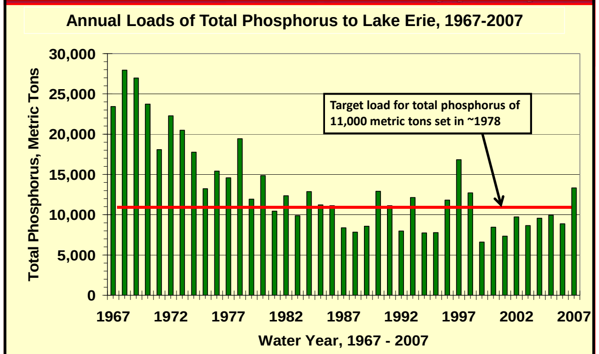

Source: Hiedelberg University

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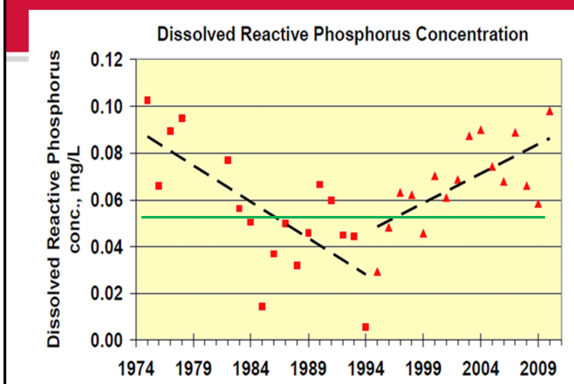

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Lake Erie and Nutrient Loading

- Issue in 1960-1970's was Total P Loading
- Issue in 1990-2000's is Bioavailable or Dissolved Reactive Phosphorous
- Key facts about P: 90% of P runoff occurs in 1-2 rainfall events each year.
- 80% of the P is coming from roughly 20% of the land.
- Current P efficiency is 10% to 30%.

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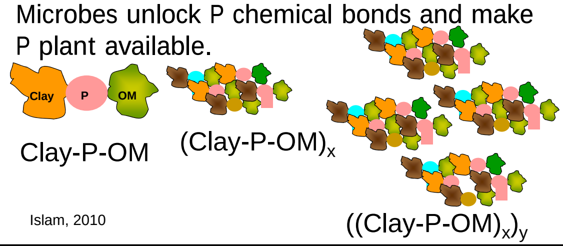
Organic Phosphorus

50-80% of the Available P in soil is organic.

Our current P use efficiency is 10-30%. Microbes unlock P chemical bonds and make P plant available.



Islam, 2010

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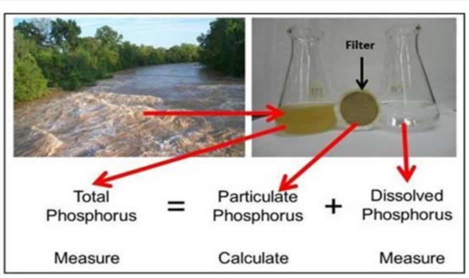
Phosphorus Testing



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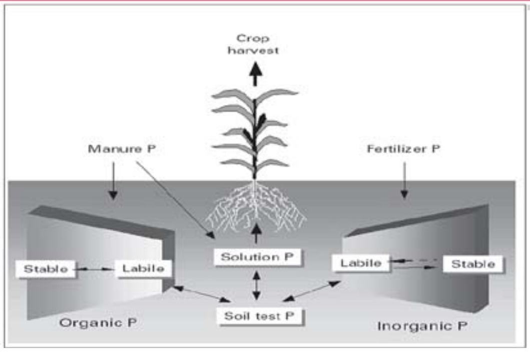
Phosphorus Form/Availability to Algae

	P form	% Bio Availability	Results
	Particulate	30	Algae grow slower
	Soluble	100	All available Fast growth

Phosphorus in Crop Production



Phosphorus Speciation

Plant Available P

- **Soluble Reactive (SRP) P_i Inorganic P - P_i**
- **Exchangeable (EP) P_o Active Carbon- P_o**

Phosphorus Speciation

Slowly or Not Plant Available P

- Ca^{2+} /Mg $^{2+}$ Calcium/Magnesium- P_i
- Fe^{3+} /Al^{3+} Iron/Aluminum- P_i
- Res P_o Humus - Residual P_o
- Total P = All P_o + All P_i

Ferric–P to Ferrous-P

2 Fe^{3+}-3H_2PO_4 → H_2PO_4 + 2 Fe^{2+}-2H_2PO_4

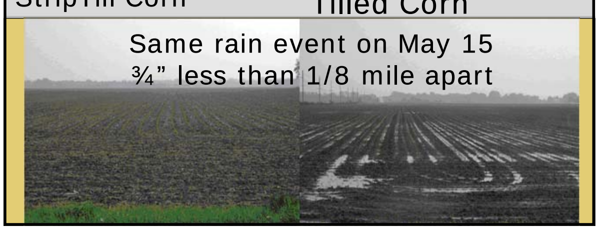
Fe^{3+} → P + Fe^{2+}

Caused by Saturated Soil Conditions and Lack of Oxygen in soil profile.

Iron is releasing SRP when soils become flooded with water.

Long Term No-Till vs. Rotational Tillage

NT soybeans/ StripTill Corn	NT Soybeans Tilled Corn



Saturated Soils

- Under saturated soil conditions, soil microbes strip or release oxygen.
- Example NO^{3-} becomes N_20 and N_2 with bacteria striping the oxygen away from the nitrate causing denitrification.
- Iron, Copper, Manganese transform and release SRP.

OSU Research Study

- Sundermeier, Islam, Hoorman 2013-2014
- Took 50 soil samples comparing no-till versus conventional, cover crop versus bare soil, organic versus conventional, manure (poultry, dairy, none), and crop rotation on Hoytville clay soil.
- Samples taken at following depths:

4-8-12 inches

Key Findings

- Management influences P soil distribution.
- Most soil P tied up by Residual P_o, Fe/Al, and Ca/Mg.
- Only a small amount is SRP or P_i (<0.5%)
- Concentration of P decreases with increasing soil depth.
- SRP and EP (which are plant available) are influenced by management practices and soil depth.

Crop Rotation Phosphorus

	SRP	EP	FeP
Forest	1.5 a	7.3a	1.4a
Waterways	1.7 a	7.0a	18.3c
Alfalfa	0.9 b	5.7a	1.4a
C-S-W	0.2 c	2.6c	6.8b
C-C	0.3 c	3.4c	19.4c
C-S	0.3 c	0.6d	28.1d
S-S	0.3 c	0.3d	24.1d

Cover Crops versus Control

SRP	EP	Res P	Total P
Cover			
0.34b	**1.23a**	**147.7b**	**196.1b**
	8.8X		
Control			
1.42a	**0.14b**	**162.8a**	**209.5a**
4.2X		**1.1X**	**1.07**

Cover Crops: Lower SRP, Higher EP

Cover Crops vs Control Stratification

SRP	EP	Total P
Cover		
0.4b	**61.7a**	**2.0a**
	9.1X	**1.25X**
Control		
1.8a	**6.8b**	**1.6b**
4.5X		

Cover Crops:

Lower SRP Stratification

Higher EP Stratificaton

Mercer County Study

- Grand Lake Watershed, Mercer County, Ohio
- Two contrasting soils: Blount and Pewamo
- Seven sites for each soil (low to extremely high Bray P_1, grass, and forest).
- Soil samples:<25, 25-75, 75-150, 150-300, and >300 PPM Bray P_1.
- Depth (0-1, 1-3, 3-6, 6-9, and 9-12 inches).

Pewamo Soils

	Humus/Fe	SOM%
Grass	9.5	5.2%
Woods	7.2	5.1%
Low (<25PPM)	5.3	2.9%
Medium (25-75 PPM)	4.7	3.1%
High (75-150 PPM)	2.6	2.9%
V. High (150-300 PPM)	1.7	1.6%
Ex High (>300 PPM)	1.9	3.3%

Blount Soils

	Ratio Humus/Fe	SOM%
Woods	12.7	5.1%
Grass	8.6	5.2%
Low (<25PPM)	3.2	2.9%
Medium (25-75 PPM)	2.7	3.1%
High (75-150 PPM)	3.1	3.0%
V. High (150-300 PPM)	1.8	1.6%
Ex High (>300 PPM)	1.3	3.3%

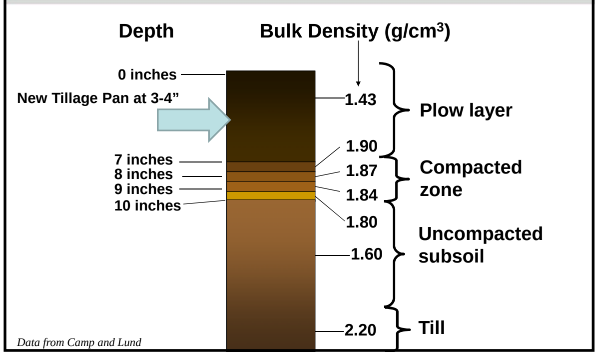
Has Phosphorus Changed?

1) Weather: Increase number, higher intensity of rains, longer duration.
2) We have better environment for cyanobacteria. Warmer weather + more nutrients = Explosion HAB
3) Change in farm size
4) More tile spaced closer together with more surface inlets.

Has Phosphorus Changed?

5) Fertilizer applications have changed. More fall application to accommodate farm size.
6) More vertical tillage, larger farm equipment, more soil compaction.
7) Fertilizer Enhancers (Avail/Jumpstart)
8) Less Soil Organic Matter
9) Climate Change/Freezing Thawing

Bulk Density and Compaction



Dynamic Properties: Infiltration

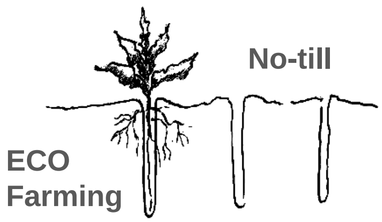
- If rainwater runs off field…. It is not available to the crop
  - Dynamic Soil Property greatly influenced by management

Tillage System	Water Infiltration Rate after 1 Hour (in/hour)
Plowed, disked, cultivated, bare surface	.26
No-tillage, bare surface	.11
No-tillage, 40% cover	.46
No-tillage, 80% cover	1.04

Bare Soil
Low Residue Cover
High Residue Cover

- Residue cover prevents soil crusts

No-TILL creates macropores

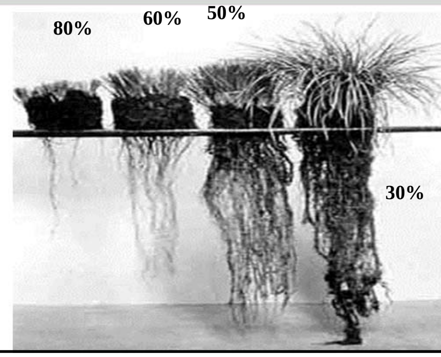


ECO Farming & live roots acts like a biological valve to absorb N and P.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman

Bringing Knowledge to Life

Management & Nutrient Recycling



Bringing Knowledge to Life

Benefits of Cover Crops

- Increase water infiltration – Move SRP_i down into soil profile.
- Decrease bulk density and increase pore space for both air and water – Less saturated soils.
- Increase soil organic matter content which improves soil structure and holds P tighter
  $SRP_i < EP_o$ and $FeP_i < Res\ P_o$

Bringing Knowledge to Life

Best Cover Crops to Tie up P

Grasses
- Cereal Rye
- Annual Rye
- Triticale
- Barley
- Wheat
- Oats

Brassicas
- Kale
- Rape

Legumes/Clovers
- Crimson Clover
- Sweet Clover
- Red Clover
- Hairy Vetch
- Canadian/Winter Pea

Mixtures

At least one cover crop that survives the winter!

Avoid: Short pastures, OSR, Long-term Alfalfa

OHIO STATE UNIVERSITY EXTENSION

Daikon radish

The Ohio State University
College of Food, Agricultural, and Environmental Sciences

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Nutrient Uptake by Daikon Radish

Nutrients	Concentration (%)	Content (lbs/a)
Nitrogen	1.89	650
Phosphorus	0.97	23
Potassium	3.27	230
Sulfur	0.81	60
Calcium	2.17	150
Magnesium	0.26	20

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Fertility Applications

- Frozen and snow covered applications have the greatest risk of off site movement whether manure or commercial fertilizer.

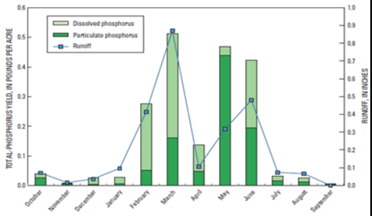

Figure 22. Mean monthly particulate- and dissolved-phosphorus yields and runoff, Discovery Farms and Pioneer Farm, water years 2003–8.

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Cost Effectiveness of BMP's

BMP	$/Ton of Sediment	BMP	$/Ton of Sediment
Cover Crops	$1.99	Diversions	$18.10
No-till	$2.99	Sediment Retention	$50.21
Permanent Cover	$6.95	Average Cost	$8.71
Wind break	$12.10	CRP Program	$22.95
Sod water way	$13.50		

Bringing Knowledge to Life

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Water Quality Benefits from Winter Cover Crops

- Reduces nutrient and pesticide runoff by 50% or more.
- Decreases Soil Erosion by 90%
- Reduces Sediment Loading by 75%
- Reduces Pathogen Loading by 60%
- May decrease flooding potential by increasing water infiltration

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Bringing Knowledge to Life

Keeping Phosphorus Out of Surface Water

Tying Up Soluble Reactive Phosphorus (SRP)

Jim Hoorman, Assistant Professor, Agriculture and Natural Resources
hoorman.1@osu.edu

THE OHIO STATE UNIVERSITY EXTENSION

UVM Extension Fact Sheet: **Northwest Crops & Soils**
Champlain Valley Crop, Soil and Pasture Team

No-Till Corn Planter Checklist: Planter Maintenance & Upgrades

by Jeff Sanders, Agronomy Outreach Professional

1) Planter tires, worn treads, correct psi

2) Hitch height should be between 14 and 15 inches from ground to bottom of hitch plate

3) Check tool bar for level- torpedo level needs to be level down in the field
   a. If not pulling up or pushing down on the planter

4) Parallel arms are tight and bushings good
   a. Bouncing around will affect how the planter works in the ground

5) Vee Openers- important for the creation of a good seed trench
   a. Replace at 14.5 inches
   b. Check with two pieces of paper 1.75 -2 inches 3mm
   c. Heavy duty 3.5mm openers should be about 1.25 inches
   d. Move shims achieve proper contact.
      i. If you can turn one against the other easily they are not shimmed properly
      ii. If you shim them to tight you will put additional stress on bearings

6) Check the Keaton Seed Firmers for wear and adjust as needed
   a. They should be snugged up with the adjusting screw
      i. NEVER back up with the planter down or they will be damaged

7) Check all drive chains make sure not bound up. Do not oil chains daily—dust and dirt will stick and bind up and shorten life of chains. Best is to remove and place into the seed boxes

8) Check shafts for alignment and bearing
   a. Problems will lead to skips

9) Check seed tubes for wear and breaks very important
    a. A leading cause of skips and doubles

10) Check rock guards
    a. Replace worn guards as your seed tubes will break and wear faster if you do not

11) Check downforce pressure
    a. Should be able to turn gauge wheels when planter is on the ground
    b. Too much down pressure will create sidewall compaction and impede root system
    c. If spring system check for broken springs
    d. Ideally you will want to run around 125 pounds of downforce on the planting unit

12) Gauge wheels need to checked for wear and bearings need to be checked for wear
    a. Gauge wheels need to rub on vee openers any gap will result in plugging and trench filling in resulting in problems
    b. Check scrapers at this time as well

13) Check closing system for true running
    a. Any slop in the bushings and arms will result in diminished performance
    b. Check distance between wheels 1.75 inches
    c. Check springs for wear and the mounting holes for wear and replace repair as needed

14) Check fertilizer system for problems
    a. Check lines for cracks
    b. Check monitoring system for leaks
    c. Check inline filters and screens
    d. Check hardware holding tanks well
    e. Make sure dry fertilizer tanks are cleaned make sure augers are put in correctly
    f. For dry fertilizer make sure the banding set up is correct (2X2) and all other
    g. Liquid fertilizer make sure the in row lines are dropping the fertilizer in the correct location or your vee openers will get wet or your keatons will get wet and plugging and dragging will result.
    h. Make sure the ground pump you are using to fill and hoses are all in good shape and the fittings are not busted.
    i. Make sure planter pump is calibrated so you do not burn your seed (in row) or misapply fertilizer.
        i. Tape a bottle to one hose, drive 136 ft each oz. is a gallon on 30 inch rows

15) Test seed meters
    a. Air meters need to check brushes, seals, etc…
    b. Fingers check belts and other components should be checked annually
    c. Lubricate seed drives annually
    d. Clean seed boxes and plates with warm soapy water

16) Check vacuum system on an air seeder check vacuum gauge
    a. When planting during the day depending on air temperature, humidity, hydraulic oil temp, this pressure will change and you need to keep track or the population will change

17) Check planter standards for cracks and repair as needed

18) Check electronic meter system before you head to the field
    a. Use dielectric grease on connection between planter and tractor

19) Make sure all hydraulic hoses are properly run and tied off so they do not get pinched or blown

20) Check marker arm measurement so that you row spacing is even and that the marker wheels bearings and guards are in good shape. Check fittings for tightness and leaks.

21) Follow planter recommendations for the seed you plant and use seed lubricant if recommended by the planter manual. Pay attention to seed weights and shapes and make the proper adjustments to planter to insure proper planting population.

For more information:

Please contact the UVM Extension Champlain Valley Crop, Soil & Pasture or Northwest Crops & Soils Programs

Jeff Sanders	Agronomy Outreach Professional	jeffrey.sanders@uvm.edu	524-6501 x 453
Rico Balzano	Agronomy Outreach Professional	rico.balzano@uvm.edu	388-4969 x 338
Jeff Carter	Extension Agronomy Specialist	jeff.carter@uvm.edu	388-4969 x 332
Heather Darby	Extension Agronomy Specialist	heather.darby@uvm.edu	524-6501 x 437
Kirsten Workman	Agronomy Outreach Professional	kirsten.workman@uvm.edu	388-4969 x 347

23 Pond Lane, Suite 300 Middlebury, VT 05753 802-388-4969 or 800-956-1125 www.uvm.edu/extension/cvcrops
278 South Main Street, Suite 2 St. Albans, VT 05478 802-524-6501 or 800-639-2130 www.uvm.edu/extension/cropsoil

UVM Extension Fact Sheet: Champlain Valley Crop, Soil and Pasture Team

The Living, Breathing Soil: Farming with Soil Biology

by Kristin Williams, Agronomy Outreach Professional

Soil health is the cumulative soil condition based upon chemical, physical and biological properties. While measures of soil often focus on chemical properties, and to a lesser extent physical properties, biological properties may be overlooked. However, your soil is alive! One cup of soil may hold as many individual bacteria as there are people on Earth! *The complex of living organisms in soils plays a critical role in the processes that create and maintain soil health and impact crop yields, quality and vigor.*

∗ Carbon cycling and retention:

Organic matter is the foundation of the soil food web which is constantly being transformed through soil organisms. Many kinds of soil organisms are involved in the process of shredding and decomposing complex plant residues into constituent parts. Different soil organisms are particularly adapted to process different kinds of organic matter.

∗ Nutrient cycling and retention:

When soil organisms decompose plant residues, nutrients such as nitrogen and phosphorus may also become more available to plants. Decomposers transform plant matter and release nitrogen, which is subsequently transformed by other bacteria and chemical processes (see Figure 1). Organisms are like a slow release fertilizer. Soil fauna that consume bacteria often consume and excrete excess nitrogen, thereby transforming it into plant available forms (either ammonium or nitrates). Organisms also hold nutrients in their bodies which are released upon death – this can help hold nutrients in the soil, particularly during periods of slower crop uptake.

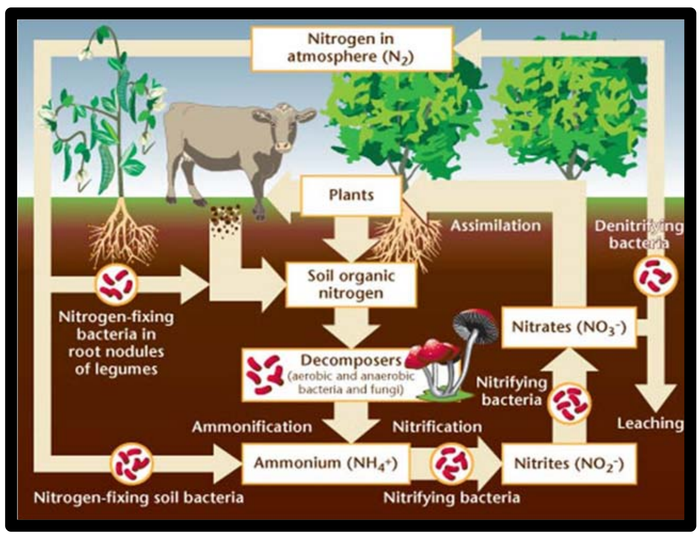


Figure 1. The Role of Soil Organisms in the Nitrogen Cycle.
(Soil fauna are missing from this illustration)

∗ Soil physical properties:

As biota transform and ingest soil organic matter, soil particulates, and other organisms, biota exude sticky binding agents (polysaccharides and glomalin) which hold soil particles together and create spaces in the soil. Soil biota can increase soil aggregation and porosity, and therefore can improve both infiltration and water-holding capacity, providing a more habitable environment for plant roots.

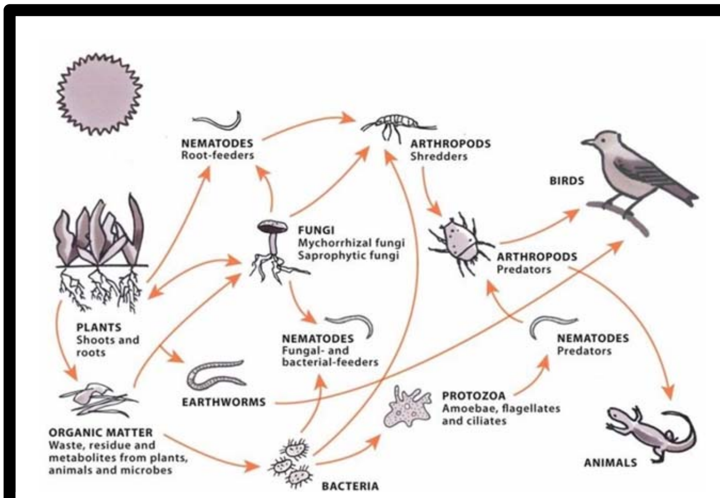
∗ Disease Suppression and Plant Health:

It's easy to get into the trap of thinking of soil biota as "enemies" because we are often focused on agricultural pests. However, most organisms are beneficial to crops. Beneficial soil biota can aid plant health both indirectly and directly. Indirectly, they can create a better growing environment for crops through the processes described above. Directly, soil organisms have been shown to stimulate root growth and development. Soil organisms can also compete with and prey on pest species.

* Environmental protection:

Healthy soil provides many functions that are of greater service to both farmers and the larger human communities that agriculture supports. Soils are an important source of biodiversity, which serve many functions in creating stable ecosystems. Soil biota are involved in soil water filtration, as soils retain and break down pollutants before they reach surface or ground waters. Soil biota are also part of the long term process of soil formation.

A Review of Soil Biota: Food webs are a way to envision how nutrients and energy are transmitted and recycled from one group of organisms to another (see Figure 2). Trophic level is how many steps a group is from the primary producer. The base of the soil food web is plant litter, exudates, roots and animal residues. Soil food webs are composed of bacteria and fungi (soil flora, or soil microbes), and many types of soil animals (soil fauna) including protozoa, nematodes, earth worms, and arthropods.



Original source: NRCS, http://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_049822.jpg
Adapted from: http://www.agriculturesnetwork.org

Figure 2. An Illustration of the Soil Food Web.

<u>Bacteria:</u> Bacteria are miniscule, single celled organisms with a big function in soil. Many bacteria are decomposers, breaking down organic matter into simpler substances. Some bacteria form a symbiosis with leguminous plants creating nodules in the roots that transform nitrogen from the soil-air into usable forms for plant growth. While some bacteria obtain energy from carbon, other bacteria use and transform substances containing nitrogen, hydrogen, sulfur, or iron. Some bacteria must have oxygen, others are somewhat flexible, and still others can only exist without oxygen. Some bacteria cause disease in plants, while others cause disease in other organisms. The classic example is the bacteria *Bacillus thuringiensis (Bt)* which creates an insecticide utilized by agriculturalists. Still other bacteria create compounds that inhibit fungal diseases or stimulate plant growth.

<u>Fungi:</u> When you think of fungi, you might think of the mushroom you had for dinner. However, the mushroom is the fruiting body (reproductive part) of the fungi. Underground, or in the growing medium, these fungi produce many hyphae – thin root-like structures that extend out in search of food. Some of the largest organisms on Earth are actually fungi! In contrast other fungi, such as yeasts, exist as single celled organisms. Fungi provide an important part of decomposition, breaking down more resistant forms of organic matter. Specific fungi can usually survive drought conditions more than bacteria. Fungi generally require oxygen, meaning that saturated soils are usually hostile to them. Mycorrhizae fungi form a special symbiosis with plants, transforming phosphorus into usable forms and bringing macronutrients, micronutrients and potentially water through their hyphae to plants roots (in exchange for photosynthetic carbon from the plant). In effect mycorrhizae extend plant roots. Hyphae also bind soil particles together and enhance soil structure. Most agricultural crops form these associations (some vegetables such as cabbage and beets excluded), and some may for 'hyphae highways' between different crops. While some fungi are detrimental crop diseases others prey on soil pests. A great example is the nematode trapping fungus (see Figure 3).

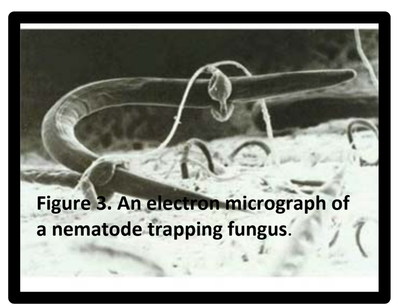


Figure 3. An electron micrograph of a nematode trapping fungus.

<u>Protozoa:</u> Protozoa are single celled animals that graze on microbes in the soil and sometimes other protozoa and organic materials. Protozoa are grouped by cell structure, which is related to mobility: amoeba, which have a unique blob-like movement with "pseudopods" or finger-like projections of their

cell; flagellates, with whip or tail-like projections; and ciliates, with many fine hair-like projections. Protozoa are important in particular for nitrogen cycling; in grazing on bacteria they consume more nitrogen than needed for their growth, and therefore excrete excess ammonium-N, creating up to a 10 fold difference in nitrogen mineralization. Because biological activity is often near plant roots, this nitrogen then becomes available for plant uptake as well as for other organisms. By grazing on microbes, protozoa can also help control plant diseases.

Nematodes: While the most well-known nematodes are pests occupying and feeding on plant roots (such as the lesion nematode and the soybean cyst nematode), in fact most nematodes are beneficial organisms. Nematodes are extremely important because they consume a diverse array of food sources, which places them at multiple trophic levels in the soil food web. Nematodes are mostly microscopic, and occupy water pores in soil but also rely on air pores for diffusion. Nematodes are a diverse group of animals, and can be found in almost all soil types and climates including Antarctica. Some nematodes consume bacteria and others fungi. Like protozoa, nematodes have a role in nitrogen mineralization, disease control of microbes, and root growth stimulation. Still other nematodes are opportunistic or omnivorous and feed on a variety of food sources including protozoa. Specific nematodes are used in biological application to consume the larvae of invertebrate pests (e.g. Japanese beetles). Still other nematodes are specifically predators, feeding exclusively on other nematodes. Due to this nature, scientists use nematodes as biological indicators in soil. Nematode community measures are related to the structure of the entire food web and also reflect both chemical and physical disturbances.

Earthworms: Earthworms have many benefits and are also the easiest indicator of biology because they do not require a microscope for observation. Earthworm burrows create increased soil structure and porosity, and habitat for other soil organisms. Earthworms digest substantial quantities of organic matter, turning it into more available nutrients. Different earthworms occupy different places in the soil profile; therefore earthworm diversity is important in maintaining soil health. Interestingly, earthworms are actually not believed to be native to Vermont due to past glaciation, and there has been some recent awareness of potential drawbacks with earthworm communities (however that is particularly in forests, and more inconclusive or debated in agriculture).

Other Soil Organisms: Other soil fauna include arthropods, potworms (also called enchytraeids) and water bears (also called tardigrades). Soil arthropods may spend all or only a part of their life in the soil. While some are pests, many are strictly shredders, breaking down plant litter as they feed on microbes, and like earthworms, enhance soil structure with their fecal pellets and burrows. Some also have a role in nitrogen mineralization (e.g., collebolans). Larger, mobile arthropods actually function to move smaller soil organisms around, dispersing them into new settings where they can then assist in decomposition. Potworms are native, somewhat common, small, light colored worms and serve similar functions to earthworms, but affect smaller pore structure. Like nematodes, water bears live in soil water and through a unique kind of suspended metabolism (crytobiosis) can withstand substantial stresses of moisture loss, temperature extremes, high pressure and even the vacuum of space . They feed on plant residues, algae and small invertebrates, playing a role in nutrient turnover.

How Management Practices Can Impact & Enhance Soil Biota

The great news is that the actions we take to remediate phosphorus pollution or enhance nitrogen uptake can also benefit soil biology. Both physical and chemical disturbances can affect the abundance and diversity of soil organisms, and in particular soil fauna that are higher up on the food web. The complexity and type of a soil food web can vary substantially from one soil and management practice to another. Generally speaking agricultural soils tend to have a greater population of bacteria, and therefore more soil organisms that feed on bacteria, in comparison to forest soils, which tend to have a greater number of fungi and soil organisms that feed on fungi. However, within agricultural soils, management practices can shift the dynamics of the soil food web over time in either direction. Complexity is an important concept in studying soil biology, because it relates to how many kinds and groups of organisms there are. More complex and diverse food webs usually confer more benefits to plants.

Increasing quantity and complexity of soil habitat and food sources, and maintaining water-air balance generally increases biological complexity. For example, providing a diverse array of food sources from organic matter applications, plant rotations and cover crops allows for more diversity in soil biota that feed on the organic matter. Similarly, decreasing compaction and increasing soil structure encourages soil biota. This is both due to increased water infiltration and to diversity in soil pores – allowing for a range of pore sizes that support a range of soil biota. Owing to the fact that soil organisms are so tiny and soil is complex, physical space is a really important piece of maintaining soil biology. Places of high biological activity in soil are mainly near plant roots, in plant litter and earthworm and arthropod burrows. Therefore, increasing soil quality for root growth development can also benefit soil biota. Also, if your soils are permanently saturated only anaerobic organisms- those that do not need oxygen to survive – will be able to live there. This is important for nitrogen cycling because if affects how well nitrogen is mineralized. Many organisms, including nematodes, live in water films; if you have a soil that is in serious drought conditions on a regular basis, many will die, or go into a kind of temporary stasis until more water is available. Soil organisms can also be sensitive to chemical disturbances and low pH to differing degrees by species; however earthworms and other soil animals are usually more sensitive.

While tillage can lead to a bloom of soil activity as organic matter is incorporated into the soil, this activity is generally bacterial in nature and short lived. Every time you till the soil, you are shifting back the soil community either by direct damage or by homogenization of the habitat. Reducing tillage can have positive effects on biology and in particular fungi and larger animals. Reducing tillage leaves more roots intact, and allows more stable, slowly decomposing organic matter and physical structure to develop through time. While a no-till system might not be ideal or practical in all farming situations, reduction and better management of tillage can benefit soil biology. Research has suggested that reducing tillage and increasing plant residues may be a mechanism for suppression of plant disease by supporting a complex food web with organisms that compete with or control the pest of concern.

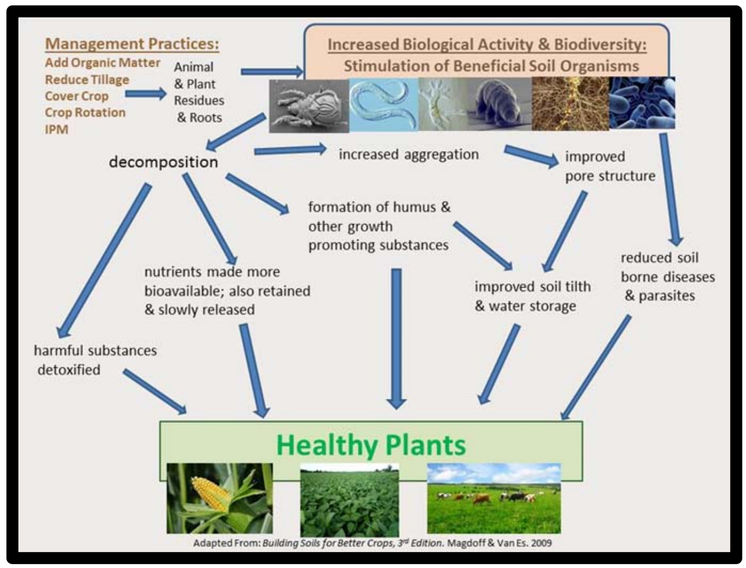


Figure 4. Management techniques that lead to healthy plants are mediated by soil biota.

In summary: Practices that increase quantity and quality of organic matter and physical habitat have beneficial impacts on soil biota. *A diverse array of foods and habitats generally leads to a more complex and stable food web.*

Supply diverse organic matter – which provides both food and habitat for soil biota. Practices that increase diversity of food sources, encourage beneficial biota, and interrupt pest cycles include:

- applying compost & manure
- planting cover crops and legumes (consider inoculation)
- crop rotation
- planting a diversity of crops or forages
- maximizing plant residues
- reducing tillage

Protect the soil habitat. Soil organisms need space to live, and they need a balance of air & water. Soil organisms also need intact root structures. Practices that can preserve and improve soil habitat include:

- minimizing compaction
- reducing tillage
- improving drainage (in wet soils) or supplying moisture or cover (in dry soils)
- minimizing/managing pesticides & inorganic fertilizer use (IPM & NMP)
- optimizing pH (as with agronomic crops)
- managing grazing to increase plant root biomass

Developing healthy soil biota in your soil is a feedback process on your farm. When conditions are more favorable for soil biota they will begin to sustain and enhance their own habitat and provide conditions more conducive to other organisms. The long term biological goals on agricultural soils would be to establish a set of management practices that maintain a semi-stable condition for soil biota, so that the community is less affected by more extreme conditions that farmers cannot control – like a drought or flood. Management would focus first on the farm or field specific soil properties that are most limiting for soil biota. A healthy soil community – just like a healthy agricultural community – will be more capable of bouncing back from a disturbance than one that is already highly stressed before the disturbance occurs.

Measuring Soil Biology:

Estimations of soil activity can be made through indirect means that measure activity (e.g., enzymes or respiration), the community as whole (e.g., DNA or RNA), or direct extraction and identification of individuals (usually requires a microscope). Unlike soil chemistry, there is no 'standard' test for soil biology, and testing usually costs more money. Research and development is still underway to make soil health and soil biology tests more accessible to farmers. The University of Maine does offer a soil biological test based upon microbial biomass. One of the best commercially-available measures in our area is the Cornell Soil Health analysis, which indirectly accounts for biology through analysis of carbon and nitrogen partitioning and an assessment of potential plant root health by growing beans in the soil sampled. Also included is an analysis of physical properties including aggregation and compaction. On-farm observations of this nature can also be done by a farmer or agronomist, which assist in understanding the habitat availability for soil organisms. Cornell also has a protocol that a farmer can use in determining pest nematode populations by growing plants in the soil and counting root lesions. Being attentive to soil organic matter content from a regular soil test and being observant to how much and what kind of plant residue is left on the field can be very informative. Visual field observations of organic matter and manure decomposition rates can also give you a qualitative understanding of soil biology activity. Visual inspection of soil for earthworms and their burrows and casts is another simple way to get a qualitative understanding of soil biology.

More Reading:

NRCS Soil Biology Website: http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/

Building Soils for Better Crops (Chapter 4: The Living Soil), (2010) online at:
http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition

Cornell Soil Health Website: http://soilhealth.cals.cornell.edu/

University of Minnesota, Extension Service Website: http://www.extension.umn.edu/agriculture/tillage/soil-management/soil-management-series/soil-biology-and-soil-management/

For more information, please contact the UVM Extension Champlain Valley Crop, Soil & Pasture Team

Jeff Carter	Extension Agronomy Specialist	jeff.carter@uvm.edu	388-4969 x 332
Kirsten Workman	Agronomy Outreach Professional	kirsten.workman@uvm.edu	388-4969 x 347
Rico Balzano	Agronomy Outreach Professional	rico.balzano@uvm.edu	388-4969 x 338
Cheryl Cesario	Grazing Outreach Professional	cheryl.cesario@uvm.edu	388-4969 x 346
Nate Severy	Agronomy Outreach Professional	nsevery@uvm.edu	338-4969 x 348
Kristin Williams	Agronomy Outreach Professional	kristin.williams@uvm.edu	388-4969 x 331
Daniel Infurna	Research Field Technician	daniel.infuna@uvm.edu	338-4969 x 337

23 Pond Lane, Suite 300 Middlebury, VT 05753802-388-4969 or 800-956-1125 www.uvm.edu/extension/cvcrops

Options for a first year No-till and Cover Crop cropping system

Champlain Valley Crop, Soil & Pasture Team

Project Leader
Jeffrey Carter
Extension Agronomist

Agronomy Outreach
Rico Balzano
Kirsten Workman
Cheryl Cesario

Nate Severy
Kristin Williams

Field Technician
Daniel Infurna

(802) 388-4969
cvcrops@uvm.edu
blog.uvm.edu/cvcrops
23 Pond Lane, Ste. 300
Middlebury, VT 05753

Are you interested in no-till corn this year? No-tilling into sod is a great way to get into a no-till/cover crop system. The following chart is composed of management guidelines that we think will give farmers the greatest chance of success based on what we have seen in the field. This sheet is meant to act as a guideline and is not comprehensive. The system that you choose will ultimately be as unique as the farm itself.

Contact your local Extension office for more information and guidance on how to change over to this new cropping system.

*The knee test is helpful to determine if a soil is dry enough to plant no-till. When on your knees, if they get wet, the land is probably too wet and you risk sidewall compaction and poor germination

No Till into grass sod

Remove first cut of hay at the end of May

THEN / OR

No-till plant "Short Season" corn into living sod as soon as soil moisture permits (do the knee test*)

↓

Apply an additional 30lb N to compensate for lack of tillage mineralization

↓

Spray herbicide 7 to 10 days after harvesting first cut hay, or at time of planting if not harvesting hay

Apply cover crop

Broadcast 25lb/ac annual ryegrass with side dress fertilizer if no residual herbicide

OR

Broadcast 112lb/ac winter cereal rye with Helicopter or highboy in August if adequate soil moisture

OR

Broadcast and incorporate or drill 75lb/ac winter cereal rye as soon as possible after corn harvest in early-mid September

Spread Manure

Inject liquid manure with injector shanks, disks, or aerway after corn harvest in early-mid September

OR

Surface apply manure (3,000-7,000gallons/ac. for liquid) after corn harvest in early-mid September

Options for a first year No-till and Cover Crop cropping system

First year no-till into sod **EXAMPLE**

Are you interested in no-till corn this year? No-tilling into sod is a great way to get into a no-till/cover crop system. The following example is what we think will give farmers the greatest chance of success based on what we have seen in the field. This sheet is meant to act as an example of one possible cropping system. The system that you choose will ultimately be as unique as the farm itself.

Contact your local Extension office for more information and guidance on how to change over to this new cropping system.

Month	April	May	June	July	August	September
Planting		No-till plant 92day RM corn into grass stubble as soon as soil moisture permits				Plant cover crop winter rye immediately after corn harvest
Harvest, Herbicide, or Tillage		Remove first cut hay at the end of May	Spray herbicide 7 to 10 days after harvesting first cut			Harvest corn in the beginning to middle of September
Manure/Fertilizer		Apply additional 30lb N at planting to compensate for lack of soil mineralization		Apply fertilizer at side dress according to PSNT		Spread manure within one week after cover crop

Options for a first year No-till and Cover Crop cropping system

First year no-till into sod **PLAN**

Using the example above, write down your plan for no-till and cover cropping into sod. Specify the RM corn you plan to plant, anticipated planting and harvest date, planned herbicide program, the type and quantity of fertilizer/manure, what cover crop you plan to plant and how it will be applied.

Contact your local Extension office for more information and guidance on how to change over to this new cropping system.

Month	April	May	June	July	August	September
Planting						
Harvest, Herbicide, or Tillage						
Manure/Fertilizer						