NRCS-ENTSC National Soil Quality team

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Keys to the kingdom of improving soil health

- Understand your context

- Protect the Soil Habitat
  - Manage more by Disturbing Soil Less
  - Keep the Soil Covered as Much as Possible

- Provide Diverse Food (carbon)
  - Diversify with Crop Diversity
  - Grow Living Roots Throughout the year
Understanding Soil Health: The Brown Revolution!
The greatest roadblock in solving a problem is the human mind!
Janine Benyus shares nature's designs

TED2005, Filmed Feb 2005; Posted Apr 2007

3.8 Billion Years of R&D
10-30 Million Species
Well-Adapted Solutions
Janine Benyus shares nature's designs

Biomimicry is the Conscious Emulation of Life's Genius
Janine Benyus shares nature's designs
Janine Benyus shares nature's designs
Janine Benyus shares nature's designs

5. Quenching Thirst

QinetiQ/Univ of Bath/ Biomimicry Guild/ Rocky Mountain Institute
Janine Benyus shares nature's designs
SOIL QUALITY/HEALTH is

The continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans.
Cover Crop Challenges

there are benefits, but will it pay?

Steve Berger
Washington Co.
Ecology: the study of relationships between people, animals, and plants, and their environment. Interconnectedness.
Focus On Nature’s Similarities then Dissimilarities

Africa

Virginia
Natural Succession of Plants & Soil

- High Disturbance
  - Low Diversity
- Low Disturbance
  - High Diversity

Bacterial

Natural Flow of Energy

Balanced

Hur Fungal
Disrupted Soil Ecosystem

This soil is naked, hungry, thirsty and running a fever!

Ray Archuleta 2007
Erosion from bare fields 5/2007

Is the Buffer working? 6/2007

Australia

Lubbock Texas Oct. 17, 2011
Battle Starts Here
Same Soils: Dynamic Soil Properties Changed!

62.8% loss of SOM after 17 yr intensive tillage

Forest SOM = 4.3%

17 yr- Soybean monoculture SOM = 1.6%
Study: Use-dependent Soil Properties

Land uses:
- Woodland
- Cropland: Conventional tillage, corn-soybean rotation

Dr. Cathy Seybold, NASS-NRCS

<table>
<thead>
<tr>
<th>Infiltration rate</th>
<th>Soil Nitrate loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 in./hr</td>
<td>1.8 lbs. N/ac.</td>
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Wooded Soil: Bulk Density- 1.01 g/cm³

Conventional Tillage- Corn-Soybean: Bulk Density- 1.40 g/cm³

<table>
<thead>
<tr>
<th>Infiltration rate</th>
<th>Soil Nitrate loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>.50 in./hr</td>
<td>15 lbs. N/ac.</td>
</tr>
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</table>
Subsoil tillage

Mold bold plow

Chisel plow

Different tillage = Different rates of SOM loss

Reicosky, 2000

\[ \text{CO}_2 \uparrow \]

SOM loss

3X

2X

1X
Tillage stimulates: R-Strategist (Opportunists bacteria) Copitrophic
Evaluate How Your Soil System is Functioning

- All parameters are important; typically we focus on physical and chemical - but Biology is King!
Soil Health

“Every chemical-based pesticide, fumigant, herbicide and fertilizer tested, harms or outright kills some part of the beneficial life that exists in the soil, (or on the leaf surfaces) even when applied at rates recommended by their manufacturers... Less than half of the existing active ingredients used as pesticides have been tested for their effects on soil organisms.”

Dr. E. Ingham, 2002, Soil Food Web, Oregon State University
Inorganic Based Soluble State

- $\text{NH}_4^+$
- $\text{P}_2\text{O}_5$
- $\text{H}_2\text{PO}_4^-$
- $\text{NO}_3^-$
- $\text{H}^+$
- $\text{K}^+$
- $\text{Ca}^{++}$
- $\text{Fe}^{++}$
- $\text{HPO}_4^{--}$
- $\text{BO}_3^{--}$
- $\text{SO}_4^{--}$
- $\text{O}_2$
- $\text{CO}_2$

Ecologically Based

- 40 to 60% $\text{N}$ and $\text{P}$ Loss
  Cassmen 2002
- Bare fallows 4-8 months
- Decoupled $\text{C,N,P}$ cycle

- Dr. Drinkwater, Dr. Swift

- Organic-mineral pools
- Microbially plant mediated process
- Strategic use of variable nutrients sources
The Soil Livestock is a complex and diverse mix of species and represents the greatest concentration of biomass of anywhere on the planet.
Shovel: A Tool to determine soil health
A hierarchical approach to evaluating the significance of soil biodiversity to biogeochemical cycling

All Major Factors Playing a Role on Formation and Stabilization of Aggregates

J. Six a,b,*, H. Bossuyt c, S. Degryze d, K. Denef b 2004
Cottage Cheese
Aggregation best under least disturbance.

Tillage can only destroy soil aggregates… it cannot build them…

Tillage results in poor habitat for the soil foodweb.
These Processes have profound effects on SOM dynamics and nutrient cycling.

1. Physically protect soil organic matter (e.g. Tisdall and Oades, 1982).
2. Influence microbial community structure (e.g. Hattori, 1988),
3. Limit oxygen diffusion (e.g. Sexston et al., 1985),
4. Regulate water flow (e.g. Prove et al., 1990),
5. Determine nutrient adsorption and desorption (e.g. Linquist et al., 1997)
5) Reduce run-off and erosion (e.g. Barthes and Roose, 2002)
NM Desert Soil
Soil in the left has been tilled (garden): poor aggregate stability

Soil in the middle has been ripped (alfalfa field): somewhat good aggregate stability

Soil in the right (alfalfa field): high aggregate stability

NOTE: the same soil in the same field; different management.

This phenomenon repeated itself throughout NM on Various cropping systems.
Aggregatusphere: Occluded Habitat of Micropores

- Protects organic matter from decay
- Storage site for organic matter
- Habitat of Oligotrophic and Copiotrophic bacteria
- Protects and maintains the integrity of the porosphere

They are linked mainly by fungi hyphae, roots fibers, polysaccharides, Glomalin, rhizodeposition, and aromatic humic materials

Glomalin is naturally brown. A laboratory procedure reveals glomalin on hypae and soil aggregates as the bright green material shown here.

Dr. Kris Nichols - Microbiologist - USDA ARS
HOW DOES GLOMALIN WORK?
The so-called phyllosphere “the largest biological surface inhabited by microorganisms”

Julia Vorholt, a professor at the Institute of Microbiology
Fungi hold on to Calicum
Bacteria Minerals to Create Grid: Transport Electrons
Actinobacteria
(HS) Humic Substances
Electron Image: Clay Particle
Arthrobacter
Liquid carbon pathway unrecognised

At cropping conferences when soil carbon is discussed, a conclusion usually drawn is that it is not possible to lift levels to a significant extent in a short timeframe. Most scientists contend carbon is a useful factor to consider for agronomy but not for sequestration. But Dr Christine Jones disagrees. She contends soil carbon can be increased quickly for both purposes and that most scientists are using a flawed model to measure carbon.

A soil carbon improvement of only 0.5% in the top 30 cm. of Australia’s estimated 445 million hectares of agricultural land would safely and permanently sequester the entire nation’s annual emissions of carbon dioxide. Sequestering atmospheric carbon in soil as humified organic carbon would also restore natural fertility, increase water-use efficiency, markedly improve farm productivity, provide resilience to climatic variation and inject much-needed cash into struggling rural economies.

The ‘soil solution’ to removing excess carbon dioxide (CO₂) from the earth’s atmosphere is being overlooked because current mathematical models for soil carbon sequestration fail to include the primary pathway for natural soil building. The process whereby gaseous CO₂ is converted to soil humus has been occurring for millions of years. Indeed, it is the only mechanism by which topsoil can form. When soils lose carbon, they also lose structure, water-holding capacity and nutrient availability.

Understanding soil building is thus fundamentally important to future viability of agriculture. Rebuilding carbon-rich topsoil is also the only practical and beneficial option for productively removing billions of tonnes of excess CO₂ from the atmosphere.

‘Biological sequestration’ begins with photosynthesis, a natural process during which green leaves turn sunlight energy, CO₂ and water into biochemical energy. For plants, animals and people, carbon is not a pollutant but the stuff of life. All living things are based on carbon.

Besides providing food for life, some of the carbon fixed during photosynthesis can be stored in a more permanent form, such as wood (in trees or shrubs) or humus (in soil). These processes have many similarities.

1) Turning air into wood: Formation of wood requires photosynthesis to capture CO₂ in green leaves, followed by lignification, a process within the plant whereby simple carbon compounds are joined together into more complex and stable molecules to form the structure of the tree.

2) Turning air into soil: The formation of topsoil requires photosynthesis to capture CO₂ in green leaves, followed by humification, a process within the soil whereby simple carbon compounds are joined together into more complex and stable molecules to form the structure of the soil.

How can it be that trees are still turning CO₂ into wood, but soils are no longer turning CO₂ into humus?

The answer is quite simple. In order for trees to produce new wood from soluble carbon, they must be living and covered with green leaves. In order for soil to produce new humus from soluble carbon, it must be living and covered with green leaves.

Building stable soil carbon is a four-step process that begins with photosynthesis and ends with humification. The humification part of the equation is absent from most broadacre agricultural produc-
The root is a Leverage Point: Engineering
Root Exudates:

Amino Acids
Organic Acids
Sugars
Vitamins
Purines/Nucleosides
Enzymes
Inorganic ions and Gaseous Molecules

West 1939, Fries and Forseman (1951), Gagnon and Ibrhaim (1998)
Scum Test

1. Switchgrass
2. Switchgrass - Immediately After Placing in Water
3. Switchgrass - After Submerging and Disruption

4. Switchgrass
5. Big Bluestem
6. Alfalfa
Spring 2008 Weed Suppression (ND)

No Cover Crop 2007

Cover Crop 2007
Fungi- Service they provide

- Decompose Organic Matter
- Glomalin secretion develops soil structure
- Extract nutrients
- Hold nutrients
Diversity conduit for energy and nutrients
Mimic Nature
Biomass Production
Annual Cropping Systems

Missed opportunities for resource assimilation and dry matter production

Dry matter production or resource loss (mass/time)

Annual grain crop

Winter cover crop

Spring Summer Autumn Winter

Additional opportunities for resource losses

after A.H. Heggenstaller

A. H. Heggenstaller, University of Alberta
Biomass Production
Annual Cropping Systems

Cover crops for resource assimilation and dry matter production

Dry matter production or resource loss (mass / time)

Annual grain crop

Winter cover crop

Spring Summer Autumn Winter

after A.H. Heggenstaller

opportunities for resource losses

less

A. H. Heggenstaller, University of Alberta
Farmers Talking To Farmers About Soil Health

Marilyn Richter

Gabe Brown

Troy Vollmer

Linn Berg

Glenn Bauer
The Answer is to Imitate Native Rangeland
Utilize energy efficiently—understand the power of diversity: **Collaboration** is more apparent than **Competition**. ND case study: 2006 Production On Burleigh District Plot with 1.8 in. of rain.
Turnip July 31
Oilseed Radish July 31
Cocktail July 31
Sept. 13 (60 days)
Burleigh County
Soil Conservation District

ADVANCING SOIL HEALTH

Menoken Farm

www.bcscd.com
Established 2009
September 4, 2009
No Commercial Fertilizer

- Sunflower 1 lb
- Soybean 15 lbs
- Cowpea 10 lbs
- Turnip 1 lb
- Radish 2 lbs
- Proso Millet 4 lbs
- Pearl Millet 4 lbs
- Sweet Clover 1 lb
Planting Corn Into Last Year’s Cover Crop Residue
May 20, 2010
West Side
No Commercial Fertilizer
No Compost
No Compost Tea
122.3 Bushels per Acre

East Side
No Commercial Fertilizer
1-2 Ton of Compost
2 Compost Tea Applications
128.8 Bushels per Acre

The Menoken Farm
Power of Crop Diversity
Both Sides were Planted into Last Year’s Cover Crop Residue

2006 – 2010 Burleigh County FSA Committee Reasonable Yield Established by Year = 100 Bushels per Acre
Darrell Oswald Ranch: Cover crop Mix
12 species
190 bu/ac corn grown with zero N input at planting

Cover Crop Economics
All Data is Per Acre Except Where Noted

Nitrogen input:
60/40 blend of Super U and Ammonium Sulfate, at $0.795/lb

190.8 bu/ac
Zero Units / N

205.6 bu/ac
60 Units / N

198.1 bu/ac
90 Units / N

196.9 bu/ac
120 Units / N
Nature’s residue managers
Giant Australian earthworm

*Megascolides australis* can get up to 11 feet!!
Soil Engineers: Earthworms
Subsoil macropores - Model of earthworm burrow systems

75 ind/m²
- 30% endogeic (Ø 2-3 mm)
- 70% anecic (Ø 6 mm)
- Ø core 212 cm

Brown’s Ranch
Same Field

June 16, 2009
Corn planted into last year's cover crop residue

July 1, 2009
Rapid residue decomposition
This enrichment of the surface layer with SOM maintains soil quality by enhancing aggregation and facilitating aeration (Doran and Parking, 1994; Franzluebbers, 2007).
Soil Temperatures
When soil temperature reaches...

140 °F  Soil bacteria die

130 °F  100% moisture is lost through evaporation and transpiration

113 °F  Some bacteria species start dying

100 °F  15% of moisture is used for growth, 85% moisture lost through evaporation and transpiration

95 °F

70 °F  100% moisture is used for growth

J.J. McEntire, WUC, USDA SCS, Kernville TX, 3-58 4-R-12198, 1956
Plants Regulate Soil Temp and Moisture

http://www.ecoseeds.com/juicy.gossip.fourteen.html
Soil temperature with 9.2 ton ha\(^{-1}\) (Brachiaria Decumbens) and without crop residues on the soil surface (NT - 10 years – GO, 16 °S L)

(Two years average: 14/01/2003 and 13/01/2004 at 2pm)

No Crop Residues

9.2 ton ha\(^{-1}\)

62.9 °C

32.6 °C

30.3 °C = 86.5 °F

Sá et al., 2004 and 2007
What the heck did Archuleta get me into...
Last time I am go to North Dakota with him...
What am I going to do with all this material?
John Pickler Planting Corn into cover crop Mix
No-drill Plants into Residue
Curtis Furr Cotton planted into 8 Way Rye Cover Crop Mix
Brandon Rocky: Colorado
Cover Crop Mix:
Cover Crop Mix
Winter Pea intercropped into Potato
20 years of similar tillage intensity and C inputs but contrasting types of organic inputs
Why do we still have a thicker layer of snow on the plot under CT than in NT?

Soil temperature
-4°C = 24 °F
Air Temperature at noon
8°C at noon

Soil temperature
+4°C = 39 °F
Air temperature
8°C at noon

Conventional Tillage (10 years)
No-tillage (10 years)

Sandy soil (92 % of sand) – Saint Pierre des Corps – France (47° 23’ North Latitude)
Sandy soil (92 % of sand) – Saint Pierre des Corps – France (47° 23’ North Latitude)

Conventional Tillage (10 years) vs. No-tillage (10 years)

In sandy soils the silica is an excellent heat conductor and the freezing of water is higher, while the residues on the soil surface causing an insulating effect and the freezing is lower.

No-till has higher content of labile C and higher microbial population compared to conventional tillage. In this case, biological activity will be higher due to rising temperatures and therefore higher energy as heat is released.

<table>
<thead>
<tr>
<th>Component</th>
<th>Conventional Tillage</th>
<th>No-tillage</th>
</tr>
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<tbody>
<tr>
<td>Cellulose</td>
<td>45%</td>
<td></td>
</tr>
<tr>
<td>Sugars and gomes</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Hemicellulose</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Lignin</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>Wax and Fat</td>
<td>2%</td>
<td></td>
</tr>
</tbody>
</table>

Enzimatic oxidation: $\text{CO}_2 + \text{H}_2\text{O} + \text{energy}$
Soil carbon is the “Keystone” for all soil physical, chemical and biological processes and properties.

Management platform

Dr. D.C. Reicosky, ARS, Morris, MN.
Ohio 2012 Drought:

Vertical Tillage

No-till With Covers
Building Soil

How did nature make all that soil in the first place?
Mimic Nature grazing template: Mob tall grazing (250k-500k lbs./ac.)

- Reduce individuality, it stimulates aggressive, less selective grazing habits.

Aggressive grazing is primal instinct that herbivores must relearn
Mimic Nature grazing template:

• High numbers stomp, chip and shred unused grass onto the soil surface to increase biogeochemical nutrient cycling
High Density Grazing
Ultra High Density Grazing
Tundra?
Layers enjoying the cover crop
Next Move
Noxious weeds: 20 years of no animal impact (Symptom)
U.S. Drought Monitor

October 4, 2011
Valid 8 a.m. EDT

Intensity:
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:
- S = Short-Term, typically <6 months (e.g., agriculture, grasslands)
- L = Long-Term, typically >6 months (e.g., hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://droughtmonitor.unl.edu/

Released Thursday, October 6, 2011
Author: Rich Tinker, CPC/NCEP/NWS/NOAA
May 5, 2008- Started Moving cows 2 times per day
Weed and Brush Control

Smooth Sumac in St. Clair County
Neighbor’s Pastures 2011 Drought  Mark Brownlee’s Pastures
February 2010
Strip Grazed Hayfield – Fall Re-Growth
Tom Matoushek
Gabe Brown 6000 acres:
A 4 Week Supply Based on 3% of Body Weight
Bale Grazing Results

Tame Pastures

Pasture With Bale Grazing

8573 lbs/ac
11.95% Crude Protein
59.43% TDN

Pasture Without Bale Grazing

2559 lbs/ac
7.96% Crude Protein
60.70% TDN
Why Should We Care? Future World Challenge!

SCIENTIFIC AMERICAN
Earth 3.0

Energy vs. Water
Why Both Crises Must Be Solved Together

Climate Correction
How Much CO₂ is Too Much?

Biodiversity
The Fight over How to Save Species

MisLEEDing?
When Green Architecture Isn’t Green

Presidential Agenda 2009
What Obama or McCain Must Do about Global Warming

PLUS
Future High-Rise Farms
China’s Eco-City

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Arid Lands

DISTRIBUTION OF NON-POLAR ARID LAND (after Meigs, 1953)

- Extremely arid
- Arid
- Semi-arid

0 1000 2000 MILES
0 1000 2000 KILOMETERS
Soil Temps All Over the World
1961 Photo: Sahara Deseret
Re-vegetation brings the Rain
Answer: Ecological Restoration
Restoration

Lake 100 meters deep
James Kinter, director of the Center for Ocean-Land-Atmosphere Studies at the Institute of Global Environment and Society,
James Kinter, director of the Center for Ocean-Land-Atmosphere Studies at the Institute of Global Environment and Society,

Research by Kinter's collaborators showed that low-resolution models of the East Coast Gulf Stream put rain associated with the weather pattern in the wrong place, whereas high-resolution models delineate the bands of rain off the East Coast with accuracy.
In The African Sahel: Trees Stop Sahara Desert

Bruce Wight NRCS National Forester (E&E News July 2012)
<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Estimated Percent Increase</th>
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<tbody>
<tr>
<td>United States</td>
<td>6.3%</td>
</tr>
<tr>
<td>China</td>
<td>71.4%</td>
</tr>
<tr>
<td>India</td>
<td>58.8%</td>
</tr>
<tr>
<td>Middle East</td>
<td>42.0%</td>
</tr>
<tr>
<td>Africa</td>
<td>33.6%</td>
</tr>
<tr>
<td>Central and South America</td>
<td>29.4%</td>
</tr>
<tr>
<td>Total World</td>
<td>25.2%</td>
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</tbody>
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China and India combined will increase their oil consumption by 65.1% in the next 21 years.
Healthy Soils Save Oil and Toil!

Energy Used in Different Corn Production Systems
(gallons of diesel per acre)

- **Conventional/Chemical**
  - Tillage: 231.7
  - No-till: 199.2

- **Organic/Regenerative**
  - Tillage: 121.6
  - No-till: 77.5

Regenerative organic systems sharply reduce energy use, according to research by David Pimentel, Ph.D.
Use Soil to make oil (biodiesel) for Transport, Planting, Spraying, and harvesting!

http://www.journeytoforever.org/biodiesel_link.html
Use Soils to make oil for irrigation!

http://www.journeytoforever.org/biodiesel_link.html
Creating Soil Health Demonstration Farms: Centers of Sustainability
ND Soil Health Center

150 acres

Cluster or Network of SH Farms
Missouri Chariton County
SWCD Soil Health Center

110 acres

Cluster or Network of SH Farms
Cluster or Network of SH Farms

David Brandt Soil Health Center (Ohio)
Healthy Profit$ From Healthy Soil$
"it is time for the United States to STOP paying for the degradation of the soil!"
“You and your generation have a choice to make and the entire planet lies in the balance! You can continue the way your parents did and the planet will surely perish with you. Or, you can take what you know, never by afraid to try something new, continue to learn and ask questions, and completely change the face of agriculture, feed a growing planet along the way and hand the planet to your kids with much more pride than i am handing it to mine!! YOU have been CHOSEN to protect the planet while feeding it's people, an honor very few get! And, the planet is not handed to you from your parents, you are borrowing it from your kids!! “

Gail Fuller Kansas Farmer