Mitigating and Adapting to Climate Change with Regenerative Organic Agriculture

Dr. Kris Nichols
Rodale Institute
Research Director
Soil Health - The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.

Healthy Soil =
Healthy Food =
Healthy People =
Healthy Planet

Wrote on a blackboard in 1942.
The Carbon Problem
Soils Deficient in Carbon

Dave Brandt Farm
Carroll, Ohio
The Carbon Problem

From Lal et al., 1998
Texas Dust Storms in 1930s and 2012
Erosion on Cropland, by Year
(Billions of Tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Sheet &amp; Rill Erosion</th>
<th>Wind Erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>1.68</td>
<td>1.38</td>
</tr>
<tr>
<td>1987</td>
<td>1.49</td>
<td>1.30</td>
</tr>
<tr>
<td>1992</td>
<td>1.18</td>
<td>2.17</td>
</tr>
<tr>
<td>1997</td>
<td>1.04</td>
<td>1.89</td>
</tr>
<tr>
<td>2002</td>
<td>1.01</td>
<td>1.81</td>
</tr>
<tr>
<td>2007</td>
<td>0.96</td>
<td>1.73</td>
</tr>
</tbody>
</table>

Cropland includes cultivated and non-cultivated cropland.
Basic Photosynthesis

\[ C_6H_{12}O_6 + 6O_2 \]

Light Energy

Carbon Dioxide

Oxygen

Soil Bank

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C

C
What does Solving the Carbon Problem do?

- Mitigates climate change while helping crops thrive under weather uncertainty.

- Increases\Improves:
  1. Healthier People
  2. Biological activity – growth and diversity of microflora
  3. Water infiltration, holding capacity, quality, and efficiency of use
  4. Soil tilth and structure
  5. Natural fertility – nutrient cycling and storage and capacity to handle manure
  6. Cation and anion exchange capacity
  7. Adsorption of pesticides

- Decreases\Reduces:
  1. Soil erosion
  2. Soil compaction
  3. Air pollution

Carbon is the hub, each spoke is an environmental benefit which adds strength and support to the wheel to maintain environmental quality.
Growing topsoil in decades rather than centuries.
• Higher percentages of water stable aggregates
• Higher carbon levels
• Higher levels of glomalin
• Potentially more arbuscular mycorrhizal (AM) fungi
Soil Organic Matter Composition

Soil organic matter
1-6% of total soil mass

Soil microbial biomass
3-9% of total SOM mass
(0.03-0.56% of total soil mass)

Mineral particles

Stable (humus)
70-90%
(0.7-5.4%)

Labile (POM)
7-21%
(0.07-1.26%)

Bacteria & actinomycetes
30%
(0.01-0.16%)

Fungi
50%
0.02-0.27%

Animals
10%
(0.003-0.054%)

Yeast, algae, protozoa, nematodes
10%
(0.003-0.054%)

- Modified from Building Soils for Better Crops, Magdoff and van Es, 2000
Interactive Carbon Economy

- Plants trade carbon to fungi and bacteria
  - Mycorrhizal fungi
  - Rhizobium – N fixation
  - P-solubilization
  - Aggregate formation
    - Porosity
    - Soil structure

- Nematodes and Protozoa eat bacteria and fungi for N

- Microarthropods prep residues for bacteria
Root of the Problem is the Root of the Solution

The Soil Food Web

Plants
- Shoots and roots

Organic Matter
- Waste, residue and metabolites from plants, animals and microbes.

Fungi
- Mycorrhizal fungi
- Saprophytic fungi

Bacteria

Nematodes
- Root-feeders

Arthropods
- Shredders
- Predators

Protozoa
- Amoebae, flagellates, and ciliates

First trophic level:
- Photosynthesizers

Second trophic level:
- Decomposers
- Mutualists
- Pathogens, parasites
- Root-feeders

Third trophic level:
- Shredders
- Predators
- Grazers

Fourth trophic level:
- Higher level predators

Fifth and higher trophic levels:
- Higher level predators

Animals

Birds
STARVING AND HOMELESS

- Soil is organic (i.e. living)
- Billions of different organisms from millions of species
- Total weight of living organisms in the top six inches of an acre of soil can range from 5,000 to 20,000 lbs.
- Soil from one spot may house a very different community from soil just a yard (meter) away
Water Use Efficiency

- Porosity - 45% increase in porosity equals infiltration increase of 167% 25 mm (1 inch) and 650% 50 mm (2 inches)
  - Karlen et al., 1998

- Water holding capacity doubles when soil organic matter increases from 0.5-3% depending on soil texture
  - Hudson, 1994

- Water used for nutrition
  - W.A. Albrecht, University of Missouri, 1950’s
    - Unfertilized corn needed nearly 5 times the amount of water as the fertilized corn.
      - Achieve efficient fertility biologically rather than chemically.

Wheat fields at Rodale Institute’s Farming Systems Trial after a rain event.
Brown Ranch near Bismarck, ND after 13 inches (330 mm) of rainfall in 24 hrs in 2009

Infiltration Rates increased with management:
1991 – 0.5 inches per hour
2011 – 8 inches per hour
Organic-manure based
- 8-year rotation (Oat/rye - Soybean/wheat - Wheat/hay - Hay - Hay - Silage/wheat - Wheat/vetch - Corn/rye)

Organic-legume based
- 4-year rotation (Corn/rye - Oats-clv/barley or rye - Soybean/wheat - Wheat/vetch)
- 4-year rotation (Corn/rye - Oats-clv/barley or rye - Soybean/wheat - Wheat/cover crop mix)

Conventional-chemically based
- 3-year rotation (Corn – Corn - Soybean
- 3-year rotation (Corn/rye – Corn/rye – Soybean/rye)
FST Corn During 1995 Drought

- Organic:
  - 134 bu/ac
  - 3.4 tons/ac

- Conventional:
  - 102 bu/ac
  - 2.6 tons/ac

Water percolation volumes were 15-20% higher.
Organic Corn  
Fertilizer only from legume cover and cash crops  
18% higher yield

Conventional Corn  
- 150 pounds N mostly as urea  
- 60 pounds phosphate

Phosphate and Nitrate Stress  
- Spring rains = nutrient runoff, leaching, or unavailable  
- Late summer and fall dry period = no nutrients during seed fill
Organic Corn – Almost Double Yield
Fertilizer only from legume cover and cash crops

Conventional Corn
150 pounds N mostly as urea
60 pounds phosphate

Phosphate and Nitrate Stress
Organic – more nodulation and nitrogen fixation
Nutrient Use Efficiency

- Plant available – synthetic vs. biologic
- 30-50% of nitrogen fertilizer is used by the plant
- 30% of phosphorus is used by the plant
- Availability, timing, water, and pH
©2010 Rodale Institute

Arbuscular Mycorrhizal Fungi

- 4-30% of C is transferred to AM – Jansa et al. 2013

- Affected by:
  - rotation (incl. cover crops)
  - fallow

- Create mycorrhizosphere in soil

- Hyphal networks can fuse together – Giovannetti et al., 2004

- Form soil aggregates
Obtain nutrients (up to 90% of N and P) -

Smith and Read, 2008

- Phosphate-solubilizing bacteria – Toro and Barea, 1996
- Mixed cultures more efficient, but this was also AMF species dependent – Walder et al 2012
- Non-legume trades P for N via AMF and rhizobia activity
Interplant transfer N for P and C

N fixation: N$_2$ via 32 ATP (needs 128 P and 320 C)
Organic Corn – Kutztown, PA

PLOW TILL
- PLOW
- DISC
- PACK
- PLANT
- ROTARY HOE
- ROTARY HOE
- CULTIVATE
- CULTIVATE
- HARVEST
- 3.63 ton/ac (143 bu/ac)

NO-TILL
- ROLL/PLANT
- HARVEST
- 4.1 ton/ac (160 bu/ac)

A two step organic production system Plant and Harvest!
### Production budgets for corn

<table>
<thead>
<tr>
<th>Expenses</th>
<th>Organic Tilled</th>
<th>Organic No-till</th>
<th>Conv Tilled</th>
<th>Conv No-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>vetch+ corn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fertilizer</td>
<td>0.00</td>
<td>0.00</td>
<td>118.04</td>
<td>90.44</td>
</tr>
<tr>
<td>herbicide</td>
<td>0.00</td>
<td>0.00</td>
<td>108.19</td>
<td>144.56</td>
</tr>
<tr>
<td>seeds</td>
<td>139.40</td>
<td>139.40</td>
<td>88.15</td>
<td>148.35</td>
</tr>
<tr>
<td>custom haul</td>
<td>30.00</td>
<td>30.00</td>
<td>30.00</td>
<td>30.00</td>
</tr>
<tr>
<td>labor</td>
<td>39.35</td>
<td>18.61</td>
<td>15.78</td>
<td>16.14</td>
</tr>
<tr>
<td>fuel</td>
<td>47.60</td>
<td>23.96</td>
<td>23.76</td>
<td>20.67</td>
</tr>
<tr>
<td>repair &amp; maintenance</td>
<td>17.56</td>
<td>10.35</td>
<td>8.42</td>
<td>8.97</td>
</tr>
<tr>
<td>interest on op.capital</td>
<td>6.35</td>
<td>4.54</td>
<td>11.50</td>
<td>13.50</td>
</tr>
<tr>
<td>fixed expenses</td>
<td>52.02</td>
<td>30.98</td>
<td>27.31</td>
<td>27.46</td>
</tr>
<tr>
<td><strong>Total Expenses ($/acre)</strong></td>
<td><strong>332</strong></td>
<td><strong>258</strong></td>
<td><strong>431</strong></td>
<td><strong>500</strong></td>
</tr>
</tbody>
</table>

### Profit ($/acre) *

| @ 100 bu/a yield          | 504            | 578             | -16         | -85          |
| @ 150 bu/a yield          | 922            | 996             | 191         | 122          |
| @ 200 bu/a yield          | 1,340          | 1,414           | 399         | 330          |

### Break-even price ($/bu)

| @ 100 bu/acre             | 3.32           | 2.58            | 4.31        | 5.00         |
| @ 150 bu/acre             | 2.22           | 1.72            | 2.87        | 3.33         |
| @ 200 bu/acre             | 1.66           | 1.29            | 2.16        | 2.50         |

These production budgets were calculated using the free on-line Mississippi State Budget Generator (MSBG), developed by the Department of Agricultural Economics at Mississippi State University. ([http://www.agecon.msstate.edu/what/farm/generator/](http://www.agecon.msstate.edu/what/farm/generator/)). When available, input and price data were taken directly from data collected at the Rodale Institute (2008-2010), otherwise default values from the Budget Generator were used.

* The 3-year average price for organic corn was $8.36/bu, for conventional corn $4.15/bu.
Integrated Crop-Livestock (GA, FL, AL)

Oat Winter Cover Crop Following Peanut and Cotton in Both Systems

©2010 Rodale Institute
Perennial grass rotations impact the farm economically, biologically, environmentally, and sociologically.
Peanuts grown in soil with Bahia roots

Peanuts grown in soil without Bahia roots
Forage biomass differences between grazing strips with G_2 having highest biomass dry weight \( (4.12 \pm 0.85 \text{ kg m}^{-2}) \) while G_3 \( (2.52 \pm 0.24 \text{ kg m}^{-2}) \) and G_4 \( (2.46 \pm 0.36 \text{ kg m}^{-2}) \) the lowest

Biomass in the exclosures was only 1.85 kg m\(^{-2}\).

Nine steers grazed for 150 days

Average daily rate of gain of 1.68 lbs day\(^{-1}\)
**Food Safety**

*E. coli* O157:H7
- one fecal sample from Rodale (4.76% prevalence rate) and two feed samples from Rodale (11.7% prevalence rate)

*Salmonella*
- One feed sample from Rodale (5.89% prevalence rate) and no fecal samples positive

Rates below published reports:

*E. coli* O157:H7
- 30.1% in livestock feed
- 14.8% in fecal sample

*Salmonella*
- 12-86% livestock feed
- 4-34% in fecal samples
Recognize proper soil management as the most ecologically and economically sustainable form of agriculture.

- Provide food, fiber, and fuel
- Provide nutrients
- Protect the soil
- Manage pests
- Consistency
- Resiliency
- Moisture to roots
- Maximize efficiency
- Make money
Thank You!

Dr. Kris Nichols
Kristine.Nichols@rodaleinstitute.org
610-683-1444

www.rodaleinstitute.org

We speak a lot of the importance of sustainable food systems for healthy lives. Well, it starts with soils.
- José Graziano da Silva, FAO Director-General

A Nation that Destroys its Soil, Destroys Itself.
– Franklin Roosevelt