The cover up: organic systems and soils

5,000 bushels per acre. 100% organic cultivation. Location: Mars.
Michelle Wander
mwander@illinois.edu
Goal is to achieve sustainable agricultural systems

Illustration from National Geographic
Prototype double crop systems for biomass production

- **Winter crop: triticale**
  - Winter soil cover
  - Spring biomass harvest

- **Summer crops:**
  - Corn
  - Sorghum x sudangrass
  - Crotalaria (legume)

1) Corn  
2) Sorgxdsudan  
3) Crotalaria  

Matt Liebman
Two crops can generate more biomass than one

- Triticale / crotalaria: 3.5 (Winter) + 2.0 (Summer) = 5.5 tons acre⁻¹
- Triticale / sorghum x sudangrass: 3.3 (Winter) + 5.9 (Summer) = 9.2 tons acre⁻¹
- Triticale / corn: 3.1 (Winter) + 6.6 (Summer) = 9.7 tons acre⁻¹
- Corn: 7.4 tons acre⁻¹
- Switchgrass: 5.8 tons acre⁻¹

Matt Liebman
Soil Quality: the foundation for organic management

“Humus benefits the soil in three ways: mechanically, as a plant food, and by fundamentally modifying the soil bionomics. Of the three, this last, hitherto largely ignored, is probably the most important”.

Lady Eve Balfour - In "The Living Soil" 1943
Soil and soil management is the foundation of organic production. Organic growing systems are soil based, they care for the soil and surrounding ecosystems and provide support for a diversity of species while encouraging nutrient cycling and mitigating soil and nutrient losses.

IFOAM Norms, 2002
National Organic Program

• Organic food is produced by farmers who emphasize the use of renewable resources and the conservation of soil and water to enhance environmental quality for future generations.

• Organic meat, poultry, eggs, and dairy products come from animals that are given no antibiotics or growth hormones and fed organic feed. Organic food is produced without using most conventional pesticides; fertilizers made with synthetic ingredients or sewage sludge; bioengineering (GMO’s); or ionizing radiation.
§ 205.203 Soil fertility and crop nutrient management practice standard.

(a) The producer must select and implement tillage and cultivation practices that maintain or improve the physical, chemical, and biological condition of soil and minimize soil erosion.

(b) The producer must manage crop nutrients and soil fertility through rotations, cover crops, and the application of plant and animal materials.

(c) The producer must manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances. Animal and plant materials include:

(1) Raw animal manure, which must be composted unless it is:
   (i) Applied to land used for a crop not intended for human consumption;
   (ii) Incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with the soil surface or soil particles; or
   (iii) Incorporated into the soil not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles;

(2) Composted plant and animal materials produced though a process that
   (i) established an initial C:N ratio of between 25:1 and 40:1; and
   (ii) maintained a temperature of between 131 F and 170 F for 3 days using an in-vessel or static aerated pile system; or
   (iii) maintained a temperature of between 131F and 170F for 15 days using a windrow composting system, during which period, the materials must be turned a minimum of five times.

(3) Uncomposted plant materials.
(d) A producer may manage crop nutrients and soil fertility to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances by applying:

1. A crop nutrient or soil amendment included on the National List of synthetic substances allowed for use in organic crop production;
2. A mined substance of low solubility;
3. A mined substance of high solubility, Provided, That, the substance is used in compliance with the conditions established on the National List of nonsynthetic materials prohibited for crop production;
4. Ash obtained from the burning of a plant or animal material, except as prohibited in paragraph (e) of this section: Provided, That, the material burned has not been treated or combined with a prohibited substance or the ash is not included on the National List of nonsynthetic substances prohibited for use in organic crop production;
5. A plant or animal material that has been chemically altered by a manufacturing process: Provided, That, the material is included on the National List of synthetic substances allowed for use in organic crop production established in § 205.601.

(e) The producer must not use:

1. Any fertilizer or composted plant and animal material that contains a synthetic substance not included on the National List of synthetic substances allowed for use in organic crop production;
2. Sewage sludge (biosolids) as defined in 40 CFR Part 503; and
3. Burning as a means of disposal for crop residues produced on the operation: Except, That, burning may be used to suppress the spread of disease or to stimulate seed germination.
§ 205.205 Crop rotation practice standard.

- The producer must implement a crop rotation including but not limited to sod, cover crops, green manure crops, and catch crops that provide the following functions that are applicable to the operation:
  - (a) Maintain or improve soil organic matter content;
  - (b) Provide for pest management in annual and perennial crops;
  - (c) Manage deficient or excess plant nutrients; and
  - (d) Provide erosion control.
Which cover for which job?

- Prevent erosion
  - improve structure, cover surface
    - buckwheat, cereal rye, manures with grass, composts, reduced tillage
  - increase infiltration
    - rye, barley, reduced tillage
- Enhance water quality
  - increase water holding capacity
    - clovers, rye, manures, reduced tillage
  - reduce leaching
    - rape seed, rye, oats
- Hasten metabolism of contaminants
  - Cereal rye
- Sequester carbon, reduce global warming
- Pest and disease suppression
§ 205.206 Crop pest, weed, and disease management practice standard.

(a) The producer must use management practices to prevent crop pests, weeds, and diseases including but not limited to:

(1) Crop rotation and soil and crop nutrient management practices, as provided for in §§ 205.203 and 205.205;

(2) Sanitation measures to remove disease vectors, weed seeds, and habitat for pest organisms; and

(3) Cultural practices that enhance crop health, including selection of plant species and varieties with regard to suitability to site-specific conditions and resistance to prevalent pests, weeds, and diseases.

(b) Pest problems ….

(c) Weed problems ….

(d) Disease problems ….

(e) When the practices provided for in paragraphs (a) through (d) of this section are insufficient to prevent or control crop pests, weeds, and diseases, a biological or botanical substance or a substance included on the National List of synthetic substances allowed for use in organic crop production may be applied to prevent, suppress, or control pests, weeds, or diseases: Provided, That, the conditions for using the substance are documented in the organic system plan.
Do organic systems relying heavily on covers perform well?

Conventional

No-till

Organic

Proportion of farms?

SOC

H₂O
Green vs Brown Manure?

- **Conventional**
  - Fertility from synthetic fertilizers
  - 8 sites

- **Manure-based organic**
  - Fertility from compost or manure
  - 7 sites

- **Legume-based organic**
  - Fertility from N$_2$ fixing legumes
  - 3 sites

- Sampled in Spring before heavy feeding crop from plow depth
Can Organic Practices Build SOM?

- 9 farming systems trials
  - 10 years old on average
  - All include organic and conventional systems

Marriott and Wander 2006
Total Organic C and Total N Concentrations

TOC concentration (g C kg\(^{-1}\) soil)

- Manure organic
- Legume organic
- Conventional

TN Concentration (g N kg\(^{-1}\) soil)

- Manure organic
- Legume organic
- Conventional
# Stepwise multiple regression

<table>
<thead>
<tr>
<th>Dependent variable†</th>
<th>Model</th>
<th>Partial R² values‡</th>
<th>All systems</th>
<th>Organic systems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>adjusted R² value</td>
<td>MAT</td>
<td>MAP</td>
<td>% clay</td>
</tr>
<tr>
<td>SOC</td>
<td>0.788***</td>
<td>0.211</td>
<td>n.s.</td>
<td>0.514</td>
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<tr>
<td>IL-N</td>
<td>0.789***</td>
<td>0.239</td>
<td>n.s.</td>
<td>0.450</td>
</tr>
<tr>
<td>POM-C</td>
<td>0.398***</td>
<td>n.s.</td>
<td>0.420</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

†† R² values adjusted for partial correlation.
‡‡ Partial R² values for each variable in the model.
SOM fraction concentrations

Wander et al. 2007
What about the landscape scale?
What about leaching

Greg McIsaac, Organic Agronomy Day 2005
Comparison of Costs

Returns = Revenue – Costs (Price*Yield)
(per acre variable costs, does not include land rent)

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conv (IL)</td>
<td>$196</td>
<td>$96</td>
</tr>
<tr>
<td>Organic (IL)</td>
<td>$189</td>
<td>$104</td>
</tr>
<tr>
<td>Organic (SD)</td>
<td>$185</td>
<td>$145</td>
</tr>
<tr>
<td>Organic (KA)</td>
<td>$87/$122</td>
<td>$71/$107</td>
</tr>
</tbody>
</table>

Corinne Alexander, Purdue University, February 1, 2006
Meeting Organic Soil Mgt Goals

• Organic management plan
  Verify compliance with NOS
• Soil testing
  To determine the proper fertilization for plants to be grown
• Nutrient management plans
  Conservation planning tool. “integrates ecological, economic, and production considerations in meeting both the owner's/operator's objectives and the public's natural resource protection needs.”
Draft Sustainable Agriculture Standard (SCS-001)

- **6.1.2.6. Agro-Ecosystem Health**
  - A listing and description of inputs (including type, application rates and amounts), a description of functional biodiversity, and a description of soil conservation and erosion control practices and procedures.

- **6.1.2.7. Ecosystem Management**
  - A description of the effects that the Agricultural Production Operation has had on flora and fauna species and habitats, and any mitigation efforts undertaken to date; a description of existing and planned vegetated buffer zones for watercourses and between areas under cultivation and non-cultivated areas; a list and accompanying maps of any areas of High Ecological Value (HEV),
Soil Quality- Outcomes and Properties (Resource Concerns)

• $\text{SQ} = f (\text{SQE1, SQE2, SQE3, SQE4, SQE5, SQE6})$
  – SQE1 is the food and fiber production,
  – SQE2 the erosivity,
  – SQE3 the ground water quality,
  – SQE4 the surface water quality,
  – SQE5 the air quality
  – SQE6 is the food-quality. Doran and Parkin (1994)

• Descriptive properties- soils, crops, and animals including wildlife. Romig et al. (1994)
“Farm Bill 2007- minimum Standard of Care”

- RUSLE2
- Soil Conditioning Index
- Soil Water Enrollment Tool
- Conservation Management Tool
Accounting examples from WORT

C sequestration
Nutrient budgets
NRCS tools
Life cycle – field to market
Summary of rotations

<table>
<thead>
<tr>
<th>Year</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>Winter Rye</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>Winter Rye</td>
<td>Soybeans</td>
<td>Winter Wheat</td>
<td>Fallow</td>
</tr>
<tr>
<td>2005</td>
<td>Perennial Ley (Alfalfa, red clover, white clover, timothy, orchardgrass)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>Paste Tomatoes, Bell Peppers</td>
<td>Winter Rye</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Transitional Cropping System Intensity:
- Low
- Intermediate
- High
### Spring Soil ‘Benchmark’ (0-15 cm)

<table>
<thead>
<tr>
<th>Year</th>
<th>SOC</th>
<th>C/N</th>
<th>Bray P</th>
<th>K</th>
<th>pH</th>
<th>Ca</th>
<th>Mg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
<td>ppm</td>
</tr>
<tr>
<td>2003</td>
<td>2.21a</td>
<td>11.9a</td>
<td>53a</td>
<td>167a</td>
<td>6.7a</td>
<td>2228a</td>
<td>245a</td>
</tr>
<tr>
<td>2006</td>
<td>2.36a</td>
<td>12.7b</td>
<td>61b</td>
<td>261b</td>
<td>6.8b</td>
<td>3062b</td>
<td>321b</td>
</tr>
</tbody>
</table>

$p$ values:

- SOC: 0.10
- C/N: 0.006
- Bray P: 0.03
- K: 0.001
- pH: 0.08
- Ca: 0.001
- Mg: 0.001

ψ SAS Proc Mixed was used to evaluate the effects of time, transition system and fertility treatment within systems. Means within columns that are not followed by the same letter are considered different.
Preliminary analysis of NRCS Tools: SWET & SCI compared with SOC in the Windsor Organic Transition Experiment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>SWET Score/Eligible?</th>
<th>SCI Score/Eligible?</th>
<th>Measured SOC (µ &amp; (stdev))</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEG</td>
<td>44 no</td>
<td>-0.46 no</td>
<td>2.45 (0.72)</td>
</tr>
<tr>
<td>VEG + manure</td>
<td>52 no</td>
<td>0.86 yes</td>
<td>2.36 (0.80)</td>
</tr>
<tr>
<td>VEG + compost</td>
<td>52 no</td>
<td>2.80 yes</td>
<td>2.39 (0.63)</td>
</tr>
<tr>
<td>ROW</td>
<td>64 yes</td>
<td>-0.12 no</td>
<td>2.17 (0.41)</td>
</tr>
<tr>
<td>ROW + manure</td>
<td>72 yes</td>
<td>1.60 yes</td>
<td>2.28 (0.58)</td>
</tr>
<tr>
<td>ROW + compost</td>
<td>72 yes</td>
<td>3.60 yes</td>
<td>2.37 (0.40)</td>
</tr>
<tr>
<td>LEY</td>
<td>101 yes</td>
<td>0.98 yes</td>
<td>2.50 (0.31)</td>
</tr>
<tr>
<td>LEY + manure</td>
<td>109 yes</td>
<td>2.40 yes</td>
<td>2.55 (0.38)</td>
</tr>
<tr>
<td>LEY + compost</td>
<td>109 yes</td>
<td>3.70 yes</td>
<td>2.24 (0.63)</td>
</tr>
</tbody>
</table>

Andrews, Widman and Wander, 2007
<table>
<thead>
<tr>
<th></th>
<th>Nutrient balance sheet</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>WORT field budget</td>
<td></td>
<td>kg ac</td>
<td>kg ac</td>
<td>kg ac</td>
</tr>
<tr>
<td>Veg</td>
<td>Leg</td>
<td>48.86</td>
<td>-9.95</td>
<td>-70.43</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>172.88</td>
<td>39.75</td>
<td>5.18</td>
</tr>
<tr>
<td></td>
<td>Compost</td>
<td>220.67</td>
<td>140.74</td>
<td>32.98</td>
</tr>
<tr>
<td></td>
<td><strong>Mean</strong></td>
<td><strong>147.47</strong></td>
<td><strong>90.70</strong></td>
<td><strong>20.36</strong></td>
</tr>
<tr>
<td>Row</td>
<td>Leg</td>
<td>-45.48</td>
<td>-15.04</td>
<td>-28.89</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>0.93</td>
<td>23.54</td>
<td>29.15</td>
</tr>
<tr>
<td></td>
<td>Compost</td>
<td>52.81</td>
<td>130.97</td>
<td>91.77</td>
</tr>
<tr>
<td></td>
<td><strong>Mean</strong></td>
<td><strong>2.75</strong></td>
<td><strong>80.00</strong></td>
<td><strong>68.23</strong></td>
</tr>
<tr>
<td>Ley</td>
<td>Leg</td>
<td>323.31</td>
<td>-11.15</td>
<td>-16.96</td>
</tr>
<tr>
<td></td>
<td>Manure</td>
<td>455.92</td>
<td>39.38</td>
<td>60.97</td>
</tr>
<tr>
<td></td>
<td>Compost</td>
<td>503.72</td>
<td>140.37</td>
<td>88.77</td>
</tr>
<tr>
<td></td>
<td><strong>Mean</strong></td>
<td><strong>427.65</strong></td>
<td><strong>90.05</strong></td>
<td><strong>75.38</strong></td>
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<tr>
<td>harvested</td>
<td><strong>Mean</strong></td>
<td><strong>345.92</strong></td>
<td><strong>82.08</strong></td>
<td><strong>67.41</strong></td>
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</tbody>
</table>
Inputs

On farm operations

Carbon footprint?

Marketing

Transportation and storage
## In Field Energy Use; RUSLE2; 2003 thru 2007

<table>
<thead>
<tr>
<th>Mgt</th>
<th>Energy Use BTU/AC</th>
<th>Fuel Cost $/Ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compost</td>
<td>5400000</td>
<td>116.9</td>
</tr>
<tr>
<td>Manure</td>
<td>5400000</td>
<td>116.9</td>
</tr>
<tr>
<td>Cover crop</td>
<td>5000000</td>
<td>107.6</td>
</tr>
<tr>
<td>Row crop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compost</td>
<td>5700000</td>
<td>124.3</td>
</tr>
<tr>
<td>Manure</td>
<td>5700000</td>
<td>124.3</td>
</tr>
<tr>
<td>Cover crop</td>
<td>5200000</td>
<td>113.3</td>
</tr>
<tr>
<td>Pasture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No harvest</td>
<td>3900000</td>
<td>84.68</td>
</tr>
<tr>
<td>With harvest</td>
<td>7000000</td>
<td>152</td>
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</tbody>
</table>

Andrews, Wander and Widman
# 4 year balance for GWI

<table>
<thead>
<tr>
<th></th>
<th>Soil Seq</th>
<th>Denit</th>
<th>Energy</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>VEG</td>
<td>8.4</td>
<td>1.94</td>
<td>8.0</td>
<td>-1.54</td>
</tr>
<tr>
<td>VEG + M</td>
<td>8.4</td>
<td>2.47</td>
<td>8.2</td>
<td>-2.27</td>
</tr>
<tr>
<td>VEG + C</td>
<td>8.4</td>
<td>2.66</td>
<td>8.2</td>
<td>-2.46</td>
</tr>
</tbody>
</table>

A= mean soil sequestration in Vegetable system  
B=estimated based on denitrification from soil  
C=LCA with GREET boundaries  
D= A-(B+C)
The Conservation Stewardship Program (CSP)

• is a voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner by:
  – Undertaking additional conservation activities; and
  – Improving, maintaining, and managing existing conservation activities.
Soil Management Assessment Framework (SMAF)

1. Indicator Selection

Minimum Data Set
- Indicator
- Indicator
- Indicator
- Indicator
- Indicator

2. Interpretation

- score
- score
- score
- score
- score

3. Integration

Index Value

- Andrews et al., 2002; 2004
Test P Interpretation

Ascending curve is based on yield response (crop dependent)

Descending curve is based on risk of P runoff to water (slope dependent)
Multiple Functions

- Nitrogen Added (kg/ha)
- Productivity
- Water Quality

- after DeFries et al., 2002
2008 Farm Bill recognizes organic practices

• Required NRCS to establish a transparent process that would allow producers to undergo organic transition while in a CSP contract

• CSP requires the use of Conservation Enhancements that provide additional environmental benefit(s)
# NRCS enrollment tools

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Total Score</th>
<th>Enter number Check here for</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Soil Conditioning Index is positive (If yes, stop here, you pass for soil quality.)</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>On how many years of the crop rotation is a moldboard plow, chisel plow or annual raised beds used?</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>How many crops (per rotation) receive fall tillage?</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Is controlled traffic (tram lines) used, OR are soil moisture conditions monitored to minimize compaction.</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>How many crops are grown during the rotation from each group listed below. (See columns boxes for full listings.)</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>a) Enter the number of years this occurs during your rotation: summer fallow, idle fields, or harvested sod</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>b) Enter the number of years any of these crops are grown during your rotation: Horticultural crops, dry beans, annual herbs, flowers (cut and seed)</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c</td>
<td>c) Enter the number of years any of these crops are grown during your rotation: Cowpea, cotton, soybeans, sorghum hay, peanuts, root crops (non-nut), pineapples, tobacco</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>d) Enter the number of years any of these crops are grown during your rotation: Corn, sugar, sorghum, small grains, tree crops, perennial herbs, horticulture</td>
<td>0</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e</td>
<td>e) Enter the number of years any of these crops are grown during your rotation: Grass, pasture, hay, CRP</td>
<td>0</td>
<td></td>
<td>0</td>
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</tr>
</tbody>
</table>

How many years are annual crops established during rotations with at least 50% residue.
Soil and Water Quality, Field Practices

![Graphs showing SQ Score, WQ Score, SWET Score, and Ratio SQ/WQ Score for Conventional, Manure, and Legume practices.]

- **SQ Score**
  - Conventional: Various values
  - Manure: Various values
  - Legume: Various values

- **WQ Score**
  - Conventional: Various values
  - Manure: Various values
  - Legume: Various values

- **SWET Score**
  - Conventional: Various values
  - Manure: Various values
  - Legume: Various values

- **Ratio SQ/WQ Score**
  - Conventional: Various values
  - Manure: Various values
  - Legume: Various values

Legend:
- **Black** - Conventional
- **Red** - Manure
- **Green** - Legume
Covers - not just another silver bullet