Crop Rotations & Soil Health
Long-term crop rotation studies

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“…What now remains compared with what then existed is like the skeleton of a sick man, all the fat and soft earth having wasted away, and only the bare framework of the land being left. . .”

- Plato from “Critias” ( ~ 360 B.C.E. )
Sustainable production has become an important aspect of maintaining and accessing the marketplace.

Can no longer just do what we think produces food in a way that protects or improves soil health ....we need to be able to provide evidence that we’re producing food in a way that protects or improves soil health

What is Soil Health?

How can we measure Soil Health?
Soil Health?

- “...is simply the ability to grow a profitable crop while maintaining the ability to do the same down the road, while not messing with our neighbours or other parts of the environment we jointly occupy and value...”

  (Les Henry, Grainnews, March 1, 2016)
Specific Elements of Soil Health

- Meaningful assessment requires “purpose” and “place”:
  
  - **Purpose** = “sustain biological productivity” or “grow a profitable crop” or “optimize crop yield” (grains, forage, grass)
  
  - **Place** = yield potential (climate regime, parent geological material, landscape position)
Soil quality is the capacity of a soil to function (in a farm or ecosystem) and thereby sustain productivity, maintain environmental quality, and promote plant and animal health.

Aim is to manage for “balance” between all three soil components.
Soil health indices

- Cornell Soil Health Assessment (CSHA) - Measures 20 soil attributes
- Grant for developing Soil Health Index for western Canada – measuring 20 soil properties:

<table>
<thead>
<tr>
<th>Texture</th>
<th>Organic matter</th>
<th>Potentially mineralizable N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available water capacity</td>
<td>Soil respiration</td>
<td>Root pathogen pressure</td>
</tr>
<tr>
<td>Surface hardness</td>
<td>Active carbon</td>
<td>pH</td>
</tr>
<tr>
<td>Subsurface hardness</td>
<td>Nutrients – N, P, K, S, Ca, Mg, micros.</td>
<td>Salinity</td>
</tr>
<tr>
<td>Aggregate stability</td>
<td>Soil protein</td>
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</tbody>
</table>


My soil health score is “5” - did I win??

- ......as Einstein once said “it’s all relative...”
- Index (score) is somewhat controversial. (e.g. Congreves, et al. 2016)
- Tracking your soil health score (lab or observational) over time can be useful
- Individual indicators perhaps more meaningful as a diagnostic tool.
Soil Organic Matter (SOM)

- Appears in all soil health indices – everyone acknowledges its importance
- Long time period (minimum of ~ 5 years) before change in SOM is measurable
- If SOM is lost after implementing a change – long time before we know
Loss of soil organic carbon:
Crop rotations

• Essential to study actual crop rotations – sustained over numerous rotations of the entire crop sequence
• Need time to establish if there is any impact (positive or negative) of a particular sequence/ operation etc.
• AAFC long term rotations studies are an indispensable resource
AAFC – Long-term sites:

Swift Current (Brown Soil)

Scott (Dark Brown Soil)

Indian Head (Black Soil)
Swift Current – Brown Soil Zone

Change in SOC after 11 or 12 yr no-till

- Sceptre clay
- Swinton Silt loam
- Hatton Sandy loam

Campbell et al., 1996, Can J Soil Sci. 76; 395-401
Cropping frequency and tillage on SOM

Cont wheat: no till
Cont wheat: conventional
Fal - wheat: no till
Fal - wheat: conventional
Swift Current – Old Rotation Study

- Initiated in 1966
- Evaluate the influence of rotation length, fallow substitute crops and fertilization (N & P)
- Spring wheat – fallow rotations for moisture conservation led to erosion, salinization and a decline in soil and water quality
Proper fertilization is essential for optimizing SOC gains
Reducing/eliminating fallow
Swift Current - New Rotation Study

- Initiated in 1987
- Evaluate (under conservation tillage) influence of crop and rotation type
Average annualized SOC gained 1981-2008

F=fallow; W=spring wheat; LGM=Legume green manure; Cont W=continuous wheat; Cont W (if water) =continuous wheat when sufficient moisture – fallow insufficient moisture; Hy=(hybrid) Canadian Prairie Spring Wheat; CWG=crested wheat grass
Scott – Alternative Cropping Systems Study

- Established in 1994
- Prior to establishing the study, area maintained in a cereal-fallow or cereal-cereal –fallow rotation
<table>
<thead>
<tr>
<th>Diversity level</th>
<th>Input level</th>
<th>Crop sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW</td>
<td>ORG</td>
<td>GrM-W-W-GrM-Must-W</td>
</tr>
<tr>
<td>RED</td>
<td></td>
<td>GrM-W-W-Chem fallow-Canola-W</td>
</tr>
<tr>
<td>HI</td>
<td></td>
<td>Fallow-W-W-F-Canola-W</td>
</tr>
<tr>
<td>DAG</td>
<td>ORG</td>
<td>GrM-W-Pea-Barley-GrM-Mustard</td>
</tr>
<tr>
<td>RED</td>
<td></td>
<td>Canola-Soft W-Pea-Barley-Flax-W</td>
</tr>
<tr>
<td>HI</td>
<td></td>
<td>Canola-Soft W-Pea-Barley-Flax-W</td>
</tr>
<tr>
<td>DAP</td>
<td>ORG</td>
<td>Must-W-Barley-Alf-Alf-Alf-Alf</td>
</tr>
<tr>
<td>RED</td>
<td></td>
<td>Canola-W-Barley-Alf-Alf-Alf-Alf</td>
</tr>
<tr>
<td>HI</td>
<td></td>
<td>Canola-W-Barley-Alf-Alf-Alf-Alf</td>
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</table>

DAG = diverse annual grain; DAP = diverse annual & perennial
Scott-ACS: Soil organic C and N

- No effect of input level or diversity on total organic C and N (0-15 cm)
Scott-ACS: Aggregate Size

![Bar chart showing the mean weight diameter (mm) for different conditions.]

- HI
- RED
- ORG
Scott-ACS: Light Fraction OM

Light Fraction Organic C (kg C/ha)

- HI
- RED
- ORG

LOW, DAG, DAP
Final Observations from Scott ACS

- Systems with greatly reduced tillage combined with perennial forages promoted improved soil quality and nutrient supplying power

- RED had more mites and more suborders of mites than the HI and ORG systems – but still much lower than native prairie reference
Established in 1957

Converted from conventional – tillage to no-tillage in 1990

Evaluate different summerfallow frequencies and fertility through the use of N and P fertilizers, legume green manures and forage crops
Nine crop rotations established:

<table>
<thead>
<tr>
<th>No Fertilizer</th>
<th>N &amp; P fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous wheat</td>
<td>Continuous wheat</td>
</tr>
<tr>
<td>F-W</td>
<td>F-W</td>
</tr>
<tr>
<td>F-W-W</td>
<td>F-W-W</td>
</tr>
<tr>
<td>F-W-W (straw removal)</td>
<td></td>
</tr>
<tr>
<td>GrM-W-W</td>
<td></td>
</tr>
<tr>
<td>F-W-W-H-H-H</td>
<td></td>
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</tbody>
</table>

F=fallow, W=wheat, GrM=green manure – sweet clover or lentil, H=hay – alfalfa + bromegrass or straight alfalfa
SOC 30 (t/ha) yr after implementation of rotation

- Use of Fertilizer increased SOC in Cont W rotation
  - not in F-W or F-W-W
- Reduction in Fallow increased SOC
- Including GrM or forage increased SOC
Relative estimate (%) of potential mineralizable N

Fertilizers as/more effective as green manure or forage legumes for increasing the quantity and quality of SOM
Soil Microbial Biomass

- Eliminating fallow increased MB-N by ~50%
  - (82 kg/ha to 122 kg/ha)
- MB-C:N indicated a shift in the microbial biomass populations in rotations with increased SOM
Final Observations from Indian Head

- Soils with low organic matter due to erosion or poor management cannot be made to produce comparably to soils with higher organic matter simply by adding inorganic fertilizers
- Building soil quality will build crop yields over time.
Take Home Messages

- More difficult to increase SOM in sandy soils than clays
  - Clays may/do protect SOM from mineralization
- Decreasing frequency of fallow (eliminating) key to increasing SOM
  - Continuous inputs of roots and aboveground residues
- Proper fertilization of growing crop key to improving SOM
  - Inorganic fertilizers as effective as organic inputs (GrM)
- Including perennial crops in rotations appears to positively impact soil quality.
Acknowledgements

- Saskatchewan Ministry of Agriculture Strategic Research Program-Soil Biological Processes
- AAFC
- Dr. Reynald Lemke
Questions?
Saskatchewan Agriculture: 130\textsuperscript{ish} years

- Production and export of wheat dominated 1880s – 1950s
- Experimental farms established 1886
- Focus on preserving the soil