Crops, Roots and Biological Processes: Synergistic Interactions

Managing soil ecosystem functions in intensive and extensive systems

Perennial grassland and annual cropland in Kansas

Apple orchards in Washington State: conventional and organic production

1994 – 2003 Study of Three Apple Production Systems

<table>
<thead>
<tr>
<th>Organic</th>
<th>Integrated</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Preston Andrews</td>
<td>• Tom Forge</td>
<td></td>
</tr>
<tr>
<td>• John Reganold</td>
<td>• Tianna DuPont</td>
<td></td>
</tr>
<tr>
<td>• Herb Hinman</td>
<td>• Jerry Glover</td>
<td></td>
</tr>
<tr>
<td>• Sasha Kramer</td>
<td>• Harold Mooney</td>
<td></td>
</tr>
<tr>
<td>• Greg Peck</td>
<td>• Brendan Bohannon</td>
<td></td>
</tr>
</tbody>
</table>

Jerry Glover
The Land Institute
glover@landinstitute.org
**1994 – 2003 Study of Three Apple Production Systems**

**Organic**
- Organic fertilizers (compost, alfalfa)
- Only organic pesticides
- Similar amounts of nitrogen applied to all three systems

**Integrated**
- Calcium-nitrate & organic fertilizers
- Reduced herbicides
- Integrated pest mgmt

**Conventional**
- Calcium-nitrate
- Herbicides
- Integrated pest mgmt

---

- Organic had higher soil quality than Conventional
- Similar cumulative yields
- Organic fruit were sweeter and as firm or firmer
- Firmness linked to fruit N and soil NO₃⁻N


---

**Soil organic nitrogen**

- Organic inputs
- Microbial biomass
- NH₄⁺
- NO₃⁻


Conventional Organic

N$_2$ highest in organic

N$_2$O not different

Organic system supports more active and efficient denitrifier communities

Integrated

Using nematode communities as indicators of key ecosystem processes

NO$_3$ leaching 4.4 - 5.6 times higher in Conventional plots
Nematode communities in organic plots are distinctly different in composition from those in integrated and conventional plots.

Although simple differences in composition don't tell us whether the differences are good or bad we can analyze correlations between the community composition statistics and those of soil properties which impacts on the soil ecosystem are well known.
Non-metric multidimensional scaling ordination of nematode communities (genus or family level identification)

The direction and length of each vector indicates the direction and strength of the association between these nitrogen cycling indicators and the specific composition of the nematode communities.

For example, higher levels of mineralizable nitrogen are associated with the nematode communities found in organic plots, and lower denitrification efficiencies are associated with communities in conventional and integrated plots.
Intensive orchard systems:

- The final form of a nutrient taken up by the crop may be the same BUT...
- The pathways through the soil ecosystem along which the nutrients were transformed and delivered are different and those differences affect crop quality and the soil ecosystem overall.

Five paired grassland/cropland sites in North Central Kansas

Perennial grassland
- Never-tilled, native tallgrass prairie plant communities
- No fertilizer or pesticide applications
- Aboveground biomass annually harvested for 75+ yrs
Perennial grassland
- Never-tilled, native tallgrass prairie plant communities
- No fertilizer or pesticide applications
- Aboveground biomass annually harvested for 75+ yrs

Annual cropland
- Immediately adjacent & on similar soils and landscapes
- Fertilizers and pesticides for ~40 yrs
- Used primarily or exclusively for wheat production for 75+ yrs

- Similar levels of nitrogen are harvested from both systems each year

ROOTING DEPTH
- 1m
- 2m

Perennial grassland
- Never-tilled, native tallgrass prairie plant communities
- No fertilizer or pesticide applications
- Aboveground biomass annually harvested for 75+ yrs

Annual cropland
- Immediately adjacent & on similar soils and landscapes
- Fertilizers and pesticides for ~40 yrs
- Used primarily or exclusively for wheat production for 75+ yrs

- Similar levels of nitrogen are harvested from both systems each year
Despite high levels of nutrient removal and no fertilization, perennial grasslands maintained high soil quality (0 – 1m)

<table>
<thead>
<tr>
<th></th>
<th>Perennial grass</th>
<th>Annual crop</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil organic carbon Mg ha(^{-1})</td>
<td>182.2</td>
<td>138.8</td>
<td>0.027</td>
</tr>
<tr>
<td>Total nitrogen Mg ha(^{-1})</td>
<td>15.4</td>
<td>11.7</td>
<td>0.013</td>
</tr>
<tr>
<td>Readily oxidizable carbon Mg ha(^{-1})</td>
<td>4.3</td>
<td>3.3</td>
<td>0.025</td>
</tr>
<tr>
<td>Water stable aggregates</td>
<td>0.87</td>
<td>0.68</td>
<td>0.011</td>
</tr>
</tbody>
</table>
Non-metric multidimensional scaling ordination of nematode communities in surface 3 depths

Vectors indicate strength and direction of association

Perennial grassland                 Annual cropland

Unlike with many soil properties, nematode communities in the perennial grass fields are less similar to those in annual crop fields at deeper depths; treatment differences increase with depth to 1 m.

Standardized indices of food web structure (Ferris et al.):
• Based on characteristics of nematode assemblages
• Indicates environmental conditions, nutrient cycling, pest & disease suppressiveness
Structure Index (SI):
• Measure of relative abundance of higher trophic groups sensitive to stress and with long life cycles
• Higher SI values indicative of greater diversity, greater complexity and more abundant resources

Enrichment Index (EI):
• Measure of relative dominance by bacterivorous and fungivorous taxa
• Higher EI values indicative of pulses of nutrient-rich inputs and increased bacterial production and nutrient mineralization

For disturbed food web conditions:
- High disturbance
- N enriched
- Low C:N ratio
- Disturbed food web

For maturing food web conditions:
- Mod. disturbance
- N enriched
- Low C:N ratio
- Maturing food web
Structure and function of soil food web at 1 m in perennial grassland is similar to that in surface depths in annual cropland.
Extensive systems:

- Increased support of ecosystem processes and functions likely to depend more on plant characteristics (e.g., rooting depth, growing season length) than on human inputs.
- Great potential to replace costly human inputs with greater access to soil resources and longer growing seasons.

Green Lands, Blue Waters

“...supports development of a new generation of agricultural systems in the Mississippi River Basin that integrate more perennial crops into the agricultural landscape.”

www.greenlandsbluewaters.org