Resource Concerns & Soil Health Indicators
Module 3

Mike Kucera
Agronomist
Objectives

• Define soil health indicators as they relate to soil function

• Locate and discuss the limitations to the soils data and interpretations that are currently available

• Identify how soil health indicators reveal the presence of resource concerns
Making Soil Health A Priority=
Taking a Soil Health Journey

• What does *Soil Health* mean?
• Soil Health Indicator actions =
  • Improving organic matter
  • Improving aggregate stability
  • Increasing water infiltration
  • Increasing available water capacity
  • Improving nutrient cycling
  • Balancing and diversifying soil biology
  • Eliminating erosion
  • Reducing compaction
**NRCS Resource Concerns**

**Resource Concern:** An expected degradation of the soil, water, air, plant, or animal resource base to the extent that the sustainability or intended use of the resource is impaired.

**Planning Criteria:** Used to determine whether or not there is a resource concern associated with a specified land use....

- Compaction
- Organic matter depletion
- Soil organism habitat loss or degradation (new)
- Aggregate instability (new)
## Compaction

<table>
<thead>
<tr>
<th>Resource Concern</th>
<th>Description</th>
<th>Objective</th>
<th>Land</th>
</tr>
</thead>
</table>
| Compaction       | Management-induced soil compaction at any level throughout the soil profile resulting in reduced:  
  • rooting depth and structure  
  • plant growth  
  • soil biological activity  
  • water infiltration and water holding capacity  
  • aeration  
  • habitat |  
  • No platy structure or restrictive layers  
  • No evidence of thickened roots or J-structure  
  • Restricted layers exceeding 300 PSI at field capacity have been identified |  
  • Crop  
  • Forest  
  • Assoc. Ag Land  
  • Designated Protected Areas  
  • Other Rural Land  
  • Pasture |
New Farm in 2018
Excessive Runoff
## Organic Matter Depletion

<table>
<thead>
<tr>
<th>Resource Concern</th>
<th>Description</th>
<th>Objective</th>
<th>Land</th>
</tr>
</thead>
</table>
| Organic matter Depletion          | Management induced depletion of soil organic matter pools, e.g. labile carbon, total soil carbon or nitrogen resulting in limited soil function and processes that support:  
  • plant growth  
  • habitat and food for soil organisms  
  • water and nutrient cycling | Total organic matter or carbon is being monitored and increasing according to approved total organic matter or carbon soil test | • Crop  
  • Assoc. Ag Land |

NRCS | SHD | Resource Concerns & Soil Health Indicators
## New Soil Health Resource Concerns

<table>
<thead>
<tr>
<th>Resource Concern</th>
<th>Description</th>
<th>Objective</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil organism habitat loss or degradation</td>
<td>• Quantity, quality, diversity or connectivity of food, cover, space, shelter and/or water is inadequate to meet requirements of soil organisms</td>
<td>• Improve habitat for soil organisms</td>
<td>• Crop&lt;br&gt;• Pasture&lt;br&gt;• Associated Ag Land&lt;br&gt;• Designated Protected Area&lt;br&gt;• Other Rural Land</td>
</tr>
</tbody>
</table>
## New Soil Health Resource Concerns

<table>
<thead>
<tr>
<th>Resource Concern</th>
<th>Description</th>
<th>Objective</th>
<th>Land Use</th>
</tr>
</thead>
</table>
| **Aggregate Instability** | Management induced degradation of water stable soil aggregates resulting in:  
• reduced water infiltration, water holding capacity, aeration  
• depressed resilience to extreme weather,  
• increased ponding, flooding,  
• increased soil erosion,  
• plant stress,  
• reduced habitat and soil biological activity: microbes, plants and animals | Improve aggregate stability | • Crop  
• Associated Ag Land |
In-Field Assessment

• Soil maps
  ▪ Info on inherent soil properties for proper interpretation
  ▪ Vegetation productivity
  ▪ Some soil health information

• Interview producer
  ▪ Current concerns
  ▪ Field/management history

• Field visit
  ▪ Field soil health assessment
Welcome to Web Soil Survey (WSS)

The Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey (NCSS).

Conservation Service

Access to the largest soil information system with soil maps and data. More than 95% of the country anticipates having online access in the future. The site is now online as the single source of survey information.

Soil surveys can be viewed at the local, state, and national levels. This investigation is not a substitute for soil quality assessment, conservation and management planning. For more detailed information, contact your USDA Service Center or your NRCS State Soil Scientist at the following link: USDA Service Center or your NRCS State Soil Scientist.

Four Basic Steps

1. Define

Use the Area of Interest tab to define your area of interest.
Limitations to Soil Health Interpretations:
Need site-specific information on cropping systems to properly assess soil health/indicators/interpretations (e.g., crop rotations, cover crops, irrigation system, irrigation water quality, soil stratification, soil texture, fertility, tillage, grazing, etc.)
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Need site-specific information on cropping systems to properly assess soil health/indicators/interpretations (e.g., crop rotations, cover crops, irrigation system, irrigation water quality, soil stratification, soil texture, fertility, tillage, grazing, etc.)
Limitations to Soil Health Interpretations:
Need site-specific information on cropping systems to properly assess soil health/indicators/interpretations (e.g., crop rotations, cover crops, irrigation system, irrigation water quality, soil stratification, soil texture, fertility, tillage, grazing, etc.)
In-Field Soil Health Assessment To Identify Resource Concern Presence

- Soil Cover
- Surface Crusting
- Residue Breakdown
- Roots & Pores
- Aggregate Stability
- Biological Activity
- Compaction
- Soil Color
Stubble and Weed Management adaptation (herbicide resistance)
**In-Field Assessment**

## Indicator: Adequate Soil Cover

<table>
<thead>
<tr>
<th>Importance</th>
<th>Description</th>
<th>Resource Concerns Addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Protection/resistance to erosion</td>
<td>Soil cover is the percent of the soil surface that is covered by plant residue, organic mulch and/or live plants.</td>
<td>• Aggregate instability</td>
</tr>
<tr>
<td>• Temperature/water moderation</td>
<td></td>
<td>• Soil organism habitat loss or degradation</td>
</tr>
<tr>
<td>• Protection of aggregates/ soil organic matter</td>
<td></td>
<td>• Soil organic matter depletion</td>
</tr>
</tbody>
</table>

Lack of cover exposes the soil to erosion and detachment of soil particles from rain and reduces the food source for soil microbes.
## In-Field Assessment

### Indicator: Adequate Soil Cover

| In-field Measurement | 1. Farmer interview of management system (recorded for current erosion model). Document tillage system, crop rotation, high biomass crops.  
|                       | 2. Use photo-comparison method or state approved estimation methods,  
|                       | OR  
|                       | 3. Use line transect as described in [https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022074.pdf](https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022074.pdf) |
| Rating Criteria       | Year-round surface cover from plants, plant residue or mulch |
|                       | **Acceptable** | **Unacceptable** |
|                       | Cover >70% after planting | Cover < 70% after planting |
In-Field Assessment: Residue Cover

- Estimate the percent of soil surface covered with dead plant material within the immediate area of your test location. The chart above shows what 25-90% residue cover looks like. Your crops will be different, but the percent cover will look the same.

## Indicator: Residue Breakdown

<table>
<thead>
<tr>
<th>Importance</th>
<th>Description</th>
<th>Resource Concerns Addressed</th>
</tr>
</thead>
</table>
| • Food source for soil organisms | • Biological shredding, fragmenting, cycling or incorporating of previous crop residue.  
• Builds soil organic matter  
• Too rapid → not enough cover  
• Too slow → management problems | • Assessed by gauging the age of previous residue and evidence of shredding, fragmenting and/or incorporating into soil without tillage |
|                             | • The rate at which residue decomposes is an indicator of relative biological activity. | • Soil organism habitat loss or degradation  
• Soil organic matter depletion |
In-Field Assessment

Indicator: Residue Breakdown

In-field measurement
Residue breakdown is assessed by looking at the existing residue cover for signs of breakdown, shredding and incorporation by soil organisms after planting.

Considerations when conducting the assessment:
1. If tillage present, then not applicable
2. How many seasons/layers of crop residue are present
3. Residue composition and type (C:N) residue crops were grown
4. Residue color and condition of most recent crop residue
5. Farmer interview of management system

Rating Criteria

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue pieces are small, mixed in surface or minimal crop residue remaining from &gt;1 cropping seasons</td>
<td>Residue in large pieces left after planting, can be handled without crumbling and/or lots of residue from 2 or more cropping seasons</td>
</tr>
</tbody>
</table>
## Indicator: Surface Crusting

| Importance | • Reduces emergence  
  • Increases risk of ponding and runoff; decreases infiltration  
  • Limits soil air and/or water exchange  
  • Reduced water storage |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Crusts form after rain or irrigation on soils with weak aggregate stability.</td>
</tr>
</tbody>
</table>
| Resource Concerns Addressed | • Aggregate instability  
  • Soil organic matter depletion  
  • Compaction  
  • Soil organism habitat loss or degradation |
In-Field Assessment

### Indicator: Surface Crusting

<table>
<thead>
<tr>
<th><strong>In-field measurement</strong></th>
<th>Typically evaluated by visual observation after rainfall/irrigation and drying (document with photos)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Note whether crusts are throughout the field or only in patches.</td>
</tr>
<tr>
<td></td>
<td>• Evidence of ponding</td>
</tr>
<tr>
<td></td>
<td>• Poor crop emergence uneven stand</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Rating Criteria</strong></th>
<th><strong>Acceptable</strong></th>
<th><strong>Unacceptable</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence of surface crust on less than 20% of field</td>
<td>Evidence of surface crust on more than 20% of field</td>
<td></td>
</tr>
</tbody>
</table>
## Indicator: Aggregate Stability

### Importance
- Improves soil air and water exchange (pore space) and water storage
- Resists erosive forces of wind & water
- Decreases risk of ponding and runoff; increases infiltration
- Increases microbial habitat, activity, and nutrient cycling

### Description
- Wet aggregate stability suggests good soil porosity and how well a soil can resist raindrop impact and erosion.

### Resource Concerns Addressed
- Aggregate instability
- Soil organism habitat loss or degradation
- Soil organic matter depletion
- Compaction
In-Field Assessment

Indicator: Aggregate Stability

<table>
<thead>
<tr>
<th>In-field measurement*</th>
<th>Choose one of the following three methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Slake test (ideally under dry conditions; if moist soils don’t slake then do a second test)</td>
</tr>
<tr>
<td></td>
<td>• Strainer test</td>
</tr>
<tr>
<td></td>
<td>• Jornada Slake test (stability kit)</td>
</tr>
<tr>
<td></td>
<td><strong>See protocols provided</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rating Criteria</th>
<th>Acceptable</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Aggregate remains intact</td>
<td>Aggregate disintegrates</td>
</tr>
<tr>
<td></td>
<td>• &gt;90% for slake test with little cloudy water</td>
<td>• less than 50% remaining (slake)</td>
</tr>
<tr>
<td></td>
<td>• “stands up” for strainer test and water leaving container is translucent</td>
<td>• Soil “slumps” into a puddle, runoff is not translucent</td>
</tr>
<tr>
<td></td>
<td>• Jornada criteria</td>
<td>• Jornada criteria</td>
</tr>
</tbody>
</table>

NRCS | SHD | Resource Concerns & Soil Health Indicators
## Indicator: Compaction

| Importance | • Decreased rooting depth, plant growth  
|           | • Decreased biological biomass & activity  
|           | • Poor infiltration, drainage, aeration, & water storage |
| Description | Management induced (6” below normal or past field operations) reduction of large pores and degraded structure (i.e., platy) that results in decreased rooting depth, plant growth and soil biological habitat and activity. |
| Resource Concerns Addressed | • Compaction  
|   | • Soil organic matter depletion  
|   | • Soil organism habitat loss or degradation  
|   | • Aggregate instability |
## In-Field Assessment

### Indicator: Compaction

| In-field measurement | Measurements should be conducted with soil moisture near field capacity using a spade, penetrometer, wire flag, or knife.  
|                       | - Evaluate multiple representative locations in the field, avoiding consistent wheel tracks.  
|                       | - Record depths of restrictive layer(s)  
|                       | - If using a penetrometer record depths and readings (PSI) of identified layers  
|                       | - Evaluate root development and distribution  
|                       | - Look for platy structure  
|                       | - Surface water ponding |

| Rating Criteria | Rating is based on multiple areas of the field that shows evidence of a restricted layers in the soil profile |

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granular structure, appropriate PSI reading, vertical channels or roots.</td>
<td>Evidence of platy structure, unacceptable PSI, root restriction, surface ponding, horizontal or abnormal root architecture.</td>
</tr>
</tbody>
</table>

NRCS | SHD | Resource Concerns & Soil Health Indicators
## Indicator: Roots and Biopores (Continuity)

<table>
<thead>
<tr>
<th>Importance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Release exudates to stimulate microbes and form aggregates and soil organic matter&lt;br&gt;• Biopores are channel that remain from season to season and are often areas of organic carbon concentration, plant nutrients, and biological activity&lt;br&gt;• Increases aeration, infiltration, drainage, and water storage and availability</td>
<td>• Roots influence the soil immediately adjacent to them through exudates, growing and leaving soil organic matter as they die</td>
</tr>
</tbody>
</table>

| Resource Concerns Addressed | • Aggregate instability<br>• Soil organic matter depletion<br>• Soil organism habitat loss or degradation |
## In-Field Assessment

**Indicator: Roots and Pores**

### In-field measurement
- Observe evidence of dark, root channels or biopores left by previous plants or earthworms

<table>
<thead>
<tr>
<th>Rating criteria</th>
<th>Acceptable</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of dark, root channels or biopores left by previous plants or earthworms</td>
<td>Roots are stressed and do not follow previous root channels, no pores evident from earthworms</td>
<td></td>
</tr>
</tbody>
</table>
# In-Field Assessment

## Indicator: Biological Activity

| Importance | Diverse population supports numerous ecosystem functions  
| Involved in aggregation and SOM formation  
| Nutrient cycling, disease suppression, detoxification |
| Description | The presence and relative abundance of earthworms and meso- and macro-invertebrates such as mites, springtails, millipedes, roundworms, beetles or termites can provide evidence of a healthy soil ecosystem.  
| Fungal hyphae may also be noticed. |
| Resource Concerns Addressed | Primary Concern:  
| Soil organism habitat loss or degradation  
| Secondary:  
| Aggregate Instability  
| Soil organic matter depletion |
## Indicator: Biological Activity

### In-field measurement
1. Brush back residue (if present) look for evidence of activity of macro arthropods, e.g. millipedes, ants, beetles, etc.
2. Look for evidence of earthworm activity, e.g. casts, mildens, large pores.
3. Break the soil apart and carefully look for earthworms or signs of earthworms channels or macro-organisms
4. If manure piles present flip over and look for insects
5. Look for signs of fungal hyphae that appear as white to light tan threads or masses (note hyphae could be from AMF or saprophytic fungi

### Rating Criteria
Rating based on observations of the presence of fungal hyphae, macro-invertebrates, earthworms, etc.

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearly evident; numerous organisms observed</td>
<td>No biological activity visible, lacking earthworms, no saprophytic fungi, low to no evidence of macrofauna</td>
</tr>
</tbody>
</table>
## Indicator: Soil Color (Optional)

<table>
<thead>
<tr>
<th>Importance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Darker colors related to higher SOM</td>
<td>• Color can be used as an indicator of loss or accumulation of organic matter.</td>
</tr>
<tr>
<td>• Can reflect moisture and/or redox conditions</td>
<td>• Typically, loss of SOM results in relatively lighter color, while accumulation results in darkening of the soil.</td>
</tr>
<tr>
<td>• Can indicate certain mineralogy</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resource Concerns Addressed</th>
<th>Primary Concern:</th>
<th>Secondary:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Soil organic matter depletion</td>
<td>• Aggregate Instability</td>
<td>• None listed</td>
</tr>
<tr>
<td>• Aggregate Instability</td>
<td>• Soil organism habitat loss or degradation</td>
<td></td>
</tr>
<tr>
<td>• Soil organism habitat loss or degradation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In-Field Assessment

Indicator: Soil Color (Optional)

<table>
<thead>
<tr>
<th>In-field measurement</th>
<th>Rating Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Use a shovel to dig a hole below the layer affected by management typically 6” to 12” to observe the soil profile</td>
<td></td>
</tr>
<tr>
<td>2. Observe color differences in the soil profile looking for layers of accumulations or accumulation along pores or root channels deeper in the soil profile</td>
<td></td>
</tr>
<tr>
<td>Ratings based on indications of color differences or presence of SOM accumulation with the lowest rating having the greatest negative affect.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acceptable</th>
<th>Unacceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td>An obvious darker surface layer with root/pores extending down into the soil profile</td>
<td></td>
</tr>
<tr>
<td>No stratified layer, soil mixing observed and/or surface is lighter in color than the horizon below</td>
<td></td>
</tr>
</tbody>
</table>

*Note soil moisture makes soil appear darker and should be noted if comparing different fields*
Lab Indicators for Soil Health

- USDA consensus on laboratory methods
- Easy & inexpensive
- Sensitive but robust
- Same methods
- Regionally calibrated

Standard Nutrient Test
Macro, Micro, SOM, CEC

Upgraded: Biological, C&N, Physical
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**Cornell Soil Health Assessment**

**Sample ID:** A125  
**Field/Treatment:** Field  
** Tillage:** No Till  
** Crop Cover:** Mix, Mix, Mix  
**Date Sampled:** 5/11/2014  
**Given Soil Type:** Anytown  
**Given Soil Texture:** Silt Loam  
**Coordinates:** 42.44750° N, 76.47570° W

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**Test Report**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Value</th>
<th>Rating</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Water Capacity</td>
<td>0.13</td>
<td>24</td>
<td>Water Retention &amp; Availability</td>
</tr>
<tr>
<td>Subsurface Hardness</td>
<td>148</td>
<td>62</td>
<td>Subsurface Penetration, Deep Rooting, Water and Nutrient Stress</td>
</tr>
<tr>
<td>Aggregate Stability</td>
<td>22.5</td>
<td>24</td>
<td>Aeration, Infiltration, Rooting, Sealing, Erosion, Runoff</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>3.2</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>ACE Soil Protein Index</td>
<td>6.5</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Root Pathogen Pressure</td>
<td>5.5</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td>1.17</td>
<td>15</td>
<td>Soil Microbial Abundance and Activity</td>
</tr>
<tr>
<td>Active Carbon</td>
<td>391</td>
<td>12</td>
<td>Energy Source for Soil Biota</td>
</tr>
<tr>
<td>pH</td>
<td>6.0</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>9.3</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>264.7</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Minor Elements</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Overall Quality Score:** 49  
**Rating:** Low

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**Notes on the Report:**

- Soil Health 5  
- Overall Fertile

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**PLFA Test**  
Gel biological testing at Ward Laboratories is conducted by analyzing phospholipid fatty acids, or PLFA. PLFA gives a representation of living soil microbial biomass and allows us to determine the presence or absence of various functional groups of interest through known PLFA biomarkers. PLFA is a snapshot of soil community structure and activities at the time of sampling. As environmental conditions such as temperature and moisture change so does the microbial community. This ability of the soil microbial community to change provides producers with a tool to compare agricultural management techniques with respect to overall better microbial community health.

**Haney Test**  
The Haney Test is a dual extraction procedure that allows the producer to assess overall soil health. This test is used to track changes in soil health based on management decisions. This test examines total organic carbon and total organic nitrogen to determine a C:N ratio used to predict general crop cover management recommendations. This test also includes the Solvita CO₂ Burst Test to look at microbial activity and potential mineralization nitrogen. The weak acid (H₂SO₄) extraction represents some available plant nutrients.

**Solvita CO₂ Burst Test**  
The Solvita CO₂ Burst Test is a new tool which easily and accurately measures soil biological CO₂ respiration (Solvita, 2012)
Lab Indicators For Soil Health

- **Soil Structural Stability & Water Partitioning**
  - Aggregate stability
  - Available water capacity

- **Soil Organic Matter Cycling**
  - Soil organic C
  - Soil organic matter

- **Carbon Food Source**
  - Permanganate oxidizable C (Active C)
  - Water extractable organic C

- **Microbial Activity**
  - Short-term C mineralization (respiration)
  - Enzyme activities

- **Bioavailable N**
  - Acid Citrate Extractable protein
  - N mineralization; Water extractable organic N

- **Microbial Community Composition/Function**
  - Fatty acid profiling (PLFA or EL-FAME)
  - Molecular characterization

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Calibration & Interpretation

- Indicator interpretation via soil based scoring functions
- Soil, climate and cropping system

GA Ultisols

IA Mollisols

Organic Matter

Organic Matter

0 1 2% 1 6%

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An Example: Assessment of Aggregate Stability

Measured Value – 10% stable

Score – 20 on a scale of 0-100

Interpretation – aggregate stability is too low for the soil type/climate and identified as a resource concern

Management Suggestion – Building more stable aggregates through appropriate cover crops, improved crop rotation, integration of livestock and/or manure into the system, mulches, surface residue, etc

Management Decision – based on production system and producer preferences
Circle the indicators that were rated unacceptable during the evaluation and follow decision tree below to determine if the given resource concern (RC) is present.

- Water stable aggregate test
- Platy structure
- Ponding
- Crusting

If any one or more indicator is rated ‘Does Not Meet’

If all indicators are rated as ‘Meets’

Aggregate instability RC

Likely also

?Habitat degradation RC

?= need further evaluation

No Aggregate instability RC
Continuous No-till, crop rotation

CRP, CSP, EQIP, Local Programs

Perennial crops

High carbon cover crops

Adaptive Management On the Kucera Farm
Mike Kucera Agronomist