Mgt. History & Record Keeping:
Mean annual Temp. & Precip.; Cropping System; Fertilizers/Pesticides; Tillage/Residue Cover, etc. & Soil Health Assessments.
Mgt. History & Record Keeping:
Mean annual Temp. & Precip.; Cropping System; Fertilizers/Pesticides; Tillage/Residue Cover, etc. & Soil Health Assessments.
Know the history of the field

Know the history of the field regarding chemical use!

- Type, Depth, Frequency, Timing, % Cover
- Pivot, Gravity, Amount and Timing, etc.
- Floods, Fires, Land-Leveling

What happened here? Herbicide carryover. Know the field history regarding chemical use!
1. On the Acequia (irrigation ditch) system, are you at the head, middle or end of the irrigation ditch?
2. Is irrigation water available on demand or on a fixed schedule?
3. Is water available throughout the growing season?
Interacting Factors Affecting Soil Health (Function) and Productivity

Management:
- Tillage/No-Till/Minimum-Till
- Planting
- Cover Crops
- Amendments
- Fertilizer use
- Irrigation (Water Quality)
- Irrigation System
- IPM

Soil Biology:
- Bacteria
- Fungi
- Protozoa
- Nematodes
- Earthworms
- Arthropods
- Mammals

Environment:
- Precipitation
- Temperature
- Humidity
- Wind
- Seasonal Length

Soil Properties:
- Organic Matter
- Soil Type
- Aggregation
- Bulk Density
- pH

Crops:
- Crop Type
- Cultivar
- Crop Rotation
- Cover Crops

Producers must use a dynamic cropping approach, where management decisions are adjusted annually based on changing climatic & economic conditions. Also, use a net return per rotational acre to measure profitability of various crop rotations.

For Cover Crop planning, must use site-specific and case-by-case local considerations, to account for variability in soils, irrigation water availability, water quality, climate, cropping systems, etc.
### SH Management Planning Process Overview

1. **Determine farm background and management history**
   Compile background info: history by management unit, farm operation type, equipment, access to resources, situational opportunities or limitations.

2. **Set goals and sample for soil health**
   Determine number and distribution of soil health samples needed according to operation background and goals.

3. **For each management unit: identify and explain constraints, prioritize**
   Soil Health Report identifies constraints, guides prioritization. Explain results based on background, and adjust priorities.

4. **Identify feasible management options**
   Management suggestions table available as part of Soil Health Report, or online with NRCS practice linkages.

5. **Create short and long term Soil Health Management Plan**
   Integrate agronomic science of 2-4 with grower realities of 1 to create a specific short-term schedule of management practices for each management unit and an overall long-term strategy.

6. **Implement, monitor, and adapt**
   Implement and document management practices. Monitor progress, repeat testing, and evaluate outcomes. Adapt plan based on experience and data over time.
Future Variability in Growing Season Precipitation

More extreme floods

More extreme droughts

CJ Anderson, ISU
Specific Tier 1 measures endorsed include:

- organic carbon,
- pH,
- water-stable aggregation,
- crop yield,
- texture,
- penetration resistance,
- cation exchange capacity,
- electrical conductivity,
- nitrogen,
- phosphorus,
- potassium,
- carbon mineralization,
- nitrogen mineralization,
- erosion rating,
- base saturation,
- bulk density,
- available water holding capacity,
- infiltration rate, and
- micronutrients
### Managing for a Living Ecosystem is Key to Optimum Production

<table>
<thead>
<tr>
<th>Tend to Reduce Soil Health</th>
<th>Tend to Promote Soil Health</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggressive tillage</td>
<td>No-till or conservation tillage</td>
</tr>
<tr>
<td>Annual/seasonal fallow</td>
<td>Cover crops; Relay crops</td>
</tr>
<tr>
<td>Mono-cropping</td>
<td>Diverse crop rotations</td>
</tr>
<tr>
<td>Annual crops</td>
<td>Perennial crops</td>
</tr>
<tr>
<td>Excessive inorganic fertilizer use</td>
<td>Organic fertilizer use (manures)</td>
</tr>
<tr>
<td>Excessive crop residue removal</td>
<td>Crop residue retention</td>
</tr>
<tr>
<td>Broad spectrum fumigants/pesticides</td>
<td>Integrated pest management</td>
</tr>
<tr>
<td>Broad spectrum herbicides</td>
<td>Weed control by mulching, cultivation</td>
</tr>
</tbody>
</table>

Choose practices that feed soil organisms and protect their habitat (soil aggregate).

“What, How” & “Why” do we Evaluate/Monitor Soil Health?

There are many Soil Health Indicators: Some are Qualitative; Some are Quantitative; Some are best measured in a lab; Some can be observed or measured in the field.

How will you know if you are on the right track?

Utilize all your senses:
- Sight
- Smell
- Touch
- Taste

Look at:
- Residue
- Soil Surface
- Soil Profile
- Plant Roots
- ???

(http://www.nrcs.usda.gov/wps/portal/nrcs/detail/nm/technical/?cid=nrcs144p2_068965)
Biological Sphere are present and well-defined

Soil Solution
- pH
- Salinity (ECss)
- Dissolved Oxygen (O2) & Carbon Dioxide (CO2)

Mineralization → Immobilization
- C:N Ratio
- Balanced
- Fungal:Bacterial Ratio
- Soluble Nutrients (e.g., OC, ON, OP, NH4+, NO3-, other: K+, Ca2+, etc.)

Dissolved Oxygen and Carbon Dioxide (O2 & CO2) are balanced.

Fungal:Bacterial Ratio

Soil Health Function:
- Sustain Plant & Animal Life
- Physical Stability & Support
- Cycle Nutrients
- Supply Water
- Filter & Buffer Pollutants

Drilosphere:
- Earthworms (#/ft.³)
- Castings
- Mittens

Earthworms

Rhizosphere:
- Root depth (in.)
- Root health/biomass (e.g. Healthy Roots have uninhibited root growth; lots of fine roots; are white & have no root pathogens)
- Soil Temperature (0-2”)
- Rhizosheaths
- Active Legume Nodules

Earthworms

Porosphere:
- Infiltration: Tabletop Rainfall Simulator or rings in the field
- Compaction: Surface & Subsurface (Penetrometer, psi)
- Root pores (visual: dig small soil pit)
- Porous soil have good gas exchange (aerobic condition; ideal Bulk Density)
- Macro-Aggregates make Macro-Pores

Water-Stable Macro-Aggregates

Soil Health Principles (Ecological Framework for Management):
1. Maximize Biodiversity
2. Provide Continuous Living Roots
3. Maximize Soil Cover
4. Minimize Disturbance
*Integrate Grazing where applicable

Additional Tests (as needed):

Soil Health Function:
- % Surface residue cover
- Signs of Residue decomposition (e.g., Shredded/Cobwebs)
- Surface Temperature (& ambient Air Temp.)
- reduced evaporation with cover

Aggregatusphere:
- Soil structure & Texture
- Slake test 0-3” depth
- Aggregate Stability (colander & spray bottle)
- % SOM (Organic Matter Pools)
- Is soil crusty?
- Soil Color/Aroma (earthy smell?)
- Feel & Appearance method (available soil moisture)
- Soil Water Holding Capacity Demo (soil texture & % SOM)
Soil Quality Test Kit

How do I use soil health assessment information?

- Understand soil processes & management impacts
- Identify constraints through soil health assessment
- Select & implement appropriate management strategies
- Monitor change and adjust management

indicator selection

Criteria

- Standardized
- Scientific/agronomic relevance
- Represent diverse processes
- Sensitive to agricultural management
- Easy and inexpensive to measure
- Interpretations accessible to many users
- Minimal infrastructure/investment

(Doran et al., 1994; Larson and Pierce, 1991; Mausbach and Seybold, 1998; Bastida et al., 2008)
Healthy Soil or Poor Soil Health?

Emphasis on Soil Organic Matter Management (Earthworms in a Chile field at Deming, NM)

Healthy Soil (i.e., a diverse Soil Food Web (SFW))

- Higher water-holding capacity
- Lower evaporation
- Higher water-use efficiency
- Lower soil temperature
- Higher infiltration rate & less runoff
- Water-stable aggregates
- Good drainage/permeability
- Optimal nutrient cycling (i.e., soil has a diverse SFW)
- Higher drought tolerance
- Higher buffering capacity
- Good Soil Tilth
- All Biological Spheres are present
- Earthworms are present
- No Compaction

Poor Soil Health

(i.e., a bacterial-dominated Soil Food Web)

- Lower water-holding capacity
- Higher evaporation
- Lower water-use efficiency
- Higher soil temperature
- Lower infiltration rate and more runoff
- Unstable aggregates
- Poor drainage/permeability
- Poor nutrient cycling (i.e., soil has a bacterial-dominated SFW)
- Lower drought tolerance
- Lower buffering capacity
- Poor Soil Tilth (Crusting)
- Some Biological Spheres not present or are in poor condition
- No Earthworms
- Compaction Present

Tillage disrupts ecosystem processes

Slake test

Infiltration demo

HIGH Soil Organic Matter

- Higher water-holding capacity
- Lower evaporation
- Higher water-use efficiency
- Lower soil temperature
- Higher infiltration rate & less runoff
- Water-stable aggregates
- Good drainage/permeability
- Optimal nutrient cycling (i.e., soil has a diverse SFW)
- Higher drought tolerance
- Higher buffering capacity
- Good Soil Tilth
- All Biological Spheres are present
- Earthworms are present
- No Compaction

LOW Soil Organic Matter

- Lower water-holding capacity
- Higher evaporation
- Lower water-use efficiency
- Higher soil temperature
- Lower infiltration rate and more runoff
- Unstable aggregates
- Poor drainage/permeability
- Poor nutrient cycling (i.e., soil has a bacterial-dominated SFW)
- Lower drought tolerance
- Lower buffering capacity
- Poor Soil Tilth (Crusting)
- Some Biological Spheres not present or are in poor condition
- No Earthworms
- Compaction Present

rudy.garcia
This soil is naked, hungry, thirsty and running a fever! Ray Archuleta 2007

Bare soil harms the natural system in many ways. Rainfall washes away precious organic matter. Organic mater holds many crop nutrients, and OM is the lightest fraction of the soil and the first to be carried off site. Bare ground harms the macro and micro organisms...because of lack of carbon (food) in the soil ecosystem. In a bare ground environment, the soil is in starvation mode with no live root to pump carbon (sugars carbohydrates- plant exudates) into the soil system. No food means little microbial activity. Important to note: Carbon is the energy (food) source in the system. Bare ground also increases soil temperature, making the soil less hospitable to soil organisms. Temperatures on bare soil can raise above 115 degrees, some microbes start shut down at these temperatures.
Tillage Addiction: Downward Spiral in Soil Health

Mineral depletion in vegetables
1940 - 1991
- Copper reduced by 76%
- Calcium reduced by 46%
- Iron reduced by 27%
- Magnesium reduced by 24%
- Potassium reduced by 16%
Source: UK Ministry of Agriculture

Mineral depletion in meat
1940 - 1991
- Iron reduced by 54%
- Copper reduced by 24%
- Calcium reduced by 41%
- Magnesium reduced by 10%
- Potassium reduced by 16%
- Phosphorus reduced by 28%
Source: UK Ministry of Agriculture
Reduced Water Holding Capacity

Soil Salinization

Soil Loss Through Wind Erosion

Pollution Through Chemical Runoff

Historic Loss of Soil Carbon

Year

From Lai et al., 1998

Reduce Soil Erosion

Raindrop impact destroys soil aggregates and disperses soil particles...

Creating soil crusts...
What is Tillage?
The physical manipulation of the soil for the purpose of:
- Management of previous crop residue
- Control of competing vegetation (weeds)
- Incorporation of amendments (fertilizer/manure)
- Preparation of a soil for planting equipment
- Recreation for folks who don’t fish or golf.

What Tillage does to the Soil
- Destroys aggregates
- Exposes organic matter to decomposition
- Compacts the soil
- Damages soil fungi
- Reduces habitat for the Soil Food Web
- Disrupts soil pore continuity
- Increases salinity at the soil surface
- Plants weed seeds

No. 1 Environmental Enemy in Production Agriculture

Tillage disrupts ecosystem processes

Tillage destroys Aggregates:
- Tilled soil
- No-till soil

Self explanatory, loss of carbon means loss of dollars and the bottom line
Agricultural soils do not have a water erosion/runoff problem, they have a water infiltration problem.

Healthy soils are held together by soil glues, or gleomalin, that are produced by fungi. Soils rich in soil biota hold together, while soils devoid of soil life fall apart and form a layer of sediment in the bottom of the jar. Pictured above, the soil on the left is from a field that has been managed using no-till for several years. The soil on the right is from a conventionally tilled field.
Downward Spiral of Soil Degradation in annual systems

1. Intensive tillage, insufficient added residues, low diversity, no surface cover

2. Soil organic matter decreases, erosion, subsoil compacted

3. Aggregates break down

4. Surface becomes compacted, crust forms

5. Infiltration decreases
   Erosion by wind and water increases,
   Yield consistency declines

6. MORE ponding & persistent wetness, but LESS soil water storage; less rooting; lower nutrient access efficiency; less diversity of soil organisms, more disease and pests

7. More soil organic matter, nutrients, and top soil lost

8. Crop yields decline

9. Hunger and malnutrition, especially if little access to inputs

Modified from Building Soils for Better Crops
conventional till corn:  
low organic matter  

perennial sod:  
high organic matter  

Soil samples collected from 20 year old conventional till corn and perennial bluegrass sod systems were saturated with water and allowed to dry. Note the soil crusting in the low organic matter conventional till sample compared to the abundance of stable aggregates in the high organic matter perennial sod sample. Photo courtesy Ray R. Weil, University of Maryland.

We need to Start Building Soil Life....ASAP!

Response to soil aggregates after one season

Bulk Density and Compaction

<table>
<thead>
<tr>
<th>Depth</th>
<th>Bulk Density (g/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 inches</td>
<td>1.43</td>
</tr>
<tr>
<td>7 inches</td>
<td>1.90</td>
</tr>
<tr>
<td>8 inches</td>
<td>1.87</td>
</tr>
<tr>
<td>9 inches</td>
<td>1.84</td>
</tr>
<tr>
<td>10 inches</td>
<td>1.80</td>
</tr>
<tr>
<td>1.60</td>
<td></td>
</tr>
<tr>
<td>2.20</td>
<td></td>
</tr>
</tbody>
</table>

Data from Camp and Loe and
Healthy Soils build water-stable aggregates & this prevents water & wind erosion.

Most Biological activity occurs in top 3 inches.

One million pounds or 500 ton of topsoil in top 3 inches.

Average Value of Cropland = $10,000/Acre

Soil Productivity Value: $5,000/500 = $10/Ton

Soil Lost at T value = 4-5 ton/acre

Lost value per acre = $10/ton soil loss * 4-5 tons

Losing $40 to $50 per acre.
Ecological Memory: 1961 Jornada Research Station

Phase shift: 2002 Jornada Research Station

Allan Savory