Soil Building Practices and Forage Nutrient Management

Stone Child College, Box Elder
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MSU Soil Fertility Extension
Why should land owners know something about soils?

• For healthy plants, tasty vegetables, good forage yields, and cover for livestock and wildlife

• To protect the environment

• For efficient use of resources (water, fertilizer, $)
Today’s topics

- Explain soil health vs quality
- Present what can be learned from a soil test
  - Soil properties
  - Soil nutrients
- Discuss which properties you can influence
- Present management for soil health
- Provide fertilizer rate and application guidelines for optimal benefit
- Consider options other than soil tests to guide soil nutrient management
Clickers are better than cell phones because:

25%  A. You don’t listen to Siri giving you wrong directions

25%  B. They don’t need to be turned off during a presentation

25%  C. They screen calls from telemarketers

25%  D. They make your dog obey
What describes a good soil?

• Good aeration, drainage and tilth
• Organic matter and organisms!
• Doesn’t crust, has few clods, and no hardpan
• Soaks up heavy rains with little runoff
• Stores moisture for drought periods
• Resists erosion and nutrient loss
• Produces healthy, high quality forage and vegetables
Mineral ~ 45%
Air ~ 25%
Water ~ 25%
Organic matter ~ 5%

Practices to benefit soil

• Minimize disturbance
• Keep soil surface covered

• Nutrient mgt (soil test; 4Rs)
• Increase diversity
• Keep living root in soil
The plant cover you don’t harvest.....

Affects

• Re-growth rate
• Root growth
• Organic matter
• Nutrient cycling, amount, storage
• Water infiltration and storage
• Soil temperature
Take ½, leave ½ for plant and soil health

<table>
<thead>
<tr>
<th>Aboveground residue (lb/acre)</th>
<th>Water infiltration (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>750</td>
<td>1.0</td>
</tr>
<tr>
<td>2150</td>
<td>8.5</td>
</tr>
<tr>
<td>5800</td>
<td>9.4</td>
</tr>
</tbody>
</table>

High elevation Utah rangeland, Allred 1950

<table>
<thead>
<tr>
<th>Grazing intensity</th>
<th>Water runoff (lb/acre)</th>
<th>Soil loss (tons/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No grazing</td>
<td>23</td>
<td>6.7</td>
</tr>
<tr>
<td>Moderate</td>
<td>121</td>
<td>6.7</td>
</tr>
<tr>
<td>Heavy</td>
<td>202</td>
<td>14</td>
</tr>
</tbody>
</table>

Texas rangeland, Blackburn et al., 1982

NRCS Grazing Management and Soil Health

*Aboveground residue (lb/acre)*

<table>
<thead>
<tr>
<th>Percent Leaf Volume Removed</th>
<th>Percent Root Growth Stopped</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>30%</td>
<td>0%</td>
</tr>
<tr>
<td>40%</td>
<td>0%</td>
</tr>
<tr>
<td>50%</td>
<td>2 to 4%</td>
</tr>
<tr>
<td>60%</td>
<td>50%</td>
</tr>
<tr>
<td>70%</td>
<td>78%</td>
</tr>
<tr>
<td>80%</td>
<td>100%</td>
</tr>
<tr>
<td>90%</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Water infiltration (in/hr)*
Questions?

On to *evaluating soil health*
Soil Quality vs Soil Health

**Soil Quality** = properties that change little, if at all, with land use management practices
- Texture
- pH
- Cation Exchange Capacity

**Soil Health** = dynamic properties which may be more subjective to measure, but can be changed
- Aggregation
- Microbial activity
- Tilth
- Nutrient availability
- Water holding capacity
- Compaction

Which are measured with conventional soil tests?

SOM often is included in both lists
Soil test

• To identify nutrient deficiency or imbalance
• To help calculate fertilizer rates
• Can increase yield and/or save on fertilizer costs, and decrease environmental risks
• Best done in early spring, but not when soil is wet, therefore in our climate perhaps best done in late fall
• See publications listed at end for details on ‘how-to’
### What to look for on a soil test report? Factors affecting plant health and production

<table>
<thead>
<tr>
<th>Factor</th>
<th>Value</th>
<th>Impact/consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient content</td>
<td>Nutrient dependent</td>
<td>Too little = hungry plants, too much = contaminate water, burn plants</td>
</tr>
<tr>
<td>Soil organic matter</td>
<td>≤ 1 (%)</td>
<td>Minimize bare soil, increase N, add legumes</td>
</tr>
<tr>
<td></td>
<td>&gt; 3 (%)</td>
<td>Little need for extra N on pasture</td>
</tr>
<tr>
<td>Soil pH</td>
<td>&lt; 5</td>
<td>Poor seedling establishment</td>
</tr>
<tr>
<td></td>
<td>&lt; 6</td>
<td>Poor legume nodulation</td>
</tr>
<tr>
<td></td>
<td>&gt; 8.3</td>
<td>Nutrients tied up</td>
</tr>
<tr>
<td>Soluble salts (EC)</td>
<td>&gt; 4 (mmhos/cm)</td>
<td>Too saline, water stress, nutrient imbalance</td>
</tr>
<tr>
<td>Soil texture and CEC</td>
<td></td>
<td>Water and nutrient holding capacity</td>
</tr>
</tbody>
</table>
### Example soil test report, submitted by Aaron for Stone Child College (2018)

<table>
<thead>
<tr>
<th>Nutrient In The Soil</th>
<th>Interpretation</th>
<th>1st Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>VLow</td>
<td>Low</td>
</tr>
<tr>
<td>0-6&quot; Nitrate</td>
<td>23 lb/ac</td>
<td></td>
</tr>
<tr>
<td>0-6&quot; Olsen P</td>
<td>5 ppm</td>
<td></td>
</tr>
<tr>
<td>0-6&quot; Potassium</td>
<td>449 ppm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N: supply intended crop and yield goal to calculate N need</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Ideally:
- Olsen-P > 16 ppm
- K > 250 ppm
- OM > 3%
- Salts < 4
- 6 < pH < 80
Comparison of soil test results (top 6”) submitted by Aaron Aquino with adequate soil levels. 4 garden soils and 9 hay field soils.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Garden Range</th>
<th>Hay Field Range</th>
<th>Adequate levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (lb/ac)</td>
<td>13-37</td>
<td>7 - 23</td>
<td>Crop dependent</td>
</tr>
<tr>
<td>Phosphorus (ppm)</td>
<td>3-11</td>
<td>2 - 5</td>
<td>&gt;16</td>
</tr>
<tr>
<td>Potassium (ppm)</td>
<td>304-457</td>
<td>263 - 449</td>
<td>&gt;250</td>
</tr>
<tr>
<td>Chloride (lb/ac)</td>
<td>-</td>
<td>3 - 11</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>Sulfur (lb/ac)</td>
<td>8-18</td>
<td>10 - 16</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>Zinc (ppm)</td>
<td>0.9-1.02</td>
<td>0.43 - 1.48</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>Organic Matter (%)</td>
<td>3.8-6.3</td>
<td>2.2 - 8.7</td>
<td>&gt; 3</td>
</tr>
<tr>
<td>Salts (mmhos/cm)</td>
<td>0.22-0.46</td>
<td>0.14 – 0.29</td>
<td>&lt; 4.0</td>
</tr>
<tr>
<td>pH</td>
<td>6.6 – 8.1</td>
<td>6.2 – 8.1</td>
<td>6.0 – 8.0</td>
</tr>
</tbody>
</table>
Soil pH – which is true?

1. Has no influence on nutrient availability
2. Is difficult to alter
3. Most vegetables prefer pH > 7.5
4. Legumes prefer pH < 6 to fix N

25%  25%  25%  25%
What were surface pH values in this region historically?

pH varies greatly across MT. North-central tends to have neutral to basic (high pH) soils, but growing pockets of acid soil especially in Chouteau County.

<table>
<thead>
<tr>
<th>pH</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5 – 5.0</td>
<td>Gray</td>
</tr>
<tr>
<td>5.0 – 5.5</td>
<td>Light Pink</td>
</tr>
<tr>
<td>5.5 – 6.0</td>
<td>Light Blue</td>
</tr>
<tr>
<td>6.0 – 6.5</td>
<td>Blue</td>
</tr>
<tr>
<td>6.5 – 7.3</td>
<td>Red</td>
</tr>
<tr>
<td>7.3 – 7.8</td>
<td>Green</td>
</tr>
<tr>
<td>7.8 – 8.4</td>
<td>Yellow</td>
</tr>
<tr>
<td>8.4 – 10.2</td>
<td>Dark Red</td>
</tr>
</tbody>
</table>

Map courtesy of NRCS
pH affects soil nutrient availability

Low pH, acidic soils – may limit N, Ca, Mg, Mo because they don’t stick tight and can leach away (Fe) or form minerals (P)

High pH, alkaline calcareous soils – may limit P, Fe, Mn, B, Cu, Zn because they stick tight to the soil, plant can’t get them
What is the best option to lower pH in highly calcareous soils?

17% A. Add elemental sulfur (S)
17% B. Add gypsum (CaSO$_4$)
17% C. Add pine needles
17% D. No reasonable option to lower significantly and QUICKLY on LARGE scale
17% E. Use ammonia based N fertilizers (e.g., urea)
17% F. Plant legumes
What might happen if you add 230 lbs S/1000 sq. ft.?

A. Soil S levels may become toxic
B. Soil salt levels may become toxic
C. You spend $366/1000 sq ft ($16K/acre)
Soil texture

**Sand:** large pore space, low surface area = low water or nutrient holding capacity

**Clay:** small pore space, large surface area, often negative charge on surface = holds water and nutrients tight

Ideal is loam to clay loam approx. equal parts of sand, silt, clay
Mason jar texture test

- Fill a straight-sided jar 1/3 with soil
- Add water until almost full
- Add 1 tsp dishwasher soap or water softener
- Shake and let settle
- Mark sand depth at 1 min.
- Mark silt depth after 6 hours (or by color/texture change with clay at 24 hr)
- Calculate clay by difference (or measure at 24 hours)
Using the soil texture triangle

Clay feels sticky when wet
Silt feels silky smooth when wet
Sand feels coarse and gritty

Loam is a combination of all these
Texture Effects on Soil Properties

<table>
<thead>
<tr>
<th></th>
<th>Drainage</th>
<th>Water holding capacity</th>
<th>Aeration</th>
<th>CEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>excellent</td>
<td>poor</td>
<td>excellent</td>
<td>low</td>
</tr>
<tr>
<td>Silt</td>
<td>good</td>
<td>good</td>
<td>good</td>
<td>medium</td>
</tr>
<tr>
<td>Clay</td>
<td>poor</td>
<td>excellent</td>
<td>poor</td>
<td>high</td>
</tr>
</tbody>
</table>

Soils with large surface areas, such as clay and organic matter, have more cation exchange capacity and surface area and therefore are generally more fertile.
Cation Exchange Capacity CEC – the parking spaces for nutrients in the soil

- CEC is the total neg. charge on a soil
- A high CEC soil (> 15) has the capacity to attract and hold nutrients with positive charges, e.g., K⁺, Zn²⁺, NH₄⁺
- Soils with large surface areas, such as clay and SOM, have more CEC and therefore are generally more fertile.
- What else might high CEC soils hold onto? Herbicides
Management influenced by CEC and texture

• Water
  - low CEC soils – short frequent irrigation (daily) – to avoid leaching nutrients
  - high CEC soils – tend to be clay, slow irrigation less often (e.g., low flow emitters, every 3-4 days)

• Nutrients
  - low CEC soil, a little at a time to avoid leaching loss
  - High CEC, incorporate them – to avoid runoff and get to plant roots
We can’t change CEC of mineral soil or soil pH very well, but can increase SOM to influence soil CEC.

SOM can change:
- Takes a long time on cropland/pasture.
- If you harvest hay, or graze pasture you are maybe maintaining, most likely losing SOM.
How long does it take for SOM to increase from 1.4% to 1.5% on CRP land in top foot?

- A. 2 yrs
- B. 5 yrs
- C. 10 yrs
- D. >20 yrs

Engel, unpub data, MSU Post Farm, 2012
Questions?

On to fertilization
To get the most out of your fertilizer investment

The 4 Rs:

• Right rate
• Right source (including legumes)
• Right timing
• Right Placement
How much fertilizer do I need to apply?

- N based on yield goal and soil tests
- P and K based on soil tests
  - Rate recommendations are provided by testing lab
  - Or from tables given in *Soil Nutrient Management for Forages: Nitrogen* and *Soil Nutrient Management for Forages: PKS & micros*
- S based on field history and deficiency symptoms
- Published rates are developed for entire state and sometimes based on neighbor state’s trials. They are likely not accurate for a particular field. Adjust based on which soil properties??
Focus of N or P and K depends on % legume in stand

Yield increases and net returns greatest if < 36% alfalfa in stand and soil N < 5 lb N/acre (Malhi et al. 2004)
P on established alfalfa

Malhi et al. 1992, Alberta
Diminishing return of increasing N
Applies to all crops, example on irrigated western wheatgrass, Blaine Co.

![Graph showing the effect of N rate on yield (ton/acre).](image)

Christiansen, unpub. data
Sulfur tissue tests and visual symptoms are better than soil tests

- Standard sulfate soil test too unreliable
- Better to use
  - visual symptoms (yellow or light green upper leaves)
  - tissue tests critical values provided by lab or our documents
  - Last year production performance
S influence on forage quality

- N conversion to protein requires S
- Increased S can lead to increased protein (FertFact #27) and digestibility, and reduced nitrate concentration (Westcott unpub data)
Questions?

On to *increasing fertilizer effectiveness*
Challenges to high N use efficiency in perennial systems

- Difficult to incorporate N
- Plant residue
  - intercepts fertilizer
  - increases volatilization
  - can tie up N
Incorporate immediately with water to increase N recovery (likely a volatilization effect)

Eckville, Alberta
Bromegrass, Malhi et al. 1995
Urea placement affects Hays annual forage yield
Optimal timing depends on source

Readily available N (urea, UAN): shortly after grass green-up

Slowly available N (manure, slow-release N)
- take time to become available
- apply well before needed – e.g. fall
Application considerations

Conventional

- Do not apply on snow, before heavy rains or snowmelt
- Apply and incorporate (nitrogen) shortly before plants ‘take off’ in the spring
- Broadcast N fertilizer needs to be incorporated by tillage or ½” water ‘event’
- Provide additional N mid-season if needed

Manure

- Incorporate in the fall or spread composted in the spring, once ground thaws, but before growth starts
- Do not apply on snow or frozen ground
- Consider the salt, weed seed, pathogen and potential herbicide content - know your source!

Other options?
Adding N – having alfalfa in mix may be best source of N

Malhi et al. 2002, Eckville, Alberta
17.5” avg annual and 10.5” May-Aug precip
Forage fertilization strategy

- If a field containing < 75% legumes will be rotated to a different crop soon, consider N for immediate gain
- If goal is low input, long-term sustainable production rather than prime quality hay, adequate P and K are key and cheaper than re- or interseeding
- If you need to buy hay or rent pasture, consider fertilizing for long term benefit
Which likely provides the best net return on dryland forage in Hill County?

33% A. 50 lb N/acre once in 5 years
33% B. 100 lb N/acre once in 5 years
33% C. 0 lb N/acre

A single 50 lb N/acre on dryland grass was more economical over 5-yrs than a single 100 lb N/acre

Balanced fertilization increases yield in mixed dryland brome hay

Started in 1980, annual spring surface broadcast 100 lb N/ac as AN and 9.8 lb S/ac as sulfate. Surface granular lime in 1992 to soil pH 7.

Malhi et al., 2011, SK

N alone reduced brome, NS increased brome in stand, bluegrass/fescue grasses did the reverse
Questions?

On to evaluate and adjust management
Evaluate plant nutrient status in addition to soil test

- Visual assessment of tissue: may identify what has been lacking to this point, once symptoms appear, yield may already be compromised. Examples posted at http://landresources.montana.edu/soilfertility/nutrientdeficiencies.html

- Tissue concentrations, not an exact science either
What is/was deficient here?

33%  A. Live grass
33%  B. Time to read the bag label
33%  C. The wisdom to quit texting while running the spreader

ID of ‘problem’ is not always clear cut
Evaluate and adjust

- Indicators of soil nutrients: yield, quality (taste, appearance, forage nitrate, grain protein), nutrient deficiencies or toxicities
- Use this year’s observations to fine tune rates next year
- What else might be unique to your operation to consider that isn’t on a soil test? Depth to water table, other?
- What other tools?
How can I manage for healthy soils?

- Know your soil’s properties and only add amendments as needed.
- The right source, rate and timing leads to optimal fertilizer use and plant health.
- Observe and adjust to your specific conditions.
- Avoid compaction by:
  - Reducing traffic and tillage when wet.
- Increase the organic matter content by:
  - Moderate grazing.
  - Adding manure.
- Maintain soil cover with vegetation.
Resources

On soil fertility website under *Extension Publications*

http://landresources.montana.edu/soilfertility/

- *Soil Nutrient Management for Forages: N* (EB0217)
- *Soil Nutrient Management for Forages: PKSMicros* (EB0216)
- *Soil Sampling Strategies* (MT200803AG)
- *Interpretation of Soil Test Reports for Agriculture* (MT200702AG)
- *Developing Fertilizer Recommendations for Agriculture* (MT200703AG)
- *Soil Sampling and Laboratory Selection* (4449-1)
  http://landresources.montana.edu/NM/
- *The Soil Scoop*
  http://landresources.montana.edu/soilfertility/soilscoop.html
Pick up a copy or download these Extension Bulletins

http://landresources.montana.edu/soilfertility/publications.html
http://landresources.montana.edu/soilfertility/soilscoop.html
Questions?

Additional info at:
http://landresources.montana.edu/soilfertility/

Photo by Ann Ronning