Soil Testing and Soil Health: Forage Focus

Sanders County Soils Workshop
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Image by Ann Ronning
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 nutrients
  - Soil properties
- Explain limitations, to know which properties you can influence
- Provide fertilizer guidelines and example calculation for forage
- Compare fertilizer sources
- Consider options other than soil tests to guide soil nutrient management
Hands-on is the best way to learn, but we’ll use clickers because....

1. I just had my nails done 33%
2. Clicker training isn’t just for dogs 33%
3. There isn’t enough “dirt” on the floor to get a good soil sample 33%
What describes a good soil?

- Good aeration, drainage and tilth
- Organic matter and organisms!
- Doesn’t crust after planting
- Soaks up heavy rains with little runoff
- Stores moisture for drought periods
- Has few clods and no hardpan
- Resists erosion and nutrient loss
- Produces healthy, high quality vegetables and crops
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 subjective to measure, but can be changed
- Aggregation
- Microbial activity
- Tilth
- Nutrient availability
- Water holding capacity
- Compaction

Which is 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>
Soil test report for 2 fields near Hot Springs, Sanders Co.

### Important info:
- Intended crop
- Yield goal
- Prior crop

#### Soil Fertility Recommendations (Pounds per Acre)

<table>
<thead>
<tr>
<th>YOUR SAMPLE NUMBER (LAB NUMBER)</th>
<th>INTENDED CROP</th>
<th>YIELD GOAL</th>
<th>PREVIOUS CROP</th>
</tr>
</thead>
<tbody>
<tr>
<td>DON (31396506)</td>
<td>ALF/GRASS - ton</td>
<td>5.0</td>
<td>WHEAT WINTER</td>
</tr>
<tr>
<td>SCH 2C (31396507)</td>
<td>ALF/GRASS - ton</td>
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#### Soil Fertility

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</table>
Soil test report for 2 fields near Hot Springs, Sanders Co.

<table>
<thead>
<tr>
<th>LAB NUMBER</th>
<th>NITRATE-N (FIA)</th>
<th>SURFACE</th>
<th>SUBSOIL 1</th>
<th>SUBSOIL 2</th>
<th>Total lb/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ppm</td>
<td>lb/ac</td>
<td>depth</td>
<td>ppm</td>
<td>lb/ac</td>
</tr>
<tr>
<td>96506</td>
<td>8</td>
<td>19</td>
<td>0-8</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>96507</td>
<td>5</td>
<td>12</td>
<td>0-8</td>
<td></td>
<td>12</td>
</tr>
</tbody>
</table>

To determine N rate you need:
1. Yield goal
2. Soil sample depth to convert ppm to lb N/acre
   (ppm x 2 x actual depth in inches / 6)
Soil test report for 2 fields near Hot Springs, Sanders Co.

- P: MSU guidelines are based on Olsen P. Bray works in pH < 7.3, Olsen works pH > 6.
- SOM: soil organic matter
- K
- pH and CEC

| LAB NUMBER | SAMPLE IDENTIFICATION | ORGANIC MATTER | PHOSPHORUS | POTASSIUM | MAGNESIUM | CALCIUM | SODIUM | pH | BUFFER INDEX | CATION EXCHANGE CAPACITY (CEC) | PERCENT: BASE SATURATION (COMPUTED) |
|------------|------------------------|----------------|------------|-----------|-----------|---------|--------|----------------|-------------------------------|----------------------------------|
|            |                        | L.O.L. percent rate | L.O.L. percent rate | L.O.L. ppm rate | L.O.L. ppm rate | L.O.L. ppm rate | L.O.L. ppm rate | SOIL pH | BUFFER INDEX | CEC | % K | % Mg | % Ca | % H | % Na |
| 96506      | DON                    | 3.7 H            | 6 VL        | 22 M       | 7 L        | 139 M   | 365 VH | 2629 H | 151 VH | 8.1  | 17.2 | 2.1  | 17.7 | 76.4 | 0.0  | 3.8  |
| 96507      | SCH 2C                 | 1.9 L            | 4 VL        | 31 M       | 5 L        | 110 M   | 243 VH | 2009 H | 7.5    | 12.4 | 2.3  | 16.3 | 81.4 | 0.0  | 0.0  |
Six questions to ask yourself before you add fertilizer

1. Which elements do I need? (N, P, K, S, Ca)
2. How much do I apply?
3. What type of material do I use?
4. Which application method is best?
5. When is the best time to apply it?
6. Will I get a return ($ or environmental) on my investment?
How much fertilizer do I need to apply?

- Estimate the amount of fertilizer needed based on soil test results and desired production.
- Focus of N vs P & K fertilization in forages depends on % legume in stand.
- MSU bulletins provide rate guidelines and MT200703AG gives example calculations.

Fertilizing with nutrients other than N favors legumes over grass.
Using this data and tables from the 2 forage soil scoops, how much N, P, and K are required to grow 3 ton/acre of grass?

Your turn

<table>
<thead>
<tr>
<th></th>
<th>OM %</th>
<th>Nitrate –N lb/ac</th>
<th>P ppm</th>
<th>K ppm</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>1.8</td>
<td>15</td>
<td>13</td>
<td>200</td>
<td>7.5</td>
</tr>
</tbody>
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N, P, and K rates?

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*Need to subtract out soil nitrate-N from available N need*
Diminishing return of increasing N
Applies to all crops, example on irrigated western wheatgrass, Blaine Co.
Challenges to high N use efficiency in perennial systems, and N options

- Urea needs 0.5” water or tillage to incorporate N
- Plant residue
  - intercepts fertilizer
  - increases volatilization
  - can tie up N
- Surface band liquid N
- Polymer coated N works for extended forage season or late cutting
- Legume in pasture mix or legume cover crop in market gardens may be best N source

Malhi et al. 2002, Eckville, Alberta
17.5” avg annual and 10.5” May-Aug precip
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
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.
- A single 50 lb N/acre on dryland grass was more economical over 5-yrs than a single 100 lb N/acre.

P and K fertilization strategy

Is a single 100-400 lb P$_2$O$_5$/ac on dryland alfalfa as good as the same amount divided over 5 annual applications?

50%  A. Yes
50%  B. No

A large application produced similar yield, protein and profit as 5 small annual applications (central Alberta, Malhi et al. 2001).

Immobile nutrients can be banked – know soil test levels and if low, build up P and K when prices low.
Questions?

On to conventional vs organic matter
Conventional/chemical fertilizers

- No carbon
- Easy to store
- Higher nutrient concentration
- Custom formulated
- Easy to use – but calibrate your equipment
- Liquid and solid
- Coated specialty products reduce leaching, volatilization, runoff losses.
Organic Fertilizers

- Bulkier
- Nutrient content low
- Nutrient content difficult to quantify
- Supply organic matter and other soil quality benefits

<table>
<thead>
<tr>
<th>Type</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure compost</td>
<td>0.3 - 0.5</td>
<td>0.1 – 0.5</td>
<td>0.2 – 0.6</td>
</tr>
<tr>
<td>Garden waste</td>
<td>1 – 1.5</td>
<td>0.2 – 0.5</td>
<td>0.5 – 1.5</td>
</tr>
</tbody>
</table>
Approximately how much total N, P, and K does 1” of manure compost supply?

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removed annually$^1$</td>
<td>3.4</td>
<td>0.3</td>
<td>3.2</td>
</tr>
<tr>
<td>Added by 1” manure</td>
<td>40</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Added by 1” manure</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>

To add 5 lb N/1000 sq. ft. takes approx. 500 lb manure compost or 11 ton/acre

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

Specialty slow release

- Incorporate and apply early in growing season or use blend of quickly available source and slow release
Application considerations: organic material

- 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
- N can be ‘tied up’ due to high C
- Manure:
  - Creates rapid buildup of P and K if fertilizing to meet N needs. Feed to P and K demands and use legumes to supply N
  - Consider the salt, weed seed and pathogen content
  - Herbicide residual; SOM has huge CEC, CEC holds onto herbicides - know your source!
Questions?

On to other factors that influence soil nutrient management
Published rates are developed for entire state and sometimes based on neighbor state’s trials. They are likely not accurate for a particular field.
Which soil property does **not** influence nutrient availability?

- A. Texture/surface area  
- B. pH  
- C. CEC (cation exchange capacity = the parking spaces in soil for nutrients)  
- D. SOM (soil organic matter)  
- E. Color

22% A. Texture/surface area
21% B. pH
16% C. CEC (cation exchange capacity = the parking spaces in soil for nutrients)
18% D. SOM (soil organic matter)
24% E. Color
**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
## Texture Effects on Soil Properties

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.
Soil pH – which is true?

1. Has no influence on nutrient availability 25%
2. Is difficult to alter 25%
3. Most vegetables prefer pH > 7.5 25%
4. Legumes prefer pH < 6 to fix N 25%
What are surface horizon pH values in this region?

There are known areas in western Montana with top 6” pH < 5.5
Ex: Near Hamilton and Plains,
Other areas have pH levels near 8.0.

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 (CaSO₄)
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
Adding elemental sulfur

Soil pH

Sulfur Added (lb/1000 sq. ft.)

Consequences?
Costs?

April
5 months later

0
23
230

10,000 lb/acre

AgVise Laboratories
What might happen if you add 230 lbs S/1000 sq. ft.?

A. You spend $366/1000 sq ft  
B. Your soil pH will drop by at least 1.5 units  
C. Soil S levels will remain well below toxic  
D. Soil salt levels will improve  

Response Counter

Same study site – added 115 lbs gypsum /1000 sq. ft. with no change in soil pH
Acid soils have many negative impacts

- Herbicide persistence (Raeder et al., 2015)
- Damaging to rhizobia (N-fixing by legumes)
- Increase in fungal diseases
- Increase Al and Mn to toxic levels
Factors that contribute to acidification

- Coarse soils
- Higher precipitation
- No-till (less subsoil mixing)
- Excess N fertilization
- See *Soil Acidification* Soil Scoops. Rick Engel is developing MT specific recommendations

Engel, Ewing, Miller unpub data

- Low organic matter
- Stubble or hay removal

![Graph showing factors contributing to acidification](image)

CRP and pea-wheat

100 lb N/acre

0.06 pH units

14-yr cumulative N inputs, lb/acre

Engel, Ewing, Miller unpub data
Select plants suitable to your soil’s pH

<table>
<thead>
<tr>
<th>Crop</th>
<th>Preferred pH</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet pea</td>
<td>7 - 8</td>
<td>You grow blueberries, the Gallatin Valley grows sweet peas!</td>
</tr>
<tr>
<td>Blueberry</td>
<td>4.5 – 6.0</td>
<td></td>
</tr>
<tr>
<td>Raspberry</td>
<td>5.0 – 7.5</td>
<td></td>
</tr>
<tr>
<td>Burr clover</td>
<td>&gt; 7</td>
<td>Select species suitable for pH and soil type, see: <em>Dryland Pastures in MT and WY</em></td>
</tr>
<tr>
<td>Alfalfa</td>
<td>&gt; 5.7</td>
<td></td>
</tr>
<tr>
<td>Blue grama grass</td>
<td>&gt; 7</td>
<td></td>
</tr>
<tr>
<td>White clover</td>
<td>&lt; 7</td>
<td></td>
</tr>
</tbody>
</table>
Questions?

On to cation exchange capacity CEC and soil organic matter SOM
SOM = Soil organic matter

What does SOM NOT do for soil?

17% A. Increase cation exchange capacity
17% B. Provide nutrients as it decomposes
17% C. Hold water which helps nutrients move from soil to plant roots
17% D. Consistently reduce soil pH
17% E. Reduce soil compaction
17% F. Increase water infiltration

High surface area and CEC (215 meq/100 g for SOM vs. 58 for clay)
Changing SOM

- We can’t change CEC of mineral soil or soil pH very well, but can increase SOM to influence soil CEC
- Guesses on how long to increase SOM from 1.4 to 1.5%
- SOM can change:
  - takes a long time on cropland/pasture – MSU study, CRP (ungrazed, unharvested alfalfa) increased from 1.4% SOM to 1.48% SOM in 10 years in top foot.
  - If you harvest hay, or graze pasture you are maybe maintaining, most likely losing SOM
What is/was deficient here?

33%  A. Ability to spell
33%  B. Time to read the bag label
33%  C. Shouldn’t have handed the dog the spreader

ID of ‘problem’ is not always clear cut
Evaluate soil 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
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
Questions?