Soil fertility and nutrient cycling in grazing systems

Dennis Hancock
Extension Forage Specialist
UGA – Dept. of Crop and Soil Sciences

“What’s in the soil, is in the plant, is in the animal, ....”

Plant Nutrients

<table>
<thead>
<tr>
<th>Macro- (Primary)</th>
<th>Element</th>
<th>Available Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>O₂, OH</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>CO₂, HCO₃, CO₃</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H⁺, OH⁻</td>
<td></td>
</tr>
<tr>
<td>Nitrogen</td>
<td>NO₂⁻, NH₄⁺</td>
<td></td>
</tr>
<tr>
<td>Phosphorus</td>
<td>H₂PO₄⁻, HPO₄²⁻</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td>K⁺</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Meso- (Secondary)</th>
<th>Element</th>
<th>Available Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>Ca²⁺</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg²⁺</td>
<td></td>
</tr>
<tr>
<td>Sulfur</td>
<td>SO₄²⁻</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Micro- (Trace)</th>
<th>Element</th>
<th>Available Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>Fe²⁺, Fe³⁺</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>Cu²⁺, Cu⁺</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn²⁺</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn²⁺, MnO₄⁻</td>
<td></td>
</tr>
<tr>
<td>Molybdenum</td>
<td>MoO₃⁻, H₂MoO₄⁻</td>
<td></td>
</tr>
<tr>
<td>Boron</td>
<td>H₃BO₃, B₂O₃²⁻</td>
<td></td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl⁻</td>
<td></td>
</tr>
</tbody>
</table>

Soil Test and Follow Fertility Recommendations

Sample hay and crop fields every year and 1/3 of your paddocks each year.

Soil Test Ranges

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Low</th>
<th>Med</th>
<th>High</th>
<th>V. High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus</td>
<td>0-30</td>
<td>31-60</td>
<td>61-100</td>
<td>101+</td>
</tr>
<tr>
<td>Potassium</td>
<td>0-60</td>
<td>61-150</td>
<td>151-250</td>
<td>250+</td>
</tr>
<tr>
<td>Calcium</td>
<td>0-200</td>
<td>Adequate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td>0-30</td>
<td>31-60</td>
<td>61+</td>
<td>Coastal Plain</td>
</tr>
</tbody>
</table>

Dr. Dennis Hancock
Extension Forage Agronomist
Dr. Dennis Hancock
Extension Forage Agronomist

2010 Georgia Grazing School:
Soil fertility and nutrient cycling in grazing systems

"All Kinds of Wacky"

Costs Increase When Soil Fertility Decreases

Let's assume P & K have been equally taken care of or equally neglected. So, let's consider bermudagrass fertility.

<table>
<thead>
<tr>
<th>P &amp; K Fertility</th>
<th>Recommended Rate of</th>
<th>Total Cost (lbs/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>P₂O₅</td>
<td>K₂O</td>
</tr>
<tr>
<td>V. High</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>High</td>
<td>250</td>
<td>30</td>
</tr>
<tr>
<td>Medium</td>
<td>250</td>
<td>60</td>
</tr>
<tr>
<td>Low</td>
<td>250</td>
<td>80</td>
</tr>
</tbody>
</table>

Assumptions: Using 28% UAN ($280/ton), DAP ($500/ton), and Muriate of Potash ($525/ton).

What affects pasture cost?

Pasture Cost ($/lb) = \frac{Total Cost ($/Acre)}{Forage Yield (lbs/Acre)}

The False Economy of Shortcuts

Cost of Production Compared to Average

<table>
<thead>
<tr>
<th>Yield</th>
<th>70%</th>
<th>80%</th>
<th>90%</th>
<th>100%</th>
<th>110%</th>
<th>120%</th>
<th>130%</th>
</tr>
</thead>
<tbody>
<tr>
<td>130%</td>
<td>54</td>
<td>62</td>
<td>69</td>
<td>77</td>
<td>85</td>
<td>93</td>
<td>100</td>
</tr>
<tr>
<td>120%</td>
<td>58</td>
<td>67</td>
<td>75</td>
<td>83</td>
<td>92</td>
<td>100</td>
<td>108</td>
</tr>
<tr>
<td>110%</td>
<td>64</td>
<td>73</td>
<td>82</td>
<td>91</td>
<td>100</td>
<td>110</td>
<td>118</td>
</tr>
<tr>
<td>100%</td>
<td>70</td>
<td>80</td>
<td>90</td>
<td>100</td>
<td>110</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>90%</td>
<td>78</td>
<td>88</td>
<td>100</td>
<td>111</td>
<td>122</td>
<td>133</td>
<td>144</td>
</tr>
<tr>
<td>80%</td>
<td>88</td>
<td>100</td>
<td>113</td>
<td>125</td>
<td>138</td>
<td>150</td>
<td>163</td>
</tr>
<tr>
<td>70%</td>
<td>100</td>
<td>114</td>
<td>129</td>
<td>143</td>
<td>157</td>
<td>171</td>
<td>186</td>
</tr>
</tbody>
</table>

Get your priorities right!

Maintaining soil pH is job #1.
• Nutrient availability
• Soil structure
• Soil biological activity
• Aluminum toxicity

“Lime is cheap.”

The University of Georgia
College of Agricultural & Environmental Sciences
2010 Georgia Grazing School:
Soil fertility and nutrient cycling in grazing systems

**How Soil pH Affects Availability of Plant Nutrients**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Amt. Used Annually</th>
<th>Unit Price</th>
<th>Dec. in Efficiency</th>
<th>Value of Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>300</td>
<td>$0.50</td>
<td>35%</td>
<td>-$53</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>60</td>
<td>$0.43</td>
<td>50%</td>
<td>-$13</td>
</tr>
<tr>
<td>K₂O</td>
<td>250</td>
<td>$0.46</td>
<td>10%</td>
<td>-$12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>-$78</strong></td>
</tr>
</tbody>
</table>

Get at the Root of a Problem:
Soil pH Problems

**Low Soil pH = Aluminum Toxicity**

Soil Acidity and CEC

Strength of cations:
Al³⁺ > H⁺ > Ca²⁺ > Mg²⁺ > K⁺

Dr. Dennis Hancock
Extension Forage Agronomist
Nitrogen Use

Use of Urea-Based Products

- Without AN, users of N face risky alternatives.
  - NH₃ volatilization loss

- Urease is abundant in thatch & organic layers
  - High N use in hay.

- Enhanced Efficiency N Fertilizer Products may reduce volatilization loss
  - Urease inhibition
  - Encapsulate & release

Ammonia Volatilization Trap Data

2008-2009 (avg. over two locations)

- Urea
- Agrotain
- ESN
- CDN

N Loss to Volatilization

Farm A
32%

Farm B
12.5%

Eason, N. M.S. Thesis. 2010.

Agrotain Treated Urea

as compared to urea applied in the same way (averaged over 4 site-yrs):

- Reduced ammonia volatilization by over 63%.
- Produced 11% more forage yield.
- Recovered 19% more of the applied N.
- Did not substantially affect crude protein content.
- Did not substantially affect the risk of nitrate toxicity.
Another Fertilization Trick

Split Your Nitrogen Applications!

- Long-term, this can increase yields by 5-10% and increase NUE by 25-30%
- Especially important under extremes
  - Leaching
  - Volatilization (in the case of urea-based products)
  - Late freeze
  - Drought

Another Fertilization Trick

Apply P in late summer or fall.

- P can essentially be applied any time during the year on established forage crops.
- Purchase P fertilizer in “off-peak” times of the year (i.e., summer and fall)
  - Demand for the product is low
  - Demand for spreading services is low
  - Less risk of P runoff

Nitrogen Response: Rules of Thumb

<table>
<thead>
<tr>
<th>Forage Type</th>
<th>Early Season</th>
<th>Mid-Season</th>
<th>Late-Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal bermuda</td>
<td>30-45</td>
<td>35-45</td>
<td>20-35</td>
</tr>
<tr>
<td>Tifton 85 bermuda</td>
<td>30-40</td>
<td>45-55</td>
<td>30-40</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>5-12</td>
<td>10-20</td>
<td>15-30</td>
</tr>
</tbody>
</table>

* N fertilization above ~40, 50, or 25 lbs of N/acre for Coastal, Tifton 85, and ryegrass, respectively.

**Cost Implications of Different Nitrogen Response Rates**

<table>
<thead>
<tr>
<th>Nitrogen Response N Response Above Critical Level</th>
<th>Forage Type</th>
<th>Early Season</th>
<th>Mid-Season</th>
<th>Late-Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbs of DM/lb of N added</td>
<td>Coastal bermuda</td>
<td>30-45</td>
<td>35-45</td>
<td>20-35</td>
</tr>
<tr>
<td></td>
<td>Tifton 85 bermuda</td>
<td>30-40</td>
<td>45-55</td>
<td>30-40</td>
</tr>
<tr>
<td></td>
<td>Annual ryegrass</td>
<td>5-12</td>
<td>10-20</td>
<td>15-30</td>
</tr>
</tbody>
</table>

**Value of the Substitute**

<table>
<thead>
<tr>
<th>Crop</th>
<th>$/bu</th>
<th>$/lb</th>
<th>$/ton</th>
<th>$/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>$4.00</td>
<td>$0.071</td>
<td>$45</td>
<td>$0.023</td>
</tr>
<tr>
<td>$/ton</td>
<td>$4.50</td>
<td>$0.080</td>
<td>$50</td>
<td>$0.025</td>
</tr>
<tr>
<td>$/lb</td>
<td>$5.00</td>
<td>$0.089</td>
<td>$60</td>
<td>$0.030</td>
</tr>
<tr>
<td>$/ton</td>
<td>$7.00</td>
<td>$0.125</td>
<td>$75</td>
<td>$0.038</td>
</tr>
<tr>
<td>$/lb</td>
<td>$7.00</td>
<td>$0.125</td>
<td>$75</td>
<td>$0.038</td>
</tr>
<tr>
<td>Corn Silage</td>
<td>$130</td>
<td>$0.065</td>
<td>$100</td>
<td>$0.050</td>
</tr>
<tr>
<td>$/ton</td>
<td>$150</td>
<td>$0.075</td>
<td>$120</td>
<td>$0.060</td>
</tr>
<tr>
<td>$/lb</td>
<td>$170</td>
<td>$0.085</td>
<td>$140</td>
<td>$0.070</td>
</tr>
<tr>
<td>$/ton</td>
<td>$200</td>
<td>$0.100</td>
<td>$175</td>
<td>$0.088</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ryegrass Baleage</th>
<th>$/dry ton</th>
<th>$/lb</th>
<th>$/dry ton</th>
<th>$/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$/dry ton</td>
<td>$100</td>
<td>$0.050</td>
<td>$120</td>
<td>$0.060</td>
</tr>
<tr>
<td>$/lb</td>
<td>$140</td>
<td>$0.070</td>
<td>$175</td>
<td>$0.088</td>
</tr>
<tr>
<td>$/dry ton</td>
<td>$175</td>
<td>$0.088</td>
<td>$200</td>
<td>$0.100</td>
</tr>
</tbody>
</table>

**K is for Persistence**

- Not Competitive
- Leafspot Diseases
- Poor Winterhardiness
- Grows Very Slow
- Poor Stress Tolerance
- The Stand is Gone!

Dr. Dennis Hancock
Extension Forage Agronomist
2010 Georgia Grazing School: Soil fertility and nutrient cycling in grazing systems

**K is the Key to a Good Stand**

*Graph showing the relationship between K₂O application rate and stand density and rhizome production.*

- Initial soil K was low (51 ppm by Texas A & M extraction)

**Another Fertilization Trick**

*Split Your Potassium Applications!*

- 40-50% in the Spring
- 50-60% in mid – late season

**Troubleshooting**

**Bad Zones**
- Tissue Sample
- Soil Sample
- Other?

**Representative Samples**
- ~ 20 similar specimens

**Tissue Sampling**

**K and Nutrition for Late Gestation and Close-Up Cows**

- Proper K conc. in bermudagrass to promote stand life is 1.8-2.0% or more.
- Close-up cows need a low DCAD (dietary cation anion diff.)
  - DCAD = (Na + K) - (Cl + S)
  - ~10 - 15 meq per 100 g DM
  - K should be < 1.5% in the diet
- K nutrition is critical for heat stress
  - K should be > 1.9% during heat stress
  - Grains, corn silage are typically low (<1.2%)
  - Brewer’s grains are one of the lowest (<0.6%)

**Chicken Litter**

Makes Good Fertilizer…

Dr. Dennis Hancock

Extension Forage Agronomist
Variability in Chicken Litter

- **“Book Number”**
  - 3-3-2
- Range in % N
  - 1.1 – 4.9%
- Range in % P₂O₅
  - 0.9 – 4.8%
- Range in % K₂O
  - 1.2 – 4.0%


Poultry Litter - Disadvantages

- Weed pressure does increase
  - Not a source of weed seed
  - Changes the fertility and makes broadleaf weeds more competitive.
- Potassium fertilization may not be adequate
  - Poultry Litter: 3-3-2
  - Ideal bermudagrass fertilizer: 5-1-4
- May result in excessive sulfur levels
  - Some evidence for a link to copper deficiency in cattle.

Variability in Chicken Litter

- **“Book Number”**
  - 3-3-2
- Range in % N
  - 1.1 – 4.9%
- Range in % P₂O₅
  - 0.9 – 4.8%
- Range in % K₂O
  - 1.2 – 4.0%


The Value of Litter

**Pre 2005 Prices**

- 60 # PAN x .28 x .5 = 8.40
- 60 # P₂O₅ x .22 x .8 = 10.56
- 40 # K₂O x .12 x .8 = 3.84
- **Total = $22.80**

**2010 Prices**

- 60 # PAN x .50 x .5 = 15.00
- 60 # P₂O₅ x .43 x .8 = 20.64
- 40 # K₂O x .44 x .8 = 14.08
- **Total = $49.72**

Benefits of Rational Grazing

1. Better utilization of forage
2. Growth rate of forage is optimized
   - Kept in linear/exponential growth phase
   - Higher yield of forage
3. Higher stocking rates
4. More animal gains/milk production per acre
5. Reduced feeding of conserved forage or supplements
6. Better persistence of desirable forages
   - Especially clover and legume species
7. Better weed suppression
8. Better manure distribution

The Value of Litter

- **Other Nutrients?**
  - Organic Matter?
  - Liming?
  - Nematode Suppression?

Too much of a good thing?

- Control
- Fertilizer
- Poultry Litter @ 4 tons/acre
- Poultry Litter @ 8 tons/acre

Dr. Dennis Hancock
Extension Forage Agronomist
Nutrient Distribution in Continuously Grazed Pastures

Manure Distribution

Efficiency of Four-legged Manure Spreaders

Nutrient Re-deposition

Pasture-based dairy in western Virginia.

2010 Georgia Grazing School:
Soil fertility and nutrient cycling in grazing systems

Dr. Dennis Hancock
Extension Forage Agronomist

White et al., 2001 J. Environ. Qual. 30:2180–2187

Rotation Frequency Years to Get
Continuous 1 Pile/sq. yard
Continuous 27
14 day 8
4 day 4 – 5
2 day 2

The University of Georgia
College of Agricultural & Environmental Sciences