Using Whole Farm Management of Crop/Livestock Systems to Reduce the Phosphorus Index

Tom Cox: UW-Madison, Ag Economist
Jim Leverich: UW-Extension On-Farm Research Coordinator
Dan Undersander: UW Extension Forage Agronomist Specialist
Randy Shaver: UW Extension Dairy Nutrition Specialist
Laura Ward Good: UW Soil Science, SNAP+ Project Coordinator

Presented at the 2009 World Dairy Expo
Wednesday, Sept 30, 2009
Phosphorus (P) Index

What is it from a practical view?

• Index of Soil and Sediment Bound and Soluble Phosphorous Nutrient Losses.
• Combines Information from RUSLE 2 with nutrient and crop runoff to predict how much P is moving off a field.

Whole Farm Management
SNAP-Plus Calculates P Index

**Entry by field:**
County, Soil, Slope, Soil test, Crop rotation, Yields, Tillage, Manure, Fertilizer

**Nutrient application calculator**

**P Index calculator**

**Output by field:**
- Fertilizer and manure application plan,
- Rotation soil loss assessment,
- Rotation P Index Value,
- Rotation P and K balance

Whole Farm Management
RUSLE2 equation is basically: $a = r k l s c p$

Average annual soil loss ($a$) = sum of Daily Soil Loss Values, where Daily Factors are:

- $r$ - Rainfall/Runoff
- $k$ - Soil erodability
- $l$ - Slope length
- $s$ - Slope steepness
- $c$ - Cover-management
- $p$ - Supporting practices
RUSLE2 Soil Loss Measurement

- So changes to overall soil loss are proportional to the \( c \) (cover management) factor differences.
- **NOTE:** Lower \( c \) (cover management) factors imply less soil loss!!!
- In turn, the WI P-Index is computed from the RUSLE2 Soil Loss Estimates.
  - Less Soil Loss Implies Lower WI P-Index!!!

- You can see more about the soil loss equation at:
RUSLE2 Soil Loss Measurement: C Factors

- Compute Cover Management Factor (C Factor) with:
- Fall Disk Chisel and Spring field cultivation.

Computations by: Judy Derricks-NW Assistant for Field Operations (NRCS/USDA)

<table>
<thead>
<tr>
<th>Management Practice</th>
<th>C Factor</th>
<th>% Change to BASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Alfalfa with no grass in a three year rotation (BASE)</td>
<td>0.062</td>
<td>0%</td>
</tr>
<tr>
<td>Direct Alfalfa with grass (we generally assume brome) in a three year rotation</td>
<td>0.031</td>
<td>-50.0%</td>
</tr>
<tr>
<td>Companion crop of oats for grain with straight Alfalfa</td>
<td>0.028</td>
<td>-54.8%</td>
</tr>
<tr>
<td>Companion crop of oats for grain with Alfalfa and grass</td>
<td>0.012</td>
<td>-80.6%</td>
</tr>
</tbody>
</table>

Whole Farm Management
Cover Management in Alfalfa Hay

- **This simple example indicates that:**
  - Adding grass (e.g., brome) to a 3 year hay rotation reduces soil loss ~50%.
  - Planting a companion (nurse) crop with alfalfa establishment provides similar performance.
    - Reduces soil loss: ~58%.
    - **SYNERGY**: Combining these Hay Cover Management Strategies provides even stronger environmental performance gains!!!
      - Reduces soil loss: ~80%.
Traditional Conservation Management Options which Lower Soil Losses and P Index

- Terracing
- Strip Cropping
- Contour Strips
- Conservation Tillage – Chisel Plowing
- Buffer Strips
New Approach: Use Whole Farm Management Options to Lower Soil Losses and P Index

- Use Snap+ to Estimate Soil and P Losses
- Identify Farm Management Options That Lower P Index & Improve Profit
- Use FARM and Optimization to Rank Options.
- Use Dynamic Feedback Decision System with Producers to Verify Feasibility of “Best” Option

Whole Farm Management
Dynamic Feedback Decision System

**Processing:**
- Analytical models, hypotheses testing, measurement protocols, predictions, validations, etc.

**SNAP+ Optimization**

**DATA**

**Feedback Loop “Processing”**
- Feedback Loop: data needs to improve information yields and usefulness, etc.
  - Scientists: “first among equals”.

**INFORMATION**

**Feedback Loop “Processing”**
- Feedback Loop: information needed to improve decision models yields and usefulness, “value added” opportunities, etc.
  - Decision Makers: “first among equals”.

**DECISIONS**

**Information:**
- Key drivers (ranked, direction and magnitude); validated measurement protocols; forecasts (means, variances and empirical distributions); triage protocols.
- Examples: PI, response functions, significant differences, etc.

**Decisions:**
- Decisions models, strategies, forecasts (means, variances and empirical distributions), performance evaluation, etc.
- Examples: SNAP+, N-Cycle, Optimization.
Whole Farm Management Options Which Can Improve P Index

- No-Till vs Conservation Tillage Corn
- No-Till vs Conservation Tillage Corn Silage
- No-till Hay Crop Seeding
- Seeding With a Companion Crop
- Seeding Different Grasses with Alfalfa Rather than Pure Alfalfa
Whole Farm Management Options Which Can Improve P Index

- Increasing Hay Acres Relative to Corn Silage Acres in Rotation
- Shortened Rotations
- Manure Application Options
- Manure Separation Technologies
Today’s Example:
Seeding Different Grasses
with Alfalfa Versus Pure Alfalfa

We’ll Talk About:

• Improvement in Water Quality
• Management Issues
  – Grass Selection
  – Harvest Timing and Management
  – Feed Quality
  – Ration Management
Seeding Different Grasses with Alfalfa Versus Pure Alfalfa

- Grass Selection: Type, Yield, Maturity
  - Yield Differences between Top/Bottom Entry in UW Grass Variety Trials.
Seed high yielding orchardgrass or tall fescue:

- Yield distribution better than Smooth Bromegrass and Timothy
- More growth after first cutting, therefore more consistent alfalfa/grass mixture.
## Seeding Different Grasses with Alfalfa Versus Pure Alfalfa

<table>
<thead>
<tr>
<th>Total Yield</th>
<th>Percent of Total Yield Available in Each Month</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% May</td>
</tr>
</tbody>
</table>

### For Northern and Central Wisconsin and Minnesota

<table>
<thead>
<tr>
<th>Grass Type</th>
<th>Yield</th>
<th>% May</th>
<th>% June</th>
<th>% July</th>
<th>% Aug</th>
<th>% Sept</th>
<th>% Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>alfalfa/grass</td>
<td>4.77</td>
<td>20</td>
<td>30</td>
<td>30</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>2.35</td>
<td>30</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>orchardgrass</td>
<td>3.79</td>
<td>25</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>reed canarygrass</td>
<td>4.73</td>
<td>25</td>
<td>20</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>smooth bromegrass</td>
<td>4.45</td>
<td>35</td>
<td>20</td>
<td>20</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>tall fescue</td>
<td>3.9</td>
<td>15</td>
<td>25</td>
<td>20</td>
<td>15</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>timothy</td>
<td>2.4</td>
<td>25</td>
<td>30</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
</tbody>
</table>

### For Southern Wisconsin and Minnesota

<table>
<thead>
<tr>
<th>Grass Type</th>
<th>Yield</th>
<th>% May</th>
<th>% June</th>
<th>% July</th>
<th>% Aug</th>
<th>% Sept</th>
<th>% Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td>alfalfa/grass</td>
<td>4.91</td>
<td>20</td>
<td>25</td>
<td>35</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Kentucky bluegrass</td>
<td>2.84</td>
<td>30</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>orchardgrass</td>
<td>4.22</td>
<td>20</td>
<td>35</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>reed canarygrass</td>
<td>4.39</td>
<td>20</td>
<td>30</td>
<td>25</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>smooth bromegrass</td>
<td>4.04</td>
<td>30</td>
<td>30</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Tall fescue</td>
<td>3.97</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>timothy</td>
<td>3.13</td>
<td>25</td>
<td>35</td>
<td>10</td>
<td>10</td>
<td>15</td>
<td>5</td>
</tr>
</tbody>
</table>
Seeding Different Grasses with Alfalfa Rather than Pure Alfalfa

- High yielding, rust resistant varieties will yield 2 to 3 t/a more than common varieties.
- Late maturing varieties head close to alfalfa harvest timing, common types head up to 2 weeks earlier before alfalfa is ready to harvest.
Seeding Different Grasses with Alfalfa Rather than Pure Alfalfa

Increased Yield of Improved Ryegrass Over Common Varieties, UW Field Trials

Annual Difference Between Top and Bottom Yielding Variety, UW Field Trials

Whole Farm Management
Seeding Different Grasses with Alfalfa Rather than Pure Alfalfa

- Maturity of Different Orchardgrass Varieties
  - Variety on the x-axis
  - Heading date on the y-axis

- Heading Date of Different Orchardgrass Varieties
  - Heading Date on the x-axis
  - Variety on the y-axis

Whole Farm Management
Seeding Different Grasses with Alfalfa Rather than Pure Alfalfa

Seasonal Distribution of Different Orchardgrass Varieties

- Variety 1
- Variety 2
- Variety 3

Whole Farm Management
Harvest Timing, Chopper Setup, Drying Time and Packing Management

- First cutting, harvest when grass heads or alfalfa at mid-bud which ever is first
- Later cuttings, grass is leaves only so cut when alfalfa is ready, have wider harvest window since grass quality does not change while alfalfa is increasing in yield and declining in quality.
- For 30 to 40 % grass harvest timing, drying management, chopper setup, and packing management little changed.
Feeding Quality RFQ

- Forage quality of alfalfa grass mixes
- Digestibility of Grasses versus Alfalfa
- Ration Balancing Differences
- N Credits

Whole Farm Management
Lactating dairy cow diet simulations with varying proportions of corn silage, alfalfa silage and grass silage.

<table>
<thead>
<tr>
<th>CS:HCS 1</th>
<th>AS:GS 2</th>
<th>Forage</th>
<th>DMI 3 (lb/d)</th>
<th>NDF from Forage</th>
<th>Total NDF</th>
<th>NEL Allowable Milk 4 (lb/d)</th>
<th>MP Allowable Milk 4 (lb/d)</th>
<th>Purchased Feed Cost 5 ($)/cow/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>r1</td>
<td>25:75</td>
<td>100:0</td>
<td>50%</td>
<td>50</td>
<td>21</td>
<td>27</td>
<td>84</td>
<td>89</td>
</tr>
<tr>
<td>r2</td>
<td>50:50</td>
<td>50%</td>
<td>50</td>
<td>23.5</td>
<td>29</td>
<td>84</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>r3</td>
<td>0:100</td>
<td>50%</td>
<td>50</td>
<td>26</td>
<td>31</td>
<td>83</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>r4</td>
<td>50:50</td>
<td>100:0</td>
<td>50%</td>
<td>50</td>
<td>22</td>
<td>27</td>
<td>85</td>
<td>90</td>
</tr>
<tr>
<td>r5</td>
<td>50:50</td>
<td>50%</td>
<td>50</td>
<td>24</td>
<td>29</td>
<td>84</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>r6</td>
<td>0:100</td>
<td>50%</td>
<td>50</td>
<td>26</td>
<td>31</td>
<td>84</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>r7</td>
<td>75:25</td>
<td>100:0</td>
<td>50%</td>
<td>50</td>
<td>22</td>
<td>27</td>
<td>86</td>
<td>91</td>
</tr>
<tr>
<td>r8</td>
<td>50:50</td>
<td>50%</td>
<td>50</td>
<td>23</td>
<td>28</td>
<td>86</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>r9</td>
<td>0:100</td>
<td>50%</td>
<td>50</td>
<td>24</td>
<td>29</td>
<td>85</td>
<td>90</td>
<td></td>
</tr>
</tbody>
</table>
Lactating dairy cow diet simulations with varying proportions of corn silage, alfalfa silage and grass silage.

| Ration | CS:HCS¹ | AS:GS² | Purchased Feed Cost⁵ ($/cow/d) | Purchased Feed Cost/NEL Milk Yield ($/cwt) | Purchased Feed Cost/MP Milk Yield ($/cwt) | % Change Relative to Corresponding BASE (CS:HCS||75:25) |
|--------|---------|--------|-------------------------------|---------------------------------------------|---------------------------------------------|-----------------------------------------------------|
| r1     | 25:75   | 100:0  | $2.79                         | $3.32                                       | $3.13                                       | -11.1%                                              |
| r2     | 50:50   |        | $2.95                         | $3.51                                       | $3.31                                       | -7.1%                                               |
| r3     | 0:100   |        | $3.11                         | $3.74                                       | $3.49                                       | -4.0%                                               |
| r4     | 50:50   | 100:0  | $2.94                         | $3.46                                       | $3.26                                       | -7.4%                                               |
| r5     | 50:50   |        | $2.94                         | $3.50                                       | $3.26                                       | -7.4%                                               |
| r6     | 0:100   |        | $3.04                         | $3.62                                       | $3.34                                       | -7.1%                                               |
| r7     | 75:25   | 100:0  | $3.21                         | $3.73                                       | $3.53                                       | --                                                  |
| r8     | 50:50   |        | $3.25                         | $3.78                                       | $3.57                                       | --                                                  |
| r9     | 0:100   |        | $3.32                         | $3.90                                       | $3.68                                       | --                                                  |

Whole Farm Management
Lactating dairy cow diet simulations with varying proportions of corn silage, alfalfa silage and grass silage.

1Proportions of forage DM from corn silage or haycrop silage. Assumed corn silage composition of 8.5% CP & 45% NDF (DM basis) & 60% ivNDFD (% of NDF).
2Proportions of haycrop silage DM from alfalfa silage or grass silage. Assumed 100%-alfalfa silage composition of 21% CP, 40% NDF, & 1.5% Ca (DM basis) & 50% ivNDFD (% of NDF). Assumed 100%-grass silage composition of 16% CP, 55% NDF, and 0.60% Ca (DM basis) & 60% ivNDFD (% of NDF).
3Dry matter intake; Assumed that the greater ivNDFD assigned corn silage & grass silage relative to alfalfa silage allowed for similar DMI with increasing diet NDF from forage and total NDF concentrations. Gray shading indicates that DMI, and hence estimated allowable milk yields, may be reduced by feeding 26% NDF from forage diets; research is needed with these types of diets.
4Net energy and metabolizable protein allowable milk yields estimated using the 2001 Dairy NRC Model.
5Includes only costs for corn grain, protein supplements, and Ca-Mg-K-S supplements. Assumed (as fed basis) $3.35/bushel for dry ground corn, $400 per ton for soybean meal 48%, $450 per ton for heat-processed soybean meal, $100 per ton for calcium carbonate, and $450 per ton for magnesium sulfate and Mg-K-S.
Value of Alfalfa in Rotations.

• Legume credits for next crop
• Breaks disease and insect cycles
• Improves soil condition
• Increases yield of next crop – beyond nitrogen credit benefit.
• Corn yields 10 to 15% more following alfalfa than following corn (for either grain or silage)
Increasing Hay Acres relative to Corn Silage Acres in Rotation: N Credits

<table>
<thead>
<tr>
<th>Stand Density</th>
<th>Medium/Fine Soils</th>
<th>Sandy Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-----Regrowth after last cutting-----</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;8 inches</td>
<td>&lt;8 inches</td>
</tr>
<tr>
<td>Good, &gt; 4 plt/ft²</td>
<td>190</td>
<td>150</td>
</tr>
<tr>
<td>Fair, 1.5 to 4 plt/ft²</td>
<td>160</td>
<td>120</td>
</tr>
<tr>
<td>Poor, &lt; 1.5 plt/ft²</td>
<td>130</td>
<td>90</td>
</tr>
</tbody>
</table>
Shortened Rotations: Yield

- Alfalfa yield versus age of stand, 15 years data from IA, MI, MN, Ont and WI

![Graph showing yield (%) of year 1 vs age of stand (1 = year after seeding)]
Shortened Rotations: Cost/Returns

Alfalfa Costs and Returns by Stand Age


Whole Farm Management
Shortened Rotations: Value of Alfalfa to Corn Production

Value of Alfalfa to Corn Production

- Profit per acre

- Corn after alfalfa
- Corn after corn

# Shortened Rotations: N Credits

<table>
<thead>
<tr>
<th>Stand Density</th>
<th>Medium/Fine Soils</th>
<th>Sandy Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>----- Regrowth after last cutting -----</td>
<td></td>
</tr>
<tr>
<td>Good, &gt; 4 plt/ft²</td>
<td>190</td>
<td>140</td>
</tr>
<tr>
<td>Fair, 1.5 to 4 plt/ft²</td>
<td>160</td>
<td>110</td>
</tr>
<tr>
<td>Poor, &lt; 1.5 plt/ft²</td>
<td>130</td>
<td>80</td>
</tr>
</tbody>
</table>

---

Ib nitrogen/acre

---
Increasing Hay Acres relative to Corn Silage Acres in Rotation

- Feed Inventory and Ration Adjustments
- Corn and Protein Needs with Differing Ratios
- N Credits
Value of Alfalfa in Rotations

✅ Wheat yields 10 to 15% more following alfalfa than following wheat, also has 1% higher protein

✅ Similar responses noted for corn and other crops

✅ Reduces erosion of cropping system

✅ Control weeds for succeeding crops

✅ Improved economic return
Economics versus Environment: Corn versus Hay Silage.

- Yield Differences
- Forage Needs
- Cover Crops for Corn Silage
- Tillage
Seeding With a Companion Crop

• Selecting the Companion Crop
  – Traditional is oats, but low palatability for dairy cattle.
  – 2 lbs/acre Italian ryegrass is very palatable and is similar in quality to alfalfa so mixes well in bunker.

• Harvest timing and feed Inventory
Manure Application Options

• Management of Applications:
  – Space, Time, Form:
    • Liquid: No-Till Inject for Crops; Surface Spread on Hay (1-2 days after cutting, before green-back).
    • Solid: Conservation Tillage.
    • Separated manures: “fractionate”.

• N Credits:
  – 1-3 year credits; slow release versus 1st year available; variability/measurement; precision apply (with fertilizer “backfill”).
No-Till Seeding

- Fertilizer Management
- Residue Management
- Seed Selection
Using Whole Farm Management of Crop/Livestock Systems to Reduce the Phosphorus Index

Tom Cox: UW-Madison, Ag Economist
Jim Leverich: UW-Extension On-Farm Research Coordinator
Dan Undersander: UW Extension Forage Agronomist Specialist
Randy Shaver: UW Extension Dairy Nutrition Specialist
Laura Ward Good: UW Soil Science, SNAP+ Project Coordinator

Presented at the 2009 World Dairy Expo
Wednesday, Sept 30, 2009