Using Dairy Manure as a Fertilizer Source for Forage Crops

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Central Valley Regional Water Quality Control Board

Dairy Waste Discharge Requirement

**Total N applied**
1.4 to 1.65% of crop uptake.

This is hard.
Nitrogen Budgets

Provide to the crop the nitrogen it needs
in the right form
in the correct amount
at the proper time

Due July 1, 2009
How much nitrogen do forages remove?

Lbs dry matter/A x % N
Lbs dry matter/A x % protein/6.25
Tons/A @ 70% x % protein x .96
Winter forage planted Oct 25
Corn planted April 29

Goal: have nitrogen available in soil when the crop needs it
### N Uptake of Corn Grain Crop

<table>
<thead>
<tr>
<th>Growth stage</th>
<th>% total uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 leaf</td>
<td>5-10%</td>
</tr>
<tr>
<td>12 leaf</td>
<td>30-35%</td>
</tr>
<tr>
<td>18 leaf</td>
<td>70-75%</td>
</tr>
<tr>
<td>Tassel/silk</td>
<td>75-80%</td>
</tr>
<tr>
<td>Blister</td>
<td>80-85%</td>
</tr>
<tr>
<td>Dough</td>
<td>100%</td>
</tr>
</tbody>
</table>

Based on classic work by Hanaway, 1962
## N Uptake of 30 Ton Corn Silage Crop

**lbs/acre**

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Lbs. N tops</th>
<th>Total Lbs.</th>
<th>% total uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 leaf</td>
<td>9</td>
<td>4%</td>
<td></td>
</tr>
<tr>
<td>8 leaf</td>
<td>14</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>12 leaf</td>
<td>36</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>Tassel out</td>
<td>102</td>
<td>161</td>
<td>66%</td>
</tr>
</tbody>
</table>

Based on paper by Karlen, et al.
### N Uptake of 30 Ton Corn Silage Crop lbs/acre

<table>
<thead>
<tr>
<th>Growth Stage</th>
<th>Lbs. N tops</th>
<th>Total uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silks coming</td>
<td>-12</td>
<td></td>
</tr>
<tr>
<td>Blister</td>
<td>13</td>
<td>66%</td>
</tr>
<tr>
<td>Early dent</td>
<td>83</td>
<td>100%</td>
</tr>
<tr>
<td>Mature</td>
<td>.6</td>
<td>246</td>
</tr>
</tbody>
</table>

Based on paper by Karlen, et al
Grain:
80% before tassel/silking

Silage:
1/3 after tassel/silking

Corn K uptake is similar to N in amount & timing
Nitrogen Uptake by Winter Forage
Less than 50 lbs/A N
Jointing
Cut at from late boot to flower or at soft dough for maximum N uptake
There are differences in the N uptake pattern depending on the amount of winter growth.
Daily Crop N needs

Goal: have nitrogen available in soil when the crop needs it
What's in the liquid manure?

- Ammonium-N
- Organic form-N*
- Nitrate form-N
  Only if fresh water $\text{NO}_3$ is excessive. This is rare.

*Remember: TKN or Total N minus Ammonia N = Organic N
What's in the dry manure?

Almost all N is in the organic form.

Ammonium form-N if it's fresh.

Nitrate form-N if it's composted.
What forms of N can crops use?

Non-plant available nitrogen
  • Organic nitrogen (Org-N)
    – by-pass proteins and feed
    – Microbes

Available Nitrogen
  • Ammonium nitrogen (NH$_4$-N)
    – sticks to soil
  • Nitrate nitrogen (NO$_3$-N)
    – leaches readily
Nitrogen Transformations in the Soil

- Organic nitrogen
  - mineralization
    - Ammonium (NH$_4$-N)
      - nitrification
        - Nitrate (NO$_3$-N)
Nitrogen Movement in the Soil

Nitrate (NO₃-N)

Leaching

below root zone

**Most likely in loam to sand soils**
What happens to the nitrogen when we apply liquid manure to the soil during an irrigation?
Liquid Manure Nitrogen

• Doesn’t leach when applied (remember Ammonium – N form)

• May leach during the following irrigation, after conversion to nitrate!
Nitrate Leaching Under Central Valley Conditions

- 12 sampling events
- Soil sampled to 3 or 4 feet just prior to and just after a freshwater irrigation
Nitrate Leaching Under Central Valley Conditions

Nitrate-N losses (lbs/acre) from a single freshwater irrigation

Northern San Joaquin Valley
Fine sandy loam 1st irrigation Corn

Lbs/A nitrate-N in soil layer

June 22 June 23

Soil layer thickness and depth (inches)

0-6 6-15 15-24 24-36 36-48
Nitrate Leaching Under Central Valley Conditions

Nitrate-N losses (lbs/acre) from a single freshwater irrigation

Southern San Joaquin Valley Loam 1st irrigation Corn

Lbs/A nitrate-N in soil layer

June 24 June 29

24-36
15-24
6-15
0-6

Soil layer thickness and depth (inches)
Developing a Nitrogen Budget

1. Determine leaching risk of each irrigation
   - Can leaching risk be minimized
2. Develop a N application plan based on leaching risk
3. Can you get this through your pipelines?
4. Does the pond have enough capacity?
Step 1. Determine Leaching Risk of Each Irrigation

For each field:

- Evaluate each irrigation event
- Identify if leaching could occur
- Can leaching risk be minimized?

<table>
<thead>
<tr>
<th>Winter Crop</th>
<th>Irrigation Event</th>
<th>Water Applied</th>
<th>Water Needed</th>
<th>Can This Irrigation Leach?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Crop</td>
<td>Preirrig</td>
<td>7</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td>Winter Rain</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st Irrig</td>
<td></td>
<td>7</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td>2nd Irrig</td>
<td></td>
<td>5</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td>3rd Irrig</td>
<td></td>
<td>1.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>Preirrig</td>
<td>8</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>1st Irrig</td>
<td>6</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>2nd Irrig</td>
<td>4</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>3rd Irrig</td>
<td>4</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>4th Irrig</td>
<td>4</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>5th Irrig</td>
<td>3.5</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>6th Irrig</td>
<td>3.5</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>7th Irrig</td>
<td>3.5</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>8th Irrig</td>
<td>3.5</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>9th Irrig</td>
<td>3.5</td>
<td>1.9</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>43.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How Do I Prevent Movement of Nitrate Below the Root Zone?

Minimize drainage below roots by reducing the amount of water applied

– Shorten fields
– Increase flow rate
– Adjust slope
– Smooth soil surface
– Sprinklers
How Do I Prevent Movement of Nitrate Below the Root Zone?

1. Minimize drainage below roots

2. Prevent excess nitrate in the soil when water is moving past the roots
Synchronized-Rate Nutrient Application

Only the amount of nitrogen that can be utilized by the crop before the next one or two irrigations is applied at any one time.
Synchronized-Rate Nutrient Application

Generally apply between 30 and 80 lbs N/acre in each of 5 corn irrigations.
High leaching—multiple low dose applications of available nitrogen

Winter: 150 lbs/A available N

30 120

Corn: 260 lbs/A available N

30 40 60 50 40 40
Inject specific amounts of lagoon nutrients into the fresh water...just like we’ve always done with water run N.
Flow meter
Throttling valve
Sampling spigot
Metering run
What gpm of liquid manure do I need to inject into my fresh water to give me the desired application rate?

Need to know:

- The **target** pounds per acre
- Concentration in lagoon water
- How long the irrigation will take
Is my pump/pipeline capable of applying this amount?

GPM from N concentration and irrigation run time

<table>
<thead>
<tr>
<th>Target application:</th>
<th>50 lbs N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>acres/hr</td>
<td>2</td>
</tr>
<tr>
<td>250</td>
<td>800</td>
</tr>
<tr>
<td>300</td>
<td>667</td>
</tr>
<tr>
<td>350</td>
<td>572</td>
</tr>
<tr>
<td>400</td>
<td>500</td>
</tr>
<tr>
<td>450</td>
<td>445</td>
</tr>
<tr>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td>550</td>
<td>364</td>
</tr>
<tr>
<td>600</td>
<td>334</td>
</tr>
<tr>
<td>650</td>
<td>308</td>
</tr>
<tr>
<td>700</td>
<td>286</td>
</tr>
</tbody>
</table>
Is my pump/pipeline capable of applying this amount?

GPM from N concentration and irrigation run time

<table>
<thead>
<tr>
<th>Target application:</th>
<th>50 lbs N/A</th>
<th>0.8</th>
<th>0.7</th>
<th>0.6</th>
<th>0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>hrs/ac</td>
<td>3</td>
<td>2</td>
<td>1.5</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>133</td>
<td>200</td>
<td>266</td>
<td>399</td>
<td>499</td>
</tr>
<tr>
<td>300</td>
<td>111</td>
<td>166</td>
<td>222</td>
<td>333</td>
<td>416</td>
</tr>
<tr>
<td>350</td>
<td>95</td>
<td>143</td>
<td>190</td>
<td>285</td>
<td>357</td>
</tr>
<tr>
<td>400</td>
<td>83</td>
<td>125</td>
<td>166</td>
<td>250</td>
<td>312</td>
</tr>
<tr>
<td>450</td>
<td>74</td>
<td>111</td>
<td>148</td>
<td>222</td>
<td>277</td>
</tr>
<tr>
<td>500</td>
<td>67</td>
<td>100</td>
<td>133</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>550</td>
<td>61</td>
<td>91</td>
<td>121</td>
<td>182</td>
<td>227</td>
</tr>
<tr>
<td>600</td>
<td>55</td>
<td>83</td>
<td>111</td>
<td>166</td>
<td>208</td>
</tr>
<tr>
<td>650</td>
<td>51</td>
<td>77</td>
<td>102</td>
<td>154</td>
<td>192</td>
</tr>
<tr>
<td>700</td>
<td>48</td>
<td>71</td>
<td>95</td>
<td>143</td>
<td>178</td>
</tr>
</tbody>
</table>

mg/L in undiluted pond water
Relationship of pipe diameter, concentration & gpm to velocity in pipe

<table>
<thead>
<tr>
<th>target N (lbs/acre)</th>
<th>pond N concentration (mg/L)</th>
<th>run time (hrs/acre)</th>
<th>GPM needed</th>
<th>pipe diameter (inches)</th>
<th>velocity in pipe (feet/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 hour /acre</td>
<td>50</td>
<td>360</td>
<td>1.0</td>
<td>277</td>
<td>10</td>
</tr>
<tr>
<td>8 inch pipe</td>
<td>50</td>
<td>360</td>
<td>1.0</td>
<td>277</td>
<td>8</td>
</tr>
<tr>
<td>6 inch pipe</td>
<td>50</td>
<td>360</td>
<td>1.0</td>
<td>277</td>
<td>6</td>
</tr>
<tr>
<td>increase concentration</td>
<td>50</td>
<td>700</td>
<td>1.0</td>
<td>143</td>
<td>6</td>
</tr>
<tr>
<td>increase application rate</td>
<td>100</td>
<td>700</td>
<td>1.0</td>
<td>285</td>
<td>6</td>
</tr>
</tbody>
</table>

2 to 5 ft/sec for 4 to 10% suspended solids
Source: NRCS
Make your nitrogen budget before you plan your infrastructure changes

Consider:
• Highest & lowest target application rates
• Highest & lowest pond concentrations
• Fastest & slowest irrigation run times
If your current infrastructure is putting out more than you would like in a single application, what can you do?
Two basic options:

1. Design a nitrogen budget that doesn’t require frequent small doses (only if you don’t leach every irrigation)

2. Change your management and infrastructure to allow you to apply smaller amounts
Leaching only during irrigations that follow cultivations
Leaching Only During Irrigations That Follow Cultivations
Leach only after cultivations
Use dry manure, fewer, larger lagoon applications

Winter: 175 lbs/A total available N
Corn: assume at least 100 lbs N/A of manure N applied in fall can be used by corn. Add 70 units available N in 2nd and 4th irrigations, test to see if more is needed later in season.

75 avail /300 total dry

UCD Alfalfa Workgroup
Two basic options:

1. Design a nitrogen budget that doesn’t require frequent small doses (only if you don’t leach every irrigation)

2. Change your management and infrastructure to allow you to apply smaller amounts
Field study: field length = 1200’, avg. irrigation amount = 7.1”

<table>
<thead>
<tr>
<th>Liquid Manure Added:</th>
<th>Nitrogen Applied (lbs/ac)</th>
<th>Uniformity of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>During entire irrigation</td>
<td>242</td>
<td>+</td>
</tr>
<tr>
<td>When freshwater advance at 75% of field length</td>
<td>86</td>
<td>++</td>
</tr>
<tr>
<td>When freshwater advance at 85% of field length</td>
<td>31</td>
<td>++++</td>
</tr>
</tbody>
</table>
Ideas to reduce application rates

Inject freshwater into the liquid manure distribution line near the pond just after the flow meter

- Send mixed water through the distribution pipe at a higher flow rate

- Install pump right next to pond
  OR
  Install freshwater pipeline to pond
Solids Separation is CRITICAL for Nutrient Management.

Sludge in the system can result in HUGE nitrogen applications.
• The laws of physics set limits on what your system can deliver.

• Know the highest and lowest rates you will need to apply.

• Think outside the box; explore different options.
Can I put nitrogen on in one or two large doses?

**NO**
- Multiple low dose applications
- System must allow for low volume liquid manure application
- Substantial infrastructure investment may be necessary
- Difficult to utilize organic N
- Need excellent solids separation
- Most solids must be moved off the dairy

**MAYBE**
- N banking possible part of the year
- One or two higher dose applications
- Infrastructure changes *MAY* be less
- May be able to successfully utilize dry manure and high solids liquid manure
Is Pond Capacity Sufficient?

Leach only after cultivations
Use dry manure, fewer, larger lagoon applications

100
75
70

Fall solid manure
Storage needed from late June to mid January
Leach only after cultivations
Use dry manure, fewer, larger lagoon applications

Is Pond Capacity Sufficient?

Now longest storage is about 4 months

Fall solid manure

Daily nitrogen demand (lbs/acre/day)
When does the nitrogen in the pond need to be used?

% of total annual nitrogen applied in each use period

Need to save up for heavy use times of the year!
Developing a Nitrogen Budget

1. Determine leaching risk of each irrigation
   - Can leaching risk be minimized

2. Develop a N application plan based on leaching risk

3. Can you get this through your pipelines?

4. Does the pond have enough capacity?
N budgets

Goal: have nitrogen available in soil when the crop needs it

Budget is worthless

If the infrastructure can’t deliver the budgeted application rates