Role of perennial forages in prevention and remediation of nitrate impacts

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So, what’s the problem with nitrate losses?

- Drinking water quality
  - Blue baby syndrome
  - Possible chronic effects
- Hypoxia (The “Dead Zone”)
- Fresh water quality
- Nitrous oxide emission
  - Greenhouse gas
  - Ozone depletion
- Economic loss
So, what’s the problem with nitrate losses?

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Increased expenses
Increased regulation
Uncertain future
The public is interested

- Over 80% are concerned about water and air pollution, and loss of habitat \(^1\)
- Over 80% agreed that stricter laws are needed to protect the environment \(^2\)
- Nearly 90% in the Midwest favor additional incentives for farmers \(^3\)

\(^1\) nationwide Gallup Organization poll, 2001
\(^2\) nationwide poll by Pew Research Center for the People and the Press, 1999
\(^3\) regional poll by American Farmland Trust, 2001
Excess N loading of soils and water occurs by:
- traditional agricultural practices (e.g. inappropriate timing)
- shallow or sandy soils
- tile drained soils
- excess manure or fertilizer application
- unaccounted-for sources (N deposition, mineralization)
- spills during manufacture, storage, and transport
Perennial forages protect the environment

• Reduced runoff
• Less nitrate drainage
• Removal of excess N
• Reduced N fertilizer needs
• Improved air quality
• Enhanced wildlife habitat
GOAL: Reduce nitrate leaching

- Reduce the flow of water
  - Increase water use
  - Manage irrigation
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1. High yield
2. Large leaf area
3. Extended growing season
4. Deep roots

1. Minimum rates
2. Know your soil
3. Watch the weather
GOAL: Reduce nitrate leaching

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- Lower the nitrate concentration
  - High N requirement
  - Long season of uptake
  - Improved rates, timing
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Timing of growth, water use, N demand

Cool-season vs. Warm-season

Precipitation
Alfalfa
Corn

Precipitation or ET (inches)
Timing of growth, water use, N demand

Cool-season vs. Warm-season
Rooting depth

Russelle et al., 1993
Perennial forages reduce nitrate loss from tile drains – a partial solution for hypoxia?

>40 million acres are tile drained in the Upper Midwest

Randall, Huggins, Russelle et al., 1997
Strategic planting of perennials to prevent nitrate loading of ground water

Holland wellfield soils map

Hwy 75

Holland

Kelley and Russelle, 2001
Predicted nitrate loss
no irrigation
GLEAMS

Alfalfa

Corn/bean
90 lb N/a

< 2 lb N/a  Dark green
2-4 lb N/a  Light green
4-8 lb N/a  Yellow
8-16 lb N/a  Orange
> 16 lb N/a  Red

Corn
100 lb N/a

Corn
130 lb N/a

Kelley and Russelle, 2002
Predicted nitrate loss
irrigation
GLEAMS

Alfalfa
Corn/bean
90 lb N/a

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Kelley and Russelle, 2002
<table>
<thead>
<tr>
<th>Water regime</th>
<th>Alfalfa</th>
<th>Continuous Corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryland</td>
<td>610</td>
<td>29,300 192,400</td>
</tr>
<tr>
<td>Irrigated</td>
<td>32,400</td>
<td>61,700 335,500</td>
</tr>
</tbody>
</table>

Irrigation was applied when available water supply fell to 25%. Used 1989-1998 weather record; did not predict future weather. Water was added to attain 90% available water holding capacity of each soil. Assumed 5 ppm nitrate-N in irrigation water.
Timing and rate of N

Vetsch et al., 1999

Forage yield (t DM/a)

N rate April 23 (lb N/a)

0 50 100 150 200 250 300 350 400

Harvest 1
Harvest 2
Harvest 3

150 lb N June 14
No N after April

Vetsch et al., 1999
Timing and rate of N

Forage yield (t DM/a)

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Vetsch et al., 1999
Ground water supplies are protected under well-managed grazing in the Midwest

In WI and MN, *little nitrate is lost by leaching* with moderate N rates on fine-textured soils under rotational grazing with sheep, lactating dairy cows, and dairy heifers.

Leaching may occur in *sandy soils*, but groundwater impacts appear to be short-lived. *Hypothesis*: Pastures may enhance denitrification.

Serious questions remain about *wintering livestock outside*. 
Fertilizer N improves pasture productivity, but increases the likelihood of nitrate leaching in the Midwest

Russelle et al., 1997
Legumes help balance N

Fertilizer N rate (lb/acre)

DM yield (t/acre)

Lamb et al., 1995

450 lb N/acre

Agate
Ineffective Agate
Legumes help balance N

![Graph showing the relationship between fertilizer N rate (lb/acre) and DM yield (t/acre). The graph includes data points for Agate and Ineffective Agate varieties, with a peak yield of 450 lb N/acre.]

![Another graph showing the fraction of N from N_2 derived from soil and manure (kg N/ha) for Harvest 1, Harvest 2, and Harvest 3.]

Russelle et al., 2003
Nearly 2 billion pounds of N!

Russelle and Birr, 2002
Derailment near Bordulac, ND
It all depends on yield and N content:

- 160 bu/acre corn grain: 120 lb N/acre
- 20 tons corn silage/acre: 220 lb N/acre
- 4 tons/acre alfalfa hay: 220 lb N/acre
Can we improve alfalfa tolerance to wastewater and manure applications?

Lamb, Russelle, and Schmitt

Salt or NH$_4$ added to swine manure slurry

Applied broadcast 10 days after harvest
Manure alone

Manure + NaCl

Manure + NH₄⁺

Manure + NaCl + NH₄⁺
Can we select for NO₃ uptake in legumes?
Lamb and Russelle

*Higher NO₃ uptake*: ground water protection
improved N recycling on farm

*Lower NO₃ uptake*: mixtures with nonlegumes

![Graph showing the relationship between Total herbage N (g/plant) and Fraction of N from nitrate. The graph compares data from 1999 and 2000.]
Why perennial forages?

- N removal:
  perennial crops > annual crops *(may not be sufficient)*
  harvested > grazed > non-harvested

- Economic return:
  alfalfa > grass forages *(but adaptation differs)*

- Additional benefits to soil protection and quality, air quality, wildlife, and aesthetics