Realistic nitrogen use efficiency goals in dairy production systems: a review and case study examples

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Key question addressed

What are realistic nitrogen use efficiency goals for dairy systems?

That depends....
Outline

- Definitions
- Summary of published dairy NUE results
- N Input/output framework EU nitrogen expert panel
- NZ catchments case study
- Key conclusions/discussion points
Definitions

Whole farm NUE

Crop NUE
- N in imported feed
- N fertiliser
- Biological fixation

Animal NUE
- N in products
- Gaseous loss
- Manure

Whole farm N surplus = N input – N output
Whole farm NUE (%) - dairy systems

Up to 90%

Crop NUE

Animal NUE

N input (kg N/ha/yr)
Challenge of striking the right balance – productivity vs N surplus
N input – output framework

- **NUE high**
  - Risk of soil mining
  - NUE e.g. 90%
  - Max N surplus e.g. 80 kgN/ha

- **NUE low**
  - Inefficient N use
  - Minimum N output in product e.g. 80 kg N/ha
  - NUE e.g. 50%

EU Nitrogen Expert Panel, 2015
Results mapped onto input-output framework

Experimental data from global dairy systems

Whole farm NUE ~ 20-40%
75% of farms: N output > 75 kg N/ha
50% of farms: N surplus > 200 kg N/ha
7% of farms: N surplus < 100 kg N/ha
Theoretical limits?

Whole farm NUE ~ 32%

Animal NUE ~ 40%

Crop NUE ~ 80%

INPUT
N in imported feed

INPUT
N fertiliser
Biological fixation

OUTPUT
N in products

Gaseous loss

N loss to water

manure
NZ catchments case study – 2001-2011

- Bi-annual farm and soil surveys
- Overseer® Nutrient Budgeting Model
- Effect of mitigation measures on Whole farm NUE, N surpluses and N losses to water:
  - Measures
    - Efficiency measures
    - Mitigation measures
    - System changes
## Mitigation measures – progressive implementation

<table>
<thead>
<tr>
<th>Aim</th>
<th>Potential options</th>
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<tbody>
<tr>
<td>Increase Crop NUE</td>
<td>Improved fertilizer and manure management</td>
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<tr>
<td>Increase Animal NUE</td>
<td>Higher genetic merit animals</td>
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<td>Lower cow replacement rate</td>
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<td></td>
<td>Better quality feed (optimizing protein &amp; ME contents)</td>
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<tr>
<td>Reduce N losses</td>
<td>Nitrification and urease inhibitors</td>
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<td>Restricted grazing to avoid urine deposition at high risk times</td>
</tr>
</tbody>
</table>
Effect of measures on Whole farm NUE (%)
Effect of measures on other N metrics relative to Base farm – Waikakahi

- Base
- Efficiency
- Mitigation
- System
Key findings of NZ catchment study

‘Between-catchment’ variability in NUE > ‘within-catchment’

NUE largely insensitive to mitigation options, but N surpluses and especially N leaching losses were reduced

To simultaneously achieve higher NUE and lower N surplus → better utilise N within the system

Key management attributes
  • reduce fertiliser/feed N inputs,
  • reduce number of less productive animals,
  • grazing management to reduce the risk of N losses in autumn/winter
Other considerations

All N metrics based on estimates of N inputs and N outputs

- Need to be adequately measured or estimated, despite the methodological challenges (e.g. fixation in clover-based systems)

Agreement required on what should be included in N input and output terms.

What is the system boundary?

~ 150-200 kg N/ha/yr
N fertiliser to produce imported feed

Whole farm NUE

INPUT
Fertiliser N to produce feed

N in imported feed

N fertiliser
Biological fixation

OUTPUT
N in products

Gaseous loss

N loss to water
Effect of system boundary on NUE (%)

Assumes Crop NUE = 60%

<table>
<thead>
<tr>
<th>N input:</th>
<th>0% imported feed</th>
<th>25% imported feed</th>
<th>50% imported feed</th>
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<tbody>
<tr>
<td>N input:</td>
<td>300 kg N/ha (fert, fix)</td>
<td>225N fert, fix + 75N feed</td>
<td>150N fert, fix + 150N feed</td>
</tr>
<tr>
<td>N output:</td>
<td>90 kg N/ha (milk, meat)</td>
<td>90N</td>
<td>90N</td>
</tr>
</tbody>
</table>

Assumes Crop NUE = 60%
Manure exported off-farm

INPUT
N in imported feed

N fertiliser
Biological fixation

NEGATIVE INPUT
Manure N export

OUTPUT
N in products

Gaseous loss

N loss to water

EU Nitrogen Expert Panel, 2016
NUE (%) global dairy systems
In conclusion...

Realistic NUE goals for dairy systems requires:

- Consideration of the agro-climatic context
- Theoretical limit ~ 35%?
- Agreement on how it is calculated – Role for INMS...
- Understanding impact they are primarily aimed at

Crop and Animal NUE valuable indicators for optimising fertiliser and feed use

Whole-farm NUE of limited value for environmental goals; N surplus more useful
Thank you for your attention
Effect of measures on N metrics relative to Base farm – Toenepi

- NUE
- N surplus
- Total N loss/MS
- N loss air
- N loss water

- Base
- Efficiency
- Mitigation
- System

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Effect of negative inputs on NUE (%)

<table>
<thead>
<tr>
<th>N input:</th>
<th>300N (fert, fix)</th>
<th>300N</th>
<th>300N (fert, fix)</th>
<th>300N</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>300N</td>
<td>- 20N</td>
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<td>- 40N</td>
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<tr>
<td>N output:</td>
<td>90N (milk)</td>
<td>90N</td>
<td>90N (milk)</td>
<td>90N</td>
</tr>
<tr>
<td></td>
<td>20N (feed or manure)</td>
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<td>40N (feed or manure)</td>
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