How efficient with nitrogen can we be:
Lessons from the Discovery Farms NUE project

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At our core: A farmer-led water quality research and educational program
Challenge: farmers are under extreme pressure to optimize N values due to decreasing economic returns to N inputs and nitrate leaching to groundwater.

Typically if farmers wanted to adjust N rates or management, they would base this on:
- trial and error
- UW recommendations
- farmer led groups (peer recommendations)
- crop consultants/agronomists
- actual N rate trial

Nitrogen Use Efficiency (NUE) is a self-evaluation tool that can shape these management decisions.
N recs are a great place for producers to begin. But there is still a lot of variability between economic optimum N and yield.

NUE can complement N recs to improve N management for a given field.
NUE is an easy to use assessment tool for farmers, crop consultants and conservationists who want to evaluate current N management.

**General**
- N recommendations
  - Based on a dataset with a lot of variability

**Intensive**
- On-farm N rate trials
  - Determine EONR
  - Probably not feasible for every farmer to do

Complement to N recs

NUE assessment
NUE is not used to determine the optimal N rate for a field, but can be used to assess…

- how N is currently being managed
  - NUE complements N recs and nutrient management plans
  - And it demonstrates field and soil dynamics within a specific farm and system

- if improvements can be made

- if shifts in management are effective
NUE can be measured and implemented in many ways.

<table>
<thead>
<tr>
<th>Simple Assessment</th>
<th>How efficient is a field compared to WI benchmarks?</th>
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<tbody>
<tr>
<td>• Partial Factor Productivity</td>
<td>• 300 site years of data to create benchmarks and decision tools to guide farmers on how to improve N management</td>
</tr>
<tr>
<td>• Partial Nutrient Balance</td>
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<tr>
<th>Potentially Leachable Nitrogen</th>
<th>How much N was not used by the crop, and therefore could be potentially leached</th>
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<tbody>
<tr>
<td>• Nitrogen Balance</td>
<td>• An indirect way to assess the amount of nitrogen that could potentially be leached</td>
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<table>
<thead>
<tr>
<th>Intensive Assessment</th>
<th>How efficient was any additional fertilizer/manure inputs?</th>
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<tbody>
<tr>
<td>• Agronomic Efficiency</td>
<td>• Zero-N strips are included to assess how much N was supplied by the soil.</td>
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<td>• Uptake Efficiency</td>
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THE NUE Project began in 2015 with a NRCS Conservation Innovation Grant to help farmers assess their current N management practices in corn production and how they can improve.

Project Goals:

1. **Benchmarks for different NUE metrics**: individual farmer assessment tool
2. **Trends in our dataset**: what contributes to higher or lower efficiencies

- 15 counties
- 85 farmers
- 300+ fields

[Map showing 15 counties highlighted in green and past projects in light green.]

**Extension**
**UNIVERSITY OF WISCONSIN–MADISON**

**DISCOVERY FARMS WISCONSIN**
The NUE dataset includes data from corn grain and corn silage fields. The dataset represents WI’s diverse soils and systems, including a variety of N sources (manure, fertilizer, legume), tillage practices, cover crops, and crop rotations. 70% of soils are well drained, silt loams. As more data is collected, benchmarks can be refined based on soil type.
Discovery Farms staff, producers and partner organizations collaborate to collect soil & plant samples and agronomic data throughout the season for an NUE assessment.

We have developed 2 compatible methods for data collection, based on producer/partner needs.

The project began with **hand-checks** to calculate yield and N uptake.

We have developed additional protocols to use **yield monitors** for NUE assessments.
With partnerships we can reach more farmers, better tailor programming and outreach to fit county needs, and improve the sustainability of on-farm N monitoring.

- Land & Water
- UW Extension
- NRCS
- Producer-led groups & DATCP
- Private crop consultants & agronomist

Steve Olson (Dunn Co LCD) learning how to calculate yield and N uptake for corn silage with Kevan Klingberg (Discovery Farms)

Philip Laatsch (private crop consultant) and Robert Bird (Dodge Co LCD) soil sample for NUE assessments in collaboration with Dodge Co Healthy Soils & Healthy Water
One simple measurement of NUE is Partial Factor Productivity. PFP is valuable for self-evaluation and benchmarking.

\[
\text{Partial Factor Productivity} = \frac{\text{Yield (lb/ac)}}{\text{N applied (lb/ac)}}
\]

To improve PFP - increase yield, or decrease N applied (without an economic loss)
Partial factor productivity (PFP) = \( \frac{\text{Yield (lb/ac)}}{\text{N applied (lb/ac)}} \)

**Corn Grain Benchmarks**

- **High Use Efficiency**
- **Mid-High Use Efficiency**
- **Low-Mid Use Efficiency**
- **Low Use Efficiency**

Compared to other research, our WI PFP data is above average.

WI-specific benchmarks are created for corn grain and corn silage.
Partial Factor Productivity (PFP) is influenced by both yield and N supplied. The formula is:

\[
PFP = \frac{\text{Yield (lb/ac)}}{\text{N applied (lb/ac)}}
\]

PFP Category:
- **High Use Efficiency**: >1.5 bu/lb N
- **Mid-High Use Efficiency**: 1.3-1.5 bu/lb N
- **Low-Mid Use Efficiency**: 1.1-1.3 bu/lb N
- **Low Use Efficiency**: <1.1 bu/lb N
Though rate is a good place to start, it isn’t everything. At rates within 50 lb N/ac of the N recs (at 0.10 price N:corn ratio), all efficiency categories can be achieved.
Improving NUE of low use and low-mid use efficiency fields is valuable to reduce risk to water quality.

High N rates from:
- organic N sources & challenge of crediting
- “insurance N”
Increase Yield and/or Reduce N rate.

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<tr>
<th>Increase yield at a given N rate</th>
<th>Reduce N rate, while maintaining yield/profit</th>
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<tbody>
<tr>
<td>N management</td>
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<tr>
<td>Soil health</td>
<td>Manure management</td>
</tr>
<tr>
<td>Soil fertility</td>
<td>Crop rotation &amp; legumes</td>
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<tr>
<td>Pest management</td>
<td>Soil health (organic matter, nutrient cycling)</td>
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<tr>
<td>Variety selection</td>
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Improving NUE may look different from field to field
Outreach materials and decision-making tools are available to guide producers and agronomists through the process of utilizing NUE on their farms.

**LOW USE EFFICIENCY**
Grain: PFP 0-58 / PNB 0-0.60  
Silage: PFP 0-80 / PNB 0-0.92

A field with an NUE value less than the first quartile has an efficiency value in the lower 25% of monitored fields. Use the series of questions to determine ways to increase efficiency.

**START**
Did you achieve the yield goal for this field?

**YES**
- If manure and/or legumes are included in your rotation, did you appropriately credit them?
  - **YES** Did not have manure and/or legumes
  - **NO**

**NO**
- Did something other than nitrogen limit yield (weather, disease, insect damage, etc.)
  - **YES**
  - **NO**

**Reduce N**
Consider decreasing nitrogen applied by reducing your N rate or altering your N source, timing, or placement to allow for a lower rate.*

**Take credits**
Take credits for manure/legumes and try reducing nitrogen applied from commercial fertilizer.

**Identify cause**
Identify the cause of the lower yield and shift management to address the challenges. Reassess NUE on the field after yields recover.

**Assess goals**
Assess how yield goals were determined. Are they realistic based on available information?

*See the low-medium use efficiency box below for suggestions on how to decrease N rate.
Key Lessons from our simple NUE assessments

- All fields applying over 250 lb N/ac had **low use efficiency**
- At the N recommended rate (and within a 50 lb/ac range), N rate is not the sole driver
- Organic N sources can be a challenge to achieve higher efficiencies without properly crediting manure and alfalfa
- Improving yield at a given N rate can be just as valuable for NUE
So far, we have not found significant trends or differences in:

- timing of applications, inhibitors/slow release products, management practices
  - Our data set isn’t big enough (yet!) to evaluate how to fine-tune
- median values/ranges by
  - year
  - region
  - management type (dairy/beef/grain)
  - soil type*

*our dataset primarily consists of silt loam soil types. As we gather more data, we will reevaluate benchmarks based on soil type
Nitrogen balance is an indicator for potentially leachable N and the risk to water quality.

\[ \text{NITROGEN BALANCE} = \text{N supplied} - \text{N removed} \]

- Leachable N
- Change in N stored as organic matter
- N loss through volatilization, denitrification, ammonia loss
Lower efficiencies demonstrate greater risk to water quality and even without directly monitoring nitrogen content of corn plants, we can assess potential risk.
DF median N balance is 40 lb N/ac, which is a good goal for producers.

Very few fields that applied below the recommended N rate had an N balance above 40 lb N/ac.

However—there are still fields that had higher N rates and efficiently used that N.
Key Lessons about Nitrogen Balance

- Monitoring Partial Factor Productivity allows us to estimate range of N Balance (reduces the need to monitor with grain N samples)
- N recs are a good place to start to prevent high N balances
- Improving NUE will decrease potentially leachable nitrogen
More intensive monitoring of NUE is accomplished through a zero-N test strip

- Indicator of soil health
- Economic profit/loss of additional inputs
- How much nitrogen was not utilized and could be lost to the environment
Uptake Efficiency (UE) indicates how much of the applied N was taken up by the plant.

\[
\text{Uptake Efficiency (UE)} = \frac{\text{N uptake (lb/ac)} - \text{N uptake of zero N strip (lb/ac)}}{\text{N applied (lb/ac)} - \text{N applied of zero N strip (lb/ac)}}
\]

And how much N could be lost?

The variability of the data suggests that every field's soils and systems are different - and N management needs to be considered on a field by field basis.
Zero-N and Low-N test strips support farmers in making decisions that are best for profitability and water quality on their farms.

Having data from a half rate and a full rate test strip can provide enough data to producers to decide if they want to test a small reduction in N, without doing a full N rate trial.
Take home message: Assessing NUE has value to improve economic efficiency and reduce N loss

1. Simple NUE assessment is a quick tool to assess if there are realistic opportunities to improve N management.
   - i.e. is there even a reason to consider changing your N management?
2. NUE assessments can compare across field, growing seasons, or changes in management.
3. Zero-N test strips can evaluate the soil health of a field
4. Zero-N and Low-N test strips are used to assess if N rates can be decreased
5. N Balance (for simple assessments) and Unused Nitrogen (for zero-N assessments) can serve as indicators for potentially leachable nitrogen.

No matter what method or calculation is used, NUE is valuable for producers, agronomists and partners to consider N management and the economic and environmental implications of nitrogen use based on their own farm data.
Looking ahead: expanding programming through partnerships to meet producer needs and water quality protection efforts

Project 1: Simple and Intensive NUE assessments through partnerships
  • Increase monitoring and education efforts
  • Build dataset to refine benchmarks and tease out management impacts

Project 2: On-farm comparison studies to evaluate the effectiveness of management practices to reduce nitrogen loss
  • Manure timing
  • Cover crop
  • Reductions in N rate