NUE, N balance, and N yield – a combined indicator system to evaluate N use in crop production systems

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Content

• Introduction to Nitrogen Use Efficiency (NUE)

• A novel NUE indicator system developed by the EU Nitrogen Expert Panel

• Application of the new concept

• Summary
Definition of Nitrogen Use Efficiency (NUE) and methods to derive NUE

NUE quantifies how much of the available N is actually utilized by an agricultural system.

- Use of labeled N to trace the fate of applied N
  - Precise, but expensive method that is only applicable in scientific experiments at field scale and for a limited period of time

- “Difference method”
  - \((N\text{ crop uptake fertilized} - N\text{ crop uptake unfertilized}) / N\text{ fertilizer input}\)
  - A “zero N” plot is only available in field trials (field scale)
  - Only valid for long-term field trials

- **NUE = N output / N input**
  - easy-to-use indicator not only for scientists but also for practice and policy
  - data usually available from farms and statistics
  - applicable at different scales (crop/rotation, farm, region/country) and over time
  - to be interpreted in relation to productivity (N output) and N losses to the environment (N surplus = N input – N output)
Established spring 2014 based on an initiative of Fertilizers Europe
Consists of about 20 members from science, policy, practice and industry

General mandate
• to contribute to improving the nitrogen use efficiency in food systems in Europe, through
  – communicating about NUE in food systems in Europe
  – generating new ideas, and recommending effective proposals and solutions
  – acting as referee in controversial issues about nitrogen and communicating as authority

• First mandate of the EU Nitrogen Expert Panel:
  – To prepare a well elaborated proposal for assessing NUE in EU, to be used as indicator by policy and practice.

www.eunep.com
Nitrogen Use Efficiency (NUE)
- an indicator for the utilization of nitrogen in agriculture and food systems

Prepared by
EU Nitrogen Expert Panel


Recommended citation:
EU Nitrogen Expert Panel (2015) Nitrogen Use Efficiency (NUE) - an indicator for the utilization of nitrogen in agriculture and food systems. Wageningen University, Alterra, PO Box 47, NL-6700 Wageningen, Netherlands.
N input and N output data provide multiple information about sustainability of agricultural production systems

- N output / N input *100 = NUE (%) -> Resource use efficiency (society)
- N output (kg N/ha) -> Productivity (economy)
- N input – N output = N surplus (kg N/ha) -> Potential N loss (environment)

The approach of the EU N Expert Panel:
All three indicators are combined into a two-dimensional input – output diagram that allows system performance to be assessed in relation to all three dimensions.
### Input and output items considered for the NUE indicator system

<table>
<thead>
<tr>
<th>N input</th>
<th>N output</th>
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</thead>
<tbody>
<tr>
<td>Mineral fertilizers</td>
<td>Crop products</td>
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<tr>
<td>Feed and fodder (net)</td>
<td>Animals (net)</td>
</tr>
<tr>
<td>Biological nitrogen fixation</td>
<td>Animal products (milk, egg, wool)</td>
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<td>Atmospheric N deposition</td>
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<td>Compost and sewage sludge</td>
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<tr>
<td>Seed and planting material</td>
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<tr>
<td>Bedding material</td>
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<tr>
<td>Animal manure (net)</td>
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</tbody>
</table>
Definition of acceptable boundaries for N output/input ratios giving a desirable range for NUE (all numbers are provisional for illustration only)

- **NUE too high, i.e. “soil mining” (NUE > 90%)**
- **NUE = 90%**
- **NUE too low (NUE < 50%)**
- **NUE = 50%**

**Provisional boundaries for NUE:**

Desirable range for NUE

N output, kg/ha/yr

N input, kg/ha/yr
Definition of acceptable boundaries for N output/input ratios giving a desirable range for NUE – supplemented by a desired minimum productivity level (all numbers are provisional for illustration only)

N output, kg/ha/yr

N input, kg/ha/yr

Provisional boundaries for NUE:

- NUE = 90%
- NUE = 50%

Desirable range for NUE:

- NUE too high, i.e. “soil mining” (NUE > 90%)
- NUE too low (NUE < 50%)

Desired minimum productivity level (N output = 80 kg N/ha)
Definition of acceptable boundaries for N output/input ratios giving a desirable range for NUE – supplemented by a target value for N balance (all numbers are provisional for illustration only)

Provisional benchmark values:
- NUE = 90%
- N balance = 80 kg N/ha
- NUE = 50%
- N yield = 80 kg N/ha

NUE too high, i.e. “soil mining” (NUE > 90%)

NUE too low (NUE < 50%)

“Safe operating space” for N fertilization

N output, kg/ha/yr

N input, kg/ha/yr
Application of the new NUE indicator system

1) Winter wheat grown at different N rates in a long-term experiment (Broadbalk Experiment, Rothamsted/UK)
   • as monoculture wheat and
   • in a rotation with other crops.

2) Winter wheat grown at different N rates in one-year field trials (Yara R&D, Hanninghof/DE) with focus on economic optimum N fertilization
   • using in-season plant analysis (N-Tester) for N fertilizer recommendation
Long-term N response trial (Broadbalk, UK) with winter wheat as monoculture (black) and in a rotation (red)

N output, kg/ha/yr

N input, kg/ha/yr

Soil mining
NUE > 90%

Too low productivity
< 125 kg N/ha *

Inefficient N use
NUE < 50%

N balance
> 80 kg N/ha

* 7.26 t/ha * 0.86 * 20 kg N/t (avg. wheat yield in UK in 2011-2013, FAOSTAT database (2016)
Average of 189 one-year N response trials with winter wheat on farmer fields all over Germany (2003-2015)

Soil mining
NUE > 90%

N-Tester

N balance
> 60 kg N/ha

Too low productivity
< 128 kg N/ha *

Inefficient N use
NUE < 50%

* 7.45 t/ha * 0.86 * 20 kg N/t (avg. wheat yield in DE in 2011-2013, FAOSTAT database (2016)
Nitrogen Use Efficiency (NUE) – an indicator for the utilization of nitrogen: summary

NUE assessment shall take 3 dimension into account
- N output / N input = NUE -> resource use efficiency & long-term sustainability
- N output = N yield -> productivity & economy
- N input – N output = N surplus -> environmental risks

Advantage of this approach
- Growers will not be limited by a ceiling in N fertilizer use but can aim for a target corridor.
- The N fertilizer rate alone is no criterion for efficiency.
- The approach can be used demonstrate performance of improved fertilizer management e.g. through precision farming

Challenge
- The concept needs explanation
- Crop and region specific target or benchmark values need to be developed, preferably for complete crop rotations
Thank you for your attention