Nitrogen use efficiency as an agro-environmental indicator

Frank Brentrup\textsuperscript{1} & Christian Palliere\textsuperscript{2}
\textsuperscript{1} Yara International, Research Centre Hanninghof
\textsuperscript{2} Fertilizers Europe (EFMA)

OECD workshop “Agri-environmental indicators: lessons learned and future directions”, 23-26 March 2010, Leysin, Switzerland
Nitrogen Use Efficiency (NUE) is a term used to indicate the ratio between the amount of fertilizer N removed from the field by the crop and the amount of fertilizer N applied.

Methods to measure or calculate NUE

- Use of labeled $^{15}$N to trace the fate of applied N
  - Precise, but expensive method that is only applicable in scientific experiments
- “Difference method”
  - $(\text{N crop uptake fertilized} - \text{N crop uptake unfertilized}) / \text{N fertilizer input}$
  - A “zero N” plot is only available in field trials
  - Only valid for long-term field trials
- Output-input ratio
  - Crop N removal / mineral N fertilizer input
  - Applicable under practical conditions, data are usually available
  - Needs an additional interpretation scheme
**N balance**
- established OECD indicator
- **difference** between N inputs (fertilizer, manure etc.) and N outputs (arable, permanent and fodder crops)
- expressed in kg N per country or hectare
- provides information about the **absolute flow** of nitrogen that is not captured in agricultural products and therefore potentially available for losses
- gives no information on the use efficiency

**N use efficiency (NUE)**
- can be calculated as the **ratio** between the amount of fertilizer N removed with the crop and the amount of fertilizer N applied
- expressed in %
- provides information about the **relative utilization** of additional N applied to a agricultural production system of a country or region
- NUE considers **productivity** more than the N balance
### N balance vs. NUE in different European countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Portugal</th>
<th>Sweden</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>N balance (kg N/ha) *</td>
<td>47</td>
<td>48</td>
<td>54</td>
</tr>
<tr>
<td>NUE (%) **</td>
<td>40</td>
<td>64</td>
<td>63</td>
</tr>
</tbody>
</table>

* Source: OECD (2008)
** Source: own calculation based on data from FAO and IFA statistics

-> A low N balance does not always relate to a high N use efficiency.

-> N balance and NUE do not necessarily lead to the same conclusions.
Mineral fertilizer application compensates for exported, lost and additionally needed nitrogen

- Export of N with harvest
- Necessary production increase
- Unavoidable N losses

NUE = N removal with harvest / mineral N input * 100

-> this ratio describes the efficiency of N fertilizer utilization in crop production

On country/regional level:
- N removal = yield of arable and permanent crops (FAOstat) x avg. N content
- mineral N input = N fertilizer consumption (EFMA/IFA statistics)
Target of an indicator

- To show developments in countries/regions
- To compare countries/regions with each other

Requirements
- The same method should be used in all countries/regions
- Data shall be easily available
- Easy calculation and update

- With the same way of calculation, any method should give comparable results
N removal, N application, and NUE in a long-term trial with winter wheat at increasing N application

NUE = N removal / N application * 100

Broadbalk long-term trial with winter wheat in Rothamsted, UK
Example: NUE of mineral fertilizer application in a long-term field trial with winter wheat

<table>
<thead>
<tr>
<th>N application rate (kg N/ha)</th>
<th>N removal (kg N/ha)</th>
<th>NUE (%)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>26</td>
<td>-</td>
<td>Soil mining ¹</td>
</tr>
<tr>
<td>48</td>
<td>56</td>
<td>116</td>
<td>Risk of soil mining ²</td>
</tr>
<tr>
<td>96</td>
<td>92</td>
<td>96</td>
<td>Balanced in- and outputs ³</td>
</tr>
<tr>
<td>144</td>
<td>126</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>192</td>
<td>151</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>166</td>
<td>69</td>
<td>Risk of high N losses ⁴</td>
</tr>
</tbody>
</table>

1. Soil mining = N removal exceeds N input -> declining soil fertility and yield = unsustainable
2. Risk of soil mining = additional N requirement for roots and straw is not met by N input
3. Balanced in- and outputs = N fertilizer input meets total crop demand (grain, straw, roots)
4. Risk of high N losses = N fertilizer input exceeds total crop demand -> increased risk of leaching

Data from the long-term “Broadbalk Experiment”, Rothamsted/UK, winter wheat, avg. yield of 1996-2000
Use of output-input ratio to calculate NUE for different regions

- moving average of 3 years, arable & permanent crops, only mineral N

Source: own calculations based on FAO, IFA
**UN ECE: Revision of the Gothenburg Protocol**

- **Context:**
  - The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone is currently under revision. Annex IX addresses NH$_3$ emissions in agriculture.
  - UN ECE defines mandatory quantitative targets on NH$_3$ emission savings.

- **NUE** is proposed by an UN ECE Task Force as a « legal instrument » to monitor the implementation of the revised Gothenburg protocol.

**EU: Development of bio-energy**

- **Context:**
  - 10% biofuels in 2020 in bio-energy targets.
  - Biofuels should comply with sustainability criteria.

- **NUE** is proposed by a group of scientists as a sustainability indicator for the evaluation of the sustainability of first generation biofuels
Summary and conclusions

- We propose to calculate NUE of mineral fertilizer use as the output-input ratio, i.e. the ratio between the N removal with the harvested crop and the N input as mineral fertilizer.

- NUE provides information about the utilization of additional N applied to an agricultural production system of a country or a region.

- NUE considers agricultural productivity more than the N balance.

- NUE has already gained increasing importance in agro-environmental policies, e.g. the revised UNECE Gothenburg Protocol.

- NUE can be calculated and updated based on robust and available statistical data.

- NUE results need interpretation scheme in order to make communication also clear to non-specialists.