Carbon Footprint of crop production and ways to reduce it – focus on mineral fertilizer

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Case study: winter wheat
Germany, up to the farm gate

[Bar chart showing the breakdown of CO₂ emissions in kg CO₂e/t wheat grain for different sources:
- CO₂ from lime
- N₂O from soil
- Transport and on-farm energy
- Production of other inputs
- Production of mineral fertilisers]
Life-cycle assessment (LCA) methodology to calculate carbon footprint of fertilizers

- Ideally, the analysis covers GHG emissions and absorptions throughout every stage of the ‘life’ of a fertilizer, i.e. from cradle to grave.
- This allows a better understanding of what can be done to improve the overall carbon balance.
- However, in practice fertilizer PCFs are calculated at different scales.
Content of my presentation

- Carbon footprint of fertilizer production
- Reducing GHG emissions by improving N use efficiency
- N fertilizer management to reduce N$_2$O emissions
The Fertilizers Europe Carbon Footprint Calculator (CFC) performs a cradle-to-gate analysis.

- The European fertilizer industry developed the tool jointly as an industry standard. The calculator is independently validated by DNV-GL. It is not yet fully compliant with general carbon footprinting standards such as PAS2050.
The basis for mineral fertilizer: Air, energy, and minerals

Nitrogen (N₂) from air

Hydrogen (H₂) (e.g. from natural gas)

Ammonia (NH₃)

Finished products:
- Urea
- UAN
- Nitrates (CAN, AN)
- NPK
- Specialty fertilizers

Natural minerals:
- Phosphate rock (P)
- Potassium salts (K)
Reduction of the carbon footprint of CAN production in Europe from the 1990s until 2014

kg CO2e / kg N

1990s: 8.81
2006: 6.26
2010: 4.19
2014: 3.52

Ecoinvent (2002) & Fertilizers Europe reference values
Catalyst technology converts N$_2$O into N$_2$ and O$_2$
Carbon footprint of AN and Urea production in different world regions (2014 data)

kg CO₂e / kg N

- Emissions released up to plant gate
- CO₂ from urea hydrolysis

AN (prilled)

<table>
<thead>
<tr>
<th>Region</th>
<th>Emissions released up to plant gate</th>
<th>CO₂ from urea hydrolysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>CIS</td>
<td>7</td>
<td>2</td>
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<td>3</td>
</tr>
<tr>
<td>CN</td>
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</table>

Urea

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The new fertilizer production carbon footprint (and LCA) information is included in important tools and databases (and hopefully more will follow…)

[Logos of CFT, Cool Farm Tool, World Food LCA Database, GaBi Databases, and ecoinvent]
Carbon Footprint of Yara products

- calculated with same method
- independently verified by DNV-GL
- available for all products from main European plants
Reducing GHG emissions by improving N use efficiency
Two main opportunities: (1) optimize N use efficiency and (2) use “climate-friendly” N fertilizers

Our suggestion for optimizing NUE:

• Crop-specific and balanced crop nutrition programs
• Reliable and readily plant-available nitrogen source
• Integration of all nutrients available on farm
• Improved fertilizer recommendation tools: N-Sensor (tractor-mounted N measurement tool), N-Tester (handheld N measurement tool), ImageIT (mobile app)
Tools to optimize the fertilizer N use efficiency
A 3-years field trial at Gut Piesdorf compared fertilizer strategies in terms of yield, quality and carbon footprint.

**Treatment A:** Farm practice (variable between years; 163-220 kg N/ha)

**Treatment B:** Nitrogen applied in 3 dressings as CAN; 113-150 kg N/ha
N rate according to soil and plant analysis (Yara N-Tester)

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**Yield (t/ha, 86%dm):**

- Treatment A: 11.11 t/ha
- Treatment B: 10.84 t/ha

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**Protein (%):**

- Treatment A: 11.4%
- Treatment B: 11.7%

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**CFP (kg CO2e/t grain):**

- Treatment A: 198 kg CO2e/t
- Treatment B: 131 kg CO2e/t
Working with the food chain: The Cool Farm Alliance

- The Alliance provides the Cool Farm Tool as a on-farm GHG calculation tool that is credible and standardized.

- Mission: enable growers globally to make more informed on-farm decisions that reduce their environmental impact.
N fertilizer management to reduce $N_2O$ emissions
Yara does research to reduce N$_2$O emissions from soil after N fertilizer use
Two natural processes release N$_2$O from soil both are the consequence of microbial activity

**Nitrification**

Urea/Ammonium $\rightarrow$ Nitrate $\rightarrow$ N$_2$O

Soil organisms use ammonium (NH$_4$) as energy source

**Denitrification**

Nitrate $\rightarrow$ N$_2$ gas $\rightarrow$ N$_2$O

Conditional: if oxygen (O$_2$) is depleted (water logging), soil organisms use oxygen from nitrate (NO$_3$) for respiration

N$_2$O from both processes $\approx$ 1% of N (IPCC, 2006)
Process that release N$_2$O from soil are governed by soil moisture

- Increasing soil humidity reduces soil oxygen content which in turn increase N2O emission from N fertilizer
- Therefore the scheme below applies

<table>
<thead>
<tr>
<th>Soil moisture</th>
<th>Emission level</th>
<th>Nitrat vs. ammonium</th>
<th>Urea vs. ammonium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low to normal* = Well aerated</td>
<td>low</td>
<td>nitrate &lt; ammonium</td>
<td>urea $\geq$ ammonium</td>
</tr>
<tr>
<td>Wet = Low oxygen</td>
<td>medium</td>
<td>nitrate &gt; ammonium</td>
<td>urea $&gt;&gt;$ ammonium</td>
</tr>
<tr>
<td>Very wet = Anaerobic</td>
<td>high</td>
<td>nitrate $&gt;&gt;$ ammonium</td>
<td>urea $\approx$ ammonium</td>
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</tbody>
</table>

* For temperate climate during growing season
N$_2$O emissions during the growing season of winter wheat fertilized with urea or CAN

4 experiments with winter wheat during growth period; N rate = 220 kg N ha$^{-1}$

Publications of $N_2O$ emission show differences between grassland and arable land.

Higher emission factors (EF) are more frequently reported from grassland.

Data are not directly comparable includes measurements of different experimental length, soils, etc.
In summary …

• Fertilizers Europe has developed a carbon footprint calculator for fertilizer production that includes reference values for all world regions.

• European fertilizer production has the lowest CFP in the world. This is particularly valid for nitrate-containing products.

• Certified CFP values for all Yara products from the main European plants are available.

• Improving N use efficiency has multiple benefits for the farmer, the environment, and the climate.

• N₂O emissions from different forms of N (urea, ammonium, nitrate) depend on environmental conditions and no single N form performs best under all conditions.