Agronomic Efficiency and Environmental Impact of N Fertilizers in the Tropics: A Life-Cycle Assessment (LCA)

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Outline

- Overview on agronomic performances and relevant greenhouse gas emissions of nitrogen fertilizers (i.e. urea/ammonium nitrates-based)
- Carbon footprint of crop production with different nitrogen fertilizers from Life-Cycle Assessment (LCA) viewpoint
- Options to improve the carbon footprint of crop production from fertilizer’s perspective
Agronomic performance of N fertilizers

• Mineral nitrogen fertilizers, depending on their chemical and physical composition do not react in the same way in the soil and have distinct impacts on crop yield, its quality and the environment.

• There are several factors that do influence the impact and crop use efficiency of applied N fertilizers:
  • Provided N form on uptake (N form preferences)
  • Provided N form on acidification processes (soil and rhizosphere acidification)
  • N losses (ammonia volatilization, N2O emission, leaching)
  • N transformation in soil (immobilization by microorganisms)
  • Fertilizer N recommendation and management (diagnostic, timing)
Agronomic performance of N fertilizers

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  • Fertilizer N recommendation and management (diagnostic, timing)

• Comparison of the main performances and impacts of two main straight nitrogen fertilizers: urea and ammonium nitrates (AN)
Agronomic differences of surface applied AN vs urea in major crops (Brazilian systems)

Crop yield (100% = AN fertilizers)

- **Corn**: Urea (80%) vs AN (90%)
- **Citrus**: Urea (70%) vs AN (80%)
- **Sugarcane**: Urea (70%) vs AN (90%)

Optimum fertilizer N rate: yield response trials are required

Site: LEM (Bahia) on main season corn (2012/2013)

Grain yield 87% - MS (kg/ha)

Grain yield at Nopt (P<0.05)

Source: Fundation Bahia – Yara Brazil (2013)
Higher ammonia losses from surface applied urea compared to AN in tropical acid soils
(Brazilian systems)

NH3-N loss (% of applied N)

Nitrous oxide (N2O) emissions in tropical acid soils

<table>
<thead>
<tr>
<th>Fertilizer type</th>
<th>Nitrous oxide emissions factors (N2O-N % of N applied)</th>
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Data base included data and depending on:

- Crop type
- Nitrogen rate
- Nitrogen application timing and split
- Product forms: liquid and solids
- Soil type
- Soil water availability (precipitation)
- C/N ratio

Sources: Allen et al. (2010); Weitz et al. (2001); Crill et al. (2000); Zanatta et al. (2003); Signor et al. (2013)
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Carbon footprint of crop production with different nitrogen fertilizers
Carbon footprint

- A carbon footprint is “the total set of GHG (greenhouse gas) emissions caused directly and indirectly by an individual, organization, event or product” (Carbon Trust, 2007).

- All GHG emissions (e.g. nitrous oxide, N$_2$O) are combined into carbon dioxide equivalents (CO$_2$eq) and related to a common unit (e.g. per kg of fertilizer or nutrient or crop produce).

- A measurement of the relative effect of a product and/or activity on climate change.
Life-cycle assessment (LCA) methodology to calculate carbon footprints

- LCA of fertilizers determines GHG emissions and absorptions throughout every stage of the ‘life’ of a fertilizer.
- This allows a better understanding of what can be done to improve the overall carbon balance and decrease impacts.
- The carbon footprint of mineral fertilizers includes production, transportation and use (farming)
Carbon footprint of no-tillage maize production in Brazil - systematic description

- Raw materials
  - Fossil fuels
  - Minerals

- Production
  - Fertilizer, seeds and agrochemicals

- Transportation
  - Fertilizer

- Cultivation
  - Direct and indirect fertilizer related GHG
  - On-farm activities

Inventory of GHG emissions (per t grain)

- Global warming potential in kg CO₂-equivalent ("carbon footprint")
  - N₂O
  - CO₂
  - CH₄

1 t corn
Carbon footprint for maize production under no-tillage in Brazil – input parameters

As per fertilizer N forms (urea or ammonium nitrates)

- Crop yield (t/ha) and N uptake – removal (kg/ha) (Local data)
  - 6.8 % grain yield difference between urea and AN.
- Ammonia volatilization from fertilizer N applied (NH3 in %) (Local data)
  - 30 and 2 % for urea and AN respectively
- Nitrous gas emissions from fertilizer N applied (N2O in %) (1% - IPCC factor)
Carbon footprint for producing 1 ton of corn grain using Urea

- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
- N2O - fertilizer application
- N2O - NH3 volatilization
- CO2 - urea hydrolysis
- CO2 - on-field operations
- CO2 - fertilizer transport
- CO2eq - seeds/Agrochemical
- CO2eq - fertilizer production

Fertilizer manufacturing
Carbon footprint for producing 1 ton of corn grain using Urea

- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
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- CO2 - on-field operations
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- CO2eq - seeds/Agrochemical
- CO2eq - fertilizer production

kg CO2 eqv / t corn grain
Carbon footprint for producing 1 ton of corn grain using Urea

Inputs/operations

- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
- N2O - fertilizer application
- N2O - NH3 volatilization
- CO2 - urea hydrolysis
- CO2 - on-field operations
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- CO2eq - seeds/Agrochemical
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Carbon footprint for producing 1 ton of corn grain using Urea

- Urea (Global ave)
- AN
- AN (+BAT)

Key:
- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
- N2O - fertilizer application
- N2O - NH3 volatilization
- CO2 - urea hydrolysis
- CO2 - on-field operations
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kg CO₂ eqv / t corn grain
Carbon footprint for producing 1 ton of corn grain using Urea

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Direct/indirect due to Urea hydrolysis
Carbon footprint for producing 1 ton of corn grain using Urea

- N₂O - crop residues
- CO₂ - liming
- N₂O - NO₃ leaching
- N₂O - fertilizer application
- N₂O - NH₃ volatilization
- CO₂ - urea hydrolysis
- CO₂ - on-field operations
- CO₂ - fertilizer transport
- CO₂eq - seeds/Agrochemical
- CO₂eq - fertilizer production

Direct from fertilizer/soil

kg CO₂ eqv / t corn grain

Urea (Global ave)  AN  AN (+BAT)
Carbon footprint for producing 1 ton of corn grain using Urea

- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
- N2O - fertilizer application
- N2O - NH3 volatilization
- CO2 - urea hydrolysis
- CO2 - on-field operations
- CO2 - fertilizer transport
- CO2eq - seeds/Agrochemical
- CO2eq - fertilizer production

kg CO\textsubscript{2} eqv / t corn grain
Carbon footprint for producing 1 ton of corn grain using Urea

- N2O - crop residues
- CO2 - liming
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kg CO₂ eqv / t corn grain
Carbon footprint for producing 1 ton of corn grain using Urea

- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
- N2O - fertilizer application
- N2O - NH3 volatilization
- CO2 - urea hydrolysis
- CO2 - on-field operations
- CO2 - fertilizer transport
- CO2eq - seeds/Agrochemical
- CO2eq - fertilizer production

Direct/indirect due to remaining nitrogen

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Carbon footprint for producing 1 ton of corn grain using Urea and std AN

- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
- N2O - fertilizer application
- N2O - NH3 volatilization
- CO2 - urea hydrolysis
- CO2 - on-field operations
- CO2 - fertilizer transport
- CO2eq - seeds/Agrochemical
- CO2eq - fertilizer production

kg CO2 eqv / t corn grain

Urea (Global ave) AN AN (+BAT)

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Catalyst tech (+BAT) significantly improves carbon footprint vs std AN

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AN (+BAT): Improved in nitric acid production

Nitric acid plant

Nitrous oxide (N2O) abatement catalyst
Lower carbon footprint for producing 1 ton of corn grain with (+BAT) vs Urea

Options to improve soil emissions?

- N2O - crop residues
- CO2 - liming
- N2O - NO3 leaching
- N2O - fertilizer application
- N2O - NH3 volatilization
- CO2 - urea hydrolysis
- CO2 - on-field operations
- CO2 - fertilizer transport
- CO2eq - seeds/Agrochemical
- CO2eq - fertilizer production

kg CO$_2$ eqv / t corn grain

Urea (Global ave) vs AN (+BAT)
Options to improve the Carbon footprint of crop production from fertilizer use perspective...?
Tools to optimize the fertilizer N use efficiency
Variable N application technology...
Variable – crop based application improves fertilizer N use efficiency

Ref. Bragagnolo et al. (2013). Average of 3 sites / 2 seasons (2008-2010). Fert N rate of 140/150 kg N / ha
Best management practices improve the carbon footprint for producing 1 ton of corn grain

[Bar chart showing the comparison between Std N mgm and Precision N farming in terms of kg CO₂ eqv / t corn grain]
Best management practices improve the carbon footprint for producing 1 ton of corn grain.
Summary

How improve the Carbon footprint of crop production from fertilizer’s perspective...?
Fertilizer Production

Mitigation potential:

- Improve the energy efficiency of ammonia production and other production systems
- Install and further optimize catalytic cleaning of N$_2$O
Fertilizer Use

Mitigation potential:
- Balanced nutrition
- Tailored N-application
- Just-in-time application
- Use of precision farming tools
- Select appropriate fertilizers

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Supporting R&D to develop GHG inventories in Brazil ...
N-form and GHG emissions research in Sugarcane
(Cooperation with IAC Campinas/ATPA Piracicaba)
N-form and GHG emissions research in maize and coffee (Cooperation with Embrapa)