Fertilizers and Climate Change

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Principle of crop nutrition
Mineral nutrients are essential building blocks of crop material and help the crop to grow and to produce yield.

The carbon in crops originates from CO₂ absorbed by leaves.

From soil crops take water and inorganic ions - the plant nutrients.

Plant nutrients are necessary building blocks of crop biomass.

Any higher crop yield requires more plant nutrients.

Any deficiency of nutrients reduce crop yield.
Fertilizer replace nutrients that are removed from the field and add nutrients for higher yield

Supply of crop residues and organic fertilizer

Export of nutrients with the harvest

Unavoidable losses from the field

Growing demand for food & feed

Crop residues are decomposed to minerals

Organic substance, humus

Mineralisation

NPK

N, P, K, S, Ca, Mg

• Organic substance, humus
• NPK
• Crop residues are decomposed to minerals
• Supply of crop residues and organic fertilizer
• Export of nutrients with the harvest
• Unavoidable losses from the field
• Growing demand for food & feed
Increasing supply of nitrogen help the crop to produce more protein and more yield.
Additional nitrogen will not contribute to more yield because other factors limit crop yield.

Grain yield tons / ha

N-fertilizer rate kg / ha

Based on Broadbalk Experiment, Rothamsted/UK,
Crops capture by far more CO$_2$ than what is emitted during their cultivation – fertilizer enhance this effect.

If the harvested crop is used as food or feed, the CO$_2$ fixation is only short-term and cannot be considered.
Fertilizer and Climate
For arable farms, N fertilizer induced GHG emission dominate the carbon footprint of crop production.

Based on a long-term field trial data with winter wheat (UK), N source = Ammoniumnitrate
Contribution of the agricultural sector and land use change to global GHG emission

Total: 49.4 Billion t CO$_2$-equivalents

Agriculture (10.2%):
- Livestock & manure (6.8%)
- Mineral fertilizer (1.2%)
- Rice (1.0%)
- Residues & org. soils (1.2%)

Land use change** (11.2%)

11.2% of global GHG emission are ~ 5.5 Billion t CO$_2$-equivalents.

Total EU28 GHG emission in 2010 were ~ 5.0 Billion t CO$_2$-equivalents

* Based on IFA (2009)
GHG emission of regions with strong agricultural growth are dominated by land use change and agriculture

Emissions from land use change are mainly related to deforestation

FAOSTAT data
GHG emission of regions with strong agricultural growth in comparison to Europe and N-America

Large emission caused by land use change to agriculture suggest not to increase arable land but to increase productivity on existing agricultural land by closing yield gaps.

For comparison:

In Europe and N-America forests are a net-sink for CO2
Example: Cocoa production in Africa

Current practice:

2 million tons of cocoa beans are produced on 5 million hectares of land
Modern agriculture with best fertilizer management

2 million tons of cocoa beans can be produced on 1 million ha of land.

Land available for biodiversity, other food crops or forest carbon sequestration.
Good agricultural practices including mineral fertilizer make agricultural land productive and mitigate land use change.

Example from Tanzania (average of 3 years, 2012-14; Welela, Njombe region)

Grain yield: 2.9 t/ha

Grain yield: 7.7 t/ha
Good agricultural practices including mineral fertilizer make agricultural land productive and mitigate land use change.

Example from Tanzania (average of 3 years, 2012-14; Welela, Njombe region)

**Farmer practice with no or little fertilizer input**
- Grain yield: 2.9 t/ha
- GHG emission: 163 kg CO2e per t maize grain

**Balanced nutrition with NPK fertilizer**
- Grain yield: 7.7 t/ha
- GHG emission: 262 kg CO2e per t maize grain
Good agricultural practices including mineral fertilizer make agricultural land productive and mitigate land use change.

Example from Tanzania (average of 3 years, 2012-14; Welela, Njombe region)

Farmer practice with no or little fertilizer input

Carbon footprint in kg CO2e per t maize grain

Balanced nutrition with NPK fertilizer

Carbon footprint in kg CO2e per t maize grain

Additional GHG emissions from land use change to compensate for yield difference
If crop yields were still at the 1961 level, GHG emission from agriculture at current production would be 4.5 times higher than today.

Source: acc. Burney et al. (2010); Stanford Univ.
The carbon footprint of mineral fertilizer
In arable farms, N fertilizer induced GHG emission dominate the carbon footprint of crop production.

Based on a long-term field trial data with winter wheat (UK), N source = Ammoniumnitrate
Reduction of GHG emissions from European fertilizer production through technology development (example Ammonium Nitrate, AN)

kg CO$_2$eq / kg AN-N

- **1990s**: 8.7
- **2006**: 6.2
- **2014**: 3.4

Ecoinvent (2002)  
Fertilizers Europe reference values*

* 2006 value from Brentrup & Palliere (2008); 2014 value derived from Fertilizers Europe Carbon Footprint Calculator v2.1 (2016)
The European fertilizer industry has the lowest GHG emission from N fertilizer production (Ammonium Nitrate, AN, 2014).

* Assumption for ammonia production in China: 75% coal-based, 25% gas-based

All data derived from Fertilizers Europe Carbon Footprint Calculator v2.1 (2016)
In arable farms, carbon footprint of crop production is reduced with N fertilizer from European production.

Based on a long-term field trial data with winter wheat (UK), N source = Ammoniumnitrate.
How to reduce $\text{N}_2\text{O}$ emission from soils

1. Higher crop Nitrogen Use Efficiency NUE

   $\text{NUE} = \text{share (\%)}$ of fertilizer absorbed by crop

2. What can be measured can be improved
Measures to improve fertilizer use efficiency and to reduce $\text{N}_2\text{O}$ emission from soil

- Fertilizer planning including organic fertilizer
- Use organic fertilizer in the most efficient way
- Focus on a balanced nutrition of all nutrients
- Use the most efficient mineral fertilizer product, including inhibitors where appropriate
- Adjust fertilizer rate within growth season to actual crop demand
N fertilizer use efficiency (NUE) in EU15 is increasing since the late 1980s.

Today Europe has the highest Nitrogen Use Efficiency (NUE) of any region in the world.
In Europe (EU 15) NUE has increased while $\text{N}_2\text{O}$ emissions from agricultural soils have decreased.

Source: United Nations Framework Convention on Climate Change (UNFCCC, 2011)
Sources of N\textsubscript{2}O and emission from agricultural soils in Europe

- **Mineral fertilizer N**: 59 Mio t CO\textsubscript{2}eq
- **Biological Nitrogen Fixation**: 24.4%
- **Crop residues**: 2.9%
- **Organic soils**: 7.9%
- **Manure application & grazing animals**: 12.0%
- **Volatilization & leaching**: 12.4%

\[ 241 \text{ Mio t CO}_2\text{eq} \]

Source: United Nations Framework Convention on Climate Change (UNFCCC, 2016)
The Cool Farm Alliance

- The Cool Farm Alliance is a group of **multinational companies, NGOs and academics working together** to measure how improved agricultural practices can mitigate greenhouse gas emissions.
- **The aim?** To enable millions of farmers globally to make more informed on farm decisions towards sustainable agriculture.
- The Cool Farm Alliance works together to improve and increase the use of Cool Farm Tool.
What is the Cool Farm Tool?

An easy to use and standardised online tool for calculating the on-farm environmental impacts, currently greenhouse gas emissions, associated with a range of crop or livestock products, applicable globally

The cool farm tool
✓ is scientifically robust
✓ is farmer-friendly
✓ is Industry-backed
✓ will create incentives for low GHG emission
Summary

- Main contributions from the ag. sector to GHG emission are land use change and livestock farming, to a smaller extent mineral fertilizer and rice cultivation.
- Converting natural land into arable land should be avoided by closing yield gaps on existing farm land.
- Mineral fertilizer contribute to productive agriculture and thus contribute to mitigate GHG emission from land use change.
- The European fertilizer industry has developed technologies to reduce the carbon footprint of nitrate fertilizer production by more than 50%.
- Improving crop N use efficiency is climate-smart and has multiple benefits for the farmer and the society.
- N use efficiency is highest in Europe and will further improve through innovation in agricultural practices and balanced crop nutrition.