ENERGY EFFICIENCY AND GREENHOUSE GAS EMISSIONS

IN EUROPEAN NITROGEN FERTILIZER PRODUCTION AND USE

SUSTAINABLE
AGRICULTURE
IN EUROPE

ENERGY EFFICIENCY AND GREENHOUSE GAS EMISSIONS IN EUROPEAN NITROGEN FERTILIZER PRODUCTION AND USE

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Abstract

The use of mineral fertilizer is an essential component of sustainable agriculture. Mineral fertilizers are applied in order to balance the gap between the nutrients required for optimal crop development and the nutrients supplied by the soil and by available organic sources.

On the other hand, the fertilizer industry is a consumer of energy and an emitter of carbon dioxide (CO_2) and other greenhouse gases (GHGs). However, the GHG emissions during the production and use of the fertilizers should not be evaluated without considering the benefits of fertilizers in agricultural production. This publication therefore investigates the climate change impact of fertilizers, including their production, transportation and use.

The energy balance of crop production is positive, because it is the nature of crop production to convert solar energy into crop biomass. Appropriate use of mineral fertilizer further improves this positive energy balance. Depending on the crop, fertilizer application helps to fix 10 to 15 times more energy than consumed by the production, transportation and application of the fertilizer. If the energy contained in the biomass produced is used as bio-fuel, it replaces fossil fuels and thereby mitigates CO_2 emissions.

The responsible production and use of mineral fertilizers in agriculture should be considered not only as an essential part of the global production of food, but also as part of the solution to climate change problems. The publication addresses the impact of fertilizers on climate change and how new production technology and optimum fertilizer application lead to significant improvements in the GHG balance of crop production.

Contents

Introduction

Crops need nutrients to grow. They take up these nutrients in the form of minerals irrespective of their origin, which might be organic (e.g. manures, residues or soil organic matter) or mineral fertilizer. A recent review by Erisman et al. (2008) estimates that today about 50% of the world's population is only able to be fed due to the use of mineral nitrogen fertilizers.

Taking into account the additional future growth in global population accompanied by increasing demand for animal products, it will almost certainly be necessary to use more mineral fertilizers in the future. Limited land resources further confirm the need for intensive crop production with optimal input of plant nutrients.

Despite the fundamental benefits of mineral fertilizers in terms of food security, their production and use have an environmental footprint. Energy use and losses of nitrogen compounds to the environment contribute to several environmental impacts such as the eutrophication of water bodies, acidification and climate change. This publication concentrates on the impacts of fertilizer production and use on climate change.

Mineral fertilizer - essential component of sustainable food production

The availability of plant nutrients in sufficient amounts and their correct balance is a prerequisite for plant growth and hence yield. The use of mineral fertilizer as one source of plant nutrients is an essential component of sustainable agriculture.

Mineral fertilizers are applied in order to balance the gap between the nutrients required for optimal crop development and the nutrients supplied by the soil and by available organic sources. This gap is due to the permanent export of nutrients from the field with harvested crops and the increasing demand for agricultural products (see Figure 1). Today the nutrient gap is closed by an annual application of 176 million tonnes of mineral fertilizer comprising nitrogen (N), phosphate (P_2O_5), and potash (K_2O) (IFA, 2013).

However, not only the amount of available nutrients needs to be considered, but also the balance between these. Soils can naturally provide plant nutrients only according to their respective geology and geographic location. This regularly implies unbalanced nutrient availability, and only one nutrient missing can severely limit yield. Mineral fertilizers allow a targeted application of individual nutrients at adjusted rates and thereby provide balanced nutrition for the crop, while improving soil fertility.

Figure 1

MINERAL FERTILIZERS CLOSE THE GAP BETWEEN THE NUTRIENT SUPPLY FROM THE SOIL AND ORGANIC SOURCES AND THE DEMAND FOR OPTIMUM CROP DEVELOPMENT

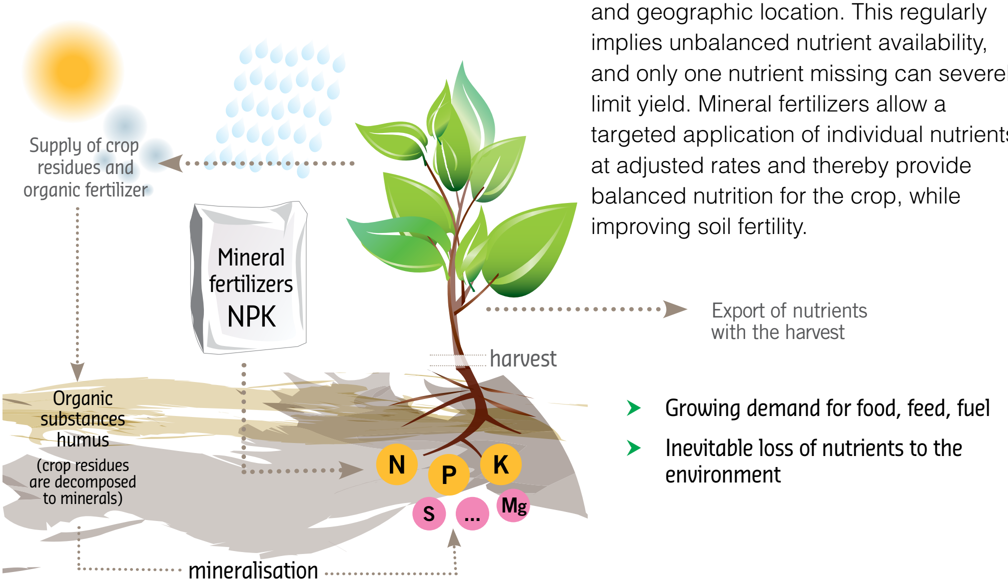


Figure 2 shows global trends in cereal production, world population, fertilizer use, and arable land as projected by the FAO (2003). The world population is assumed to reach more than 8 billion people by 2030, a 40% increase compared to the mid-1990s (FAO, 2003). During the same time period, cereal production is predicted to grow even more (+50%). This over-proportional increase is mainly due to increasing wealth, with growing demand for meat in transition countries like Brazil and China.

Since available arable land can only be expanded by 7%, the rising demand for food and feed has to be met from a limited area (i.e. crop yields per unit area have to increase). In particular, in many developing countries an insufficient nutrient supply limits crop yields (Sanchez and Palm, 2007). Therefore, increasing fertilizer inputs (+37%) are regarded as an important component in improved productivity in future crop production.

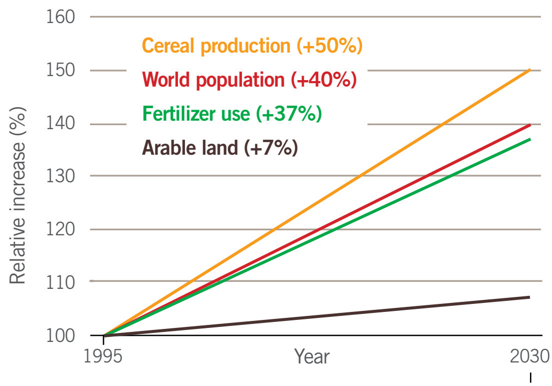
Erisman et al. (2008) estimate that today 48% of the total global population is nourished due to the use of mineral N fertilizers. Considering the historic trends and future projections published by Smil (2001), the FAO (2003, 2006a), and Erisman et al. (2008), the importance of the mineral nitrogen supply in food production will even increase.

Appropriate fertilizer inputs are needed to sustain a sufficient global supply of food, feed and bio-energy. Intensification aiming at higher production per unit area helps to prevent natural areas like forests from being changed into agricultural land. This kind of land use change is regarded as a major global threat for environmental problems such as decreasing biodiversity and climate change (Bellarby et al., 2008).

Agricultural production in general and the use of fertilizers in particular has, as have all human activities, an 'environmental footprint'. With regards to N fertilizers, this is mainly related to the eutrophication and acidification of natural and semi-natural ecosystems, and the release of greenhouse gases (GHG). In the following sections the focus will be on the GHG emissions ('carbon footprint') of agriculture and crop production in general, and the role of mineral N fertilizer in particular.

Figure 2

PROJECTED DEVELOPMENT OF CEREAL PRODUCTION, WORLD POPULATION, FERTILIZER USE AND ARABLE LAND



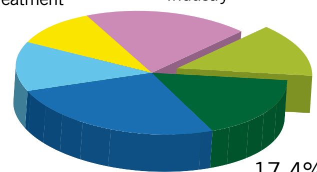
Source: FAO, 2003

Agriculture's contribution to climate change

Figure 3 shows the contribution of different sectors to global GHG emissions in 2004 according to the 4th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007).

Figure 3

CONTRIBUTION OF DIFFERENT SECTORS TO GLOBAL GHG EMISSIONS (2004)



Source: IPCC, 2007

Agricultural GHG emissions include:

- Methane (CH_4) emissions from enteric fermentation (cattle farming);
- CH_4 from rice cultivation;
- Nitrous oxide (N_2O) from application of organic and mineral N sources;
- N_2O and CH_4 from manure handling (storage etc.);
- N_2O and CH_4 from burning of crop residues etc.

The emissions of these different gases are converted to an equivalent value, using a tonne CO_2-equivalent (CO_2-eq) as the basic GHG unit. As the GHG effect of CH_4 is 23 times more that of CO_2, a tonne of CH_4 emitted is multiplied by 23 to become the CO_2-equivalent. Nitrous oxide (N_2O) has 298 times the effect of CO_2 and N_2O emissions are therefore multiplied by 298 to become CO_2-eqivalents.

However, when considering agriculture, there are also some GHG emissions assigned to sectors other than agriculture that are directly linked to agricultural production. This is the case for natural areas (mainly forest) that are converted into agricultural land (in IPCC assigned to 'Forestry'). Bellarby et al. (2008) estimate that about 12% (range of 6-17%) of the global GHG emissions are due to land conversion to agriculture. The production of N fertilizer (in IPCC assigned to 'Industry') releases another 410 million tons of CO_2-eq per year (Bellarby et al., 2008), which is equivalent to 0.8% of global GHG emissions (Figure 4).

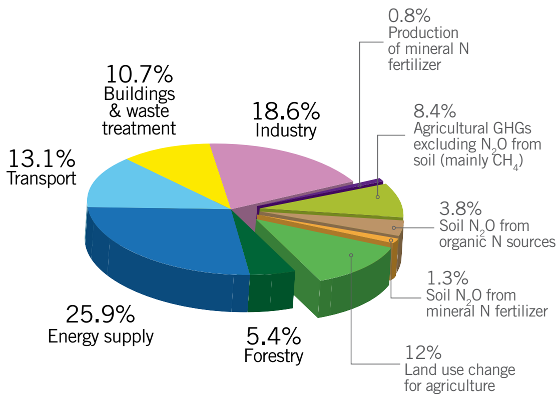
According to Bellarby et al. (2008) agricultural soils emit 2,128 million tonnes of CO_2-eq as N_2O. Applying the IPCC estimation methodology (IPCC, 2006) to a global consumption of 90 million tonnes of mineral N (IFA statistics for 2004/2005), indicates a combined direct and indirect N_2O emission of 561 million tonnes CO_2-eq. This represents 1.3% of the total global GHG budget or 26% of the N_2O emissions from agricultural soils. The remaining 1,567 million tonnes CO_2-eq emitted from soils as N_2O have to be allocated to the different organic N sources such as manure, crop residues and sewage sludge.

The European GHG budget (Figure 5) differs significantly from the global situation. The agricultural contribution (without N fertilizer production) is about 9.2% in the EU-27 compared to 13.5% worldwide. At the same time, the IPCC category 'land use, land use change, and forestry' (LULUCF) acts as a sink of 432 million tonnes CO_2-eq in Europe, which is of the same order of magnitude as the total agricultural emissions.

This might be interpreted as an indication of the high efficiency of European agriculture, which does not need conversion of additional land into cropland to supply sufficient produce, thereby supporting the conservation of forests and other natural carbon sinks in Europe.

Figure 4

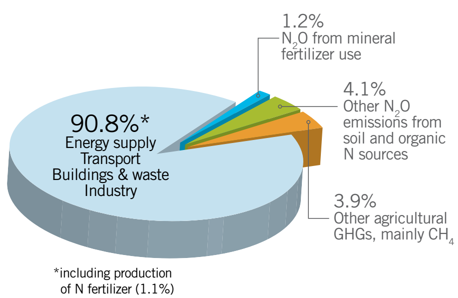
CONTRIBUTION OF ACTIVITIES RELATED TO AGRICULTURE TO GLOBAL GHG EMISSIONS IN 2004 (EXCLUDING NATURAL BACKGROUND EMISSIONS)



Source: IPCC, 2007; Bellarby et al., 2008; authors' calculations.

Figure 5

CONTRIBUTION OF THE DIFFERENT SECTORS TO EU-27 GHG EMISSIONS IN 2005



Sources: EC, 2008a; UNFCCC, 2008; authors' calculations based on Fertilizers Europe statistics and fertilizer specific emission rates (see Annex).

The role of mineral fertilizers in the carbon footprint of crop production

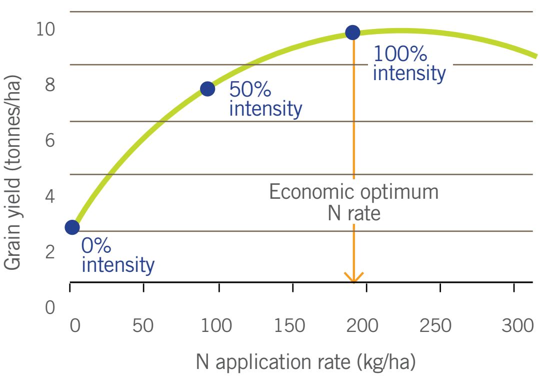
Numerous field trials have been conducted to investigate the impact of different N fertilizer application rates on yield. In addition to the yield response environmental parameters such as nutrient losses to water and air, energy consumption or emissions of GHGs have also been analysed in relation to the N application rate.

The results presented in this publication are based on a life-cycle assessment (LCA) study (Brentrup et al., 2004) that uses data from a long-term comparison of increasing rates of ammonium nitrate (AN) application to winter wheat ('Broadbalk Experiment' at Rothamsted Research, UK, see Figure 6).

The grain yield increased from 2.1 t/ha at zero N application to a maximum of 9.3 t/ha at 240 kg N/ha.

Figure 6

YIELD RESPONSE TO INCREASING N APPLICATION IN A LONG-TERM FIELD TRIAL WITH WINTER WHEAT



Source: 'Broadbalk Experiment', average yields for 1996-2000, Rothamsted, UK, (for details see Brentrup et al., 2004).

The economic optimum nitrogen application rate is at about 195 kg N/ha (at current wheat and fertilizer prices). The following analysis will focus on three production intensities, which are 'without N' (0 kg N/ha, 2.07 t grain/ha), '50% of optimum' (96 kg N/ha, 7.11 t grain/ha), and 'economic optimum N rate' (192 kg N/ha, 9.25 t grain/ha). The N fertilizer used in this field trial is ammonium nitrate.

Figure 7 shows the carbon footprint per hectare applying a life-cycle assessment approach, which considers all GHG emissions occurring from the supply of raw materials (fossil fuels, minerals), the production and transportation of farming inputs (fertilizer, pesticides, machinery, seeds), and agricultural activities (tillage, harvest etc.).

For fertilizer production, average European technology for ammonium nitrate production according to Jenssen and Kongshaug (2003) has been assumed. The carbon footprint for the economic optimum N rate, the 50% optimum, and without N is 2,516, 1,569 and 295 kg CO_2-eq/ha, respectively (see Fig. 7). At the same time, the crops fix about 1.6 tonnes of CO_2 per tonne of biomass through photosynthesis (Greef et al., 1993).

At a yield of 18.5 t/ha (grain plus non-grain biomass including straw at economic optimum N rate) this amounts to 29.6 t CO_2 fixation per hectare (i.e. almost 12 times the CO_2 emissions).

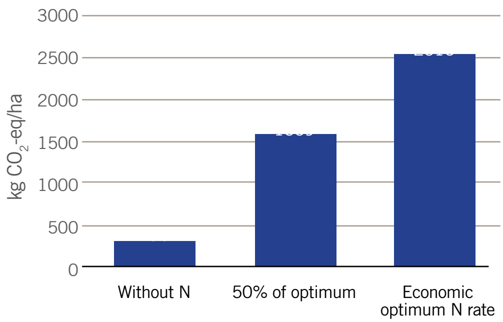
If this biomass is used as biofuel (e.g. for direct incineration) and thereby prevents fossil fuels from being burned, a substantial net saving of CO_2 emissions is the result. However, by far most of the grain is still consumed as food or feed and in this case the CO_2 fixation is only short to medium-term and is usually not considered as a credit.

Assuming that most farmers in the developed countries operate at an intensity represented by the 'economic optimum N rate', which is equivalent to recommended 'good agricultural practice', and considering the current and future demand for cereals as indicated in Figure 2, any reduction in the production intensity in one area has to be compensated by additional production at another. In many cases this results in changes in land use from natural areas into agricultural land (FAO, (2006b) and Fig. 2).

Figure 8 shows the additional CO_2 emissions that would occur due to conversion of temperate forest into cropland in order to compensate for the lower yields in the 'without N' and '50% of optimum' treatments

Figure 7

GREENHOUSE GAS EMISSIONS OF WHEAT PRODUCTION (INCLUDING PRODUCTION AND TRANSPORT OF FARMING INPUTS) AT DIFFERENT N FERTILIZATION INTENSITIES

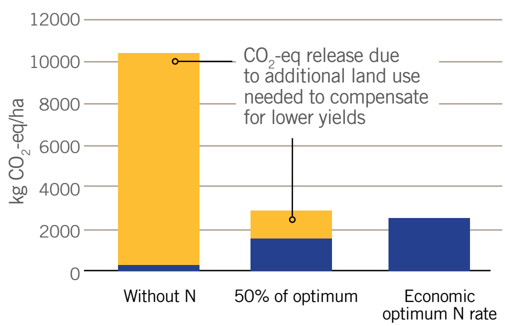


(based on data in Bellarby et al., 2008). The additional CO_2-eq emissions due to land use change has been spread over a time period of 100 years (i.e. 2.6 t CO_2/ha/yr).

Without any nitrogen input, the grain yield is so low (2.07 t/ha) that the land required to compensate this yield loss would lead to four times higher CO_2 emissions than those of the intensive system.

Figure 8

GREENHOUSE GAS EMISSIONS OF WHEAT PRODUCTION (INCLUDING PRODUCTION AND TRANSPORT OF FARMING INPUTS AND LAND USE CHANGE) AT DIFFERENT N FERTILIZATION INTENSITIES.



Taking into account scarce land reserves, it becomes obvious that a 'zero nitrogen' system is not a viable option. Also the '50%' treatment shows a higher carbon footprint if the additional land use needed to compensate for lower yields is considered. Therefore, it can be concluded that intensive crop production, aiming at most efficient utilisation of resources including the agricultural area, saves GHG emissions by preventing natural areas from having to be converted into cropland.

From a climate change point-of-view, it is nevertheless important to further reduce the carbon footprint of the currently most efficient option, i.e. the 'economic optimum N rate'. Possibilities for the reduction of GHG emissions from fertilizers used in crop production are discussed in the following section.

Options to improve the carbon footprint of fertilizers in crop production

In order to focus effort for improvement on the most relevant sources of GHG, it is necessary to identify the 'hot-spots' in the crop production system. The LCA approach allows the tracking back of the GHG emissions to their sources. Figure 9 reveals that N_2O emissions from N fertilizer production and from the agricultural field are the predominant sources of GHGs.

GHG emissions from nitrogen fertilizer production

GHG emissions from N fertilizer production are mainly from two sources. These are CO_2 from the use of fossil energy sources (mainly natural gas) as feedstock and fuel in ammonia synthesis and N_2O emitted from nitric acid production.

Figure 9

CARBON FOOTPRINT OF WHEAT PRODUCTION, SEPARATED INTO DIFFERENT GREENHOUSE GASES AND THEIR SOURCES

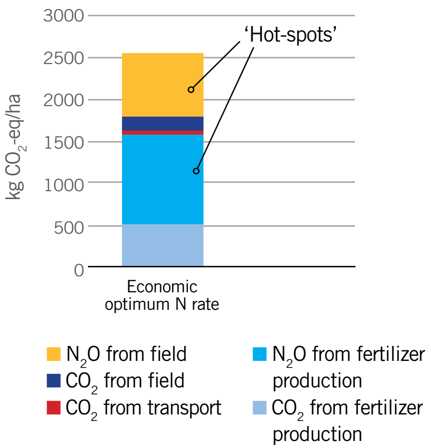
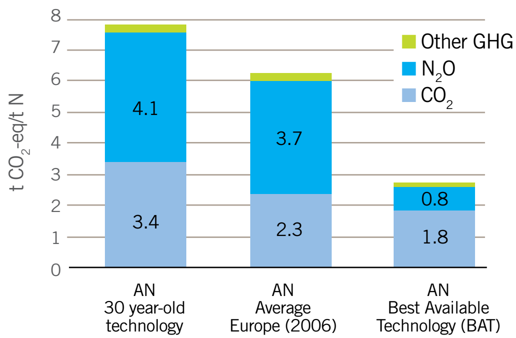


Figure 10

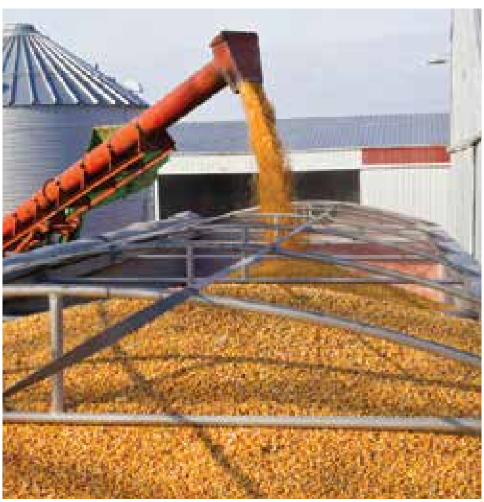
GREENHOUSE EMISSIONS OF AMMONIUM NITRATE PRODUCTION AT DIFFERENT LEVELS OF PRODUCTION TECHNOLOGY



Source: Derived from Jenssen and Kongshaug, 2003 for '30 years old tech.' and Fertilizers Europe data for 'Average Europe 2006' and 'BAT today'.

Approximately 70% of the natural gas feedstock (methane) used to make ammonia provides 60% of the hydrogen (H_2) required for the reaction with nitrogen (N_2) from the air for ammonia synthesis. The other 40% of the H_2 is derived from water in modern steam-reforming ammonia plants. These reactions are almost at their maximum theoretical efficiency. The other 30% of the methane is used as fuel to heat the processes. Figure 10 gives the levels of GHG emissions from ammonium nitrate production at different levels of technology.

Improvement in energy efficiency is the main target of developments in N fertilizer production technology. Due to reduced energy requirements, CO_2 emissions have already decreased from 3.4 to 2.3 t CO_2/t AN-N. More recently, N_2O abatement technology is being used to reduce N_2O emissions from nitric acid production. Catalytic systems are being developed which break down N_2O under high temperature into harmless nitrogen (N_2) and oxygen (O_2). This process enables a reduction in N_2O emissions of up to 70% to 85%. Using de-N_2O catalyst systems brings the total carbon footprint of ammonium nitrate production down to a level below 3 t CO_2-eq/t AN-N (see Figure 10).

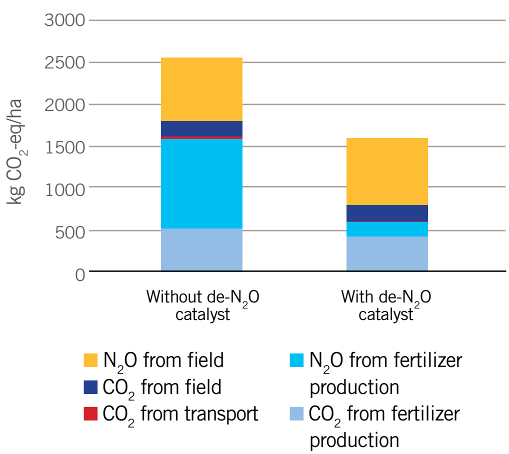


These systems for the catalytic abatement of N_2O emissions are being fitted to many nitric acid plants and virtually all operating plants in Europe had abatement systems since the mid-2010s. For more data on energy consumption and GHG emissions from European fertilizer production and use, see Annex.

Figure 11 shows the impact of de-N_2O technology on the carbon footprint of wheat production at the economic optimum N fertilizer application rate. In this particular example, where ammonium nitrate is the only source of added nitrogen, the CO_2-eq emissions are reduced by about 40%.

Figure 11

CARBON FOOTPRINT OF WHEAT PRODUCTION AT OPTIMUM N APPLICATION RATE WITH AND WITHOUT INSTALLATION OF AN N_2O ABATEMENT CATALYST IN AMMONIUM NITRATE PRODUCTION



GHG emissions from nitrogen fertilizer application

Another main source of GHG in this study (see Figure 11) but also in agriculture in general (see Figure 4), is N_2O from fertilized soils. Nitrogen, whether it is from organic or inorganic sources, is subject to various natural microbial conversion processes in the soil, some of which may produce N_2O. The main inorganic forms of nitrogen in the soil are ammonium (NH_4^+) and nitrate (NO_3^-). Ammonium originates either directly from mineral fertilizers containing NH_4^+ (e.g. ammonium nitrate or ammonium sulphate), from the conversion of organic nitrogen (e.g. manure or crop residues) or from urea fertilizer.

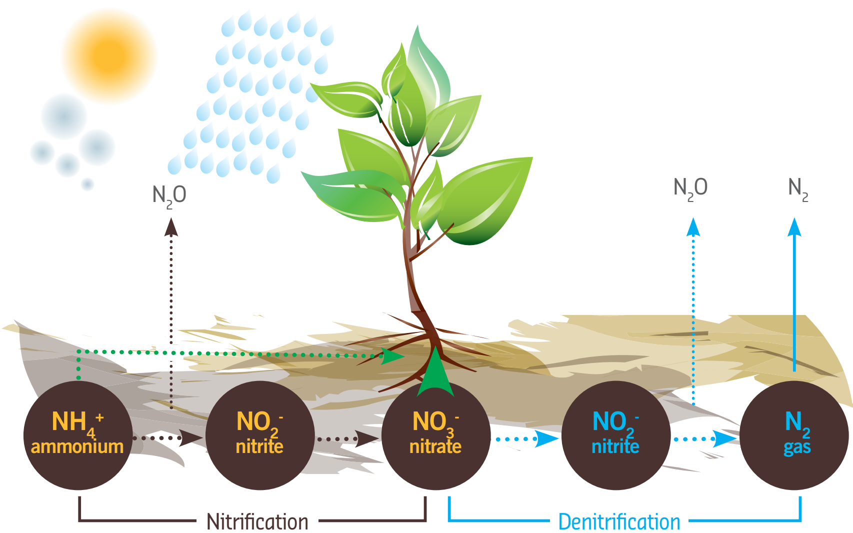
Nitrate is either directly applied as nitrate mineral fertilizer (e.g. ammonium nitrate or calcium nitrate) or results from the microbial oxidation of ammonium (nitrification, see Figure 12). Nitrate is dissolved in the water in the soil and cannot be stored in the soil over the long term. During the period of crop growth, nitrate is taken up at high rates.

However, at times of low or zero crop demand, and under certain environmental conditions, nitrate can be lost either to the air via denitrification or to water by leaching. Ammonium is not mobile and most of it has to be converted into nitrate before crops can take it up. Losses of ammonium from the soil occur via volatilisation of ammonia (NH_3).

Figure 12 focuses on the two microbial conversion processes of nitrogen in the soil that produce N_2O emissions - nitrification and denitrification. Nitrification

Figure 12

NITROUS OXIDE IS NATURALLY RELEASED DURING NITRIFICATION OF AMMONIUM (NH_4^+) TO NITRATE (NO_3^-) AND DURING THE DENITRIFICATION OF NITRATE TO DI-NITROGEN GAS (N_2)



is the oxidation of ammonium to nitrate. This natural process supplies energy to the nitrifying bacteria. During the oxidation of ammonium to nitrite, N_2O is produced as a by-product.

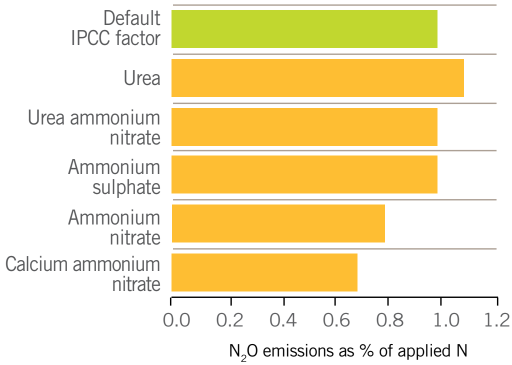
Denitrification means the reduction of nitrate to di-nitrogen gas (N_2). Under anaerobic conditions, denitrifying bacteria use NO_3^- instead of oxygen as an electron acceptor in order to respire organic carbon compounds. Since O_2 is the more favourable electron acceptor, denitrification only takes place under limited oxygen conditions.

The quantity of N_2O released from denitrification depends on the environmental conditions - more or less N_2O is produced instead of N_2. The more favourable the conditions for denitrification (e.g. completely water-saturated soil), the more N_2 is proportionally produced. Changing the conditions (e.g. from wet to dry soils) favour N_2O release (Granli and Bockman, 1994).

Bouwman et al. (2002) analysed about 900 field measurements of N_2O emissions from 139 published studies. The authors developed an empirical model to estimate N_2O emission rates from fertilized fields based on the following input parameters: crop type, fertilizer type, soil texture, soil organic carbon content, soil pH, soil drainage, climate and N application rate. In addition to this model, Bouwman et al. (2002) developed generic emission factors for different N fertilizer types in case other more specific parameters are lacking or are not available.

Figure 13

AVERAGE NITROUS OXIDE EMISSION FACTORS FOR DIFFERENT N FERTILIZER PRODUCTS



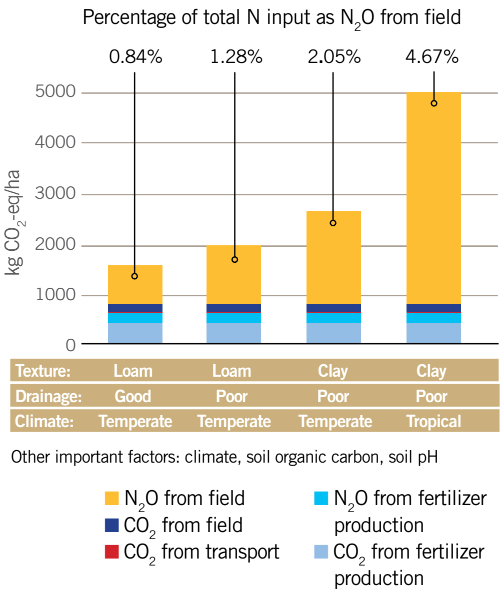
Source: Bouwman et al., 2002.

Figure 13 gives the average N_2O emission factors for different N fertilizer types. From these data it can be concluded that the higher the share of nitrate in the fertilizer the lower the N_2O emissions. This appears logical because the use of a urea or ammonium-based fertilizer almost always implies nitrification to nitrate followed by potential denitrification. Applying nitrates circumvents the nitrification step and implies only the risk of denitrification.

As already indicated, in addition to the N fertilizer type, other parameters also determine the rate of N_2O soil emissions. Figure 14 describes the potential impact of soil drainage, soil texture and climate on the emission rate of N_2O in a sensitivity analysis using a model developed by Bouwman et al. (2002). The left-hand column shows the actual conditions in the Broadbalk field trial used for this study.

Figure 14

IMPACT OF SOIL AND CLIMATE ON THE CARBON FOOTPRINT OF CROP PRODUCTION



Source: calculated according to Bouwman et al., 2002 (uncertainty range: - 40 to 70%).

In particular, changing from temperate to tropical conditions increased the N_2O emissions estimate by more than five times.

This is mainly due to the combined effect of warmer and wetter conditions that result in increasing the activity of the denitrifying bacteria.

Because growers cannot influence the climatic conditions under which they operate, efforts should be focused towards maintaining a good soil structure that enables good drainage and avoids waterlogging. The choice of the right N fertilizer product under the given conditions (e.g. nitrate-based products applied on non-waterlogged soils) can help minimize N_2O emissions from the soil.

In general, any means that increase nitrogen use efficiency (NUE) are effective in reducing N_2O emissions, since nitrogen is best protected against all types of loss as soon as it is taken up by the crop. Increasing NUE means increasing the share of N that is taken up by the crop compared to the amount N applied to the soil.

Effective ways used to improve NUE are, for instance, to adjust the N application rate to the crop's N demand (e.g. by considering the results of soil and plant analysis) and to synchronize N application timing with crop N uptake (e.g. through split applications and 'just-in-time' fertilization) or to use fertilizers with nitrification inhibitors.

EU targets to reduce GHG emissions from agriculture

The current EU targets on renewable energy and climate change are often referred to as the '20-20-20-10 package' (EC, 2008b). It includes the following mandatory targets for 2020: a 20% increase in energy use efficiency, a 20% reduction in GHG emissions (compared to 1990); a 20% share of renewable energy in overall EU energy consumption, with 10% biofuel components in vehicle fuels.

The GHG emissions reduction target is split into two: Emission Trading Sheme (ETS) sectors requiring a 21% saving in 2020, compared to 2005 and non-ETS activities (households, traffic, agriculture) needing 10% savings in 2020, compared to 2005.

An important step for mitigating GHG emissions in agriculture has been the introduction of sustainability criteria for biofuels. They are currently under development and will imply stricter environmental constraints. They will also apply for imported biofuels. The minimum acceptable GHG saving compared to equivalent fossil fuels will start at 35% and will increase up to a 50% GHG saving from 2017 onwards.

Further sustainability criteria concern restrictions on land use change to protect nature reserves, permanent pastures and non-cultivated forests, as well as to protect the high soil carbon contents of wetlands, peat and continuously forested areas. In addition, the production of biofuels should always respect good agricultural practice (GAP) as defined in the EU Common Agricultural Policy (the cross-compliance principle).

Fertilizers Europe's position and actions

In response to the EU initiative, Fertilizers Europe has defined its position and strategy on Energy and Climate Change.

Fertilizers Europe's position can be summarized by the following key statements:

- Mineral fertilizers will play an increasingly important role in facing the challenge to feed the world population in future.
- Mineral fertilizers have a significant impact on GHG emissions, but at the same time they also imply a big mitigation potential by contributing to better land productivity and to reducing the need for land use change.
- By improving nutrient use efficiency, highly productive farming systems contribute to GHG mitigation.
- All approach should be based on life cycle analysis (LCA) principles. Fertilizer production and use are strongly interlinked and cannot be disconnected.
- Lack of information and knowledge requires particular attention to allow constructive debate. This is not only a technical debate: public awareness needs to be carefully considered.

In order to put life into these statements, Fertilizers Europe has developed an action plan that aims at making 'hard facts' available and promoting 'Good Agricultural Practices' to mitigate negative climate change effects. Communications tools such as conferences, workshops and written material are being used to enter into an open discussion on fertilizers and climate change with all the stakeholders involved in the issue (farmers, NGOs, politicians, consumers, etc).

In parallel, a comprehensive dataset of GHG emissions from fertilizer production and use is being built up. This is important in order to provide up-to-date figures on the fertilizer life cycle being used in external environmental assessments (e.g. the 'Well-to-Wheels' study on biofuels (EC, 2008)). The most recent data on energy consumption and GHG emissions from European fertilizer production and use can be found in the Annex of this publication.

Conclusions

The following conclusions can be drawn from this publication:

- Mineral N fertilizers are essential to sustain the crop yields needed to satisfy the increasing global demand for food, feed and bio-energy.
- Agriculture's contribution to climate change is significant, with land use change (CO_2 from deforestation), cattle farming (CH_4 from enteric fermentation), and crop production (N_2O emissions from organic and mineral N inputs) being the major sources.
- Producing agricultural crops on the existing agricultural area at optimum intensity helps to preserve natural ecosystems with their high carbon sequestration potential and high biodiversity.
- Improved fertilizer production technology (high energy efficiency, de-N_2O catalysts) combined with best agricultural management practices enable a significant reduction in the carbon footprint of crop production.
- Future EU regulations on climate change will most probably include measures for agriculture.
- Fertilizers Europe supports any action towards improved nitrogen use efficiency and is open to sharing its knowledge on energy and GHG balances from fertilizer production and use.

Annex

Fertilizers Europe carbon footprint reference values for European mineral fertilizer production and use in 2011.

			GHG emissions		
Fertilizer product		Nutrient content	Fertilizer production	Fertilizer use	
			At plant gate	CO_2 from urea hydrolysis	Direct N_2O from use
			kg CO_2-eq/		
Ammonium nitrate	AN	33.5% N	1.18	0.00	1.26
Calcium ammonium nitrate	CAN	27% N	1.00	0.00	0.89
Ammonium nitrosulphate	ANS	26% N, 14% S	0.83	0.00	1.10
Calcium nitrate	CN	15.5% N	0.68	0.00	0.65
Ammonium sulphate	AS	21% N, 24% S	0.58	0.00	0.98
Ammonium phosphates	DAP	18% N, 46% P_2O_5	0.73	0.00	0.76
Urea	Urea	46% N	0.91	0.73	2.37
Urea ammonium nitrate	UAN	30% N	0.82	0.25	1.40
NPK 15-15-15	NPK	15% N, 15% P_2O_5, 15% K_2O	0.76	0.00	0.56
Triple superphosphate	TSP	48% P_2O_5	0.26	0.00	0.00
Muriate of potash	MOP	60% K_2O	0.25	0.00	0.00

Fertilizer production

GHG emissions and energy consumption representing European production technology in 2011, as provided by Fertilizers Europe in 2014 (calculated with FertEU Carbon Footprint calculator V 1.0).

Key assumptions:

- Emission and energy figures for fertilizer production are simple averages, i.e. not weighted according to production volumes per site
- Feedstock for ammonia production is natural gas
- Emissions from supply of energy (feedstock and fuel) are included (EU average European Ecoinvent 2.0, not weighted according to production volumes per site)
- Emissions from typical transport of raw material is included (for details see FertEU Carbon Footprint calculator V 1.0)
- Steam export from ammonia, nitric acid and sulphuric acid units is fully utilized in the site steam network.

GHGs are converted into CO_2 equivalents (IPCC 2007, i.e. 1 kg N_2O = 298 kg CO_2-eq).

(GWP 100 yrs: IPCC, 2007)					Energy consumption*
(soil effects)			Fertilizer production + use		Fertilizer production
Indirect N_2O via NH_3	Indirect N_2O via NO_3^-	CO_2 from liming and CAN	Total	Total	On-site
kg product			kg CO_2-eq/kg product	kg CO_2-eq/kg nutrient	MJ/kg product
0.01	0.35	0.27	3.06	9.14	14.02
0.01	0.28	0.20	2.40	8.88	11.78
0.02	0.27	0.40	2.62	10.09	10.61
0.00	0.16	0.00	1.50	9.67	7.23
0.02	0.22	0.50	2.30	10.95	8.07
0.01	0.19	0.34	2.03	11.27	6.76
0.28	0.48	0.36	5.15	11.19	23.45
0.10	0.32	0.24	3.13	10.43	13.84
0.01	0.16	0.12	1.61	10.71	7.59
0.00	0.00	0.01	0.27	0.56	0.18
0.00	0.00	0.00	0.25	0.43	3.00

Transport and handling

Only included for raw materials, not for final products, which are all assumed to be produced in Europe (usually not very relevant for nitrogen fertilizers produced and used in Europe; could be significant for import/export).

Fertilizer use (soil effects)

CO_2 from urea hydrolysis

Only relevant for urea and urea-containing fertilizers. Urea is hydrolysed shortly after application in the field. This process releases CO_2 (the amount is equivalent to the amount fixed during urea production, 733 kg CO_2/t urea).

N_2O from fertilized soils

N_2O emissions due to microbial conversion of the fertilizer-N in the soil (nitrification and denitrification, so called "direct N_2O emission"). Emission rates are based on fertilizer-specific emission factors developed by Bouwman et al. (2002). N_2O is converted into CO_2 equivalents (N_2O = 298 x CO_2).

** Energy consumption refers only to energy used on the production site.*

N_2O from NH_3 volatilization

N_2O emissions from fertilizer-N that has been first emitted to air via NH_3 volatilization and deposited afterwards (so-called "indirect N_2O emission"). NH_3 volatilization losses estimated according to EMEP/UNECE Guidebook (2009). N_2O-N emission from deposited NH_3-N = 1% (IPCC, 2006). N_2O is converted into CO_2 equivalents (N_2O = 298 x CO_2).

N_2O from NO_3 leaching

N_2O emissions from fertilizer-N that has been first lost to water via NO_3 leaching and that is denitrified afterwards (so called "indirect N_2O emission"). Average leaching loss = 30% of all nitrogen applied (IPCC, 2006). N_2O-N emission from leached NO_3-N = 0.75% (IPCC, 2006). N_2O is converted into CO_2 equivalents (N_2O = 298 x CO_2).

CO_2 from applied lime and CAN

Direct CO_2 emission from limestone or lime/dolomite containing CAN (0.1 kg CO_2/kg CAN) applied to soil. Liming rate according to lime demand to counteract the acidification of different N fertilizers (see table below, $CaCO_3$ x 0.44 = CO_2). No indirect figures from production and spreading for limestone.

Lime demand of different N fertilizers
(in kg $CaCO_3$/kg nutrient)

Ammonium nitrate	1.8
Calcium ammonium nitrate	0.86
Ammonium nitrosulphate	3.5
Calcium nitrate	-1.51
Ammonium sulphate	5.4
Mono-ammonium phosphate	6.05
Di-ammonium phosphate	4.28
Urea	1.8
Liquid urea ammonium nitrate	1.8
Triple superphosphate	0.07
Muriate of potash	0

Source: KTBL (2005)

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