# FEEDING THE EARTH

# THE ROLE OF FERTILIZERS IN AGRICULTURAL MITIGATION STRATEGIES

## *How to Improve Greenhouse Gas Budgets Through Good Agricultural Practices*

**Contrary to other sectors, agriculture is not only an emitter of greenhouse gases (GHG) but also a carbon sink. To grow more food with less impact on the climate, it is necessary to increase productivity while reducing agricultural GHG emissions. Managing plant nutrients more effectively is one of the solutions to manage such trade-offs. The fertilizer industry has an important role to play, in particular in the promotion of Fertilizer Best Management Practices and Integrated Soil Fertility Management. These best practices result in increased nutrient use efficiency while reducing emissions and maintaining soil fertility and yield increases, as demonstrated in a number of countries. Further research is, however, needed to address research gaps in GHG agricultural budgets, document comparisons between different cropping systems and across regions and devise new adaptation and mitigation strategies for climate-friendly agricultural production systems worldwide.**

## Converting natural habitats to cultivated land is the main source of GHG from agriculture

Agriculture contributes around 10-12 % of total global GHG emissions but is the main source of non-carbon dioxide ($CO_2$) GHGs, emitting nearly **60 % of nitrous oxide ($N_2O$) and nearly 50 % of methane ($CH_4$)**. $N_2O$ is produced by microbial transformations of nitrogen (N) in soils and animal waste and therefore often associated with nitrogen (N) fertilizer inputs in agricultural systems. $CH_4$ is generated when organic matter decomposes under anaerobic conditions and is mainly associated with ruminant livestock, manure storage and rice production under flooded conditions.

These emissions are currently estimated as 3.3 Pg $CO_2$-eq $yr^{-1}$ from $CH_4$ and 2.8 Pg $CO_2$-eq $yr^{-1}$ from $N_2O$ emissions. **Large exchanges of $CO_2$ occur between the atmosphere and agricultural ecosystems but emissions are thought to be roughly balanced by uptake**, giving a net flux of only around 0.04 Pg $CO_2$ $yr^{-1}$, less than 1 % of global anthropogenic $CO_2$ emissions. However, land use change towards more cultivated land may contribute a further 5.9 ± 2.9 Pg $CO_2$ -eq $yr^{-1}$, representing 6-17 % of total global GHG emissions, and if indirect emissions from agrochemical and fuel usage are also included, an extra 0.4-1.6 Pg $CO_2$ -eq $yr^{-1}$ (0.8-3.2 %) can be attributed to agriculture. In total, direct and indirect emissions from agricultural activity and land use change to agricultural use could contribute around a third of all GHG emissions.

Globally, agricultural land use has increased by 0.8 % between 1991 and 2002, and these changes are split with an increase of 2.1 % in developing countries partially mitigated by a 1.5 % drop in the developed world. This trend is likely to continue with projected increases in world population, and shifts in diet requiring more resources per unit of food produced, being concentrated in areas such as South and East Asia.

## Research gaps in measuring the contribution of agriculture in total global GHG emissions need to be addressed

If agricultural production is going to significantly increase while also minimizing its impact on future climate change, it is important to understand both its current contribution to GHG budgets and how agricultural management practices can influence them. Key gaps in our knowledge and problems which are setting back our understanding have to be identified. These include the **lack of work addressing GHG emissions on the basis of agricultural productivity rather than cultivated area, and inconsistent methodologies for measuring things like soil carbon under different tillage regimes and for calculating $N_2O$ emissions**, which make comparisons between systems difficult. There is also a distinct lack of research covering **tropical regions**, a gap which needs to be urgently addressed given the likely increases in production in these regions. This is especially important because the current trend, for example in Latin America, is towards increasing areas of cultivation rather than intensifying production on existing agricultural land. This will have a disproportionately large impact on GHG budgets due to the loss of stored soil organic carbon (SOC) which occurs when forests and grasslands are converted to cropland.

## Fertilizer Best Management Practices and Integrated Soil Fertility Management increase yields and reduce $N_2O$ emissions

If agriculture continues to develop according to existing trends and no action is taken to mitigate GHG emissions from the sector, they are expected to reach around 8.2 Pg $CO_2$-eq $yr^{-1}$ by 2030. However, there is significant potential to mitigate these emissions using existing agricultural technology. Estimates of this potential vary, especially when economic considerations are included in the calculations, but around 1.5-4.3 Pg $CO_2$-eq $yr^{-1}$ seems reasonable, with the greatest potential laying in cropland management practices. Of these practices, improving nutrient management is particularly crucial, especially given the need to increase agricultural productivity while cultivating as little new land as possible. Key to this is **improving crop N use efficiency (NUE)** through the use of fertilizer best management practices, using the right source, at the right rate, at the right time, and at the right place (see www.fbmp.info). Implementation of fertilizer best management practices (BMPs) has been shown to both reduce N applications and associated $N_2O$ emissions and increase yields. For example, in China, the world's largest consumer of mineral N fertilizers, BMPs have been shown to reduce N inputs by 20-40 %, increase yields by 2-12 %, increase N recovery rates by 10-15 % and reduce N losses by 10-50 %, in comparison with traditional farming practices. Even in developed countries with existing trends of improving NUE, there is still the potential for further mitigation.

Currently, nitrogen use efficiency is falling in many countries, such as China, where some cropping systems are over-fertilized, while soils in other regions, such as parts of Africa and India, still suffer from chronic nutrient deficiency. **Better integration of organic resources** such as animal waste and crop residues into crop nutrition programs can assist in improving soil fertility while also helping to mitigate indirect emissions from fertilizer production. These indirect emissions currently contribute around 420 Tg $CO_2$-eq $yr^{-1}$ and there is considerable scope to mitigate these, and any future increases, using existing methods such as carbon capture and $N_2O$ abatement technologies. This could save around 200 Tg $CO_2$-eq $yr^{-1}$. **Other GHG mitigation strategies include the use of no-till or reduced tillage regimes.** There is debate regarding the mitigation potential of tillage measures. This is because assessing the net impact on GHG emissions requires comparing the impacts on both SOC, which is often biased by field measurements taken only in the top 30 cm of the soil profile, and $N_2O$ emissions, which are highly variable over time. The balance of evidence does, however, point to a net benefit for suitable soil types, although more research may still aid our understanding in this area. Reducing tillage also gives indirect savings in terms of reducing on-farm fuel use and associated emissions.

Agronomy measures are perhaps the most difficult mitigation practices to assess at present. Using catch crops, legumes and particular types of crops rotations could potentially reduce GHG emissions per hectare of cropland but can also impact on yields, potentially requiring additional land to be cultivated at great cost in terms of SOC losses. For example, the global warming potential (GWP) of an intensive continuous maize crop may be 2-3 times higher, on a per hectare basis, than that of a conventionally-tilled maize-wheat-soybean rotation, but produce only 63 % of the net GHG emissions when compared on the basis of $CO_2$-eq per Gcal of food yield. Therefore, more work is needed to compare net GHG emissions from different cropping systems over the long term and on a per unit of production basis.

## Improving the productivity of existing agricultural land is the best way to feed 9 billion people while preserving the climate and biodiversity

With predictions that 9 billion people will need to be fed by the middle of this century, agricultural production will need to increase, but the additional pressure on land availability means that improving the productivity of existing agricultural land is the best way to achieve this. **Using the existing cropland most efficiently may also contribute to preserving areas with valuable biodiversity and high carbon sequestration potential against land use changes.** There is much scope for more efficient use of resources, particularly nitrogen, within the current level of understanding. The wider implementation of BMP strategies can play a significant role in limiting the impact of agricultural production on the future climate.

Overall, **cropland management mitigation strategies, such as further implementation of fertilizer BMPs, offer the highest potential for mitigating future agricultural GHG emissions.** Fertilizer production also has a significant role to play, as the most advanced technology available today can significantly reduce the GHG emissions associated with the older, less efficient plants still used in many parts of the world.

Many uncertainties remain regarding the exact potential of various mitigation practices, not least because carbon and nitrogen dynamics in agricultural systems can be very variable, both between different sites and cropping systems and also within the same area, over time or with depth in the soil profile. This makes generalisations difficult. The paucity of data relating to tropical agricultural systems in Latin America, Southeast Asia and parts of Africa requires particular attention. However, there is more than sufficient understanding of general impacts to support strong action on the part of the international community. **The technology already exists to ensure croplands can play a significant role in mitigating climate change while still meeting the demand of feeding an increasing global population.**

**Current agronomic strategies advocated by the fertilizer industry include:**

- Improving nitrogen use efficiency;
- Increasing soil organic matter by integrating organic nutrient sources jointly with mineral fertilizers in plant nutrition programmes and
- Promoting the adoption of fertilizer BMPs.


*Climate change is one of IFA's priority areas of work. A number of publications are available to the public at www.fertilizer.org under Library and Sustainability*

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**This brief is based on the executive summary of the report "Greenhouse Gas Budgets of Crop Production, Current and Likely Future Trends", commissioned by IFA, by Helen C. Flynn and Pete Smith from the Institute of Biological and Environmental Sciences, School of Biological Sciences, University of Aberdeen, UK.**

**The full report will be available as of January 2010 at www.fertilizer.org**

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***Feeding the Earth*** represents a series of issue briefs produced by the International Fertilizer Industry Association to provide current information on the role of fertilizers in sustainable agriculture and food production.

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