INCREASING AGRICULTURAL PRODUCTIVITY TO MITIGATE GREENHOUSE GAS EMISSIONS

The world's population is anticipated to reach 9.1 billion by 2050. Projections by the Food and Agriculture Organization of the United Nations (FAO) show that feeding that many people would require raising overall food production by some 70% between 2005/07 and 2050 (FAO, 2009). This increase can be achieved through higher yields, larger cultivated area, higher cropping intensity (number of crops per year under tropical conditions), or a combination thereof. Each option will have different environmental impacts, particularly in terms of greenhouse gas emissions, water use efficiency and biodiversity conservation.

This paper addresses the benefits of enhancing agricultural productivity in order to limit further land use change and mitigate agriculture-related greenhouse gas emissions. In doing so, it analyzes the crucial role that fertilizers could play in this connection.

Agriculture and greenhouse gas emissions

Producing food, feed, fibre and bioenergy to meet the requirements of the world's population generates greenhouse gas emissions. These emissions are predicted to increase as population rises steadily and diets in emerging economies change towards more livestock products. According to the Agriculture chapter of the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (Smith *et al.*, 2007), agriculture contributes 10 to 12% of total global greenhouse gas emissions. The share of greenhouse gas emissions from fertilizer production, distribution and application represents 0.8 to 3.2% of global emissions. Deforestation and other one-time land use change due, among their other effects, to agricultural expansion and urbanization account for an estimated 6 to 17% of global emissions. In total, direct and indirect emissions from global agricultural activity and land use change could contribute between 8.5 and 16.5 gigatonnes (Gt)[1] CO_2-eq[2] per year, or 17 to 32% of all greenhouse gas emissions (Bellarby *et al.*, 2008).

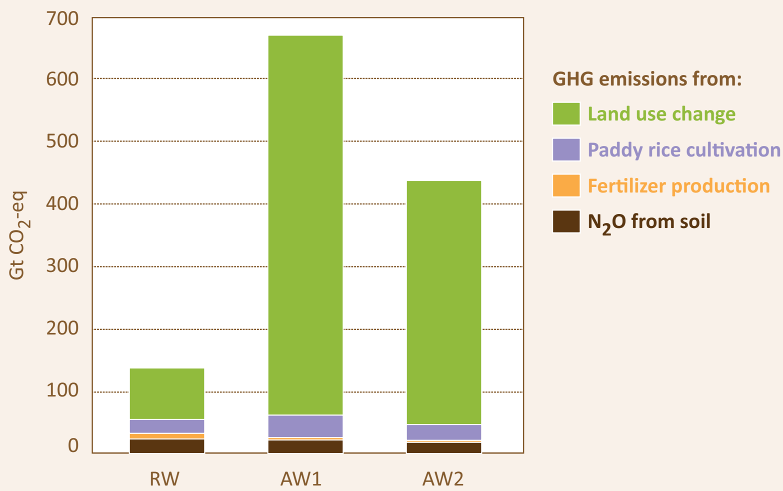
Agricultural "intensification" offers opportunities to mitigate greenhouse gas emissions while increasing food security

Although agricultural greenhouse gas flows are complex, best management practices for agricultural systems offer opportunities to mitigate them.

Analysis of the evolution of greenhouse gas emissions from agriculture between 1961 and 2005 confirms the positive role of enhanced agricultural productivity in reducing total greenhouse gas emissions. Increased emissions from rising fertilizer production and use were largely offset by lower emissions associated with the conversion of forests, savannahs, wetlands and other natural habitats to cropland.

[1] 1 gigatonne (GT) = 1 billion tonnes.
[2] CO_2-eq: carbon dioxide equivalent in terms of global warming potential, where methane and nitrous oxide are 23 and 296 times more potent, respectively, than carbon dioxide.

Increase in greenhouse gas emissions between 1965 and 2005 under three agricultural scenarios



The study analyzes the evolution of greenhouse gas emissions from agriculture under three different agricultural scenarios: a "Real World (RW) Scenario" and two alternative scenarios in which growing food needs have been met by land expansion ("extensification") rather than yield increases ("intensification"). In the "First Alternative World (AW1) Scenario" it is assumed that population, the global economy and socio-politics have evolved exactly as in the RW, but that agricultural technology and farm practices have remained as they were in 1961. In the "Second Alternative World (AW2) Scenario" agricultural production has increased only enough to maintain 1961 standards of living through 2005.

Source: adapted from Burney et al., 2010

Burney *et al.* (2010) estimate that the net effect of higher yields avoided emissions of up to 590 Gt CO_2-eq between 1961 and 2005, or 13.4 Gt CO_2-eq per year. These results emphasize the need for continuous investment in yield improvements to meet the soaring world demand for agricultural products and to reduce future greenhouse gas emissions.

Fertilization strategies to mitigate greenhouse gas emissions

For planning purposes, the impact of nitrogen (N) fertilizer production and use on total greenhouse gas emissions must be viewed in the correct context. While a small fraction of total global greenhouse gases is emitted during nitrogen fertilizer production, distribution, application and use, the contribution of nitrogen fertilizers to higher yields helps to feed billions of people and reduces the much higher greenhouse gas emissions that would result from land use change. When total greenhouse gas emissions related to crop production are considered, the overall carbon footprint per tonne of agricultural produce is lowest when N fertilizer application rates are close to the economic optimum.

Achieving high yields, a large positive energy balance, and low greenhouse gas emissions in intensive cropping systems are not conflicting goals in the case of well-managed fields. For instance, irrigated maize in central Nebraska, USA, receives relatively large energy inputs, mostly in the form of pumped irrigation water and nitrogen fertilizer. However, on average, a large positive net energy yield and ratio are achieved. If the irrigated maize system in central Nebraska were converted to a rainfed maize system in order to reduce greenhouse gas emissions per unit of land area, a 55% reduction in grain yield would result. Offsetting this yield drop would require additional maize plantings of some 124 thousand hectares in Nebraska or 277 thousand hectares in Brazil (Grassini and Cassman, 2012).

To achieve the same yield, agronomic production intensities below the economic optimum require more land and thereby increase total greenhouse gas emissions. In highly "extensive" systems, where nutrient application rates are low, cropland expansion results in surging greenhouse gas emissions per unit of crop output.

Balanced fertilization, i.e. the proper supply of all essential nutrients in a balanced ratio throughout the growth of crops, including the use of phosphorus (P), potassium (K), sulphur (S), magnesium (Mg) and micronutrient fertilizers, increases resource use efficiency by crops, particularly the efficiency of nitrogen and water use. With more crop

The fertilizer industry supports the **4R Nutrient Stewardship Framework**, which recommends using the Right Source of plant nutrients, at the Right Rate, at the Right Time and in the Right Place to deliver the economic, social and environmental benefits expected by society (Bruulsema *et al.*, 2009; IFA, 2009).

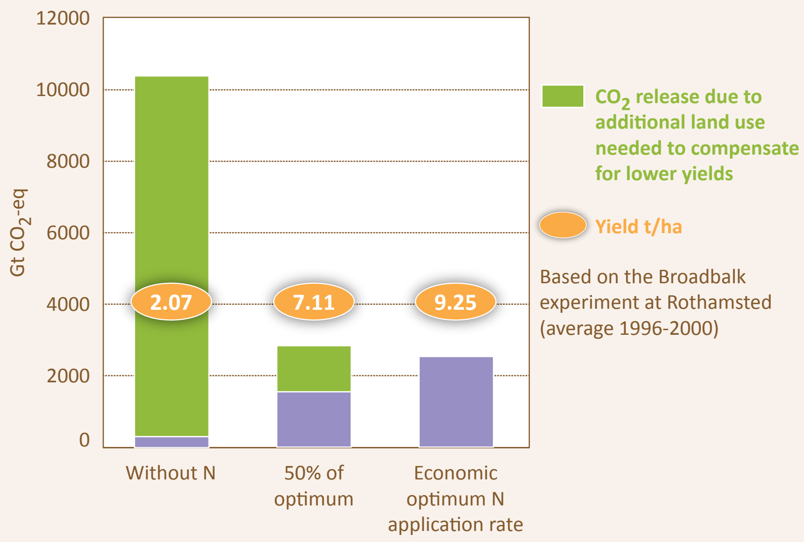
Greenhouse gas emissions from agriculture are often assessed on a "per unit of cropland area" basis. However, from a climate change mitigation perspective, measurements would be far more meaningful if they were made on a "per unit of crop output" basis. This would help to encourage better production practices on current cropland, and to prevent further undesirable land use change and the conversion of natural habitats.

Improving input use efficiency and effectiveness, particularly the efficiency of nitrogen fertilizer use, is desirable from both the environmental and economic perspectives. Because it is imperative to feed the fast-growing world population, however, this should not be to the detriment of crop yields.

per litre of rain and/or of irrigation water, productive, water-efficient agricultural systems prevent cropland expansion and related greenhouse gas emissions, especially when water resources are limiting.

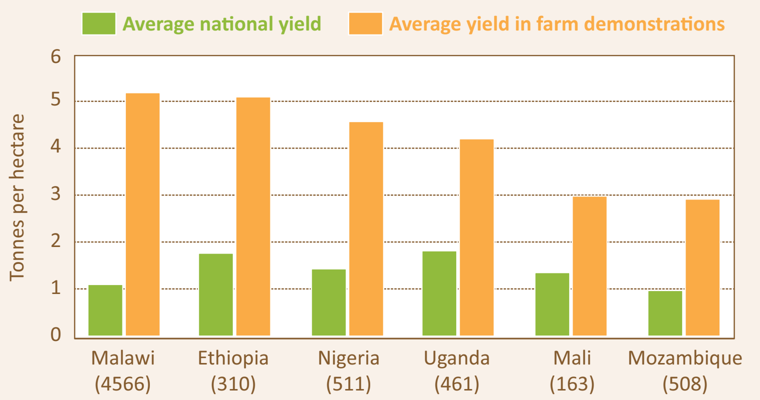
"Extensive" farming systems are still widespread globally, particularly in Sub-Saharan Africa, where there is a significant gap between average national yields and the average yields observed in demonstration plots. Closing the yield gaps on underperforming lands has been identified by Foley *et al.* (2011) as one of five strategies to increase agricultural production while reducing the environmental footprint of farming. They estimate that bringing yields of 16 important food and feed crops to within 75% of their potential could add 1.1 billion tonnes of new production per year, i.e. a 28% increase in global output without cropland expansion. Improving access to inputs, existing technologies and knowledge would make it possible to close the yield gap rapidly in these countries. This would have major environmental, economic and social benefits, as it would prevent the further destruction of natural habitats, which causes large greenhouse gas emissions.

Greenhouse gas emissions (kg CO_2-eq) for producing 9.25 tonnes of winter wheat in the United Kingdom under three different nitrogen fertilization regimes



Source: adapted from Brentrup and Pallière, 2008

Exploitable maize yield gap in Sub-Saharan Africa



Notes: Number of plots in parentheses. Open pollinated improved varieties in all cases except Nigeria, which uses hybrids. Data for 2001 for Ethiopia, Mozambique, Nigeria and Uganda; 2002 for Malawi and an average of 2001, 2002 and 2004 for Mali.

Source: adapted from World Bank, 2007

Conclusions and recommendations

The global fertilizer industry plays a fundamental and essential role in feeding the world's population. It will become even more important as the population grows. While enabling this essential benefit to humankind, the global fertilizer industry contributes a small fraction of global greenhouse gas emissions. At the same time, well-managed fertilizer use is, and will remain, essential to slow the conversion of additional natural habitats to farmland, which is a major source of greenhouse gas emissions and biodiversity loss.

Today, land use change is responsible for 6 to 17% of total global greenhouse gas emissions. Further expansion of agricultural land into forests, grasslands and wetlands is not sustainable.

Future food, feed, fibre and bioenergy demands will require growth rates for crop production that exceed historic and current ones. Agricultural "intensification" through the adoption of best management practices is therefore a desirable and necessary policy goal for governments. The alternative – agricultural "extensification" – means increased conversion of natural habitats to farmland, biodiversity loss, and a significant increase in global greenhouse gas emissions.

The carbon footprint of crop production measured per tonne of crop output is lowest at fertilizer rates that are close to the economic optimum. Improving fertilizer use efficiency is critical, but it must not be pursued to the detriment of agricultural yields.

In order to mitigate agriculture's future contributions to climate change, continuing improvement of crop yields is paramount. This will require continuous public and private investment in agricultural innovation, research, development and knowledge transfer, accompanied by the implementation of best practices in a site-specific manner.

For more detailed information on the topic, you are invited to download the extended version of the paper from IFA's website (*www.fertilizer.org*, Library/Fertilizer Use section).

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