Addressing nitrous oxide: An often ignored climate and ozone threat

Policy Brief of the workshop on “Climate change, reactive nitrogen, food security and sustainable agriculture” 15-16 April, 2019 Garmisch-Partenkirchen, Germany

> Anthropogenic emissions of N\textsubscript{2}O, of which two thirds are emitted from agricultural soils, currently contribute 6% to the anthropogenic greenhouse effect.

> Atmospheric concentrations of N\textsubscript{2}O have increased 20% since pre-industrial times. Every year, natural processes only remove two thirds of the emitted quantities, leading to continuous and increasing accumulation. With a half-life of 130 years, emissions now will continue to have direct climate impacts for future generations.

> Recent climate mitigation policies, including the Paris Agreement, are increasingly focusing on the agricultural sector, with direct implications for N\textsubscript{2}O. Furthermore, N\textsubscript{2}O is now the most abundant ozone-depleting substance and is the greatest threat to the stratospheric ozone layer; destroying ozone at a level comparable to CFC compounds when they were phased out by the Montreal protocol (signed in 1987).

> The global average nitrogen use efficiency (NUE - the ratio of the N applied to the crop to the N removed during harvest) of fertilized crops is 40%, implying that 60% is lost to the environment. The situation for OECD states is better (NUE is around 60%), but still the potential for further improvements remains.

> Given the importance of N in food production, phasing out N fertilizers is not an option. Careful consideration of crop N requirements to prevent excess use is central to any approach to reduce N-related environmental problems; particularly the increasing atmospheric N\textsubscript{2}O concentrations.

What is the issue?

Nitrogen (N) is an essential element for all forms of life. However, most nitrogen on Earth is not readily available. To make N available for agricultural production, we rely on two processes: biological N fixation by leguminous crops and (since 1910) industrial N fixation via the Haber-Bosch process. The latter has been essential to boost crop production and food security for an increasing world population. In practice, N application is inefficient (most of the developed world), lacking (most of the developing world), or both. This unbalanced use of N causes severe environmental problems, exceeding safe thresholds for human and ecosystem health. As a
consequence, in most of the developed world, food production is associated with the release of reactive N compounds to the environment that exacerbate a range of impacts, from air and water pollution to biodiversity loss and climate change. To date, agriculture is the largest source of nitrous oxide (N₂O), which is – after carbon dioxide and methane – the third most important greenhouse gas and the largest remaining threat to the stratospheric ozone layer. Lead scientists from around the globe recently came together for a meeting in Garmisch-Partenkirchen, Germany supported by the OECD Co-operative Research Programme: Biological Resource Management for Sustainable Agricultural Systems. They exchanged and assessed the latest knowledge and agreed that, despite uncertainties and the need for additional research on processes driving N₂O emissions, there is sufficient knowledge available to implement immediate action towards reducing N pollution, specifically N₂O emissions. The actions listed below demand a more efficient use of fixed and reactive nitrogen in order to reduce greenhouse gas emissions and other forms of N pollution from agricultural systems.

What should policy makers do?

The Nationally Determined Contributions (NDCs) are central components of the Paris Agreement. Given the key role of N₂O as a leading agricultural GHG, specific consideration of this gas in the 2020 NDC updates is essential.

Implement targeted mitigation options for N₂O. These must avoid the risk for “pollution swapping” – where one N compound is reduced at the expense of another. This can provide significant improvements (co-benefits) to water and air quality, biodiversity, acidification and eutrophication of soils and water bodies.
Mitigation Options

**Strongly discourage use of N in excess of crop requirement.** There is a clear non-linear relationship between fertilizer application and N$_2$O emissions, with emissions increasing exponentially when application rates exceed plant N requirements.

**Enhance NUE of mineral and organic fertilizers.** Technologies and practices to apply fertilizer at the right time, the right place, the right type and the right quantity are available (e.g. variable rate technologies, or enhanced efficiency fertilizers).

**Encourage the increased use of cover crops and perennial forages in crop rotations** as this helps retaining N within the agro-ecosystem, thus improving NUE.

**Promote novel technologies**, such as the development of **new crop varieties** that reduce N losses through **biological nitrification inhibition (BNI)** by plant root exudates. New microbiological research shows the potential to cultivate N$_2$O-reducing **bacteria** that may significantly reduce N$_2$O emissions upon application to soil.

**Improve recycling of N-containing agricultural products** typically considered as waste (circular economy). This includes optimizing animal manure management and reducing food waste (at both the industrial and household level).

**Incentivize reduced human consumption of animal-sourced protein** (meat, milk, eggs). NUE of animal-sourced protein is approximately one tenth of that for plant protein. The trend in some OECD countries of reduced consumption of animal-sourced proteins not only benefits the environment, but is also favorable to human health.

**Promote the increased use of biological or microbial derived N** (e.g. legumes) in the agri-food chain as this benefits soil health and can reduce the use of synthetic fertilizers without jeopardizing yields.

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Due to the non-linear relationship between fertilizer application and N$_2$O emissions and yields, optimal N rates avoid excessive losses with minor impacts on yields.

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