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Impact of Fertilizer Application on Nitrous Oxide Emissions

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SUMMARY
The use of fertilizers in agriculture is essential for boosting crop yields and ensuring global food security. However, this practice has significant environmental consequences, particularly concerning nitrous oxide (N_2O) emissions. N_2O is a powerful greenhouse gas, with a global warming potential much higher than carbon dioxide, and it also contributes to the depletion of the ozone layer. The main sources of N_2O emissions in agriculture include nitrification and denitrification processes in the soil, which are influenced by factors such as soil conditions and fertilizer type. Efforts to mitigate N_2O emissions while maintaining agricultural productivity involve optimizing fertilizer application, using inhibitors and stabilizers, and adopting alternative practices like cover cropping and precision agriculture. These strategies aim to reduce the environmental impact of fertilizer use without compromising the agricultural output essential for food security.

INTRODUCTION
Fertilizer application plays a critical role in modern agriculture, enhancing crop yields and supporting global food security. However, its use has significant environmental implications, particularly in the context of greenhouse gas emissions. Among these, nitrous oxide (N_2O) stands out as a potent greenhouse gas with substantial impacts on climate change and stratospheric ozone depletion. Nitrous oxide emissions mainly come from the usage of nitrogen fertilizers and animal manure although its current levels are a thousand times less than carbon dioxide, it lasts much longer and is rising rapidly. India is the world's second largest source of nitrous oxide (N_2O), a greenhouse gas that heats up the atmosphere far more than carbon dioxide. Almost 11% of such global man-made emissions in 2020 originated in India, behind only China at 16%. A global review of N_2O emissions published in the journal Earth System Science Data states that the primary source of these emissions comes from fertiliser usage **(Koshy, 2024).** Understanding the relationship between fertilizer application and nitrous oxide emissions is crucial for developing strategies to mitigate these effects while maintaining agricultural productivity.

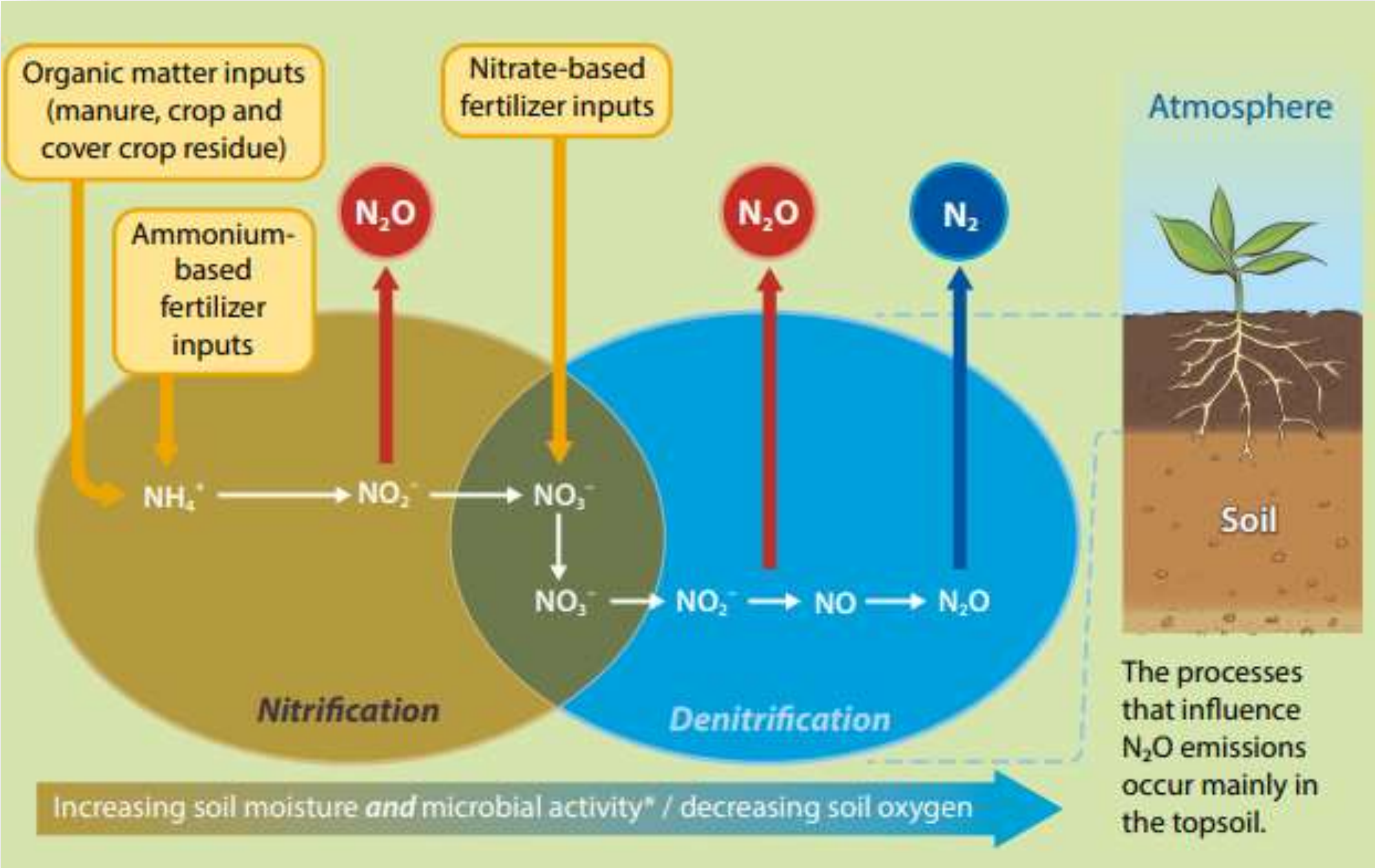
Understanding Nitrous Oxide
Nitrous oxide is a colourless, non-flammable gas with a sweet odour, and it is produced both naturally and anthropogenically. In the atmosphere, N_2O is a greenhouse gas with a global warming potential approximately 273 times greater than that of carbon dioxide (CO_2) over a 100-year period **(United States Environmental Protection Agency, 2024).** It also contributes to the depletion of the ozone layer, which protects Earth from harmful ultraviolet (UV) radiation.

Fertilizer Application and N_2O Emissions
The application of nitrogen-based fertilizers is a common agricultural practice used to enhance soil fertility and crop growth. However, this practice is a major source of N_2O emissions. The mechanisms through which fertilizers contribute to N_2O emissions include:

Nitrification: This microbial process converts ammonium (NH_4^+) in fertilizers into nitrate (NO_3^-). During nitrification, N_2O is produced as a byproduct. The rate of nitrification and consequently N_2O emissions can be influenced by factors such as soil temperature, moisture, and pH.

Denitrification: This process involves the reduction of nitrate (NO_3^-) to nitrogen gas (N_2) by soil bacteria. Under certain conditions, denitrification can produce N_2O instead of N_2. High soil moisture and low oxygen levels are conducive to denitrification and N_2O production.

Fertilizer Type and Application Method: Different types of nitrogen fertilizers (e.g., urea, ammonium nitrate) and application methods (*e.g.*, broadcasting, banding) can affect the extent of N_2O emissions. For instance, urea, when not incorporated into the soil, can undergo hydrolysis to release ammonia, which can then be nitrified to form N_2O.



Source:Verhoeven *et al.*, 2017

Fig.1. Factors influencing cropland N_2O emissions

Quantifying Emissions

Quantifying N_2O emissions from agricultural systems can be challenging due to variability in soil conditions, climate, and fertilizer application practices. Measurement techniques include:

Direct Field Measurements: Using chambers placed over the soil surface to capture and analyse emitted gases.

Remote Sensing: Utilizing satellites or drones equipped with sensors to estimate N_2O fluxes over large areas.

Modelling: Applying mathematical models to predict emissions based on soil and climate data, as well as fertilizer application rates.

Mitigation Strategies

Several strategies can help reduce N_2O emissions from fertilizer application without compromising crop yields:

Optimized Fertilizer Application: Applying the right amount of fertilizer at the right time and using site-specific recommendations can minimize excess nitrogen in the soil.

Inhibitors and Stabilizers: Products like nitrification inhibitors (*e.g.*, DCD, NBPT) can slow down the conversion of ammonium to nitrate, thus reducing N_2O emissions.

Improved Fertilizer Types: Using slow-release or controlled-release fertilizers can reduce the peak nitrogen concentrations in the soil, limiting the conditions favourable for N_2O production.

Precision Agriculture: Implementing technologies that optimize fertilizer application rates and timing based on real-time soil and crop needs.

Alternative Practices: Techniques such as cover cropping, reduced tillage, and organic amendments can enhance soil structure and reduce the potential for N_2O emissions.

CONCLUSION

The impact of fertilizer application on nitrous oxide emissions is a complex issue with significant implications for both environmental sustainability and agricultural productivity. While fertilizers are essential for modern farming, understanding, and managing their contribution to greenhouse gas emissions is critical for mitigating climate change and protecting the ozone layer. By adopting advanced practices and technologies, the agricultural sector can work towards a balance between achieving high crop yields and minimizing environmental impacts.

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