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Improving the Bottom Line Through Climate-Friendly Nitrogen Application

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The Scoop on Using Nitrogen

Nitrogen (N) is an essential macronutrient needed for plant growth and development. Nitrogen from fertilizers, composts, animal manures or plant residues provides nutrients that may not be readily available in soil, often increasing yield and farm profitability (Figure 1). Despite over 50 years of agricultural research to improve the use of N, globally, crops typically utilize 50-80% of the N that farmers apply, with the rest lost via microbial consumption, leaching, runoff, or off gassing. It is challenging to synchronize the uptake of N in its plant-available form *when and where the crops need it*. The overapplication of N increases financial costs, degrades soil, water, and air quality, and acts as a significant source of agricultural greenhouse gas (GHG) emissions. Improving the efficiency of N fertilizers by utilizing management practices that maximize N uptake by the crop and minimize the loss of N from agricultural lands can benefit the farm's bottom line while helping the environment.

Figure 1. Manure spreading for potato production (photo credit: S. Smukler)

What is Nitrogen Use Efficiency?

Nitrogen use efficiency (NUE) estimates how much of the applied N contributes to crop production. Low NUE values often indicate inefficient plant uptake, while high NUE suggests plants are using the N applied effectively. NUE can be estimated in various ways based on the ratios of the N applied or available and the N used. Strategies for calculating NUE can range from very complex, requiring multiple analyses of the crop and soil throughout the production season, to a simple estimate of the ratio of crop yield to the amount of N applied. NUE is also influenced by the form of N applied, location, timing, environmental factors, plant physiology, and soil biochemical processes. Crops mainly take up mineral forms of N, ammonium (NH_4), and nitrate (NO_3) — together, referred to as plant available nitrogen (PAN). Fertilizers containing N can be derived from rocks/minerals or synthesized through industrial processes or chemical reactions, and are rapidly released after application as PAN. Alternatively, N applied through compost, animal manure, and plant residues tends to release PAN slowly as they decompose. Effectively improving NUE requires planning the location and timing of PAN release, ideally accounting for all its sources.

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How is Nitrogen Lost to the Environment?

When N is applied to soil, regardless of its source, it is susceptible to environmental losses (Figure 2). These losses are generally controlled by microbial activity and environmental conditions, such as temperature and moisture. N that is applied without soil incorporation is especially prone to being lost through volatilization, particularly as NO_3, which is water-soluble. Additionally, N can be converted to NH_4, which is then lost through the volatilization of ammonia (NH_3) gas. As N is transformed through nitrification from NH_4 to NO_3, it is lost to the atmosphere. NO can then be converted into N_2O and nitrogen gas (N_2). Critically, N_2O is a GHG 273 times as potent as carbon dioxide and is a primary source of agricultural emissions, underscoring its impact on the climate system.

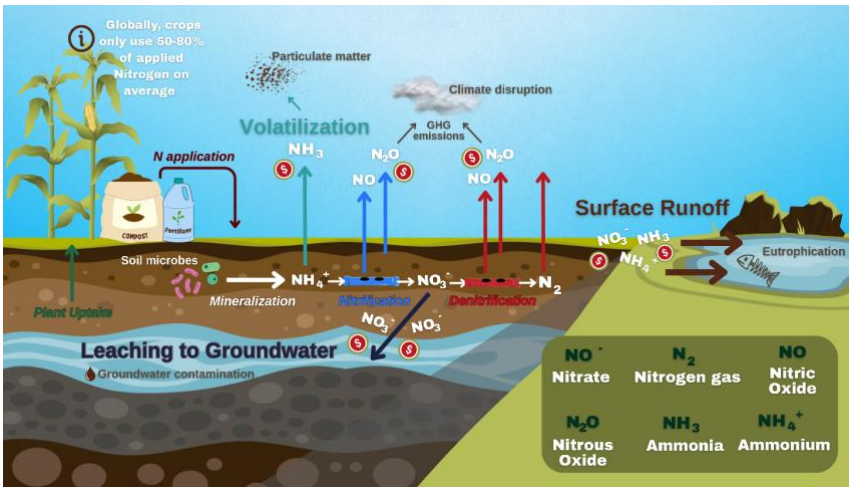

Figure 2. *Diagram showing the most common pathways where nitrogen is lost to the environment.*

Improving NUE and Results through 4R Nitrogen Management

Improving NUE can help mitigate N loss and increase crop yields and profits, as NUE is directly linked to the conversion of available N into plant biomass. This can be done by using a 4R Nutrient Stewardship approach: **R**ight source, **R**ight rate, **R**ight time, **R**ight place (see *Improving Farm Profitability and Reducing Greenhouse Gas Emissions with 4R Nutrient Stewardship* for details). Using the 4R approach has been shown to increase NUE across a wide range of agricultural systems. In a study evaluating NUE on a national scale across the United States, researchers found that a simulated 20% increase in NUE would result in an increase in **farmer profits of 1.6% per year**. Considering a sizable amount of applied N is lost to the environment, reducing the initial application rate is economically beneficial as well. In a study based in Ontario, researchers used a representative corn farm model to calculate that reducing the N application rate from 170 to 150 kg N ha^{-1} would result in an **increase in net return of $22.32–$36.25 $ha^{-1}yr^{-1}$.**

Key Takeaways

On both a global and local scale, farmers are currently overapplying N. This overapplication not only affects a farm's bottom line but also has impacts on the environment and climate. To address these issues, efforts should concentrate on improving NUE, which will simultaneously increase farm profitability and reduce agricultural GHG emissions.

References

Ali, A., Jabeen, N., Farruhbek, R., Chachar, Z., Laghari, A. A., Chachar, S., ... & Yang, Z. (2025). Enhancing nitrogen use efficiency in agriculture by integrating agronomic practices and genetic advances. *Frontiers in Plant Science*, *16*, 1543714.

Government of Ontario. (2005). Environmental impacts of nitrogen use in agriculture. Retrieved on June 10, 2025, from https://www.ontario.ca/page/environmental-impacts-nitrogen-use-agriculture

Govindasamy, P., Muthusamy, S. K., Bagavathiannan, M., Mowrer, J., Jagannadham, P. T. K., Maity, A., ... & Tiwari, G. (2023). Nitrogen use efficiency—a key to enhance crop productivity under a changing climate. *Frontiers in Plant Science*, *14*, 1121073.