Reducing Reactive Nitrogen from Agriculture

In 2021, BANR proposes to organize a broad-based workshop to develop a plan of research and action for reducing reactive nitrogen from agriculture. The workshop will convene thought leaders from science, industry, production, and public policy to:

a) clarify the dimensions of the nitrogen problem (document trends in releases; N stocks & flows, and environmental impacts); b) categorize solutions (new N sources/ways to move away from Haber-Bosch process; precision N application, improving nitrogen uptake and plant use efficiency, controlling or capturing N losses from soil), and c) identify viable options for farmers to control nitrogen in farm production.

Nitrogen is a fundamental requirement for plant growth. In natural terrestrial ecosystems, soil microorganisms and lightning convert atmospheric nitrogen (N_2) into reactive forms of nitrogen that are bioavailable to plants, and which plants use to make protein. Eventually, most of this "biologically fixed" nitrogen is stored in the soil or returns to the atmosphere as N_2, mediated by microbial processes and other earth cycles (Galloway and Cowling, 2002[1]).

In the early 20th century, the invention of the Haber-Bosch process made it possible to combine atmospheric N_2 with hydrogen from natural gas to synthesize ammonia (NH_3) and other molecules that form the basis of "industrially fixed" nitrogen for fertilizer. The amount of such fertilizer applied to crops in the United States has grown by more than 10-fold in last hundred years (Figure 1[2]).

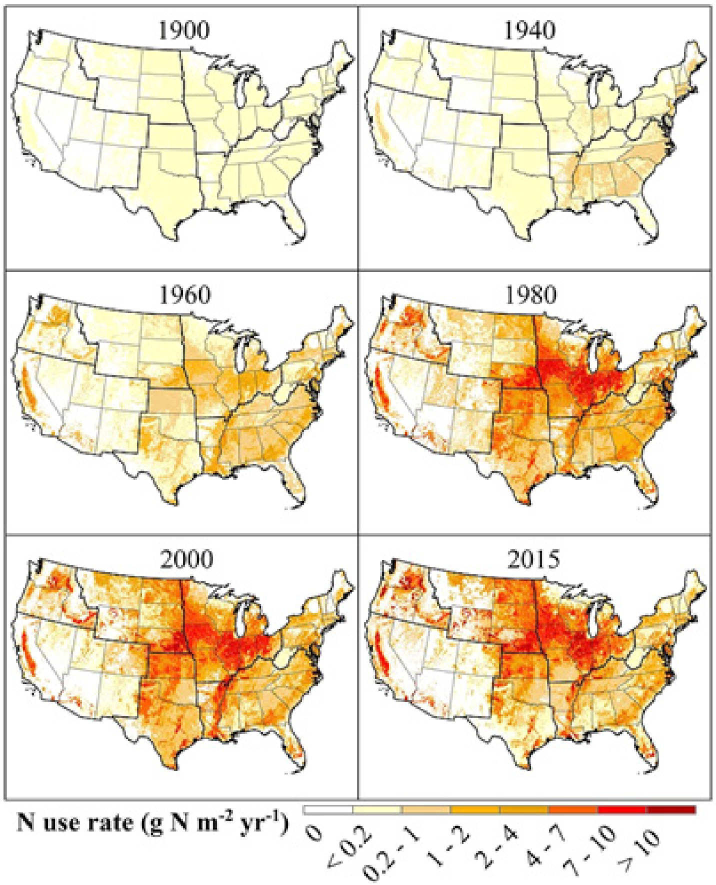

Figure 1

Because it provides a readily bioavailable input to plants, nitrogenous fertilizer has boosted crop yields and food production significantly worldwide, but it has also dramatically increased the total amount of reactive nitrogen in the environment, overwhelming the capacity of natural processes to recycle it back to the atmospheric N_2 state (Sutton, et al., 2013[3]). Crops remove about 50% of the fertilizer N applied to the croplands while the other 50% remains in the soil or is lost from the field (Lassaletta et al., 2014[4]).

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In the soil environment, some of these molecules are mobile and transported out of the soil by surface runoff or subsurface leaching into the water supply or move into the air through volatilization and then redeposited in soil and water in other reactive N forms (Li et al., 2016[5]). Some of the N comes from the waste of animals (including humans) that consumed the proteins in plant materials. In food animal production, animal manure emits N_2O gas, a process accelerated by manure storage in lagoons.

Excess amounts of reactive forms of nitrogen in the water and air are pollutants and can be toxic to humans and wildlife. The negative environmental and health risks posed by excess reactive nitrogen forms include health risks such as blue baby syndrome via excess NO3- in drinking water (Ward et.al, 2018[6]); eutrophication and algal blooms in aquatic ecosystems caused by DON and NO_3- (NRC, 2000[7]); and tropospheric ozone pollution catalyzed by NO (Galloway et al, 2003[8]). In addition, N_2O is a potent and long-lived greenhouse gas that contributes to global warming, remaining in the troposphere for approximately 100 years. Although N_2O is only 6.5% of greenhouses gases emitted in the United States annually, agricultural activities contribute the bulk of N_2O emissions, about 79% of the total (EPA 2020).

The challenge of reducing reactive nitrogen in agriculture is a longstanding problem, with no silver bullet. The challenge with N management is the fine line between insufficient N for adequate yield and excess N. In addition, N-needs are linked inextricably to the hydrologic cycle, which makes N management more challenging. New tools like sensors, gene editing, and modelling, and increasing knowledge of nitrogen transport, the soil microbiome, root genomics, materials science, and agronomic interventions, and agricultural policy and economic tools suggest that a re-examination of the nitrogen cycle (Figure 2[9]) with the goal of making system-wide improvements may provide opportunities.

Such opportunities might include, for example, improving nitrogen use efficiencies in plants and animals, improving the timing of fertilizer applications, improving the formulation of fertilizers, changing management practices to reduce nitrogen inputs overall, and finding ways to make nitrogen capture economically feasible. Ultimately, combined approaches are needed to simultaneously reduce emissions in water and air, while increasing profitability and biodiversity.

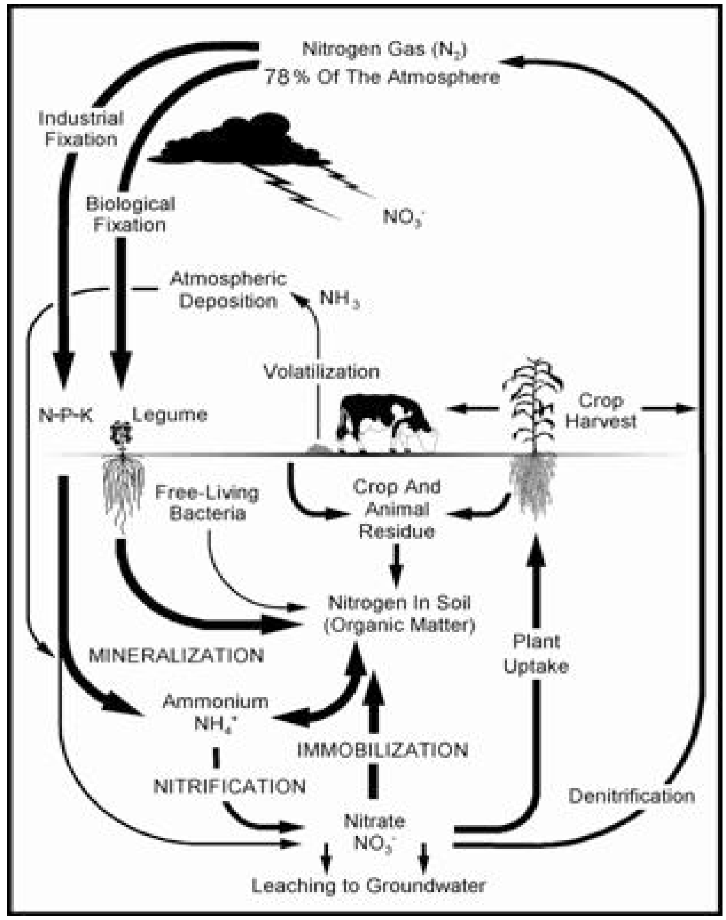

Figure 2

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[9] Source of Figure 2: McKague, K., Reid, K., and H. Simpson. 2019. Environmental Impacts of Nitrogen Use in Agriculture. Factsheet: Ontario Ministry of Agriculture, Food, and Rural Affairs. Available at: http://www.omafra.gov.on.ca/english/engineer/facts/05-073.htm