Nitrogen myths and realities

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Introduction

More than 1/3 of the nitrogen in human bodies is derived from industrially synthesized nitrogen fertilizer (Smil, 2004). Without nitrogen fertilizer, agriculture could not sustain the global population of 7 billion people living today, much less the 11 billion people expected to be living by 2100. There is no doubt: nitrogen fertilizer is critical to sustain human health and grow developing economies.

However, nitrogen is easily lost from agricultural systems to the surrounding environment where it becomes an economic loss to farmers that degrades air and water quality. Midwest US farms – among the most efficient in the world – capture less than 50% of nitrogen fertilizer inputs (Cassman et al., 2002). As we write these proceedings on a typical fall day – November 2nd, 2016 – Iowa will lose roughly 2,000,000 pounds of nitrogen to the Gulf of Mexico (IQWIS, 2016).

Common misconceptions about environmental nitrogen dynamics limit improved nitrogen retention within agricultural systems. A simple accounting of cropping systems nitrogen budgets reveals the following realities:

- Soybean is not a net contributor of nitrogen to the soil.
- Optimum nitrogen fertilizer management is required to maintain the long-term productivity of Iowa soils.
- Nitrogen fertilizer management has limited potential to reduce nitrate loss to waterways.

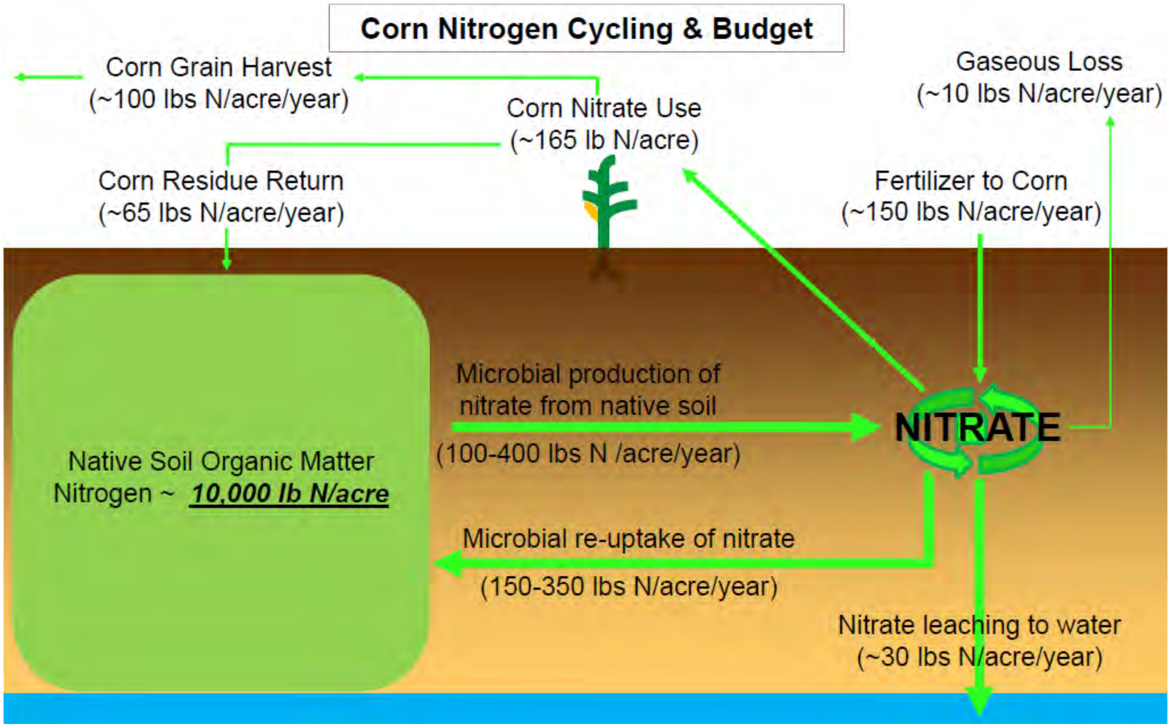

Figure 1. Approximate nitrogen budget for a well-managed corn crop (following soybeans) that yields 175 bushels per acre at 15.5% moisture. The ranges of microbial production and re-uptake of nitrate from the soil organic matter are affected by weather and management.

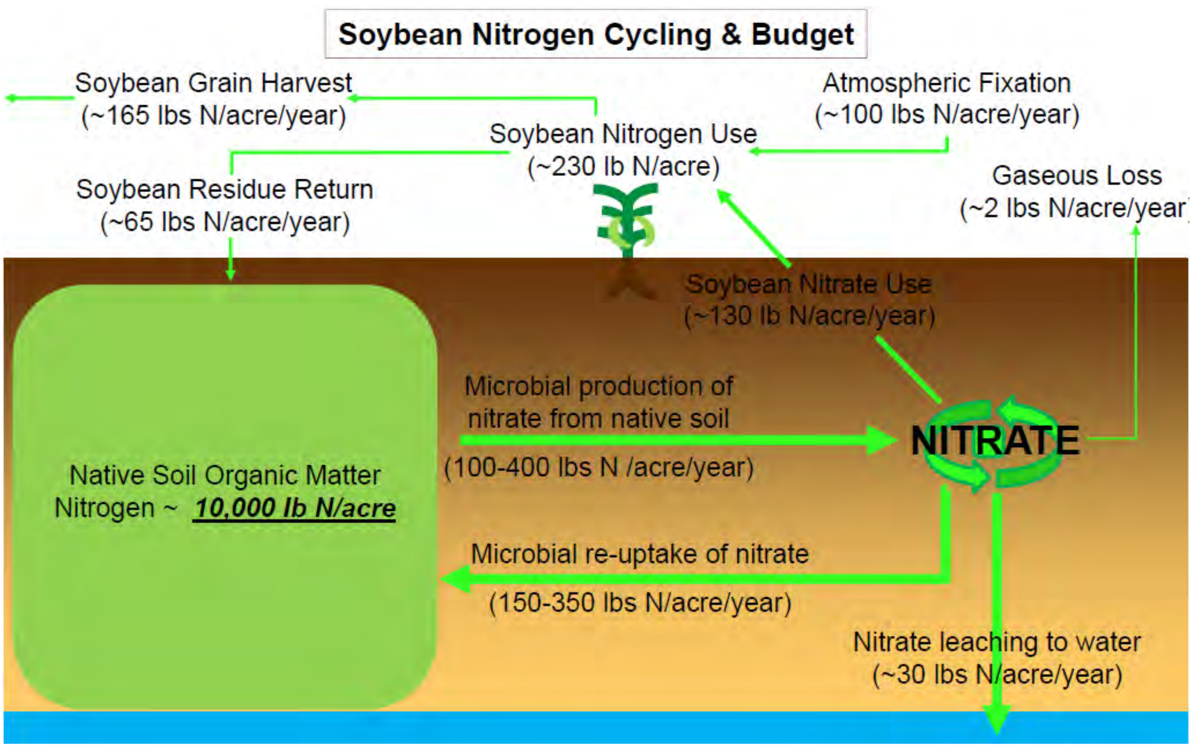

Figure 2. Approximate nitrogen budget for a well-managed soybean crop that yields 51 bushels per acre at 13% moisture. The ranges of microbial production and re-uptake of nitrate from the soil organic matter are affected by weather and management.

The soybean nitrogen credit

Soybean does not add nitrogen to the soil. In most Iowa soils and weather years, nitrogen harvested in grain is equal to or exceeds nitrogen inputs from leguminous biological nitrogen fixation.

However, corn following soybean requires less nitrogen fertilizer input to yield more grain than corn following corn. What causes this difference? The difference in nitrogen fertilizer requirement between corn following corn and corn following soybeans, referred to as the 'soybean nitrogen credit' is commonly attributed to a combination of two factors:

1. A net addition of nitrogen to the soil. In other words, nitrogen input from fixation exceeds nitrogen output in grain.
2. Soybean residues have a lower carbon-to-nitrogen ratio which hastens decomposition and nitrogen release to the following corn crop.

We explored the source of the 'soybean nitrogen credit' and found that it is not associated with biological nitrogen fixation or residue decomposition. Measurements from northwest and central Iowa (Figure 3) in 2015 confirm our estimates in Figure 2: In these locations and weather years, nitrogen harvest in grain exceeded biological nitrogen fixation. Our data are consistent with a review of soybean nitrogen fixation across a wide range of environments that found nitrogen harvest in grain often exceeds nitrogen fixation (Salvagiotti et al. 2008). We will explore possible processes responsible for the difference in nitrogen fertilizer requirement between corn following corn and corn following soybeans.

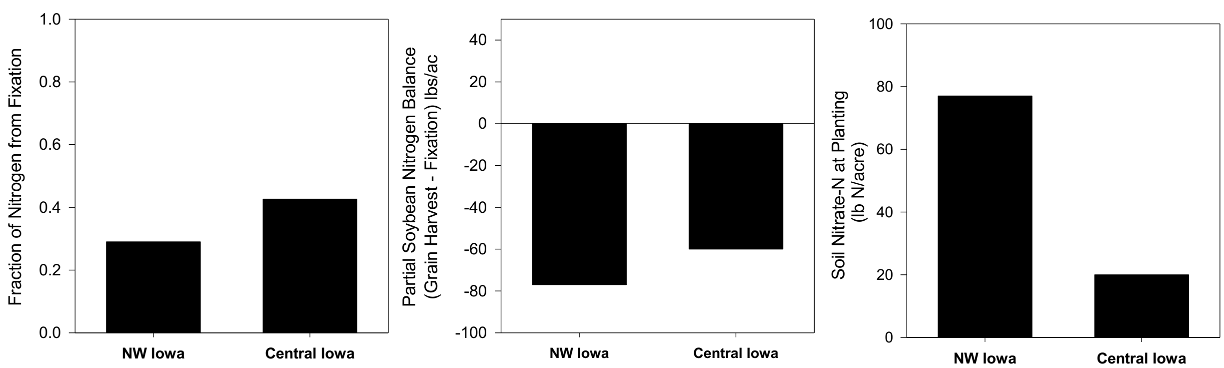

Figure 3. Soybean nitrogen fixation in 2015 in northwest and central Iowa. The left panel shows the proportion of total nitrogen uptake (grain + residue + roots) that is derived from the atmosphere (i.e., fixation). The middle panel shows the partial nitrogen balance (grain nitrogen harvest output – biological nitrogen fixation input). The right panel shows the background soil nitrate levels.

The importance of nitrogen fertilizer for the long-term productivity of Iowa soils

Soil organic matter – not nitrogen fertilizer – is the largest source of nitrogen for corn uptake. Figure 1 identifies two sources of nitrogen for corn: nitrogen fertilizer and nitrogen mineralized from soil organic matter. The soil organic matter source is larger and at least partly produced during crop growth. As a result, maintenance of soil organic matter is critical to the long-term sustainability of Iowa soils.

Nitrogen fertilizer is critical to maximize crop yield, yet the long-term effect of nitrogen fertilizer on soil organic matter is actively debated. Nitrogen fertilizer increases grain production and crop residue inputs. Crop residue is the source of soil organic matter. However, some research suggests nitrogen fertilizer also enhances residue decomposition.

Here, we show that optimum nitrogen fertilizer maximizes soil organic carbon storage (Figure 4).

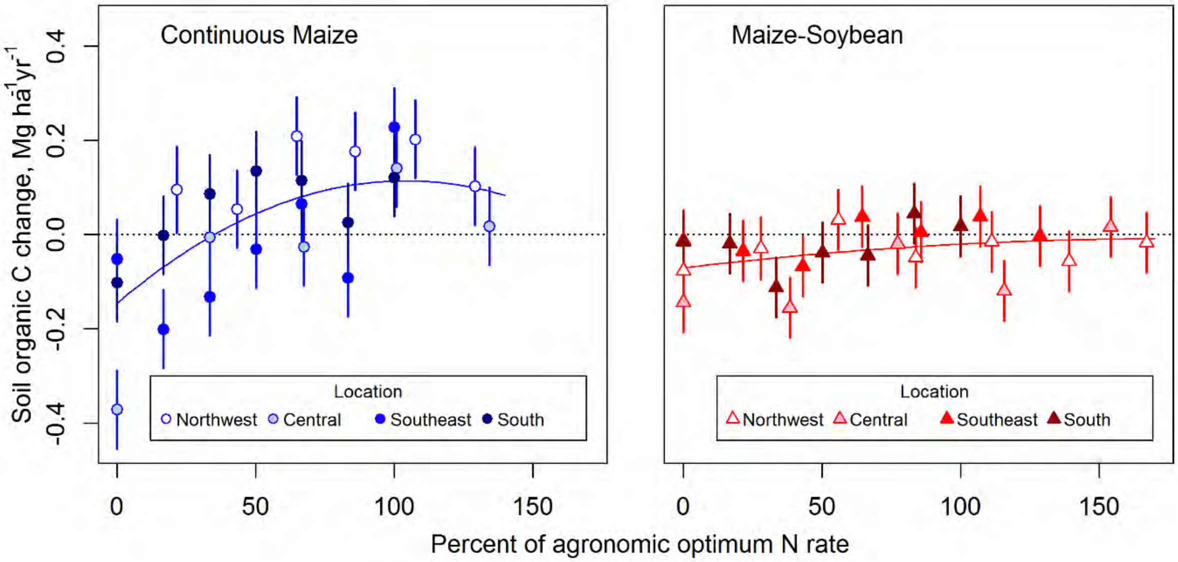

Figure 4. Change in soil organic carbon stocks in two cropping systems (continuous corn and corn-soybean rotation) from four Iowa locations as a function of nitrogen fertilizer input. At each of the sites, the nitrogen fertilizer rate is scaled to the 'agronomic optimum nitrogen rate' (AONR) for that particular site. Across sites and rotations, the AONR ranges from <150 to >250 pounds of nitrogen per acre. Soil organic carbon is a relatively constant fraction of soil organic matter.

Nitrogen fertilizer management has limited potential to reduce nitrate loss to waterways

The Iowa Nutrient Reduction Strategy is a science-based approach to reduce nutrient loss from crop fields. The strategy identifies three categories of practices to reduce nitrogen loss: Nitrogen Management, Land Use, and Edge-of-Field. The goal of nitrogen management is to avoid inefficient nitrogen fertilizer inputs – that is, nitrogen fertilizer management scenarios that use the least amount of nitrogen possible to maximize yield. Examples include sidedress nitrogen application and nitrification inhibitors. Land use includes practices that change the conventional Iowa crop systems from corn and soybeans to more diverse cropping systems including alfalfa. One example is adding two years of alfalfa to a four or five year rotation. Finally, Edge-of-Field practices treat nutrients after they are lost from the field, but before they travel downstream. Examples include wetlands and denitrification bioreactors.

Although important, nitrogen fertilizer management is the least effective nitrogen loss reduction practice. The nitrogen budgets in Figures 1 and 2 demonstrate that nitrogen mineralization from soil organic matter is a large contributor to the amount of nitrate available to crops. When the soil is warm and wet, soil microbes produce nitrate from soil organic matter whether or not a crop is growing. If there is no plant to use that nitrate (e.g., corn, soybean, rye cover crop), the nitrate is susceptible to rapid loss to Iowa waterways. This is why, although important, nitrogen fertilizer management alone is insufficient to meet Iowa's nutrient loss reduction goals.

A summary of the Nutrient Reduction Strategy and practices to avoid nutrient loss can be found at these links:

http://www.nutrientstrategy.iastate.edu

https://www.cals.iastate.edu/nutrientcenter

https://www.cals.iastate.edu/sites/default/files/misc/183758/sp435.pdf

References

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