Nitrogen Management-Good for the Environment and the Wallet

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Introduction

On-farm nitrogen (N) management is important to ensure that you are meeting production goals, maximizing return on investment, and protecting air and water resources. Nitrogen is essential to the growth of all plants and animals and is typically the most limiting nutrient in agricultural production. Therefore, it is a necessary component of feed for your cattle and crops. With global populations expected to double (or more) by the end of the next century, intensive agricultural systems will require large quantities of fixed N to support the growing population (Potter et al., 2010). Currently, approximately 40 to 60% of the global population depends upon crops produced with synthetic nitrogen fertilizer (Davidson et al. 2012). Demand for increased agricultural production has led to intensification in many industries, dairy included. As dairy production has consolidated, regional nutrient balances of N have increased, creating "hotspots" of N accumulation where in many cases manure N alone exceeds the assimilative capacity of the surrounding agricultural land. In several dairy producing states, such as CA, ID, NM and TX, manure N surplus (relative to crop uptake at the farm gate) ranges from 62 to 471 lbs N per acre. This surplus can be even greater if one considers the additional N imported with fertilizers and that fixed through biological N fixation with crops such as alfalfa.

Nitrogen use efficiency in agricultural production is inherently low. Estimates of the conversion of N used in food production to that actually consumed by humans ranges from 10 to 20% (Bordirsky et al., 2012; UNEP and WHRC, 2007) with greater than 50% of the N fertilizer applied to cropland lost to downstream and downwind habitats (Davidson et al. 2012). The current rate of N loss to the environment due to agricultural production is more than 10 times the rate that occurred at the end of the 1800's (UNEP and WHRC, 2007). This loss is of increasing concern for its negative consequences on human, animal and environmental health.

Nitrogen transforms and is lost through many pathways as it cycles through livestock/cropping systems (Figure 1). The goal is to capture the available N in the protein of the products produced, but substantial losses occur. In animal production most of the N losses are from manure during animal housing, storage and field application (Rotz et al., 2004). The major N loss is often in the form of NH_3. When animals are housed on unpaved surfaces, leaching, nitrification and denitrification processes can also emit NO_3, N_2O and NO. Thus, the amount and type of N loss varies widely with the type of housing used. The major loss in crop production is often in the form of NO_3 lost through leaching to groundwater and runoff in surface water. Ammonia emissions can also be substantial, particularly when urea fertilizer and manure is applied to the field surface. In the soil, N undergoes nitrification and denitrification processes. During this transformation, small amounts of N_2O and NO are produced, which can be emitted to the atmosphere. Incomplete denitrification occurs though producing N_2O and NO, which may escape to the atmosphere. The losses through these pathways are dependent upon many management and environmental conditions. Modeling of dairy systems has indicated that environmental losses of N were equivalent to 50 to 77% of N imported annually (Holly et al., 2018). The majority of N loss is due to NH_3 volatilization in western states with drier climates and NO_3 leaching in midwestern to eastern states with large amounts of annual precipitation. These losses of N also represent an economic loss. For example, a typical urea application on corn under a pivot (~143 acres at 434 lbs/acre) at current urea prices means that you would be losing close to $4,600 worth of N applied. Therefore, maximizing your N use efficiency could save you a substantial amount of money over time.

Nitrogen Sources and Management

Nitrogen is imported onto the farm in three main ways. There is a large amount of N “imported” via biological fixation when leguminous crops, such as alfalfa, are grown. A typical dairy will also import a significant amount of N in the form of feed and fertilizer. Nitrogen leaves the farm in the form of milk, cattle, manure (if exported) and feed (if excess feed is produced by the farm). There is also some N “storage” on the farm as there is N stored in cattle, manure and soil. The average lactating cow has a N use efficiency of approximately 30%, with the majority of this N going into milk. Managing dietary N can be important, as each lb of N fed over what is needed for lactation and maintenance is excreted by the cow therefore increasing the amount of N that has to be managed in the manure. This represents an overall decrease in dietary N use efficiency. Typical N use efficiencies of crops is less than 40%, with the remainder of N either being stored in the soil or lost through leaching, runoff and volatilization. Therefore, managing both feed and manure/fertilizer N is important.

The goal of on-farm N management is to maximize your return on investment while protecting air and water quality. Maximizing return on investment is not the same as maximizing yield. At some point there are diminishing returns for each additional unit of N used to produce any given product. The ideal is to maximize your profit, therefore inputting enough N to get the best production for the least cost. At the same time, managing N to protect both water and air quality is an important part of the decision-making process. The 4R principles of nutrient stewardship can help guide the on-farm decision making process. This consists of using the **R**ight source, **R**ight rate, **R**ight time and **R**ight place. While these are good guidelines to follow and sound simple, the reality of on-farm management can be quite a bit more complex and therefore solutions will need to be flexible to fit each farms needs.

The **Right Source** involves matching fertilizer type to crop needs. Most dairy producers will use a mix of both manure and synthetic fertilizers for crop production. Producers outside of the dairy industry may also use a variety of both synthetic and organic N sources. There are many types of both synthetic and organic N fertilizers that can be used in crop production. Some of the more common fertilizers consist of urea, UAN, mono and di ammonium phosphate. There are also specialty fertilizers that have been designed to enhance N use efficacies in cropping systems such as slow release fertilizers, fertilizers with nitrification/denitrification/urease inhibitor, and enhanced fertilizers such as Anuvia etc. Organic N sources can come from a wide range of sources including plant and animal with each source having it’s own unique characteristics and applications. Two things to keep in mind with organic sources is that the N may not be available right away as it will have to go through a mineralization/nitrification process in the soil and some of these amendments may have other benefits such as improving soil quality which will provide benefit beyond the N value. However, some organic amendments may not be suitable for all crops as there could be other issues to consider, for example the use of fresh manure on lettuce or other vegetable crops which could be at risk for pathogen contamination. The plant available N in traditional fertilizers is readily available and therefore easy to account for in N budgets. Organic N sources may vary greatly and may not be readily plant available, therefore testing prior to application and assuming some sort of availability factor will be necessary.

The **Right Rate** matches the amount of N fertilizer to crop needs. While this sounds straightforward this can be tricky. The amount of N needed will be driven by factors such as: yield, how much N will be taken up by the plants, how much N is available in the soil, how much N is available from crop residues, and from the source applied. It is important to use a realist yield goal based on past performance of the field. While it is tempting to assume that you will get "the best yield ever" this year, you don't want to overestimate as excess N applied is a loss of money and potential environment concern. Once you have a realistic yield goal, then you need to determine the amount of N that will be taken up by the crop over the growing season, which can be based on previous tissue testing or book values. It is important to remember that the same crop grown in the same field can take up different amounts of N from year to year due to changes in crop health, weather, irrigation, the N source used, the rate used, etc. You also will need to know how much N you are starting with, therefore soil testing to at least 2' should be done prior to applying fertilizer. For certain crops, such as corn, waiting till later in the season to soil sample may be advantageous to better estimate the amount of N that will be available from the soil as testing later allows you to capture some of the N that is mineralized by the soil. You will also need to calculate an N credit for any crop residue or N fixing crop (such as alfalfa) that may have been in the field the previous year. When using organic amendments, you will also have to assume a mineralization rate for the current application as well as from any past applications. Estimating the amount of N mineralization that will occur over the growing season from organic N amendments is one of the most difficult parts of determining the right rate. The amount of N mineralized will depend on the type of organic amendment, the soil type, climate, irrigation, crop rotation, etc. If possible, try to use estimates that were determined using similar materials on similar soils in similar climates.

The **Right Time** makes nutrients available when the crops need them. In an ideal world you would slowly feed N to crops as they need it. For most crops, the majority of N uptake happens during the mid-stages of plant growth. Making N available during the times when the plant uptake is the greatest can enhance the N use efficiency provided all other management factors are optimal. Doing split applications of N when possible can help better match the crops uptake patterns. Other options include the use of slow release fertilizers. Many organic N sources behave like a slow release fertilizer as N is slowly mineralized over time. Using in season soil and plant tissue testing can also help better match N needs with N supply. In season applications of manures may not be feasible and therefore N supply will be dependent on when manure can be applied and the conditions (soil, water, climate) that control microbial activity which ultimately mineralizes N and make it plant available. It is important to remember that N mineralization can occur late into the year and may still be occurring after crops have been harvested, therefore field management can be important to help reduce losses of this N post growing season.

Applying N in the **Right Place** keeps nutrients where crops can use them. There can be large variability in N fertility across a given field. Large fields or fields with unique landscape features may have larger variability than other fields. Therefore, the N needed to meet crop needs will vary across a given field. Precision application of N can help target N to areas where it is needed, saving money and reducing potential losses. However, the technology for variable application rates may be cost prohibitive for many producers. A less expensive option may be to divide your field into management units based on topography, soil type or other unique field features. By doing so you may be able to better evaluate the N status of those areas and therefore the N needed in those areas. How you apply N can make a difference as well. Surface applications of urea and manures can be prone to ammonia (NH_3) volatilization, therefore losing valuable N. Using urease inhibitors can reduce the losses of NH_3 from urea by slowing the conversion to NH_4. Injecting or incorporating manures immediately following application can reduce NH_3 losses. For example, in on farm studies where liquid manure was injected there was a 67% reduction in NH_3 losses compared to surface applied manure. When solid manure was disked into soil immediately following application, NH_3 losses were reduced 35% compared to surface application. However, there can be tradeoffs between practices. Any N that is not lost through NH_3 volatilization can be lost due to denitrification (as N_20) or nitrate (NO_3) leaching. In terms of N losses, N_20 is a small fraction with typically less than 1% of total N applied being lost. However, N_2O is a very potent greenhouse gas and when these emissions are summed over the many acres receiving N it has the potential to have a significant impact on climate change. Any N that remains in the soil can be lost over time via NO_3 leaching. As NO_3 does not bond tightly to soils, it moves with water, therefore it can be lost when soils are irrigated or in rainfed areas. These losses can be exacerbated in areas with shallow soils, high water tables or tile drainage as N movement through the profile and via preferential flow can transport large quantities of N.

Keeping the Balance

On-farm N budgeting is a tricky balancing act. You have to balance all the on-farm inputs (soil, biological fixation, plant residue, organic amendments, fertilizer) with outputs (N removed by crops) and what is stored on farm (soil, manure). As N use efficiencies tend to be low, you will always have losses from the system. Overapplying N in the form of fertilizer or manure can create a situation where large amounts of N losses can occur, particularly through leaching, with either improper irrigation or large rainfall events. Therefore, it is very important to keep good records of how much N is going into and coming out of the system. Soil sampling should also provide information on how much N is being stored in the soil. However, keep in mind that using soil sampling alone to determine whether or not you are doing a good job managing N is not a reliable practice. If you have low soil N, that may mean that you did a good job of matching inputs to outputs, but it could also mean that you did a poor job with irrigation management or you had enough rainfall to leach the NO_3 out of the soil profile. Keeping detailed records can help evaluate your overall N use efficiency over time and help identify areas where you could make improvements. Keep in mind that when more N ends up in the products you are producing, that is less money spent to produce those products and less N available for loss to the environment.

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