NITROGEN BALANCES IN DAIRY PRODUCTION SYSTEMS IN SOUTHERN IDAHO

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ABSTRACT

Nitrogen (N) is essential for agricultural production, but excess quantities can be detrimental to both water and air quality. The increase in dairy cattle populations in the Magic Valley of southern Idaho has lead to concerns over the impact of N losses to the environment and the impact on both water and air in the region. This work examines the N flows and balances at the production facility, whole farm and regional scale. At the production facility, approximately 60% of N imported was lost to the environment, this improved to only 41% lost when we considered the whole farm system. At the regional level, 45% of available N (fertilizer and excreted N by cattle) was lost as NH_3-N. This loss of NH_3-N is greater than the amount of fertilizer N imported to the region. These calculations indicate that there may be ways to improve efficiency of N use on farms in the Magic Valley which will ultimately benefit producers and the environment.

INTRODUCTION

Approximately 34 percent of the total U.S. population of milk cows is located in the semi-arid to arid western U.S., with California and Idaho being two of the top four dairy-producing states. The total 2012 dairy cattle population in Idaho was580,000 milk cows with 82% of those being located in the Magic Valley (USDA, 2014). The counties comprising the Magic Valley include Cassia, Gooding, Jerome, Lincoln, Twin Falls, and Minidoka. There was approximately 1 million harvested acres within these counties in 2012 (USDA, 2014) with Cassia and Twin Falls Counties having the largest harvested acres, while Gooding and Jerome Counties had the largest dairy cattle populations. On average, in the Magic Valley, there is approximately 2.2 harvested acres of cropland per milking cow. The influx of dairy cattle into Idaho over the past two decades has changed cropping systems in the region as well. Cattle populations increased approximately 240% since 1990, along with that there was a 280% increase in corn acres harvested (USDA, 2014). Essentially there have been two acres of corn added for every three milking cows. It is also important to point out that this region is arid and all crop production is accomplished with irrigation and soils in this region tend to be sandy/loamy and in some cases very shallow (~2').

As with any increase in concentrated animal production, the increase of dairy cattle populations brings an influx of nutrients. Nitrogen (N) will be imported in feed ingredients and the majority of this N will end up being excreted by the cattle. Typically, N use efficiency is only about 30%, meaning that for every 1 lb of N ingested by the animal; approximately 0.7 lbs will be excreted (Kebreab et al., 2010). On the production facility this N will then be vulnerable to losses via volatilization of ammonia (NH_3), nitrous oxide (N_2O), and other nitrous oxides (NO_x) a well as leaching losses of nitrate (NO_3) from housing (lots) as well as manure storage areas. If we include a larger view of dairy production, then we also have to include the N imported in the form of fertilizer for forage and feed crops, N fixation by forages (alfalfa), other

N that may be deposited with wet or dry deposition as well as volatilization, leaching and runoff losses of N that may occur.

As N becomes concentrated on the landscape (fertilizer, manure), losses of N to the environment can become significant and have the potential to negatively impact both water and air quality. In the state of Idaho, ground water supplies 95% of the water used in Idaho households and provides water for more than 200 Idaho cities and towns (IDEQ, 2014). Nitrate (NO_3) is one of the most widespread ground water contaminants in the state. Approximately 400,000 Idahoans (25% of the state population) live in NO_3 priority areas where 25% of the wells have NO_3 concentrations over 5 ppm. Within some nitrate priority areas, 50% or more of the wells haveNO_3concentrations over 10 ppm, which is the EPA threshold for NO_3 in drinking water (IDEQ, 2014). Within the irrigation return flow system (return flows convey unused irrigation water back to the Snake River), there has been a 160% increase in NO_3 concentrations over the past several decades in reaches where subsurface drains are present (Bjorneberg, 2014). These increases appear during the 'non-irrigation' season with stretches that have year round flow due to these subsurface drains. This indicates that NO_3 leaching from agricultural production has been increasing. In addition to water quality, air quality can be a concern, in particular, losses of NH_3 from dairies. Approximately 81% of all US NH_3 emissions are generated from the agricultural sector, with the majority (54%) of that associated with livestock production (USEPA, 2013). Once volatilized, NH_3 can interact with NO_x and sulfur oxide compounds in the atmosphere to form fine particulate matter (<2.5μm in diameter, termed $PM_{2.5}$) than can adversely affect human health (Finlayson-Pitts and Pitts, 1999; Pope and Docery, 2006). In addition, the re-deposition of this N into N sensitive ecosystems can have negative effects (Asman et al., 1998). Presently, the US EPA is developing rules for the regulation of NH_3 as a precursor to $PM_{2.5}$, however there is also pressure on EPA to regulate NH_3 as a constituent under the Clean Air Act. In Idaho, dairymen are currently governed by a "Permit by Rule" process intended to reduce NH_3 emissions by implementing on farm management practices to reduce these losses (IDEQ, 2006).

This work will present N balances derived at the farm and regional level in order to provide some basic information related to the size of the N pool in the Magic Valley region and potential pathways for N losses.

METHODS

Nitrogen flows and balances were calculated at multiple levels: production facility, whole farm, and regional. Dairy cattle populations and crop acreages by county were obtained from the 2012 USDA Census of Agriculture (USDA, 2014). Total N fertilizer sold in Idaho was obtained from The Fertilizer Institute and was used to estimate how much fertilizer N was used in the Magic Valley in 2012. The total N fertilizer was divided by the total harvested acres in the state and then multiplied by the number of harvested acres within the Magic Valley. This is a very crude method of determination, however there was no available data related to fertilizer use by county. On farm research conducted to estimate emissions (NH_3 and N_2O) from dairy production facilities (Bjorneberg et al., 2009; Leytem et al., 2011; Leytem et al., 2013) and N balances(Spears et al., 2003; Hristov et al., 2006) were used to calculate the production facility N flows and balances. We utilized on-farm research as well as the Integrated Farm System Model (IFSM; Rotz et al., 2014) to model N flows and balances at the whole farm level. All these information sources were integrated to calculate the regional N balances. It should be stressed that these flows and balances represent the production herd (lactating and dry cows) and do not include replacement heifers. At the regional level this is more important as the populations of heifers, beef cattle and other livestock groups are not included. Therefore the estimates for manure N and NH_3 losses from animal production are an underestimation of that generated within the region. Our goal was to focus on the impact of the production herd on N balances within the Magic Valley.

RESULTS AND DISCUSSION

Nitrogen Flows and Balances at the Production Facility

On average, in the Magic Valley, a typical dairy cow will consume approximately 1.5 lbs N/day. Nitrogen retention in the animal is approximately 30%, with 24% (0.37 lbs N/d) of that going into milk. Average excretion of nitrogen is 1.05 lbs N/d with approximately 0.78 lbs N/d going into storage. Manure export for land application (if averaged on a daily basis) is approximately 0.44 lbs N/d. Therefore manure export efficiency is approximately 42%. Overall, approximately 54% of feed N will be exported as "products" consisting of milk and manure and 46% of N is either retained somewhere in the system or lost to the environment. Spears et al. (2003) conducted N balances for 18 dairy farms in Idaho and Utah that grew no crops as part of their operation. Based on these 18 farms they determined that N inputs (feed, bedding, animals) were approximately 463 lbs N/cow/year and N outputs (animal products, manure/compost) were approximately 183 lbs N/cow/year leaving a surplus (lost) value of 281 lbs N/cow/yr which equated to a 40% efficiency. Based on Spears et al. (2003), this means that 60% of the N that is brought onto a typical western dairy is lost to the environment.

Nitrogen Flows and Balances at the Whole Farm Level

The majority of dairies in the Magic Valley are a combination of the dairy production facility as well as a row cropping operation that will grow some of the forage fed to the cattle. We used the IFSM model, which has been modified for use on western dairies based on our research,as well as on-farm measurements for validation, to simulate a typical dairy in Southern Idaho. The model dairy consisted of a total of 524 animals (208 lactating) using a dry lot production system. All animal groups were housed in lots and the majority of manure was stacked and applied during the fall. Parlor washwater was collected and stored in an evaporation pond that was applied to crop land on the farm each the fall. The farm had 550 acres of land in a corn, wheat, alfalfa rotation and used both the corn and alfalfa on farm for feeding cattle. The farm simulation was run for 25 yrs using weather data collected in Jerome Idaho. Results are provided on a per acre basis (Figure 1). Nitrogen imports were 321 lbs N/ac and consisted of fertilizer (24%), feed (28%), precipitation (<1%), and fixation (48%). The N exported from the farm was 189 lbs N/ac and consisted of crops not fed to the cows (47%) and animal products (53%). Nitrogen lost via volatilization was 110 lbs N/acrewith 91% of that lost as NH_3 and the balance lost as N_2O. There were approximately 22.6 lbs N/ac leached, 29.7 lbs N/ac denitrified, and 4.3 lbs N/ac lost in runoff. The overall N efficiency was 59%, leaving 41% of imported N lost to the environment. Spears et al. (2003) conducted N balances on 41 dairy farms in Idaho and Utah that grew crops and reported an overall N efficiency of 35.8%. Hristov et al (2006) surveyed 8 commercial dairies in southern Idaho and reported an average N use efficiency of 41% with a range of 25 to 64%. The farm at the higher end of efficiency is similar to the farm we modeled with IFSM.

Both the on-farm research and modeling indicate that the greatest loss of N from the dairy production facility, and possibly the whole farm system, is NH_3. Based on previous research and on-farm N balance work we estimate that approximately 221 lbs NH_3-N/cow/yr is lost from the time N is excreted till manure is land applied. This represents 40% of total N intake by the cows and 58% of excreted N. These large losses indicate the inefficiencies of N use on farm. In addition to losses throughout the production phase, there are additional emissions of NH_3 from the land application of both fertilizer and manure. Ammonia losses from land applied manure can be as high as 22% of total applied N, while losses from fertilizer depend on the type of fertilizer used but can be as high as 40% in some instances.

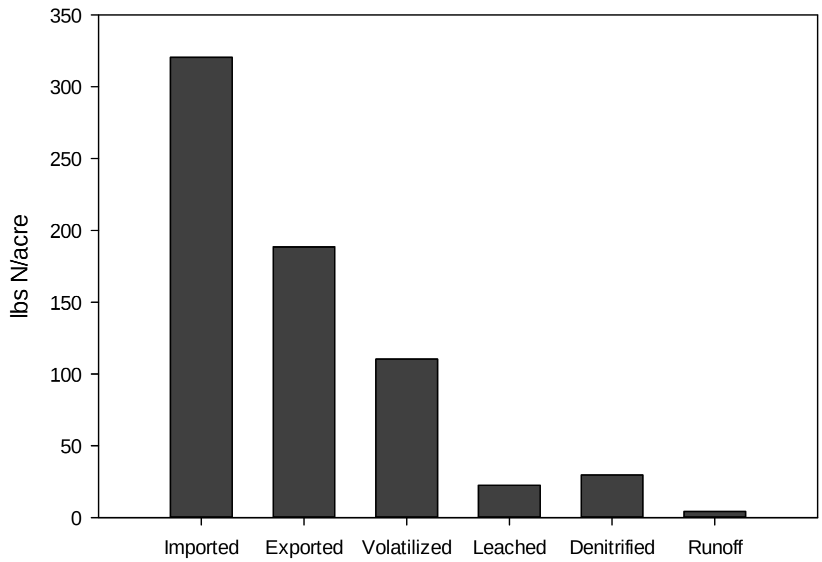

Figure 1. Nitrogen budget of a typical dairy in the Magic Valley of southern Idaho. Budget includes imports as well as exports and losses to the environment via volatilization, leaching, denitrification, and runoff.

Nitrogen Balance in the Magic Valley

The combined total fertilizer and N excretion (from production herd) in the Magic Valley was 269 million lbs N/yr for 2012 (Fig 2). Fertilizer N was estimated at 32% of the total N. The remaining 69% of N in the region was associated with dairy cattle with 23% being manure N available for crops, 6% of manure N lost as NH_3 during land application, and 39% lost as NH_3 from the production facility. This was assuming a loss of 20% via NH_3 volatilization from the land application of manures. This indicates that there was 1.4 times as much NH_3-N volatilized from the production system as fertilizer N applied in the Magic Valley region. The value of volatilized N is approximately $78 million based on the current price of urea. But how much N is needed for crop production? If the average N needs of crops across the region are approximately 100 lbs N/ac, 64% of this need would be satisfied with fertilizer N. An additional 51 lbs N/ac would be added if all of the manure was spread equally throughout the region (which we know is not the case) for a total of 115 lbs total N/ac. However, the availability of the manure N is not 100% and is likely between 10 – 30% in the first year. So theoretically, if the manure was utilized evenly across the landscape there may still be a need for additional N fertilizer applications. One thing that we do not know is the input of NH_3 deposition into the cropping system. There is approximately 101 lbs N/ac volatilized as $NH_3$from dairies and some of this N may be deposited throughout the region. More realistic application rates based on producer surveys indicate that a typical corn crop may receive 170 lbs N/ac as fertilizer on top of an application of 600 lbs N/acre of manure. In this situation the continual application of manures along with fertilizer is certainly putting some of the cropland in the region in a large N surplus. There is still a lack of information regarding the availability of this N over time, particularly with multiple heavy manure applications. Tarkalson (2014) reported that a field that had received six annual applications of manure (total of 240 tons/ac) had a soil test N (NO_3 + NH_4, 0-2') of almost 500 lbs N/ac five years after the last manure application. This indicates that more work needs to be done to be able to better predict long term N availability of manure in our cropping systems.

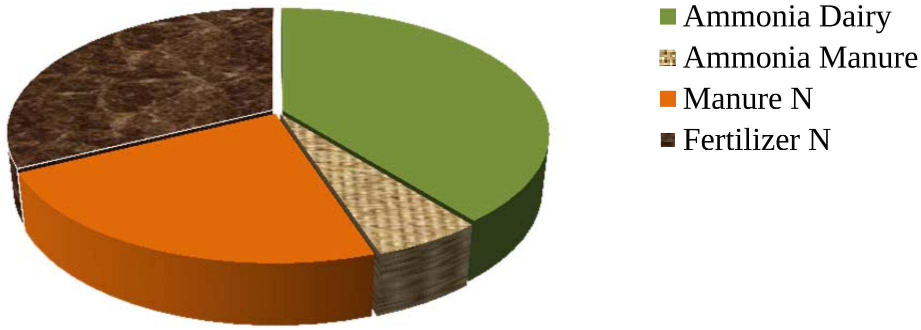

Figure 2. Distribution of nitrogen sources in the Magic Valley including those originating from fertilizer and dairy cattle production herd.Total N estimated in the Magic Valley was 269 million lbs N/yr.

SUMMARY

Based on calculated N flows and balances on production dairies in the Magic Valley region there appears to be room for improvement of N management on farm. The largest source of N losses from dairy production facilities is through NH_3 volatilization. If this N could be captured and re-used on farm it would essentially be enough N to replace on farm N fertilizer use. Although complete capture of this NH_3 would be highly unlikely, efforts to reduce N losses to the environment should be considered. The development of dairy diets that enhance nutrient utilization could reduce the total amount of N excreted on farm therefore reduce the N available for both volatilization and leaching losses. New technologies that reduce N volatilization during manure handling and storage could improve the fertilizer value of manure and therefore replace some of the N fertilizer needed for crop production. There may also be practices and technologies that can reduce N volatilization from animal housing that should be considered. Improving manure nutrient usage throughout the valley could reduce our reliance on N fertilizers and also reduce the potential impact on water quality. Taken as a whole, improvements in N efficiencies on farm could help protect both air and water quality in the region.

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