THE NITROGEN INDEX AS A TOOL TO REDUCE NITROGEN LOSS TO THE ENVIRONMENT

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Abstract

Continued population growth creates a need for increased productivity of agricultural systems around the world. Increased agricultural productivity will be needed to support a population that is anticipated to have an additional 2.5 billion people by the year 2050. Nitrogen was part of the 20th century's green revolution. Nitrogen continues to be essential for the viability and sustainability of agricultural systems that are important for feeding the growing global population. It is well known that nitrogen is a limiting factor for many agricultural systems, and that nitrogen inputs contribute to increased productivity. However, when more nitrogen is applied than necessary, increased losses of reactive nitrogen from agricultural systems occur, losses that can negatively impact the environment. Although there are always losses of nitrogen from agricultural systems via nitrate leaching, denitrification, emissions of the trace gas nitrous oxide (N_2O), ammonia volatilization, and surface runoff (among other pathways), when nitrogen is applied at rates that are higher than needed, losses via these pathways have the potential to increase significantly. User-friendly, quick-to-use nitrogen tools can be used to help us evaluate nitrogen management practices and the potential risk of nitrogen losses. The Nitrogen Index is a simple, Tier-one tool that has the potential to help nutrient managers conduct quick assessments of nitrogen management practices and to help managers make decisions that can potentially reduce the risk of losses of reactive nitrogen to the environment and increase nitrogen use efficiency. The Nitrogen Index is similar to the P Index, and uses a series of qualitative and quantitative factors to assess the potential risk of nitrogen losses to the environment. The Nitrogen Index tool/approach is being used in different areas and can be adapted to a given region, state, and/or country.

Introduction

Nitrogen inputs are used across the globe to increase crop production, which is essential for feeding the growing world population. Nitrogen inputs are key for agriculture, especially for regions such as the Midwestern USA, which serve as grain baskets and contribute to food security. However, the nitrogen losses from these and other regions have been reported to significantly contribute to negative environmental impacts such as increased concentrations of nitrate in groundwater and/or the occurrence of hypoxia in surface water bodies (Goolsby et al., 2001; Robertson et al., 2009). Additionally, nitrogen inputs have been reported to contribute to increased emissions of the greenhouse gas nitrous oxide (N_2O). Just recently, the IPCC reported that anthropogenic effects are contributing to climate change (IPCC press release, September 27, 2013). Increases in nitrogen use efficiency can potentially contribute to reductions of direct and indirect emissions of N_2O and help mitigate climate change as well as contribute to the conservation of air and water quality. As the world population continues to grow, it will be crucial that we continue to increase agricultural production while increasing nitrogen use efficiency and reducing losses of reactive nitrogen to the environment. As we move further into the 21st century, increasing agricultural production in the Midwestern region of the USA will be essential for continued food security. However, improved nitrogen management practices will also be needed in order to minimize the losses of reactive nitrogen to the environment in this key region of the USA.

While nitrogen inputs are important for increasing agricultural production, it is also essential to understand the negative impact that nitrogen losses have on the environment and the importance of taking action to reduce these losses. The challenge of nitrogen management is that nitrogen is very mobile, highly dynamic and can be quickly transformed to many different forms in agricultural systems and lost via different pathways such as nitrate leaching (which can impact underground water), losses via tile systems and surface runoff (which can impact surface waters), and ammonia volatilization (which can impact atmospheric quality). Nitrogen has been identified as one of the elements that is contributing to the hypoxia problem in the Gulf of Mexico (Goolsby et al., 2001; Robertson et al., 2009), an issue that is negatively impacting aquatic life. The good news is that nitrogen losses to the environment can be reduced with good nitrogen management at the field level. User-friendly computer tools can potentially be used to assess the risk of nitrogen losses to the environment. Tools such as the Nitrogen Index which only require a small amount of information to be entered can provide managers with additional information and aid in the decision-making process to improve nitrogen management (Delgado et al. 2006).

Potential to Increase Nitrogen Use Efficiency in the Midwest

The USDA Economic Research Service (ERS) produced a report about nitrogen management practices in the USA (Ribaudo et al., 2011). The USDA-ERS report used census data from 2006 that included information about nitrogen management such as the method, rate and time of nitrogen application. The report indicated that about 65% of the cropland area in the USA was not meeting all of three criteria for good nitrogen management (best rate, method and time of nitrogen application). The average commercial fertilizer application rate for continuous corn was 152 kg N ha^{-1}, lower than the 244 kg N ha^{-1} rate for the commercial N fertilizer and manure application (Ribaudo et al. 2011). Ribaudo et al. (2011) found that most of the cropland receiving manure was used to grow corn and that 95% of this area did not meet all three best management criteria (right rate, time and method). This Ribaudo et al. (2011) study found that the Midwest region (Figure 1; Lake and Corn Belt regions) was the largest area in the USA not using all three best nitrogen management practices for method, rate and time (Figure 2). The ERS report also found that about 71% of all the excess nitrogen being applied in the USA is located in the Midwest region covered by Ohio, Iowa, Indiana, Missouri, Minnesota, Wisconsin, Illinois and Michigan (Figure 3). The USDA-ERS report has some similarities with the assessment of nutrient management on cropland that was conducted by the Conservation Effects Assessment Project (CEAP) for the Upper Mississippi River Basin (USDA 2010). Both studies identify the potential to increase nitrogen use efficiency.

Recent studies have reported that agronomic nitrogen use efficiency increased in the USA for the period of 1975 to 2005 (Fixen and West 2002; Snyder and Bruulsema 2007). Recently, Snyder (2012) found that corn farms in the leading corn-producing states were not applying N at rates in excess of profit-maximizing university recommendations. This is good news and shows our potential to reduce nitrogen losses to the environment. However, reports during the last three decades have indicated that significant losses of reactive nitrogen to the environment are still occurring despite increases that have been reported in agronomic nitrogen use efficiency since the mid-1970s. For example, a recent 2013 report stated that the highest-ever concentrations of nitrate in the Des Moines and Raccoon Rivers were recorded in March of 2013 (Omaha World-Herald, May 11, 2013). Other recent publications have reported high impacts to surface waters (EPA, 2006; Dubrovsky et al., 2010; Goolsby et al., 2001; Robertson et al., 2009), suggesting that although there have been reports of higher agronomic nitrogen use efficiency in the last three decades, we still need to continue to improve nitrogen management practices to reduce losses of reactive nitrogen in the USA and from this region (Ribaudo et al. 2011, Figures 2 and 3).

Nitrogen Index

We could use a tool/approach like the Nitrogen Index to conduct a quick assessment of the potential risk of nitrogen losses to the environment. The Nitrogen Index does not require a large amount of information to be inputted in order to conduct a quality assessment for a given farm or a given field scenario. The Nitrogen Index has been evaluated and calibrated for cropping systems of the USA (Delgado et al. 2008), for forage systems of Mexico (Figueroa-Viramontes et al. 2011ab), for vegetable systems of a Mediterranean region of Spain (De Paz et al. 2009), for vegetable systems in Florida (Edilene Carvalho Santos Marchi, personal communication), for potato systems in Bolivia (Ana Karina Saavedra Rivera, personal communication), and for corn systems in Ecuador (Luis Escudero, personal communication; Monar et al. 2013). The Nitrogen Index is available in two languages: English and Spanish. It can be run in English or metric units and users can download the tool from the USDA-ARS-SPNR Nitrogen Tools webpage (http://www.ars.usda.gov/npa/spnr/nitrogentools). A simpler, Tier-Zero version of the tool, requires even less information to be entered, and was developed for Mexico and Malawi. The prototype of this Tier-Zero version is still in development and will be released in the fall of 2013. Figure 4 shows some of the manure inputs required by the Nitrogen Index 4.4.2, a Tier-One tool that is available for download at the USDA-ARS-SPNR Nitrogen Tools webpage (http://www.ars.usda.gov/npa/spnr/nitrogentools). Figure 5 describes the outputs of the Kentucky Nitrogen and Phosphorous Index, a Tier-One tool.

The Nitrogen Index is being used by USDA-NRCS and other national and international users. For example, during 2013, the new Kentucky Nitrogen and Phosphorous Index tool was transferred to the state of Kentucky, and allows the risk of nitrogen and phosphorous losses to be evaluated simultaneously. The new Kentucky Phosphorus Index that was developed by Bolster et al. (2013) was added to the Nitrogen Index tool. It is currently available to download at the USDA-ARS-SPNR Nitrogen Tools webpage (http://www.ars.usda.gov/npa/spnr/nitrogentools). The Kentucky NRCS revised its conservation practice standard for nutrient management (code 590) in March of 2013 and listed the new Kentucky Nitrogen and Phosphorous risk assessment tool as the official risk assessment tool for this state. Additionally, the Nitrogen Index is being used by NRCS in California. The Nitrogen Index is also being used in other countries such as Mexico and Ecuador. There have been over 800 downloads of the Nitrogen Index with downloads from approximately 50 different countries. A Nitrogen Index smartphone application was published in 2013 (Delgado et al. 2013).

The user can quickly enter the necessary information into the Nitrogen Index in order to rank the risk of nitrogen loss in three categories: leaching, surface transport, and air transport. In the Nitrogen Index tool, the user will need to navigate through only a few screens to complete the data entry process. The input screens cover: 1) soil layers; 2) manure; 3) fertilizers; 4) irrigation; 5) crops; 6) off-site factors; 7) water management/hydrology; and 8) qualitative factors. The entered information is used to quickly generate a quantitative output and qualitative ranking of the risk of nitrate leaching, atmospheric nitrogen losses, and surface nitrogen losses (Delgado et al. 2006; 2008). Recently a new subroutine was added to the new Nitrogen Index 4.5 prototype to include an assessment of direct and indirect emissions of N_2O (Figure 6).

Summary

The Nitrogen Index has been calibrated and validated across several regions. The Nitrogen Index can accurately assess the fate and transport of nitrogen under many different scenarios. The Nitrogen Index has been found to accurately predict the higher risk of nitrogen loss for scenarios of excessive nitrogen applications. The tool has been found to provide users with quick outputs that can aid decision-making regarding application of nitrogen fertilizer and manure management. The Nitrogen Index 4.5 prototype has been expanded and improved with new features. A phosphorus index and a new subroutine to assess direct and indirect N_2O emissions have been added to version 4.5. Additionally, a new subroutine to generate recommendations for nitrogen, phosphorous and potassium fertilizer applications has been added for Mexico. The subroutine to generate recommendations for nitrogen inputs (organic and inorganic) has been added to all regions. The new Nitrogen Index 4.5 is expected to be released sometime in November/December 2013 (will be available in metric and English units), followed by the release of the new Nitrogen Index 4.5 smartphone application for Android™ systems soon afterwards. This tool can help users evaluate nitrogen management practices and assess the risk of nitrogen losses to increase nitrogen use efficiency of agricultural systems.

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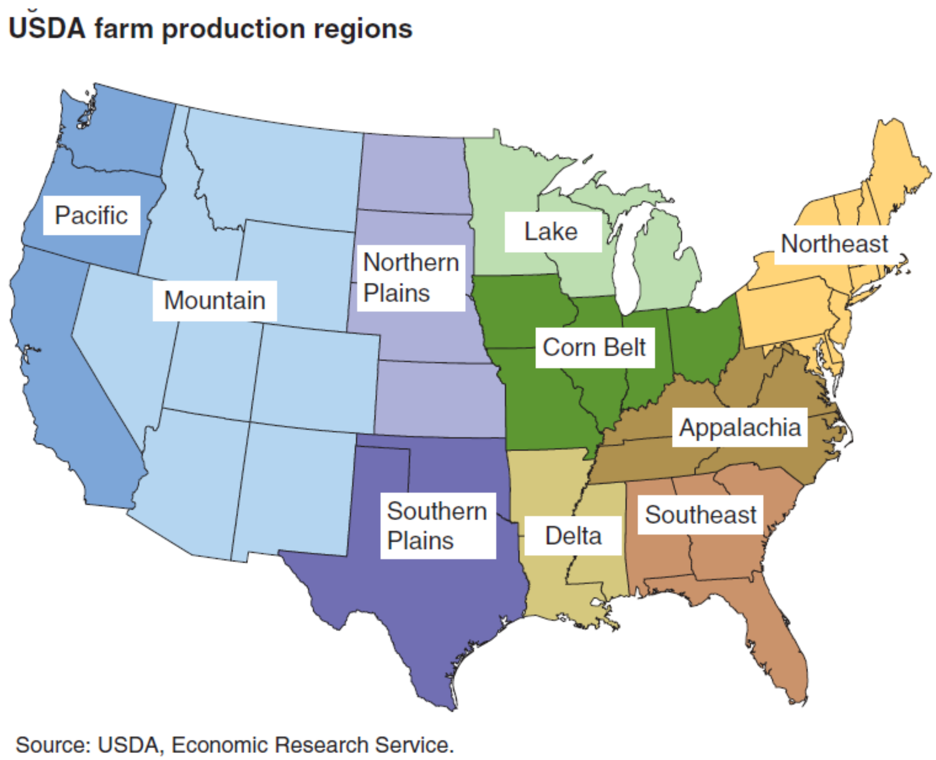

Figure 1. USDA farm production regions (From Ribaudo et al. 2011).

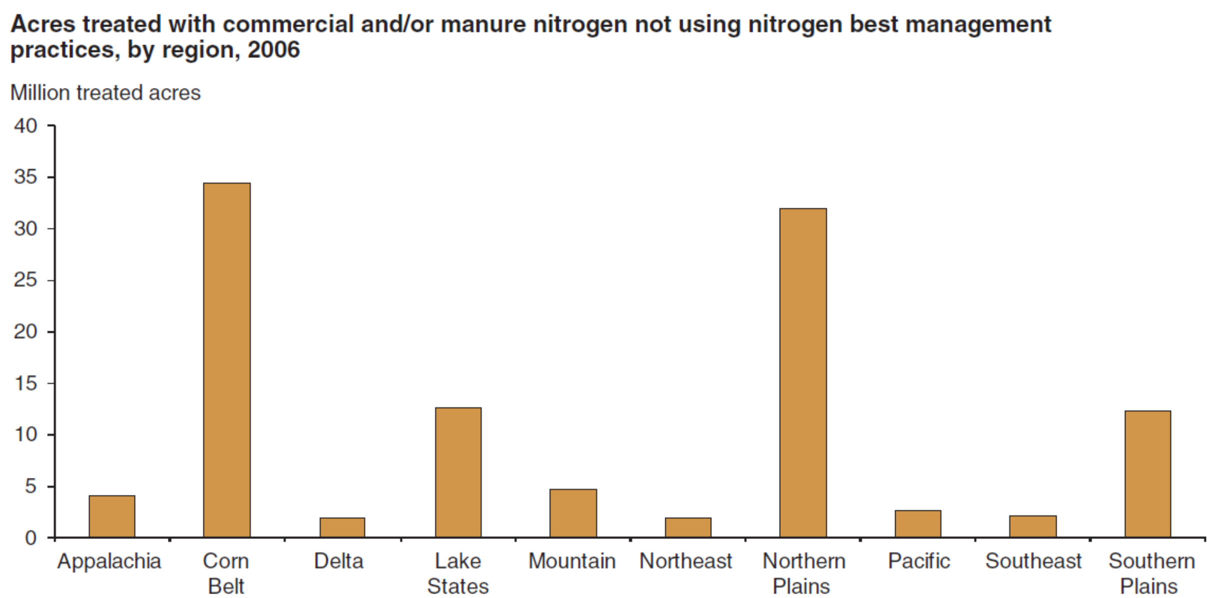

Figure 2. Acres treated with commercial and/or manure nitrogen not using best management practices, by region, 2006 (From Ribaudo et al. 2011).

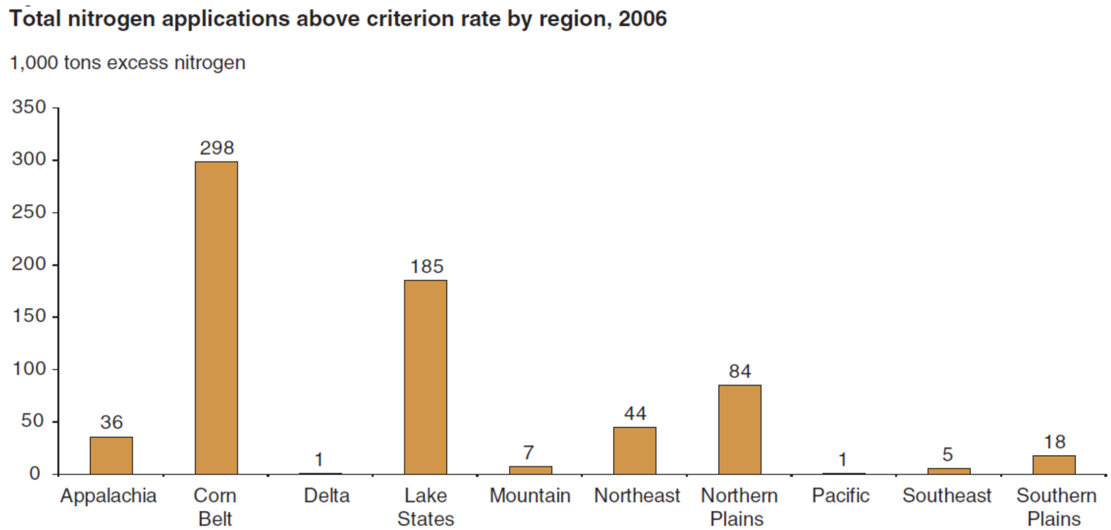

Figure 3. Total nitrogen applications above criterion rate by region, 2006 (From Ribaudo et al. 2011).

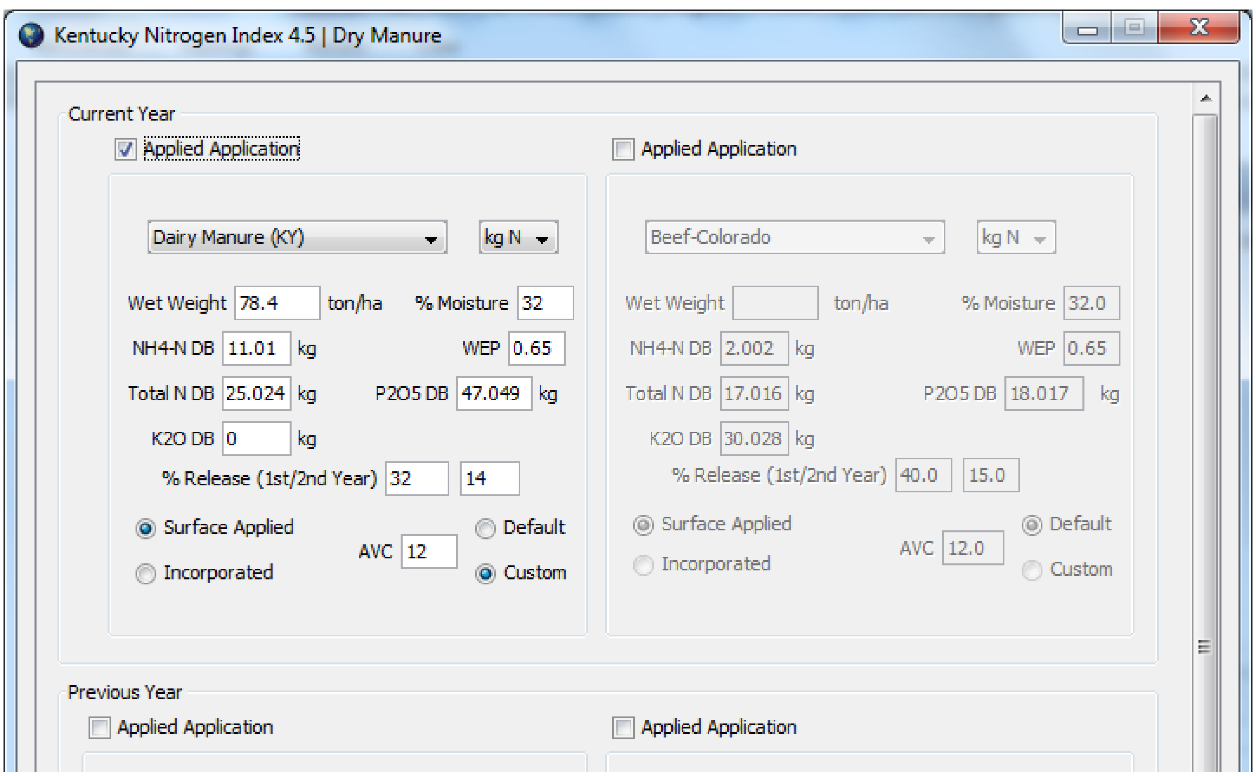

Figure 4. Dry Manure screen of the Kentucky Nitrogen and Phosphorous Index (Prototype of version 4.5; this example is in metric units).

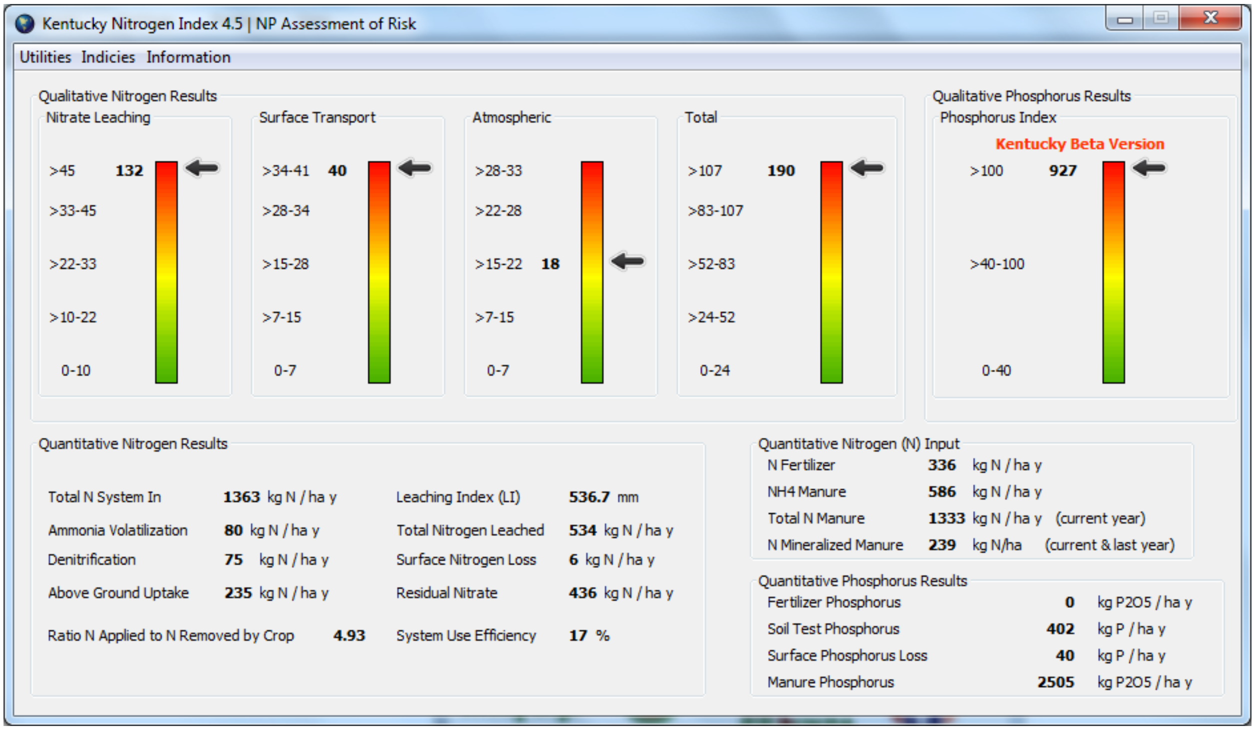

Figure 5. Assessment of Risk screen of the Kentucky Nitrogen and Phosphorous Index (Prototype of version 4.5; this example is in metric units).

Figure 6. Mexico Nitrogen Index (Tier-Zero Version): N_2O Index screen (Prototype of version 4.5; this example is in English units).

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