# Managing nitrogen fertilizers

## in the field to reduce greenhouse gases

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Improving the management of nitrogen fertilizer makes sense. It can reduce farm costs by increasing nitrogen use efficiency without reducing yields. It can also benefit our environment by reducing the emissions of a potent greenhouse gas called nitrous oxide. Better still, by improving nitrogen management, farmers can receive payment for reducing emissions of this gas through the market place.

Agriculture is a source and a sink for greenhouse gases that affect our climate. All three of the major greenhouse gases are produced naturally in agricultural soils—carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$). Nitrous oxide is the most important in all field crops but rice due to its link with the use of nitrogen fertilizer.

### What is nitrous oxide and why is it important?

Nitrous oxide is produced by microbes in soils. Because it can stay in the atmosphere for over 100 years, and is about 300 times more effective at trapping heat in the atmosphere than carbon dioxide, even small emissions matter. Globally, about two-thirds of nitrous oxide emissions produced by our activities are from agriculture; the majority of these are tied to the use of nitrogen fertilizer in farm fields.

### How does nitrogen fertilizer increase nitrous oxide emissions?

Nitrogen is added to crops as synthetic fertilizers such as urea or anhydrous ammonia, or as organic fertilizers such as manure. Most synthetic fertilizer nitrogen is readily available for uptake by the crop; most organic fertilizer nitrogen must be converted to inorganic nitrogen before it is available for uptake. Nitrogen that the crop does not use is hard to keep in the field and vulnerable to loss, particularly when it is surplus to crop needs. This mobile nitrogen can be lost as nitrate to groundwater or as the gases dinitrogen ($N_2$), ammonia ($NH_3$), or nitrous oxide. Typically only about half of the fertilizer nitrogen applied to an annual crop is taken up by it during that growing season (Figure 1).

### How can nitrogen fertilizer management decrease nitrous oxide emissions?

Because of the strong link between inorganic nitrogen in the soil and nitrous oxide production, some emissions are unavoidable. But management that prevents the buildup of inorganic nitrogen particularly nitrate, reduces nitrous oxide emissions. In general, practices that reduce nitrous oxide emissions increase nitrogen use efficiency, which keeps more of the added nitrogen in the crop and out of the environment. Many strategies can accomplish this, and there is considerable flexibility to suit a farmer's field-specific conditions. Management options include those that:

Figure 1.Simplified nitrogen cycle showing the typical fate of 100 pounds of N fertilizer applied to a corn field. The exact amounts vary with soil type, weather and crop.

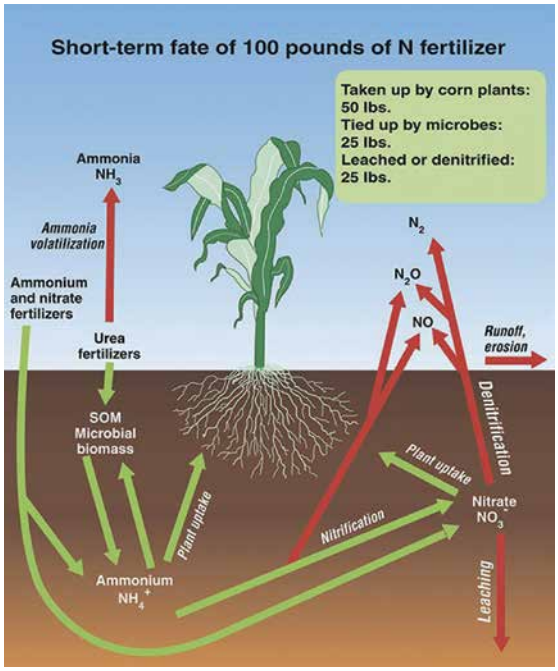
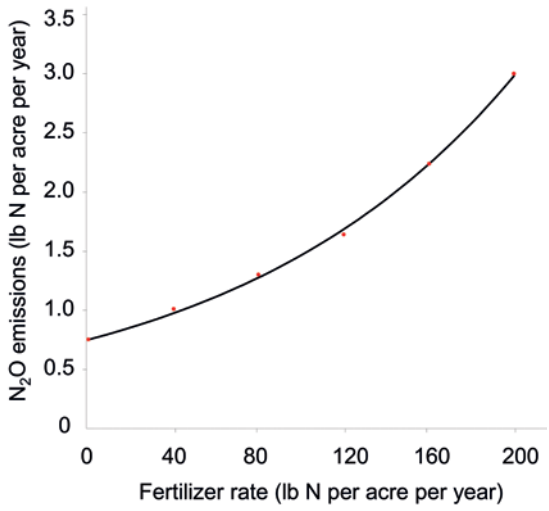



Figure 2.Data from Michigan corn fields showing how nitrous oxide emissions increase exponentially with increasing fertilizer nitrogen rate. By more precisely estimating crop fertilizer nitrogen needs, farmers can greatly reduce nitrous oxide emissions from their fields.




1. Better estimate crop nitrogen need (right rate)
2. Better time nitrogen fertilizer application (right time)
3. Improve the formulation of nitrogen fertilizer (right source)
4. Improve the placement of nitrogen fertilizer (right place)
5. Maintain continuous soil cover (cover crops)

## 1. Right rate

Nitrogen availability in the soil at any given time is the single best predictor of nitrous oxide fluxes from cropped fields. Emissions are especially high when nitrogen fertilizer (synthetic or organic) is applied at rates greater than crop need. Research in numerous crops all over the world has shown that emission rates generally grow exponentially with increases in fertilizer rate (see Figure 2). So at higher rates of fertilizer application nitrous oxide emissions increase disproportionately, particularly after crop nitrogen demands are met. Better estimating the amount of fertilizer nitrogen needed by a crop is an effective way to reduce nitrous oxide emitted from cropped fields.

## 2. Right time

Applying nitrogen fertilizer when it is most needed by the crop can help reduce nitrous oxide emissions. Splitting fertilizer applications into smaller portions added more frequently (e.g., with irrigation water), so that the majority of fertilizer is applied when the crop is growing, rather than at planting, increases the likelihood that more nitrogen will end up in the crop. Fall fertilization of spring planted crops can lead to especially large nitrous oxide and other nitrogen losses; such applications are way out of sync with the timing of crop needs.

## 3. Right source

Fertilizer formulation also can affect nitrous oxide emissions in some cropping systems. The effects are inconsistent among commonly applied fertilizer types such as anhydrous ammonia, urea, or UAN. Slow release fertilizers and controlled release fertilizers both release nitrogen gradually into the soil solution and contain nitrogen in a form that the crop cannot immediately use. Fertilizer additives or stabilizers such as nitrification and urease inhibitors delay the formation of nitrate and the dissolving of urea in soil water, respectively. At this time there are too few field trials that have investigated additives or timed release fertilizers to fully judge their effectiveness for reducing nitrous oxide emissions.

## 4. Right place

Placing nitrogen fertilizer where it is most likely to be taken up by nearby crops, i.e., close to the roots, also can reduce nitrous oxide emissions. Applying fertilizer in narrow bands rather than broadcasting, and shallow placement rather than deep placement, have been shown to reduce nitrous oxide emissions. More precise spatial application of fertilizer can also improve nitrogen use efficiency and reduce nitrous oxide emissions. Adding less nitrogen to those parts of a field with low yield potential will avoid wasting nitrogen on locations in the field that are not as likely to respond to nitrogen fertilizer. The optimal placement of fertilizer nitrogen across a cropped field can substantially reduce nitrogen fertilizer rates without affecting crop yields.

Automated greenhouse gas sampling chambers in a wheat field on the KBS Long-term Ecological Research site. These chambers measure nitrous oxide, carbon dioxide and methane emissions multiple times every day throughout the year, allowing accurate estimation of greenhouse gas emissions. Photo: J.E.Doll, Michigan State University.

> *An integrated management approach is best suited to increase nitrogen*

### 5. Cover crops

Maintaining continuous soil cover can improve nitrogen use efficiency and reduce nitrous oxide emissions. In annual cropping systems, most nitrogen loss from the soil takes place during periods when the crop is absent. Management to conserve nitrogen is effective when focused on reducing losses during these periods. For example during active growth in the autumn and spring, winter cover crops take up residual fertilizer nitrogen, which can then become available to the next crop upon decomposition of the cover crop. Much of the nitrogen taken up by the cover crop would otherwise be available for loss as nitrous oxide or as leached nitrate. The ability of cover crops to reduce nitrogen loss varies considerably, and as with nitrogen from fertilizer, any cover crop nitrogen not taken up by a succeeding crop also can be emitted as nitrous oxide.

## How can we best reduce nitrous oxide emissions from field crop agriculture?

An integrated management approach is best suited to increase nitrogen use efficiency and reduce nitrous oxide emissions from field crop agriculture. Ensuring that the timing, formulation, and placement of nitrogen fertilizer are optimized, and that cover crops are used where appropriate, provides ideal conditions for farmers to consider reducing nitrogen inputs to their field crops:

- Apply nitrogen fertilizer as close to the time of crop need as possible
- Use an appropriate nitrogen fertilizer formulation
- Apply nitrogen fertilizer as close to the crop's root zone as possible

The ability to more confidently reduce nitrogen fertilizer rate can be seen as the outcome of improvement in one or more of these and other nitrogen management practices; in effect nitrogen fertilizer rate is the integrator of an overall nitrogen management strategy.

Because the best predictor of nitrous oxide fluxes from soils is nitrogen availability, it makes sense that the most effective mitigation strategy is to reduce nitrogen fertilizer additions to the lowest levels necessary to ensure optimal crop yields. Economic based approaches to fertilizer recommendations such as the maximum return to nitrogen rate (MRTN) typically allow farmers to do this and realize fertilizer savings.

- Apply nitrogen fertilizer at the economically optimum rate

Because both nitrous oxide emissions and nitrate leaching increase

exponentially when nitrogen fertilizer exceeds crop nitrogen demand, these nitrogen savings also can result in substantially lower losses of nitrous oxide and nitrate.

## Earning carbon credits for nitrous oxide reductions

Because even small amounts of nitrous oxide in the atmosphere can greatly affect the climate, there is great interest in reducing emissions of nitrous oxide from various economic sectors, especially field crop agriculture. By integrating their nitrogen management practices as described here, farmers can reduce nitrous oxide emissions from their fields without reducing crop yield and increase their economic return. This is the basis for programs offered through carbon credit organizations that use the marketplace to pay farmers for these reductions (http://www.deltanitrogen.org/).

Most straightforward and accessible programs use a simple set of instructions (or protocols) to help individuals and organizations develop and deploy GHG reduction projects in the field. These protocols estimate nitrous oxide emissions reductions on the basis of the reduction of nitrogen fertilizer rate. Such protocols (available at Verified Carbon Standard http://www.v-c-s.org/, American Carbon Registry http://americancarbonregistry.org/, and Climate Action Reserve http://www.climateactionreserve.org/) are based on data collected on commercial farms and allow farmers to convert their nitrous oxide emissions reductions to equivalent units of carbon dioxide. These can then be traded as carbon credits on environmental markets to generate income. Participation in these projects can provide economic and environmental benefits, including increased nitrogen use efficiency, reduced nitrogen fertilizer costs, and increased revenue from carbon credits. Although the value of carbon credits today is fairly low, together with fertilizer cost savings the total return can be significant.

An integrated nitrogen management strategy, in combination with programs that pay for the environmental benefits they deliver, will help to ensure the long-term sustainability of field crop agriculture, nitrogen use, and a stable future climate. ■

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