Agricultural Nutrients and Climate Change

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IN KYOTO, Japan, in 1997, many nations of the world agreed to reduce greenhouse gas (GHG) emissions. Developed countries committed themselves to reduce emissions to an average of 5 percent below 1990 levels by the period 2008 to 2012. Now, near the beginning of the 21st century, the Earth's warming trend has become even more evident: Several recent years were the warmest ever recorded. Public support for action to reduce emissions is likely to grow. What will agriculture need to change in the way of nutrient management?

Greenhouse gases are those atmospheric compounds that hold energy, influencing the temperatures we experience. The gas most effective in keeping the planet warm is water vapor, but a small change in the amount of water vapor has very little effect on global warming. The amounts of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in the air are increasing steadily. Small changes in the concentration of these gases can impact global warming. Emissions resulting from human activities are increasing by 0.3 to 0.9 percent per year. With current trends, these three gases account for more than 70 percent of the expected increase in global warming potential, the remainder coming from emissions of industrial halocarbons such as chlorofluorocarbons (CFCs). Each of these GHGs has a different global warming potential. The global warming potential considers the effectiveness of each gas in trapping heat radiation and its longevity in the atmosphere. A pound of CH_4 emission has the same warming potential as 21 pounds of CO_2, while a pound of N_2O has the equivalent of 310 pounds of CO_2.

Agriculture both absorbs and emits large amounts of CO_2. Crops absorb CO_2 from the air during photosynthesis and release it again when roots respire, when crop residues decompose, and when crop products are consumed. Absorption of CO_2 comes close to balancing emissions. Some evidence indicates that cropland is presently a net sink for carbon (C). That is, the soil is gaining C. Agricultural soils can sometimes absorb CH_4 and N_2O, but agriculture is considered responsible for about 30 percent of CH_4 emissions and about 70 percent of N_2O emissions in the U.S. The CH_4 emissions are primarily from animal production, while the N_2O emissions are mainly from soils. Together, CH_4 and N_2O emissions in agriculture are 7 to 10 percent of the total emission of greenhouse gases in the U.S. However, estimates of both absorption and emission of all three gases are fraught with large uncertainties.

There is concern that agricultural fertilizer use may be a major contributing factor to GHG emissions. Most fertilizer materials, such as phosphorus (P), potassium (K), sulfur (S), and micronutrients do not contribute directly to GHG emissions from the soil. All forms of nitrogen (N), however, can emit N_2O. These include commercial fertilizers, N fixed from the air by legumes, animal manures, crop residues, and native soil organic matter. Applying aglime releases CO_2, but the amounts are inconsequential compared with industrial uses of limestone.

While fertilizer N is a large source of N_2O, it is not the only source. Greenhouse gas inventory calculations currently assume that adding any N source to the soil releases 1.25 percent of the amount added as N_2O. The range of certainty for this coefficient is 0.25 to 2.25 percent. Globally, N fixation by legumes adds as much N to the soil as does commercial fertilizer; thus it may contribute as much to N_2O emissions. In addition, losses of N from the soil in the form of NH_3 emissions, N

oxides, and nitrate (NO_3) leaching are subject to further releases of N_2O. It is assumed that 2.5 percent of the N escaping is ultimately converted to N_2O in the form of emissions from streams and bodies of water. However, the research that forms the basis for these conclusions is currently in its infancy.

Fertilizer applications which increase crop yield can also have a major impact on the sequestration of atmospheric CO_2 as soil C. During the process of photosynthesis, plants absorb CO_2, utilizing the C for the development of leaves, stems, roots, and seeds. Increasing crop seed yield also increases crop residue production, which when returned to the soil builds soil organic C levels. In short, soil organic matter is built up by crop residue additions. Nitrogen also helps stabilize C in soil organic matter. For every 10 to 12 pounds of C, a pound of N is tied up in soil organic matter.

The process of N_2O emission from soils is strongly influenced by soil residual N and environmental conditions, making the losses difficult to predict. However, since all losses from the soil produce emissions without contributing to crop growth, best management practices (BMPs) aimed at increasing the efficient use of N will help reduce N_2O emissions. Examples of such practices include:

- Timing of N application as close as possible before crop uptake. In drier regions, some can be applied in the late fall, but only after soil temperatures have declined and soil microbial activity that facilitates N loss has decreased.
- Placing the N where it can easily be absorbed by the plant.
- Using site-specific application methods for N fertilizer based on soil tests and crop sensing. These methods are available in some areas and are being developed in others.
- Managing manure and crop residues to provide as many nutrients to the growing crop as possible. This reduces the total amount of N required for optimum crop yields and hence the potential for N_2O emissions.
- Growing cover crops during the off-season to minimize the amount of soil NO_3 available for conversion to N_2O, retaining the N for the next crop in rotation.

In addition to N, crops require 13 other mineral nutrients. A shortage of any one of these nutrients, but especially nutrients such as P or K, will limit the ability of the crop to take up available N and, in turn, limit both crop yield and its absorption of CO_2 from the air. Research conducted in Kansas and Ohio showed that corn grown in plots with optimal soil P and K levels improved the recovery of N and reduced the residual NO_3 left at the end of the season. Fields managed for organic crop production can accumulate excess NO_3 because of nutrient imbalance. Often there is an abundance of soil N from legume crops grown in the crop rotation. However, deficiencies in other nutrients may result in inefficient use of N and increase the potential for leaching and atmospheric N losses.

With the potential emissions associated with commercial fertilizer N use, the question is often asked "Would organic sources of N better minimize GHG emissions than fertilizer sources of N"? Because organic sources release available N slowly and at a rate determined by temperature and moisture, they may continue to release NO_3 after crop uptake has ceased. This excess NO_3 is a potential source of N_2O emissions. The excess is largest when relying solely on organic sources of N. Organic N sources can be used most safely in combination with mineral N fertilizer to ensure sufficient early availability to the crop.

Research activities focused on improving the efficiency of fertilizer N use may also help to reduce the GHG emissions associated with fertilizer use. There are two processes in the soil that generate N_2O. One is nitrification, the conversion of ammonium (NH_4) to NO_3, and the other is denitrification, the conversion of NO_3 to N_2O and N_2. While in theory both processes can be delayed by using slow release forms of N such as S-coated urea, the little evidence collected to date has not shown them to reduce N_2O emissions. In some cases they can increase emissions. Nitrate-containing fertilizers may produce higher rates of N_2O emissions than urea when soils become water-saturated soon after application. The effects of nitrification inhibitors and various N sources are being evaluated in continuing research.

Given that fertilizers are part of the problem in GHG emissions, it has been suggested by some that we should reduce or restrict fertilizer use. While N fertilizers can contribute to emissions from soils, they also play a critical role in growing profitable, high quality food products. It is estimated that 40 percent of the current crop production in North America can be attributed to fertilizer additions to correct nutrient deficiencies. With growing world populations and the concern that fragile lands not be used for crop production, it is critical that our prime agricultural land be managed to optimize production. Reducing fertilizer use before we act on the many existing technologies to improve fertilizer use efficiency would be a serious mistake, not to mention a penalty to the economic advantage that current top farm managers are achieving by implementing BMPs.

Agriculture is well positioned to help society address the many challenges that we face in our efforts to reduce GHG emissions. Each time we use fossil fuels we are contributing to the net increase in atmospheric CO_2 concentrations. The use of crops for biofuels such as ethanol reduces GHG emissions, since the C in biofuels originates from the CO_2 in the air. Fuels containing 10 percent ethanol can reduce net GHG emissions by up to 4 percent, while those containing 85 percent ethanol may reduce emissions by as much as 37 percent. Using crop materials for fiber products and straw board also sequesters C away from the atmosphere.

All sectors of the economy will have to respond to the issue of GHG emissions and global climate change. Agricultural producers must focus on three strategies:

1) **Managing crops and soils to sequester as much C in the soil as possible.** This includes choosing crops and varieties with maximum yield potential, returning all crop residues to the soil, keeping the soil covered with actively growing vegetation for as much of the season as possible, minimizing tillage, and fertilizing to obtain the maximum crop production that is economically feasible.

2) **Limiting N_2O emissions through improvements in the efficient use of N inputs by the crop.** The implementation of BMPs which match the N supply with crop requirements and more closely integrate animal manure and crop residue management with crop production will result in a net reduction in N_2O emissions. In addition, providing crops with the proper balance of macro and micronutrients will more fully utilize applied and residual soil N.

3) **Producing bio-fuels.** Since fossil fuel combustion is still by far the largest source of GHGs, production of alternative fuels such as ethanol will become an increasingly attractive alternative.

Climate change issues present serious challenges to crop producers, but also huge opportunities. Focusing on the above three strategies will allow agriculture to play its part in reducing impact of climate change. ■

This article is also available in “question/answer” format, with a list of references and links to other sites with more information. Go to www.ppi-ppic.org/climatechangeq&a.

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