FEATURE

Reducing Agriculture's Nitrogen Footprint: Are New Policy Approaches Needed?

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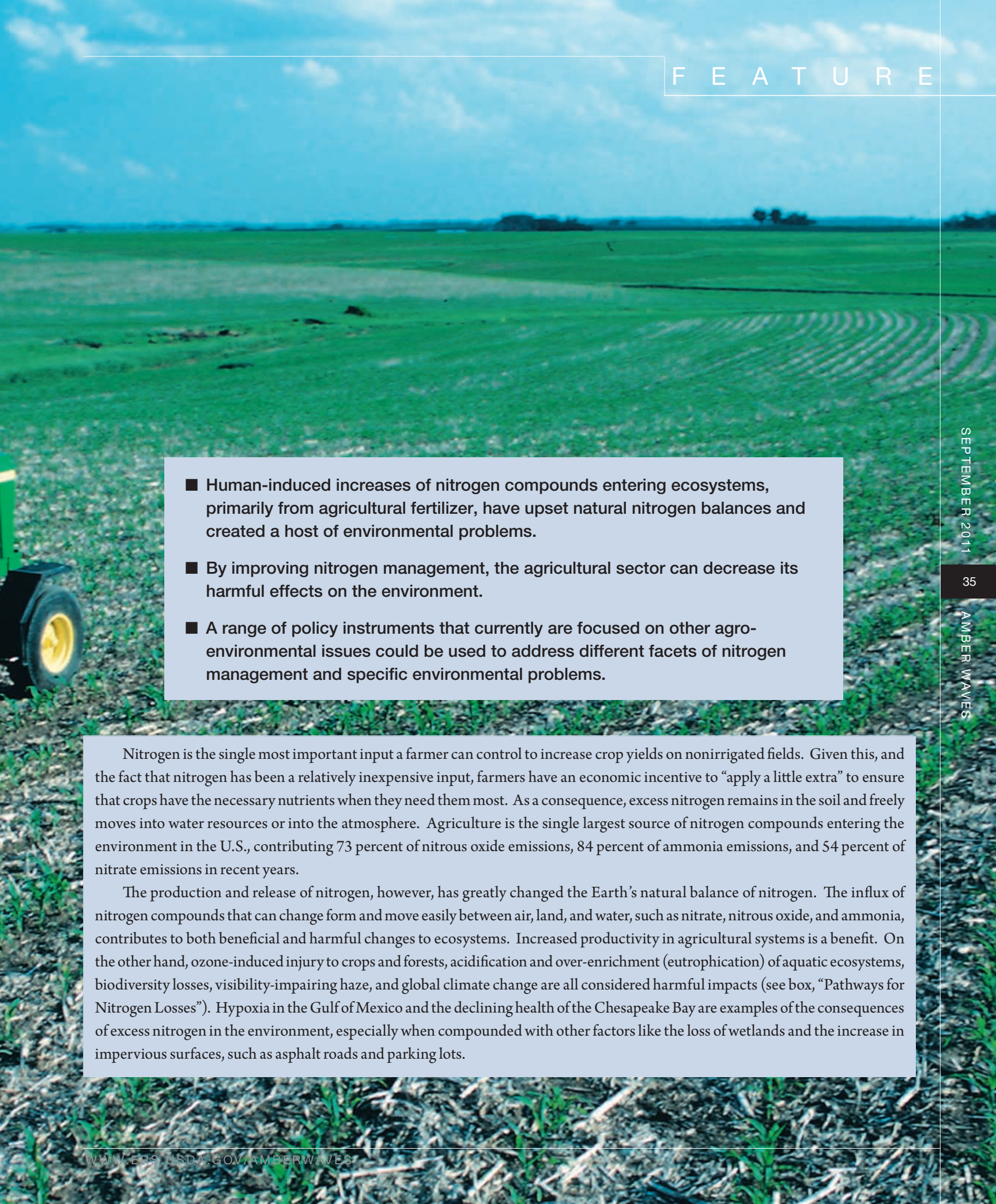
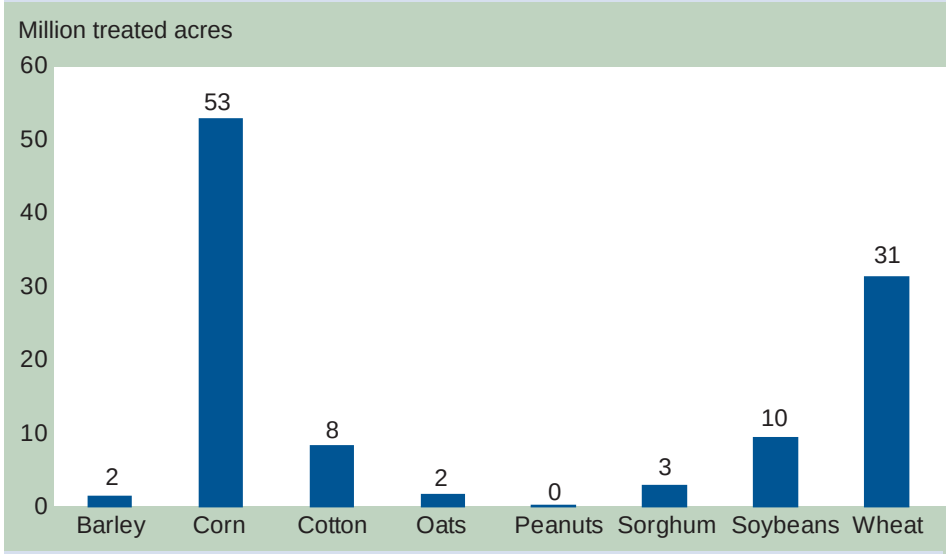


- Human-induced increases of nitrogen compounds entering ecosystems, primarily from agricultural fertilizer, have upset natural nitrogen balances and created a host of environmental problems.
- By improving nitrogen management, the agricultural sector can decrease its harmful effects on the environment.
- A range of policy instruments that currently are focused on other agro-environmental issues could be used to address different facets of nitrogen management and specific environmental problems.

Nitrogen is the single most important input a farmer can control to increase crop yields on nonirrigated fields. Given this, and the fact that nitrogen has been a relatively inexpensive input, farmers have an economic incentive to "apply a little extra" to ensure that crops have the necessary nutrients when they need them most. As a consequence, excess nitrogen remains in the soil and freely moves into water resources or into the atmosphere. Agriculture is the single largest source of nitrogen compounds entering the environment in the U.S., contributing 73 percent of nitrous oxide emissions, 84 percent of ammonia emissions, and 54 percent of nitrate emissions in recent years.

The production and release of nitrogen, however, has greatly changed the Earth's natural balance of nitrogen. The influx of nitrogen compounds that can change form and move easily between air, land, and water, such as nitrate, nitrous oxide, and ammonia, contributes to both beneficial and harmful changes to ecosystems. Increased productivity in agricultural systems is a benefit. On the other hand, ozone-induced injury to crops and forests, acidification and over-enrichment (eutrophication) of aquatic ecosystems, biodiversity losses, visibility-impairing haze, and global climate change are all considered harmful impacts (see box, "Pathways for Nitrogen Losses"). Hypoxia in the Gulf of Mexico and the declining health of the Chesapeake Bay are examples of the consequences of excess nitrogen in the environment, especially when compounded with other factors like the loss of wetlands and the increase in impervious surfaces, such as asphalt roads and parking lots.

In 2006, about 65 percent of treated U.S. crop acres did not meet nitrogen management criteria



Source: USDA, Economic Research Service using data from Phase II of USDA's Agricultural Resources Management Survey.

Nitrogen applied in excess of crop needs has the greatest risk of leaving the field and degrading air and water resources. Improved nitrogen management more closely matches nitrogen applications with the needs of growing crops, reduces the amount of excess nitrogen left on fields, and decreases nitrogen losses to the environment. Three criteria for "good nitrogen management practices" include:

- Rate—applying only the amount the crop needs;
- Timing—applying it in the spring when the crop needs it (and not before);
- Method—injecting or incorporating it into the soil (rather than leaving it on the soil surface).

All these actions, however, entail some cost or involve some degree of risk, so farmers may see little reason to alter their nitrogen management practices voluntarily.

How Are We Doing?

About 69 percent of U.S. cropland planted with major field crops (barley, corn, cotton, oats, peanuts, sorghum, soybeans, and wheat), or 167 million acres, receives commercial and/or manure nitrogen. Corn accounts for 45 percent of U.S. crop acreage receiving manure and 65 percent of the 8.7 million tons of nitrogen applied by farmers each year.

Using data from USDA's Agricultural Resources Management Survey (ARMS), ERS researchers determined the extent to which farms are meeting the three criteria for good nitrogen management. In 2006, about 68 percent of crop acres receiving nitrogen met the rate criterion; 60 percent met the timing criterion; and 63 percent met the method criterion. Only about 35 percent of crop acres receiving nitrogen, however, met all three of the nitrogen management criteria, leaving 65 percent in need of improved management.

Corn is the most widely planted field crop and requires the most nitrogen per acre. Thus, it is not surprising that treated corn acres—and the Corn Belt, regionally speaking—needed the most nitrogen management improvement. Demand for corn as a source of food and biofuels continues to increase, so widespread improved nitrogen management on corn fields could result in large environmental benefits.

Policy Tools That Influence Nitrogen Management Decisions

Improved nutrient management has been a longstanding goal of U.S. conservation programs. USDA provides financial and technical assistance so farmers can adopt a suite of practices to reduce nitrogen losses to the environment, including nutrient management planning and manure management. Nitrogen-related problems persist, however, as seen by the large amount of cropland not being farmed using good nitrogen management practices.

On the surface, it might seem that farmers would want to lower fertilizer costs by reducing excess applications and maximizing overall nitrogen use efficiency. There are barriers, however, for farmers adopting improved nutrient management systems. First, improved management requires a level of information and training that many farmers do not have. Acquiring the skills necessary to interpret soil and tissue tests and to apply fertilizers more carefully can be time consuming and costly.

Second, correctly timing applications increases the risk of not having enough nitrogen in the field when crops need it. For example, inclement weather may prevent nutrient application at a critical time during the growing season, resulting in reduced yields and lost revenue. Farmers may consider applying excess fertilizer before the crop needs it to ensure that it

is always available and to insure against yield loss.

Even though improving nitrogen management in agriculture may impose costs on farmers, the potential for improving environmental quality justifies policies designed to encourage farmers to adopt nitrogen best management practices. An efficient policy would encourage farmers who could improve nitrogen use efficiency at least cost to adopt appropriate management practices. The most efficient policies would target improvements that can be made at least cost, provide farmers flexibility in how they reduce emissions, and have low monitoring and transaction costs.

Current Levels of Financial Assistance Are Inadequate To Improve Nutrient Management

U.S. conservation policy has traditionally relied on financial and technical assistance through programs such as USDA's Environmental Quality Incentives Program (EQIP) to promote the adoption of best management practices. While such efforts are helpful, much more needs to be accomplished if U.S. cropland is to meet the three nitrogen management criteria of rate, timing, and method.

One of the drawbacks of a voluntary approach to nutrient management that relies on financial assistance is that there is no guarantee that those farmers who can reduce emissions at least cost will enroll in a program. A farmer's decision to enroll is most likely based on private benefits, rather than on offsite improvements in environmental quality. Unless improving nutrient management also increases net returns, farmers will have to be compensated annually to cover lost income.

About 108 million acres of U.S. cropland need improved nitrogen management. Assuming that farmers would adopt nutrient management practices for an annual payment of $8.88 per acre (the average EQIP payment rate made to farmers adopting nutrient management), the cost would be $959 million per year, out of a total EQIP budget of about $1.1 billion (2009-10). Since it could cost considerably more than this minimum payment to entice all farmers to adopt practices that increase nitrogen use efficiency, EQIP's current budget would be exhausted well before all acres were covered, even if all the other agro-environmental concerns addressed by EQIP are ignored. Targeting programs to areas with the most pressing nitrogen-related problems would reduce the cost but not increase the likelihood that farmers will enroll in the program.

Additional financial resources for improving nitrogen management could come from the private sector. In some situations, the beneficiaries of environmental quality improvements can pay farmers directly for those services. Developing markets for ecosystem services could encourage farmers to utilize best nitrogen management practices (see "Creating Markets for Environmental Stewardship: Potential Benefits and Problems" in the September 2008 issue of *Amber Waves*).

Water quality trading is one example of such a market. Water quality trading can occur when a discharge limit is placed on regulated sources (such as sewage treatment plants) and those subject to regulation are allowed to meet their limits by purchasing reductions, or offsets, from lower cost sources of the pollutant. Evidence suggests that farmers can reduce nitrogen emissions at lower cost than sewage treatment plants. A number of water quality trading programs have been developed that allow farmers to sell offsets to regulated sources, and more are planned. However, design issues and high transaction costs have so far limited the success of these markets. The extent to which water quality trading markets might become a reliable source of financial assistance for farmers to improve nitrogen use efficiency may be limited to specific regions and/or circumstances.

Compliance Provisions Are Different Type of Financial Incentive

Compliance provisions require farmers to meet some minimum standard of environmental protection on environmentally sensitive land as a condition for eligibility for many Federal farm pro-

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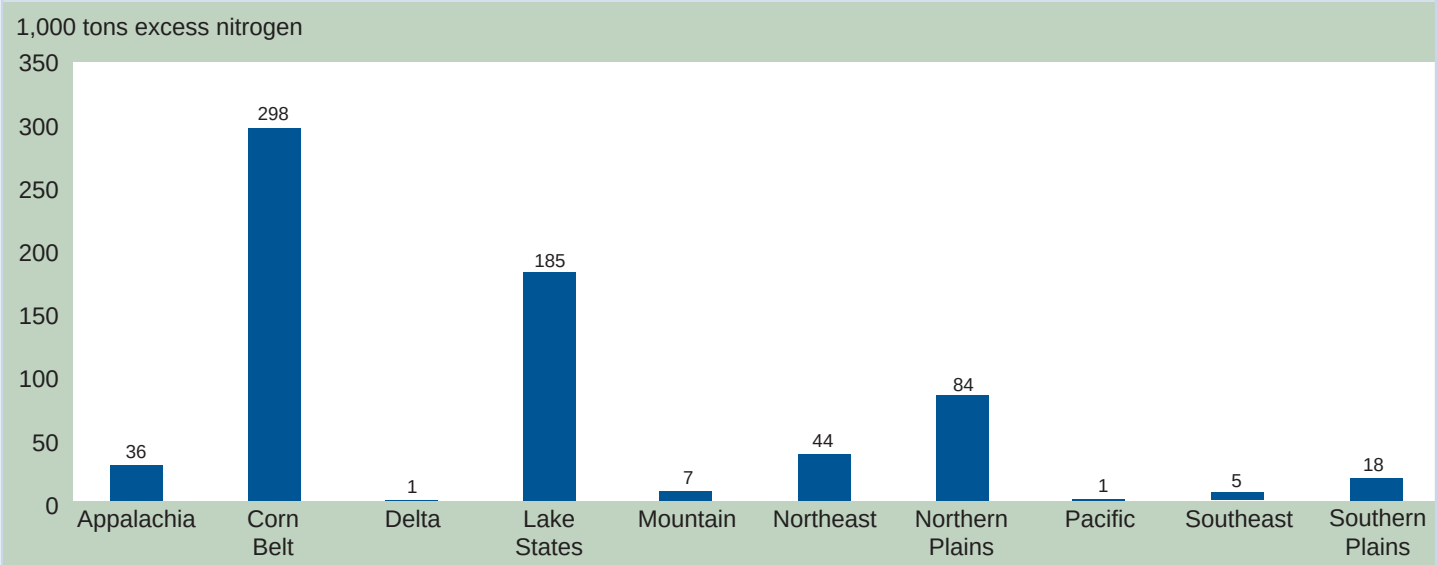
Corn Belt needed the most nitrogen management improvement in 2006



Source: USDA, Economic Research Service using data from Phase II of USDA's Agricultural Resources Management Survey.

gram benefits, including conservation and commodity program payments (see "Can Commodity Program Payments Encourage Better Nutrient Management?" in the June 2007 issue of *Amber Waves*). Farmers currently face compliance provisions that address tilling highly erodible land, converting highly erodible grasslands to crop production, and converting wetlands to cropland.

In assessing the potential efficacy of using compliance to promote nitrogen management, two key questions must be considered:

- To what extent do crop producers who have the greatest potential for reducing nitrogen emissions at least cost also participate in farm programs?
- Are Government payments to these producers large enough to encourage broad adoption of practices that improve nitrogen use efficiency and reduce nitrogen emissions?

Over 97 percent of U.S. corn acres received Government payments in 2005, averaging $51.39 per acre. This average is much higher than the average EQIP payment rate for farmers that adopt nutrient management best practices ($8.88 per acre). However, a drawback of compliance is that the strength of the incentive is dependent on the level of Government payments. Since 2005, direct Government commodity payments have declined by 50 percent because of higher crop prices. The compliance "hook" is therefore not as strong, since farmers are less likely to worry about meeting compliance provisions during periods of high prices.

Regulatory Restrictions on Nitrogen Use Provide More Alternatives

Regulations, such as mandatory best management practices, are generally seen as inefficient because farming is so diverse and many environmental regulations take a "one-size-fits-all" approach. On the other hand, regulations can be targeted to specific problem areas and provide a degree of certainty that environmental quality will improve. A number of States have resorted to regulation where particular environmental problems were not being addressed through other approaches. These regulations tend to require the development and implementation of a nutrient management plan. Nutrient management plans are inherently flexible in that they take into account a farm's resource base and cropping practices; they are not "one size fits all."

A nutrient management plan addresses the amount, source, placement, and timing of the application of plant nutrients and soil amendments. The only Federal agricultural environmental regulations involve managing manure on large confined animal feeding operations that generally have lots of manure and relatively little land to spread it on (see "Managing Manure: New Clean Water Act Regulations Create Imperative for Livestock Producers" in the February 2003 issue of *Amber Waves*). Clean

Water Act regulations require that those operations requiring a pollution discharge permit develop and implement a nutrient management plan that specifies nutrients be applied at a rate that more closely matches crop needs and lessens the risk of environmental losses.

Farms With Animals Pose Special Problems

Livestock and poultry farms have a steady supply of nutrients in the form of manure and waste. Ideally, farmers would spread manure back on their fields to fertilize feed crops, thereby completing the cycle of fertilizer-feed-waste-fertilizer. However, many animal operations purchase feed and produce more manure nutrients than their land can appropriately utilize.

Excess manure can be sold or given away to nearby farmers as a substitute for commercial fertilizer. However, manure is more costly to apply than commercial fertilizer, its nutrient content is uncertain (unless properly tested), and it may not provide all the necessary nutrients, so many crop producers do not want to apply it to their fields. This makes it difficult and costly for livestock owners to safely dispose of their manure waste, especially for the largest operations with the most manure.

While some of the largest animal operations are currently required to implement nutrient management plans that do not allow over-application of manure, only a small percentage of animal operations are regulated. Voluntary approaches are unlikely to be effective on the remaining operations unless substantial financial assistance is available for improved handling, storage, and hauling of manure.

Watch Out for Tradeoffs

An important consideration in any policy aimed at reducing nitrogen's impacts on the environment is the ability of nitrogen to change chemical form and circulate throughout the environment. Focusing on a single environmental problem can exacerbate another. For example:

- Switching from surface application to incorporation/injection to reduce ammonia emissions can increase nitrate leaching and the threat to groundwater.
- Switching from fall to spring application to reduce the threat of leaching can increase the emissions of nitrous oxide, a powerful greenhouse gas.

In both cases, *total* nitrogen emissions decrease through improved management, but losses of particular nitrogen compounds can increase. Such unintended tradeoffs are important to consider when designing a nitrogen management policy. Only reducing the amount of nitrogen applied assures a reduction of *all* nitrogen compounds.

Pathways for Nitrogen Losses

Soil erosion. Nitrogen can be lost from the soil surface when attached to soil particles that are carried off the field by wind or water. Although erosion can be observed across all regions, wind erosion is more prevalent in dry regions and water erosion is more prevalent in humid regions. Overall, little nitrogen is lost through erosion when basic conservation practices are in place.

Runoff. Surface runoff can remove nitrogen in a dissolved form (generally nitrate). Runoff is only a concern when fertilizer is applied on the surface and is carried away in rainwater before it enters the soil.

Ammonia volatilization. Significant amounts of nitrogen can be lost to the atmosphere as ammonia if animal manure or urea is not injected or immediately incorporated into the soil. Additionally, warm temperatures can accelerate the conversion of manure and other susceptible inorganic nitrogen fertilizers to ammonia gas.

Denitrification. When oxygen levels in the soil are low, microorganisms called denitrifiers convert nitrate to nitrogen gas and nitrous oxide gas. Nitrogen gas is not an environmental issue, but nitrous oxide is a powerful greenhouse gas.

Leaching. Leaching occurs when there is sufficient rain and/or irrigation to move easily dissolvable nitrate through the soil profile. The nitrate eventually ends up in underground aquifers or in surface water via tile drains and groundwater flow.

This article is drawn from . . .

ERS Briefing Room on Environmental Interactions with Agricultural Production, available at: www.ers.usda.gov/briefing/agandenvironment/

Nutrient Management chapter of the ERS Briefing Room on Agricultural Chemicals and Production Technology, available at: www.ers.usda.gov/briefing/agchemicals/nutrientmangement.htm