Potential for Extending Compliance: Nutrient Management in Crop Production

At present, compliance mechanisms are used only to encourage soil and wetland conservation, although agricultural production can result in a wider range of environmental damages (Claassen et al., 2001). In this section, we look at the potential for extending compliance to a third agri-environmental issue: reducing nutrient runoff and leaching from land in crop production.

Runoff and leaching from fertilizer application and animal manure are major sources of remaining U.S. water quality problems (USEPA and USDA, 1998). Nitrogen leaching into groundwater used for drinking can be a health hazard to infants and may pose a cancer risk for adults. Excess nutrients in surface water can lead to eutrophication, reducing the quality of water for recreation and habitat. Eutrophication results from excess algae growth which leads to high concentrations of bacteria (to break down dead algae), which, in turn, leads to accumulation of bacterial waste and oxygen depletion. Water becomes murky and develops an odor. In severe cases, aquatic plants and fish are damaged by the lack of sunlight and oxygen.

Nitrate nitrogen is highly soluble and is transported in both ground and surface water. In surface waters, nitrogen can be transported long distances, polluting estuaries throughout the Nation (Bricker et al., 1999). Nitrogen flowing into the Gulf of Mexico, largely from the Mississippi River, is the suspected cause of a large zone of oxygen-depleted (hypoxic) waters (Goolsby, 1999), creating a "dead zone" largely devoid of marine life. Phosphorus is far less soluble and is most often transported to water along with sediment (USGS, 1999). Excess phosphorus runoff from agriculture may have contributed to outbreaks of waterborne pathogens, including *pfiesteria piscicida* (Mlot, 1997).

To determine the potential of a compliance mechanism to mitigate runoff and leaching of agricultural nutrients, we consider three key questions:

- To what extent is nutrient application—either commercial fertilizer or manure—to land in crop production a source of nutrient runoff or leaching?
- To what extent do crop producers who have the greatest potential for reducing nutrient runoff and leaching also participate in farm programs?
- Are government payments large enough to encourage broad adoption of practices that could reduce nutrient runoff and leaching?

Nutrient Loss and Crop Producers

While a comprehensive solution to agricultural nutrient runoff and leaching must involve crop and livestock producers, compliance incentives are largest for farms with a significant area of land in program crop production. Crop producers—regardless of whether they are also livestock producers—will play a central role in managing nutrients and reducing nutrient runoff from agriculture. Available evidence suggests that the application of commercial fertilizer has, in the past, accounted for a significant share of agricultural nutrient runoff and leaching. Thus, crop producers can play a significant role in reducing nutrient runoff and leaching, independent of livestock producers. Moreover, as livestock production becomes increasingly concentrated on large, specialized farms, an increasing proportion of livestock is raised on farms with too little land to spread nutrients at agronomically sound rates (Kellogg et al., 2000), indicating that management of livestock waste will necessarily involve crop producers who do not raise livestock (Ribaudo et al., 2003).

In the past, commercial fertilizer has accounted for roughly 90 percent of nitrogen applied in agricultural production. Just over 12 million tons of nitrogen fertilizer was applied in 1997 (Daberkow et al., 2000). Only 1.2 million tons of nitrogen is recoverable from manure nutrients produced on U.S. farms with confined livestock (Gollehon et al., 2001), although not all of these manure nutrients are actually used in crop production.[12] Evidence also suggests that fertilizers are routinely applied in amounts that exceed crop needs. Roughly 70 percent of corn acres and 60 percent of winter wheat and cotton acres had high[13] excess nitrogen balances in 1995, while high excess phosphorus balances were estimated to exist on roughly 40 percent of corn, cotton, and wheat acres (Daberkow et al., 2000). Nutrients applied in excess of or well in advance of crop needs are particularly vulnerable to runoff and leaching.

U.S. Geological Survey (USGS) estimates also indicate that, in the past, commercial fertilizer has accounted for a significant share of nitrogen runoff to surface water. Fertilizer application accounts, on average, for more than 48 percent of all nitrogen loads to surface water in areas where nitrogen runoff per unit of land area is high (greater than 1,000 kg/km^2 annually) and more than 20 percent, on average, where runoff is low (less than 500 kg/km^2 annually) (Smith et al., 1997). Livestock waste production is estimated to account for 15 and 12 percent of nitrogen reaching surface water in high- and low-runoff areas, respectively. Where nitrogen loads are low, runoff from nonagricultural land is a relatively important source of nitrogen loading (Smith et al., 1997).

Phosphorus runoff to surface water is much more likely to be the result of livestock waste or nonagricultural, nonpoint sources. In areas where USGS researchers estimate that phosphorus surface-water concentrations exceed the Environmental Protection Agency (EPA) suggested water quality goal of 0.1 mg/L, fertilizer is estimated to account, on average, for 21 percent of phosphorus loading while livestock waste and nonagricultural land are estimated to account for 38 and 33 percent, respectively (Smith et al., 1997). As noted above, however, many cropland acres carry excess phosphorus balances. Thus, non-waste phosphorus management on cropland may still be important to reducing phosphorus damage to surface water, particularly in areas where livestock production is less prevalent and commercial phosphorus fertilizer is applied.

Nutrient Runoff and Farm Program Participation

While nutrient application in crop production contributes significantly to the runoff and leaching of nutrients to water, the potential for nutrient loss may vary across producers. If so, to what extent do producers who have significant potential for nutrient loss also participate in farm programs? To gauge

[12]While almost all manure is eventually disposed of through landspreading, it is not clear that all recoverable manure nutrients are applied to agricultural land as fertilizer. Increasing concentration in livestock production has resulted in concentrations of animal waste that often exceed the nutrient needs of crops grown on the farm. Manure may be stockpiled for extended periods, in which case much of the recoverable nutrient is lost to the environment. In some cases, transportation costs preclude full utilization of livestock manure as fertilizer (Gollehon et al., 2001; Ribaudo et al., 2003).

[13]A “high” excess nutrient balance is defined as available nutrients exceeding crop nutrient use by 25 percent or more.

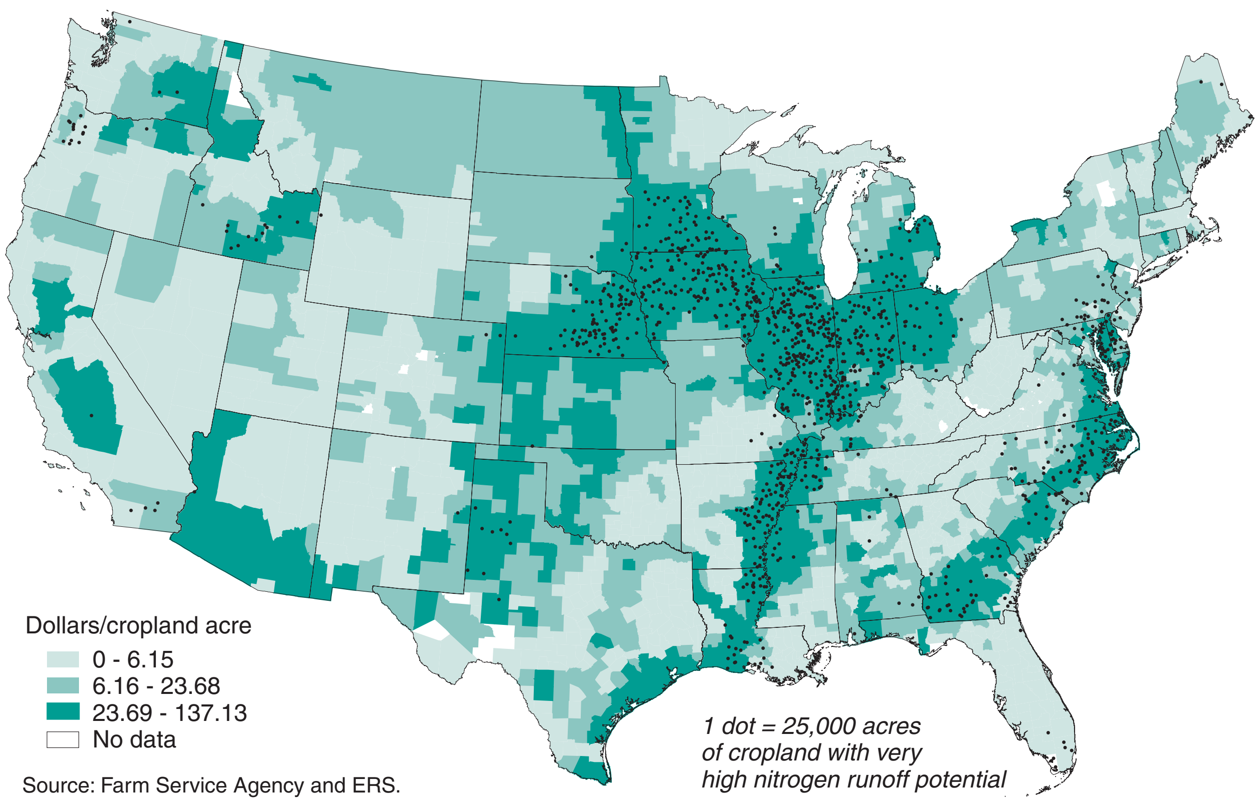
runoff potential, we use indices for potential nitrogen runoff, phosphorus runoff, and nitrogen leaching to groundwater developed by Lemunyon and Gilbert (1993), Sharpley et al., (1994) and Gburek et al. (2000). The indices are calculated for each NRI data point using NRI and other data and account for soil factors, climate, and production management decisions that affect runoff and leaching (see Appendix 2).

Using these indices, we divided cropland acres into five equal (by land area) categories by overall potential for nitrogen runoff, phosphorus runoff, and nitrogen leaching (we label these very low, low, medium, high, very high). We overlaid data on the 20 percent of cropland acres with very high potential for nitrogen and phosphorus runoff or nitrogen leaching with data on government payments (figs. 13, 14, and 15). Results suggest that acres with the highest potential for nutrient runoff and leaching are located mostly in areas with relatively high government payments. Unlike highly erodible cropland acres, which often occur in more (economically) marginal agricultural areas, nutrient runoff and leaching appear to be most problematic where crop production is the principal agricultural land use and soils are highly productive.

Using methods detailed in Appendix 1, we estimate that 75 percent or more of cropland acres with medium, high, or very high potential for phosphorus runoff, nitrogen leaching, or nitrogen runoff are located on farms that receive government payments (fig. 16). The average annual payment

Figure 13

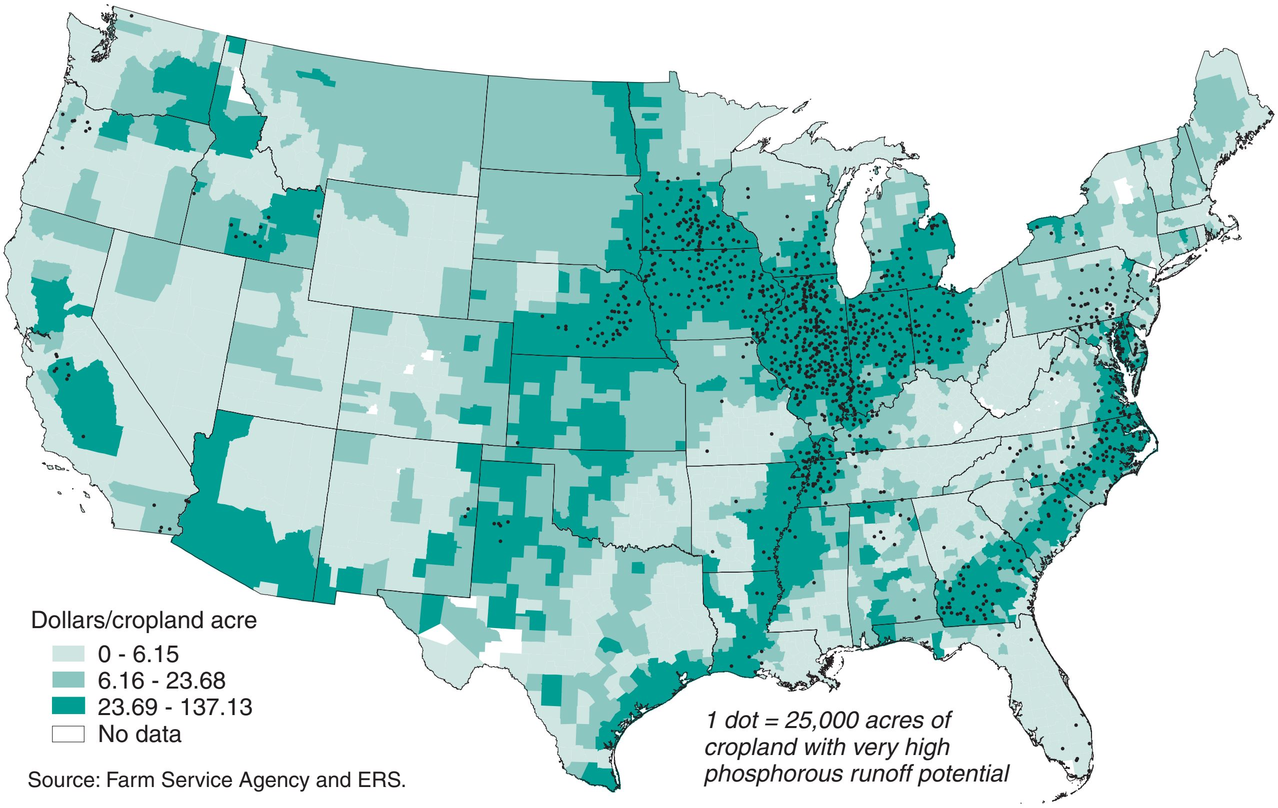
Distribution of commodity program payments and very high nitrogen runoff potential, 1998



Source: Farm Service Agency and ERS.

Figure 14

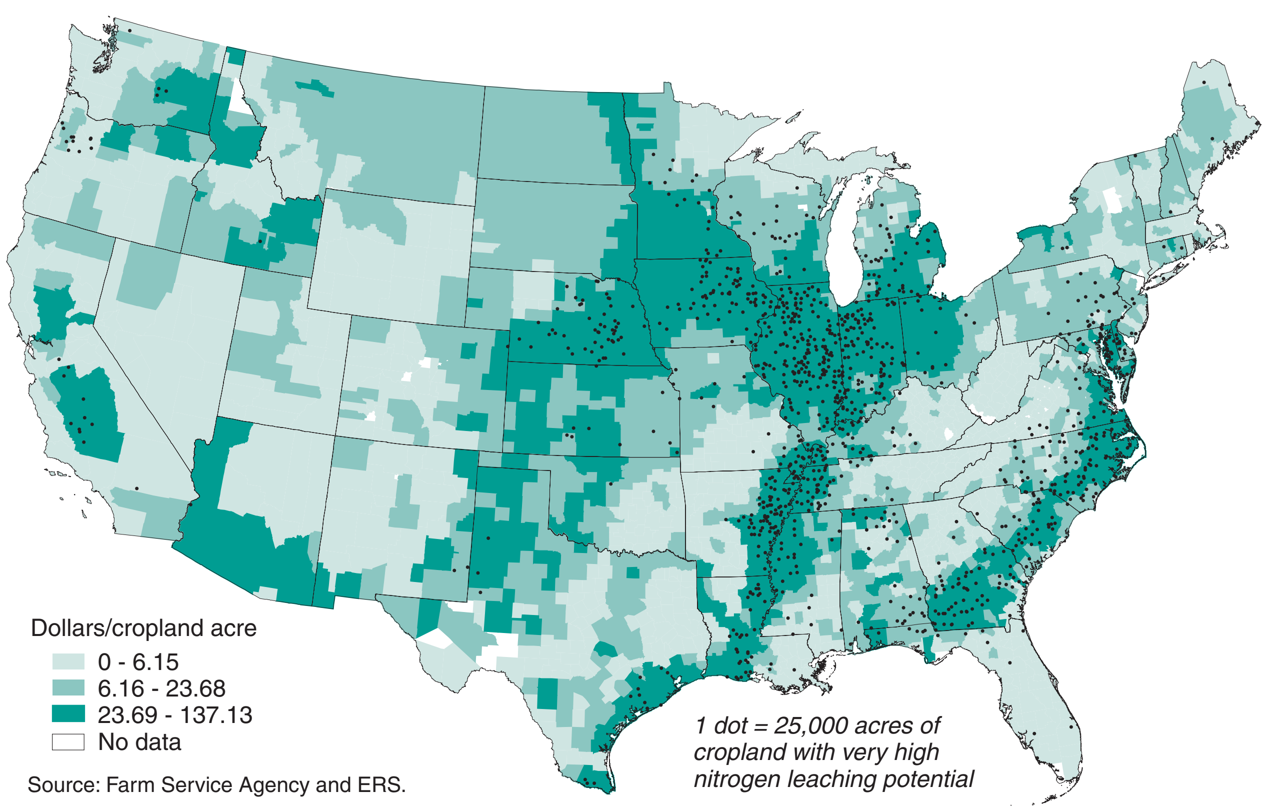
Distribution of commodity program payments and very high phosphorus runoff potential, 1998



Source: Farm Service Agency and ERS.

Figure 15

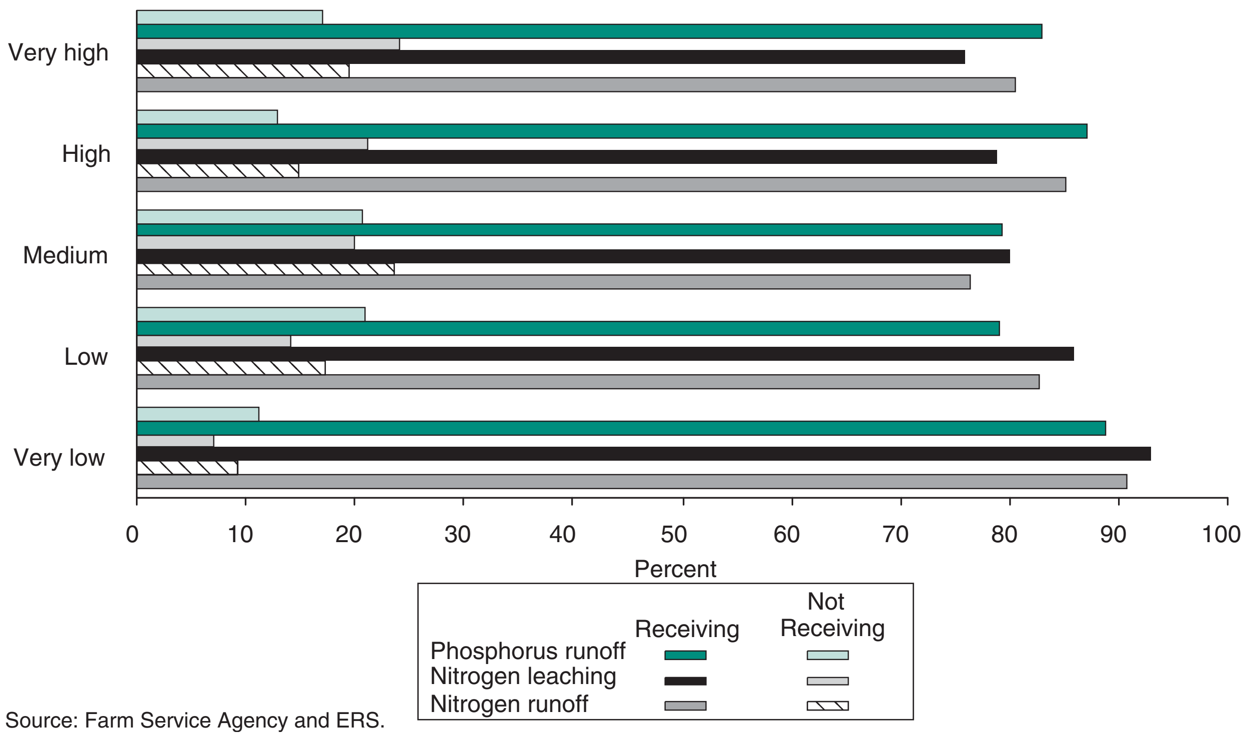
Distribution of commodity program payments and very high nitrogen leaching potential, 1998



Source: Farm Service Agency and ERS.

Figure 16

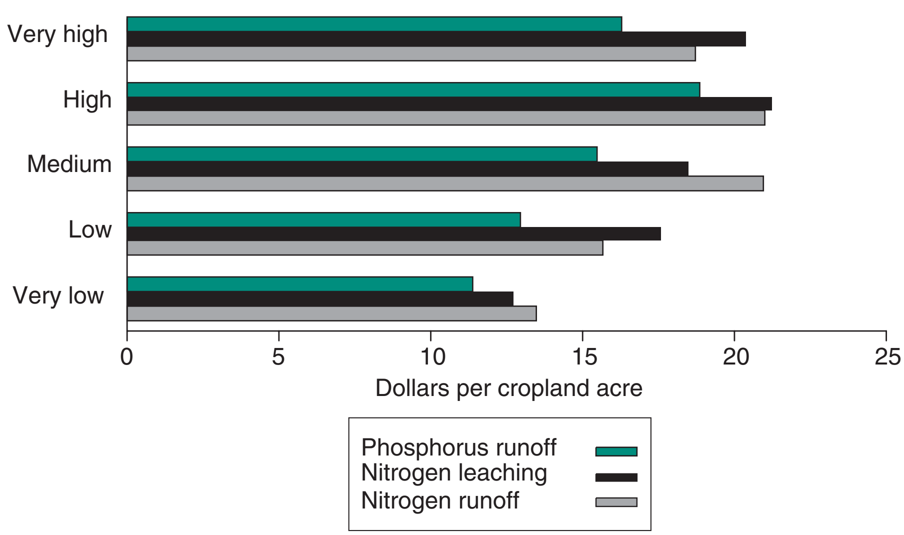
Percent of cropland acres on farms receiving and not receiving payments, by potential nutrient loss to water, 1997



Source: Farm Service Agency and ERS.

Figure 17

Average farm program payment per acre of cropland, by potential nutrient loss to water, 1997



Source: Farm Service Agency and ERS.

exceeds $15 per cropland acre on farms with medium to very high nutrient loss potential for all three nutrient loss indicators, exceeding $20 per acre in several cases (fig. 17). Thus, farms with the highest nutrient loss potential tend to participate heavily in farm programs and receive larger-than-average per-acre payments. Note, again, that the payment data used in this study are from 1997, a year of low payments relative to spending in more recent years and projected spending under the 2002 Farm Security and Rural Investment (FSRI) Act. Whether these payments are large enough to leverage actions that would produce significant reductions in nutrient runoff and leaching depends on the techniques available to reduce nutrient runoff and the cost of implementing them.

Reducing Nutrient Runoff: Nutrient Management and Buffer Practices

Our results to this point suggest that (1) nutrient application by crop producers is a large source of agricultural nutrient runoff and leaching, and (2) producers with medium to very high potential for nutrient loss also participate heavily in farm programs. Next, we consider practices for reducing nutrient runoff and leaching. Are these practices effective and enforceable? Are government payments large enough to encourage widespread adoption if program eligibility was contingent on the application of these practices?

One way to reduce nutrient loss from cropland is to encourage crop producers to manage nutrients more carefully. The objective of nutrient management is to match nutrient application rates, timing, and placement to plant needs (accounting for nutrients already available in the soil), thereby minimizing the level of "excess" nutrient (nutrient in excess of crop uptake) in the soil at any given time. Excess nutrients are most vulnerable to loss. Nutrient management is actually a collection of practices designed to help farmers match nutrient applications to nutrient needs (e.g., soil testing, split fertilizer application, legume crediting, reasonable yield goals, etc.).

Because it is a collection of practices that can be combined in many ways, nutrient management is flexible and can be tailored to each farm's unique circumstances, making it a potentially cost-effective way to reduce excess nutrients in the soil. However, because nutrient application rates, methods, and timing are very difficult to observe, enforcement could be difficult and expensive (Malik, 1993; Amacher and Malik, 1996, 1998; Johansson, 2002). Nor is it guaranteed that nutrient management will reduce runoff and leaching to levels consistent with significantly improved water quality. If heavy rains fall just after fertilizer application, significant runoff and leaching can still occur, even if application is timed to better coincide with plant needs.

A second way to address nutrient runoff is through the use of buffer practices, such as filter strips, grassed waterways, or restored wetlands to intercept nutrients before they leave the field or farm. Buffer practices can remove a substantial proportion of the sediment and nutrients from field runoff. A recent survey article (Dosskey, 2001) shows that, on average, filter strips remove 50-90 percent of nitrogen and phosphorus from runoff. Unlike nutrient management, buffer practices are easily enforceable because their existence and effectiveness are readily observed. Buffers can be more expensive to implement because some cropland is taken out of production, and will be ineffective where nitrogen leaches to ground water or reaches water bodies through subsurface flow.

Cost of Nutrient Management[14]

If nutrient management became a condition of eligibility for farm programs, use of nutrient management would increase only if nutrient management costs were lower than the net benefits of farm program participation (prior to the addition of the nutrient management requirement), and if the requirements were effectively enforced. As with soil conservation practices, the cost of nutrient management is likely to vary significantly among producers, and may depend on cropping patterns, soils, climate, management skill, and producers' risk preferences. Nutrient management plans typically include a variety of practices or management decisions that affect the overall amount of nutrient applied, the timing of fertilizer applications, and the method of application. For some producers, nutrient management could lower fertilizer bills. For others, lower fertilizer bills might be more than offset by the cost of soil and plant tissue testing, increased cost of fertilizer application, or increased risk of delayed application that can decrease crop yields.

Determining the appropriate level of nutrient application involves testing the soil to determine available nutrients, and, in cases where nutrients are applied to a growing crop (side dressing), other tests (such as plant tissue testing) to determine plant needs. Sample collection and testing can be time-consuming and costly. Even with soil and plant tissue tests, uncertainty about the relationship between nutrient application and crop yields can expose producers to the risk of low yields as they attempt to match nutrient application to plant needs. Research shows that assumptions about the relationship between nutrient uptake and crop yields can significantly affect calculation of an optimal fertilizer application rate (Grimm et al., 1987; Larsen et al., 1996), possibly leading to overfertilization or lower-than-expected crop yields. Year-to-year variation in growing conditions may also encourage overapplication of nutrients. Because crop nutrient needs are higher in years with good growing conditions, it may be profitable to use more fertilizer in anticipation of getting peak yields in particularly good years (Babcock, 1992; Dai et al., 1993).

Timing fertilizer applications to coincide with plant nutrient demand can also expose producers to higher cost and risk. Fertilizer prices tend to be lower in the fall, well in advance of planting (Huang et al., 1994), possibly making fall or early spring application less costly, even if more fertilizer is needed to make up for the runoff and leaching losses. Higher application costs are incurred in the use of "split" application, where fertilizer is applied at planting and during the growing season when plant needs are high. Moreover, delaying fertilizer application exposes producers to the risk of weather-related delays when plant needs are high. Some producers may rely on early application to reduce this risk (Huang et al., 1994; Feinerman et al., 1990). Better fertilizer placement can also reduce fertilizer use, but may increase application costs. For example, planter-mounted application attachments allow fertilizer to be placed directly in the root zone, increasing plant uptake. Fertilizer savings, however, must be considered against the cost of additional equipment.

Again, we use the EQIP database to provide a sense of the range of potential costs for nutrient management. Bear in mind that EQIP data represent

[14]The authors greatfully acknowledge the contribution of Glen Sheriff to the development of this section.

Table 7—Average and 95th percentile EQIP incentive payments for nutrient management

ERS Farm Resource Region	Average annual	95th percentile	3-year NPV of average annual	3-year NPV of 95th percentile	Number of contracts
	-------------------------Dollars per acre-------------------------				
Heartland	7.07	12.00	19.61	33.29	9,819
Northern Crescent	5.96	11.99	16.55	33.28	7,728
Northern Great Plains	7.30	13.67	20.26	37.93	847
Prairie Gateway	6.60	17.25	18.32	47.87	6,460
Eastern Uplands	8.51	10.29	23.63	28.55	2,546
Southern Seaboard	8.45	10.00	23.44	27.75	14,787
Fruitful Rim	9.66	20.00	26.80	55.50	2,922
Basin and Range	7.13	25.00	19.79	69.38	950
Mississippi Portal	4.62	5.06	12.82	14.03	3,361
U.S.	7.31	15.00	20.29	41.63	49,420

Source: ERS analysis of EQIP data.

the level of payments some producers were willing to accept (WTA) for undertaking nutrient management—not necessarily the actual out-of-pocket cost of the practices. For some practices, producer WTA may be higher than out-of-pocket costs. For example, the cost of soil sample testing may be small compared with the opportunity cost of the time required to collect soil samples. On the other hand, fertilizer cost savings could offset some portion of these costs.

Nationally, EQIP participants adopting nutrient management in crop production received an average of $7.30 per acre, while 95 percent of these producers received $15 or less. Given a 3-year payment period and a 4-percent rate of discount, the net present value (NPV) of the average payment is $19.20 with 95 percent of producers receiving $39.45 or less. By region, the NPV of average incentive payments ranges from $12.82 in the Mississippi Portal, where 95 percent of participants received $14.03 or less, up to an average of $26.80 in the Fruitful Rim, where 95 percent of participants received $55.50 or less (table 7). A $20-per-acre annual commodity program payment would translate into $95 over 6 years and $212 over 20 years—substantially more than EQIP participants in any region of the country are willing to accept for undertaking nutrient management.

Cost of Buffer Practices

The term "buffer practices" refers to a range of practices that are designed to intercept sediment and nutrients at the edge of the field or farm. For example, practices eligible for continuous signup in the Conservation Reserve Program (CRP) that are particularly relevant for nutrient runoff include riparian buffers, filter strips, grassed waterways, and contour grass strips. The cost of buffer practices may include the establishment of vegetative cover, land shaping, and the retirement of productive cropland, although only a small amount of land is required. In the case of filter strips, for example, only 1-3 percent of the area drained through a filter strip is needed in the filter.[15]

One source of information on producers' willingness to accept payment for installing buffer practices is the CRP continuous signup for high-priority practices. High-priority practices include filter strips, grassed waterways,

[15]For filter strips, minimum area depends on two factors. First, the ratio of drainage area to filter strip size depends on the RUSLE (Revised Universal Soil Loss Equation) R-factor. For R-factors of 0-35, a field-to-filter strip area ratio of 70:1 is appropriate, 60:1 is required for R-factors of 35-175, and 50:1 is needed for R-factors greater than 175. Second, filter strips must have a minimum flow length (width) of 30 feet. Depending on the size and shape of the field, this requirement may result in a larger field-to-filter strip area ratio than otherwise required. For more information, see USDA-NRCS, 2002c.

contour grass strips, and other buffer practices. Nationally, continuous signup acres receive an average payment of $92 per acre per year, more than double the average payment for land in general CRP signup ($43 per acre per year) (Barbarika, 2001). Up to 50 percent cost sharing is also provided for practice installation. Cost-share amounts for some common buffer practices include $59 per acre for contour grass strips, $69 for grass filter strips, and $209 for riparian buffers. Because buffer practices generally involve only a small proportion of cropland acres, the overall cost per cropland acre is modest.

As an example, consider installation of a grass filter strip. Assume that $92 per acre represents foregone annual returns, per acre establishment costs are twice the average cost share listed above (50 percent of cost is shared in CRP), and 2.5 percent of cropland is needed. Capitalizing forgone revenue at 4 percent, a grass filter strip would cost roughly $2.50 per cropland acre per year. This is well below the average program payment of $15-20 per acre (or more in recent years) on farms with the most serious nutrient loss potential.

Wetland restoration could also be used to intercept nitrogen runoff before it contaminates surface water. Ribaudo et al. (2001) compare nitrogen use reduction to wetland restoration strategies for reducing nitrogen flows from the Mississippi Basin to the Gulf of Mexico. For nitrogen runoff reductions of up to 26 percent, they found that reducing nitrogen use was the less expensive strategy, while wetland restoration would be more cost-effective in achieving larger runoff reductions. Wetland restoration can be more expensive than other buffer practices ($50-$800 per wetland acre in the Ribaudo study), in addition to the opportunity cost of ending crop production, and will not be appropriate for all locations. Nonetheless, wetland restoration could play a role in reducing nitrogen runoff to water.

Assuming payments will continue indefinitely, compliance could provide sufficient leverage for widespread adoption of either nutrient management to reduce the potential for nutrient loss or conservation buffers to intercept nutrient runoff. While this new compliance requirement could be leveraged with existing program payments, some producers who would be subject to the new requirement are already bearing the cost of existing compliance requirements. Figure 18 shows the potential for overlap between existing compliance requirements and a potential nutrient-related requirement. Map colors indicate land subject to existing compliance requirements—noncropped wetland and highly erodible land (HEL) near existing cropland and HEL cropland—as a proportion of total cropland. The darker the color, the larger the potential impact of existing compliance mechanisms. The dots represent land with high or very high potential for nutrient runoff and leaching—those acres most likely to be affected by a nutrient requirement.

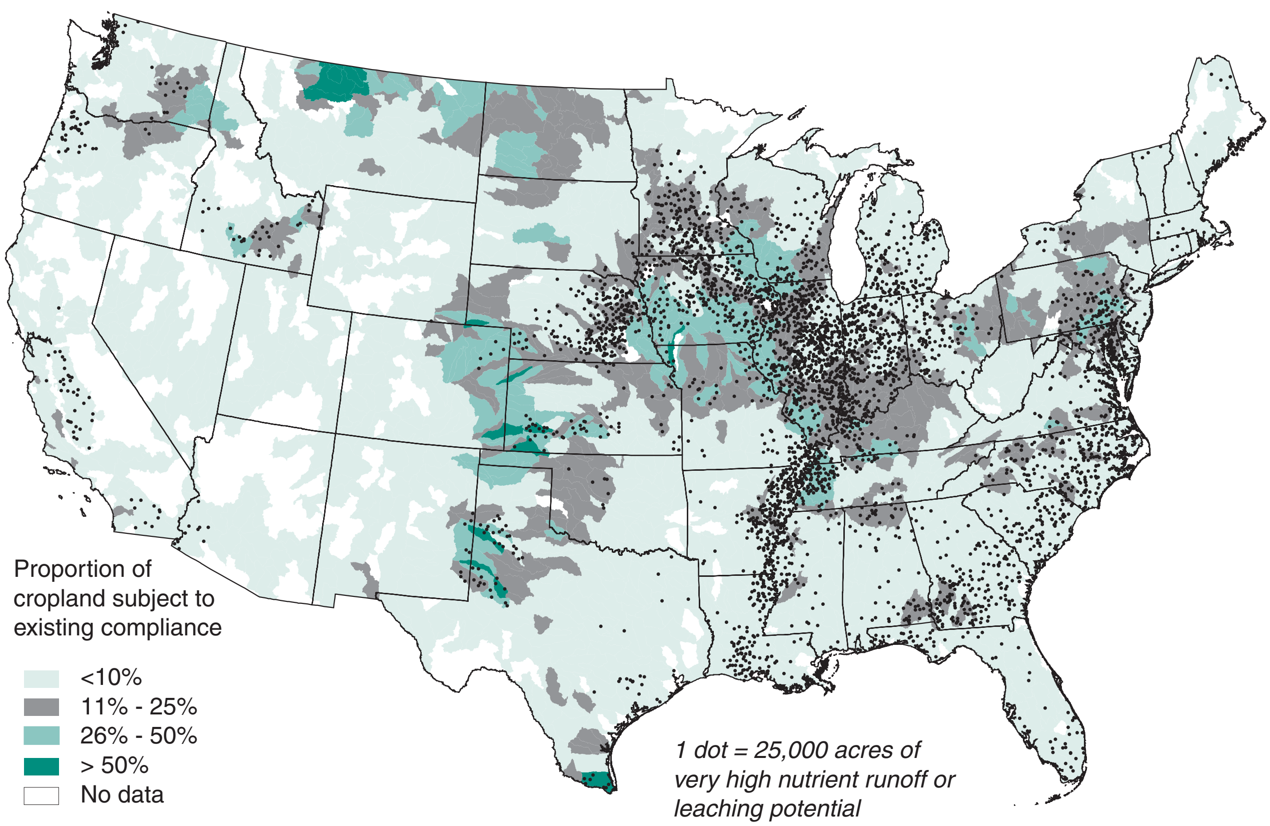
The greatest potential for overlap between the potential nutrient requirement and existing compliance requirements appears to be in the Heartland and the Mississippi Portal, particularly northern portions in Arkansas and Tennessee. Significant overlap may also occur in Eastern Pennsylvania and Maryland.

In the Corn Belt and Mississippi River Delta, crop production is a predominant agricultural enterprise and related farm program payments are relatively large. In 1997, farm program payments in most counties in these areas averaged more than $23 per acre (represented by the darkest shaded areas in fig. 1). Over the 6-year life of the farm bill, the net present value of a $23 stream of annual payments would be $109.63 per acre. Keep in mind that commodity program payments were relatively low in 1997 and that farm commodity programs are likely to continue past the end of the current farm bill.

Meanwhile, regional average costs for soil conservation and nutrient management practices are at or near national averages (see tables 5, 6, and 7). In areas where the overlap is most likely, moreover, nutrient management costs may be lower than the cost of addressing soil erosion. Because the cost of erosion reduction is modest, the combined cost of erosion reduction and nutrient management is unlikely to exceed (or even come close to) the value of farm program payments. In the Mississippi Portal region, the total cost for making a transition to the use of soil conservation practices is larger for each of the most commonly used practices. Producer willingness to accept (WTA) payments for conservation cropping, conservation tillage, and seasonal residue management are $14.86, $28.54, and $12.87 per acre, respectively, while WTA for nutrient management averaged $12.80 (see tables 5, 6, and 7). In the Heartland region, WTA for conservation cropping, conservation tillage, and seasonal residue management is $17.86, $25.26, and $18.60 per acre, respectively, while WTA for nutrient management averages

Figure 18

Potential for overlap between existing compliance requirements and nutrient requirement



Source: ERS and NRI data.

$19.60. Nonetheless, a new nutrient-related compliance requirement could cause financial stress for some producers. Specific cases of hardship could be addressed through variances (as under existing policy).

In Pennsylvania and Maryland, crop production is significant but nutrient problems are more likely to be driven by livestock waste. In most counties in these areas, nitrogen and phosphorus in livestock waste already exceed the assimilative capacity of cropland and pasture land (Kellogg et al., 2000). Farm program payments are not as uniformly high as they are in the Heartland and the Mississippi Portal, so the compliance requirement may be less effective overall. However, recently promulgated Clean Water Act regulations require comprehensive nutrient management on large livestock operations. Also, changes in EQIP eligibility requirements and funding levels will assist livestock producers in reducing environmental damage from excess nutrients. In this context, the compliance requirement may be a useful part of the overall mix of policies designed to reduce nutrient loss to the environment.