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Monitoring and modeling cropping system nitrogen for a sustainable agriculture

Delmar Vander Zee
Dordt College

Ronald J. Vos
Dordt College

Christian L. Goedhart
Dordt College

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Monitoring and modeling cropping system nitrogen for a sustainable agriculture

Abstract
Modern agriculture has become heavily dependent on fossil-fuel-based commercial nitrogen (N) for maintaining soil fertility and high crop yields. In the past, farmers have not had the means to monitor soils routinely for N concentrations, nor have they been able to match yield goals to those concentrations. In addition, the nutrient value of manure applied to fields often is not taken into account before commercial N fertilizer is applied. As a result, N has been over-applied on many midwestern farms, prompting concerns about the cost of commercial inputs into farming and the amount of nitrate in groundwater.

Keywords
Nutrient management

Disciplines
Agricultural Science | Agriculture | Agronomy and Crop Sciences | Soil Science | Sustainability

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Goals

Modern agriculture has become heavily dependent on fossil-fuel-based commercial nitrogen (N) for maintaining soil fertility and high crop yields. In the past, farmers have not had the means to monitor soils routinely for N concentrations, nor have they been able to match yield goals to those concentrations. In addition, the nutrient value of manure applied to fields often is not taken into account before commercial N fertilizer is applied. As a result, N has been over-applied on many midwestern farms, prompting concerns about the cost of commercial inputs into farming and the amount of nitrate in groundwater.

This study assessed ways to minimize nitrate loss and optimize N uptake by plants, thus reducing adverse effects on groundwater and maximizing benefit to the crop. Nitrate is a mobile form of N that is easily taken up by crop plants but that can also leach (percolate) to groundwater. Specific goals included monitoring N use and movement in soils, analyzing soils and vegetation, assessing alfalfa’s role in a cropping rotation to regulate soil nitrate concentrations, and demonstrating that farmers can develop the expertise to make soil management decisions by testing nitrate levels in their own soils.

Approach

The study, located at the Dordt College Agriculture Stewardship Center in northwestern Iowa, included two conventionally tilled fields in upland and lowland soils, one alfalfa field, and one ridge-tilled field. In addition to the sampling described below, researchers considered factors such as rainfall, cropping, land use history, and topography.

Other sites at local farms included newly planted alfalfa fields, established alfalfa fields, and alfalfa fields that had been rotated to corn. All were monitored for soil nitrate.

Researchers collected soil samples at two-week intervals from June 1988 to June 1991. During the first year, ten soil samples taken at each of three depth ranges—0-0.3 meter (m), 0.3-0.6 m, and 0.6-1.0 m, or about 0-12 in., 12-24 in., and 24-39.4 in.—were combined for analysis. Samples were taken early in the season with a tractor-mounted soil sampler and later with a hand sampling probe. Sampling was suspended during portions of some summers because the extremely dry soil would not allow probe insertion. During years two and three, researchers also analyzed individual core samples from each collection site to estimate soil-nitrate concentration variability.

In 1988, eight shallow wells placed in areas corresponding to four cropping histories (including corn, alfalfa, soybeans, and triticale/alfalfa) were drilled 16.5-41 feet (ft) deep to sample the upper, shallow aquifer. Water levels were recorded prior to sampling. Groundwater was also sampled every two weeks throughout the project except for three winter months each year. A specially developed vacuum kit drew water samples. In addition to analysis at Dordt College, duplicate samples from all facets of the study were analyzed by a commercial laboratory as an independent confirmation of results.

Suction lysimeters buried at 10-in., 20-in., and 63-in. depths near the wells sampled soil water
solution for nitrate in the root zone. Soil samples were dried and then refrigerated in preparation for one of two analysis methods.

To determine a crop's N uptake, researchers sampled plant tissue from corn, alfalfa, and/or soybeans under various tillage practices during the 1988 and 1989 growing seasons. After determining the amount of dry matter for all samples, researchers determined the dry matter's crude protein content, which in turn helped them to calculate its N values.

Because researchers observed low and relatively stable soil-nitrate concentrations in the single alfalfa field sampled in 1989, in 1990 they broadened their investigation of alfalfa to include its potential for reducing cropping-system soil nitrate.

The study examined soil nitrate in three alfalfa management scenarios: (1) newly established alfalfa with tissue samples taken at each of three cuttings; (2) existing 2-4 year alfalfa stands; and (3) fields where corn had been planted following the previous year's crop of alfalfa (to help determine how much an alfalfa stand's decomposition might contribute to soil nitrate).

Findings

All samples of well water from the study had some nitrate. Two were continuously above 10 parts per million (ppm), which is considered the limit for safe drinking water. Three additional wells had concentrations above 10 ppm at some point during the study. Samples from wells having water tables closer to the surface showed more nitrate soon after periods of intense rainfall. Wells located down-slope also showed higher nitrate readings than others, possibly because nitrate-loaded water pooled during surface runoff.

Cropping and manure fertilization history strongly affected soil nitrate concentrations in the fields studied. For example, nitrate concentrations were lowest in the alfalfa (less than 5 ppm) and up to eight times higher in the row-cropped fields, whether tilled conventionally or ridge-tilled. Fields with a history of heavy manure application showed nitrate concentrations equal to or higher than that required for corn production.

Moreover, the concentration of soil solution nitrate in some fields indicated that significant amounts of leachable nitrate existed below the root zone. For example, in the final season of the project, one conventionally tilled corn field with a history of alfalfa cropping and heavy manuring showed a nitrate soil solution of 45-75 ppm at the 1.5 m depth. The ridge-tilled field had an average of 162 ppm nitrate—among the highest of any of the fields in this study.

Table 1. Estimated savings to area farmers following reduced commercial N fertilizer application in spring 1989.

<table>
<thead>
<tr>
<th>Operator</th>
<th>Acres involved</th>
<th>Savings/acre ($)</th>
<th>Total savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>6200</td>
<td>13.70</td>
<td>84,940</td>
</tr>
<tr>
<td>2.</td>
<td>1500</td>
<td>30.00</td>
<td>45,000</td>
</tr>
<tr>
<td>3.</td>
<td>700</td>
<td>10.00</td>
<td>7,000</td>
</tr>
<tr>
<td>4.</td>
<td>62</td>
<td>13.50</td>
<td>837</td>
</tr>
<tr>
<td>5.</td>
<td>260</td>
<td>15.00</td>
<td>3,900</td>
</tr>
<tr>
<td>TOTALS</td>
<td>8722</td>
<td></td>
<td>$141,677</td>
</tr>
</tbody>
</table>

Note: $16.24 average savings per acre; corn yields in fields with reduced N were equal to or greater than adjacent fields/plots with conventional N application rates. In addition to using the late-spring soil test (now sold as the N-Trak kit), these farmers are using the fall season stalk test to determine how well the corn plants were using available N. Even on fields where N rate was reduced, the stalk test showed high N levels.
This project also clearly demonstrated that alfalfa will remove nitrate from the root zone (down to one meter, or about 39 in.), even during its first year, and that established stands can rapidly take up nitrate from manure applications.

Finally, local, on-farm soil testing for nitrate provided savings estimated at $16 to $20 per acre (see Table 1). Such information about potential savings effectively encourages farmers to recognize the economic value of soil testing. In addition, such testing promotes prudent accounting of the value of on-farm N sources such as manures. The information provided by this testing encourages greater stewardship in crop and soil management—especially given soluble nitrate’s propensity to run off or leach.

Implications

The researchers conducting this project have concluded that past land use and manuring practices contribute significantly to soil N economy and that knowledgeable application of N can be accomplished with the late-spring soil nitrate test and the fall-season stalk test. Furthermore, alfalfa in rotation or strip cropping can not only contribute to soil N (via decomposition of biomass); it can also mitigate deep soil N levels. Thus, including alfalfa in rotations and monitoring soil in late spring for nitrate has great potential for reducing groundwater pollution by nitrate.

This project has raised northwestern Iowa farmers’ awareness of the importance of proper N fertilizer use. Early in the project, researchers became distributors and trainers of the late-spring soil nitrate test and worked with selected farmers; when a test kit became available commercially, other local farmers accepted it more readily as a result.

A survey of five farmers within a 25-mile radius of the project location who used the prototype kit suggests that as a group they saved almost $142,000 in fertilizer costs the first year; follow-up has revealed that these savings are ongoing. Farmers are relying on the test kit to help them assess their N needs and fine tune their N applications. This has reduced routine fertilizer application on previously manured soils. As these farmers expand the amount of acres on which they fertilize according to the kit recommendations, their savings increase; moreover, they work in harmony with the environmental and economic goals of sustainable agriculture.

For more information contact R. J. Vos, Agriculture Stewardship Center, Dordt College, Sioux Center, Iowa, 51250, (712) 722-6285.

Adapted from L.G. Bundy, Soil and applied nitrogen, A2519, CES, UW-Extension, 1985

The nitrogen cycle.