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# Performance of cropping systems designed to reduce nitrate leaching into shallow municipal well aquifers

## **Abstract**

This on-farm experiment tested five different cropping systems with the potential to improve nitrate N management in the capture zones of community water supplies in the upper Midwest. Residual soil nitrate N concentrations were determined for each system in order to estimate the likelihood of nitrate N leaching from the system. An economic analysis also was conducted.

## **Keywords**

Water quality quantity and management

## **Disciplines**

Agronomy and Crop Sciences | Water Resource Management

## **Lead Investigators**

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## Performance of cropping systems designed to reduce nitrate leaching into shallow municipal well aquifers

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**Matthew Van Schouwen**  
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### Budget:

\$17,500 for year one  
\$14,000 for year two  
\$18,500 for year three  
\$20,000 for year four  
\$20,000 for year five

**Q** Are there Iowa cropping systems that retain N, reduce the risk of nitrate N leaking into shallow municipal aquifers and are workable for producers?

**A** Yes, but the systems with the greatest potential for retaining nitrate N utilize perennial grasses and legumes which may be less profitable than corn and soybean.



**ECOLOGY**

### Background

Sioux Center, like many Iowa communities, draws more than 50 percent of its drinking water from wells that are less than 50 feet deep. These shallow wells may be strongly influenced by land management practices in the immediate vicinity, as well as in the surrounding watershed. In recent years, several of Sioux Center's 12 shallow wells have produced water with nitrate-nitrogen (N) concentrations of more than 12 mg/L (the maximum contaminant level, or MCL, is 10 mg/L). City officials and area residents realized that the nitrate concentrations in several of the wells were excessive, and should be reduced in order to maintain a sustainable water supply. More than 200 small communities in Iowa face similar challenges.

The Sioux Center Source Water Protection community planning team was formed in 2007. Team members included the Sioux Center water plant operator and city utilities engineer, Sioux County Natural Resource Conservation Service (NRCS) personnel, local landowners and operators, and Dordt College professors. This team met with the Iowa Department of Natural Resources (DNR) Source Water Protection program staff and developed a plan to address the community's water quality concerns. One element of the plan was to reduce potential non-point source contamination of the well field. The owners of land adjacent to the city's well field were encouraged to enroll their land in the well head protection Conservation Reserve Program, but had declined to do so.

The objectives of the proposed research were to assess cropping systems with the potential to produce a reasonable financial return for landowners/operators while simultaneously reducing the risk of nitrate N movement into shallow municipal aquifers, and to share the results with those who could benefit from the information (farmers, municipalities, NRCS, Iowa DNR, and the research community).

### Approach and methods

The research team's strategy included conducting an experiment using standard farm equipment. They evaluated two cropping systems utilizing minimal commercial



*Planting corn into strip-tilled rye in the spring of 2009 using conventional farm equipment. Photo by Rob De Haan.*

sources of nitrogen fertilizer (either organic or inorganic), and three cropping systems that involved the use of commercial nitrogen fertilizer applied only at the time and rate needed for crop use. Soil nitrate N levels were monitored for each treatment in order to make comparisons. Economic data also were collected and analyzed. The team hypothesized that carefully managed cropping systems would have soil nitrate N levels similar to land in perennial vegetation typical of CRP plantings, but would generate additional income for the land owner/operator, and therefore be adopted more readily by producers than CRP plantings.

Matthew Schuiteman and AJS Farms provided land (farmed by the Schuiteman family for 30 years) and the equipment to farm it. He was responsible for all the field operations (tillage, planting, spraying, fertilizer application, harvesting) and collected yield data from the 60 ft. by 600 ft. field plots. Robb De Haan gathered and analyzed soil and tissue samples. He and Ronald Vos organized the data and put it into spreadsheet form. Vos assembled economic data and conducted the financial analyses.

## Results and discussion

Residual nitrate N in the top 6' of the soil profile in November, and average annual profit, as affected by crop rotation are shown in this table. Data show averages from four growing seasons (2010 to 2013) for residual nitrate, and three growing seasons (2010 to 2012) for profit. The 2009 cropping year was excluded from both analyses because it was a transition year. 2013 was excluded from the profit analysis because corn and soybean yields were artificially low due to management challenges.

| Crop Rotation                                       | Continuous Corn w/winter rye cover | Continuous Grass Hay | Oat/red clover – Corn (2-year rotation) | Oat/alfalfa – Alfalfa – Corn (3-year rotation) | Soybean – Winter wheat/red clover – Corn/winter rye cover (3 year rotation) |
|---|------------------------------------|----------------------|---|--|---|
| Residual Nitrate-N in the top 6' of soil (lbs/Acre) | 154                                | 31                   | 98                                      | 74   | 105   |
| Profit (\$/Acre)                                    | 230                                | (121.22)             | 106                                     | 76   | 183   |

The perennial crops in this experiment (grass hay, alfalfa, and red clover) were particularly effective in reducing nitrate N concentrations throughout the soil profile. Rainfall had a large impact with N accumulating in dry years and being flushed from the system in wet years. More N remained on the landscape following corn than for the other crops tested, with the most N found in the top 1-2' and below 4'.

The longer rotations reduced the amount of corn on the landscape, which decreased the overall risk of nitrogen leaching. In addition to longer rotations, cover crops and N fertilizer application rates based on the late spring nitrate test also were helpful.



*Experimental site in the fall of 2009 showing the West Branch of the Floyd River (foreground), alfalfa and well house surrounded by CRP (center) and most of the north half of the plot area (top). Photo by Rob De Haan.*

The tap-rooted perennial plants (alfalfa and red clover) were able to mine deep N, bringing it up in the soil profile and making it available for annual crops. Perennial grass hay resulted in uniformly low nitrate N levels throughout the soil profile.

Profitability values were generated through enterprise analysis using the ISU Ag Decision Maker program and actual yields, and by gauging economic costs for P and K removal. Although continuous corn and corn-soybean systems are favored by farm policy, rural culture, crop insurance, and ease of use, the soybean-winter wheat-corn rotation provided the best results for balancing profit and N retention.

## Conclusions

Project results indicate that it is possible for cropping systems that produce a reasonable return for farmers also to reduce the risk of nitrate-nitrogen contamination of shallow municipal aquifers. Perennial grasses and other perennial crops can work and proved to be very effective at minimizing nitrate loss into groundwater.

When compared to a continuous corn system, the soybean-winter wheat-corn rotation reduced average residual nitrate N levels in the top 6 feet of soil by 49 lbs./acre but generated \$47/acre less profit. Continuous grass hay resulted in lower residual nitrate N levels than any of the other systems, but also was the least profitable. Researchers observed that for a given cropping system, residual nitrate N levels in the soil were fairly consistent from year to year, while profit was more variable, due to fluctuations in yield and price from one year to the next.

Continued research investigating the effects of cropping systems on residual nitrate N in the soil profile at the end of the cropping season could be very beneficial. Additional variables could include collecting 6-foot deep soil cores in the spring as well as the fall, sampling a deeper soil profile (8 feet or more), looking at a range of soil types, and evaluating different cropping systems.

## Impact of results

The main objective of this research was to assess cropping systems with the potential to produce a reasonable financial return for landowners/operators while simultaneously reducing the risk of nitrate N movement into shallow municipal aquifers. Results indicate this may be possible. Based on these findings, one producer farming land in the capture zone of the Sioux Center well field has decided to utilize a corn-corn-alfalfa rotation instead of continuous corn. The field days where research was shared were well-attended, and in combination with the talks and written reports associated with the project, have increased the visibility of water quality concerns in the community and region.

## Education and outreach

### *Presentations*

- Results from years one and two were presented at a field day in September 2011. The event included a trip to the experimental site and presentations by personnel from the NRCS, Iowa DNR, City of Sioux Center, AJS Farms, and Dordt College. There were about 100 attendees.
- Initial soil nitrate N results from years 1 through 3 were presented by Robb De Haan at an Iowa Groundwater Association Meeting in March 2013. The event included presentations by personnel from the NRCS, Iowa DNR, and other researchers. Nearly 200 people attended.
- Results from years 1 through 5 were presented in March 2014 to about 150 farmers, agronomists, students, Sioux Center residents, DNR, NRCS, SWP, and Leopold Center staff.
- In August 2014 a summary of the research was presented at a field day held at the Dordt College Agriculture Stewardship Center. About 150 farmers, students, and community members attended.
- Results from the five-year study were shared with members of the Iowa Environmental Protection Commission in September 2014 on the Dordt College campus.
- In September 2014 Robb De Haan and Ron Vos presented results from the research to about 15 Northwest Iowa agronomists associated with the Farmer's Coop Society.

### *Other outreach*

- The Iowa DNR videotaped a presentation of the research results on December 15, 2014. See [http://digitalcollections.dordt.edu/faculty\\_work/149/](http://digitalcollections.dordt.edu/faculty_work/149/).
- De Haan, R.L. 2013. Nitrogen fertilizer, cropping systems, and Iowa groundwater. *IGWA Underground*, Iowa Groundwater Association. Summer, pp 4-7.

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