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FEATURE

Groundwater and agriculture: Insights from farmers in central Minnesota on how to protect both

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In agricultural areas with groundwater that is highly sensitive to pollution and surface water resources that are sensitive to groundwater withdrawal, farmers are under pressure from government agencies and environmental groups to improve their on-farm management practices (Kennedy 2015a, 2015b; Marcotty 2012). One area where conflicts over groundwater and agriculture are growing is the central sands region of Minnesota, United States (Gunderson 2014; Haugen 2014; Marcotty 2013; Robertson 2009; Vogel 2014b). This area is characterized by coarse-textured soils formed from glacial outwash (USDA NRCS 2018), a water table that is vulnerable to pollution (Adams 2016), and extensive agricultural production with crops such as corn (*Zea mays* L.), soybean (*Glycine max* [L.] Merr.), alfalfa (*Medicago sativa* L.), wheat (*Triticum aestivum* L.), oats (*Avena sativa* L.), potato (*Solanum tuberosum* L.), and dry edible beans (*Phaseolus vulgaris* L.) (USDA NASS 2014, 2017).

While the trend of change in nitrate (NO_3) concentrations over time in this region is either stable (Minnesota Pollution Control Agency et al. 2018) or slightly increasing (MDA 2015b), the extent of NO_3 contamination in groundwater is already widespread (MN EQB 2017). Nitrate concentrations in groundwater are found at elevated levels in this region for public water systems (PWS) (MDH 2018) and for private well owners (MDA 2018b). Overall, treating water contaminated by NO_3 is expensive and is currently estimated to cost the state of Minnesota US$6 million annually (Keeler et al. 2016).

Sprinkler irrigation supplied by groundwater is common (MN DNR 2017), especially for high value crops sensitive to water stress, grown on soils with low available water holding capacity (USDA NASS 2013). At the same time, the extent of agricultural irrigation is increasing across this region. Since the 1980s, the amount of irrigated cropland has almost doubled in size, and total volume of groundwater applied to cropland as irrigation has increased by more than 50% across Minnesota (MN EQB 2015). This expansion includes previously nonirrigated cropland, as well as from land that was previously forested (Marcotty 2013).

Much of the work in Minnesota to address concerns related to groundwater has been supported by a statewide investment in clean water programs funded through a constitutional amendment to raise the state sales tax. Passed by voters in 2008, this amendment generates approximately US$100 million each year (Marcotty 2018a). This has spurred innovation at the statewide and local levels and led to the development of new programs from soil and water conservation districts (SWCD) (Vogel 2014a) and the Minnesota Department of Agriculture (MDA) (MDA 2015a).

While the voluntary approach to address nonpoint source issues has been well supported, state agencies have simultaneously been developing regulatory approaches to address groundwater quality and quantity. The MDA has been in the process of developing the Groundwater Protection Rule, which would regulate the use of nitrogen (N) fertilizer (MDA 2018a). Areas with vulnerable groundwater as well as wellhead protection areas for PWS, known as Drinking Water Supply Management Areas (DWSMAs), would have N fertilizer applications restricted. If approved, this rule would mark the first time that N fertilizer applications would directly be regulated in Minnesota (Marcotty 2018b).

While this is an area of broad public concern, farmers and agricultural professionals are the key stakeholders. To support additional progress and program development by SWCDs at the local level, insights addressing issues related to groundwater and agriculture are needed from farmers.

BACKGROUND

During the winter of 2018, local farmers, agronomists, and industry professionals came together during a series of workshops to find solutions to conflicts over groundwater and agriculture. The motivating goal behind these meetings was to develop a shared understanding that farming and water go hand in hand. Hosted by the East Otter Tail SWCD in partnership with the Freshwater Society, three workshops were held across the Minnesota central sands region in Perham, Parkers Prairie, and Osage (figure 1). Over 90 farmers and other members of the agriculture community participated.

The purpose of these workshops was to gather input from area producers on local strategies to protect agricultural economies and groundwater quality at the same time. All three workshops were developed with identical content and hosted in three separate locations in an effort to reach as many producers as possible. Workshops featured small-group conversation and were based on a series of four questions:

1. For nutrient and irrigation management, what are the practices that are working in your fields and why? What makes the practices you are using in your fields feasible and beneficial to you?
2. If time and money were not a factor, what would you like your irrigation and N management practices to look like in five years?
3. With a focus on nutrient and irrigation management, what are the barriers to improving efficiencies in your fields?
4. What strategies can we use to address these barriers?

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During the workshops, each small group had a dedicated recorder from the SWCD or partner organizations to make sure all ideas shared by participants in response to questions were written down. Answers to these questions were sorted into categories by participants in their small groups, and summaries from each table were shared after each question.

All comments recorded at the meetings were analyzed by Freshwater Society using grounded theory for qualitative data analysis (Hennink et al. 2011) to identify the unifying themes across small groups and workshop location. To confirm that the stories and input shared by participants were accurately captured, a fourth workshop was held in New York Mills (figure 2). Preliminary findings from the first three workshops were presented to a group of 30 previous participants who provided feedback. At this meeting, participants were also asked specifically to identify strategies that would make the biggest difference to them in overcoming barriers they face in adopting new management practices. The findings of all four meetings were then synthesized by Freshwater Society so that the East Otter Tail SWCD could accomplish their goal of developing future programs and activities to protect groundwater.

WHAT'S CURRENTLY WORKING?

Farmers understand that they have a responsibility to protect groundwater. While economics constrain which practices are feasible in their fields, farmers are already making sacrifices of time, resources, and money to implement practices that are environmentally beneficial. Many of the practices that are currently working are those that maximize input use efficiency and meet the unique conditions for each field, each farmer, and each growing season.

For N, 4R nutrient management principles—applying fertilizer at the right time, using the right rate, in the right place, and with the right source—are the foundations of the practices that are currently working. Split-application of N was the practice most commonly mentioned, and other practices such as fertigation, controlled-release fertilizers, plant tissue

Figure 1

Map of meeting locations, political boundaries, and water table pollution sensitivity in Minnesota, United States (Adams 2016).

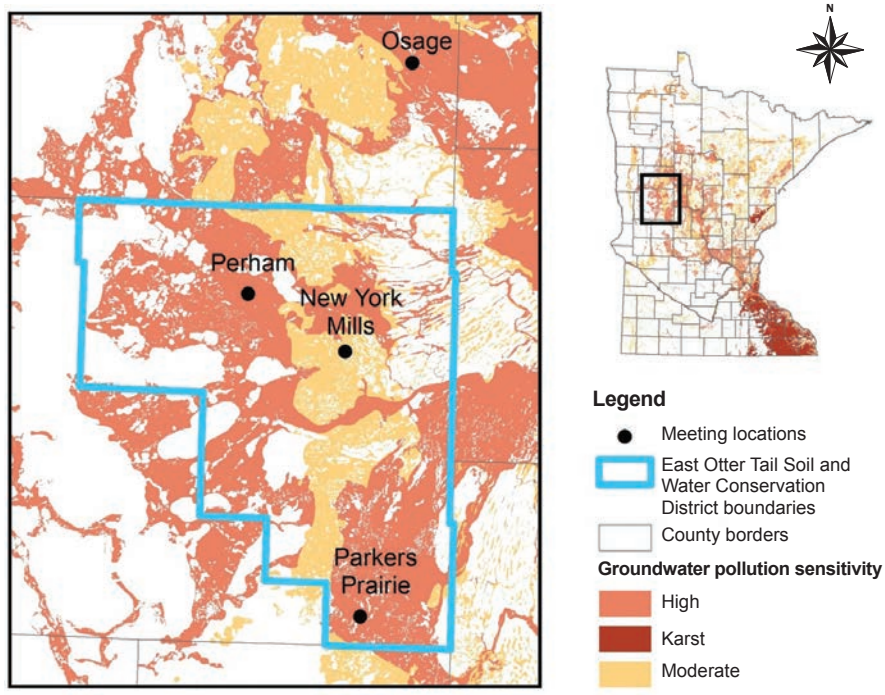


Figure 2

Final meeting in workshop series held in New York Mills, Minnesota.

sampling, variable-rate applications, N stabilizers, and soil NO_3 measurements are also being used.

An irrigation scheduling program was overwhelmingly regarded as the irrigation practice that is working best. However, irrigation scheduling means different things to different producers. For some, it means a program currently provided by East Otter Tail SWCD; for others, it means efficient irrigation management in general. Pivot uniformity testing, tracking water use, accounting for precipitation and evapotranspiration, low pressure nozzles, soil moisture probes, and using imagery to track application problems are other practices that are currently working.

Beyond irrigation and N, other management practices are being adopted depending on the conditions of a given farm and resources available to a farmer. Cover crops are being incorporated into some rotations, especially those with short-season main crops, primarily for erosion control and secondarily to reduce N losses. Other practices such as reduced tillage and manure application have been adopted for their soil health and erosion reduction benefits.

Resource efficiency, knowledge of local efficacy, and ability to manage the risk of unexpected events were the most important factors that made a given practice feasible to adopt. Participants stressed that effective management practices are those which make efficient use of physical, capital, or human resources available on a farm. Information demonstrating the local effectiveness and the mitigation of risk from unexpected weather events are also key factors for practice adoption by farmers. While some practices are feasible for producers working on a large scale, they might not be appropriate for farmers working on a smaller scale or who are approaching the end of their career and are reluctant to make major operational changes. Participants also clarified that because of the vulnerable and variable soil conditions found in north central Minnesota, they have adopted different best management practices for N than other areas of the state. These practices require more time and resources, but are a necessity for farmers to be financially viable in this region and work to protect groundwater from being contaminated with N.

WHAT COULD THE FUTURE LOOK LIKE?

We asked participants to imagine what the management practices on their fields could look like in five years. In response, we heard that there is more work to be done to improve financial sustainability and to protect groundwater. In the next five years, farmers want to shift their management practices toward those with a long-term perspective in mind: reducing tillage, incorporating cover crops, and adding alternative cropping systems into their rotations; there was a significant increase in the number of comments received mentioning changes in rotation and tillage management practices (figure 3). Shifting management practices away from annual management of inputs toward a system with a longer-term perspective has recognized soil health and sustainability benefits that are good for farmers' bottom line and for the environment. Improving soil health is an important part of how farmers in this region want to manage soil fertility and soil water availability in the future. Farmers also desire to increase the diversity and duration of their rotations, including the use of nontraditional crops, and remove marginal acres from production. Changes in tillage and rotation management practices have a longer-term return on investment, but adopting these practices will eventually result in better financial and environmental outcomes and a more sustainable farming operation.

Farmers want to continue to reduce the total rate of N applied and improve the efficiency of their fertilizer applications. Using slow-release fertilizer, applying N stabilizers, expanding fertigation, using new equipment for sidedress applications, or adding soil biological amendments are ways to improve N use efficiency. Similarly, irrigators can be improved with low pressure nozzles, gearboxes enabling faster applications, global positioning and remotely controlled systems, field corner extensions, and integrated weather stations to increase irrigation efficiency.

Farmers also want to adopt precision irrigation and N management practices that could drastically improve the efficiency of the inputs they use. These tools include variable-rate applications based on management zones or on proximal or remote sensing. Farmers are very interested in adopting precision agriculture practices in their fields as soon as these technologies are available, reliable, and have been proven to work, and are looking forward to a future where technology can provide each plant with exactly the amount of fertilizer and water needed.

The desire to shift toward sustainable systems that incorporate longer-term management practices is not enough, however. We heard from farmers that even above and beyond the limitations of time and money, other barriers could still limit what is possible in the future. For example, the scale of the farming operation and the life stage of the farmer are also important determinants of what future management practices will look like. Barriers such as these mean that interest and effort by farmers alone will not be enough to get more practices adopted that will protect groundwater.

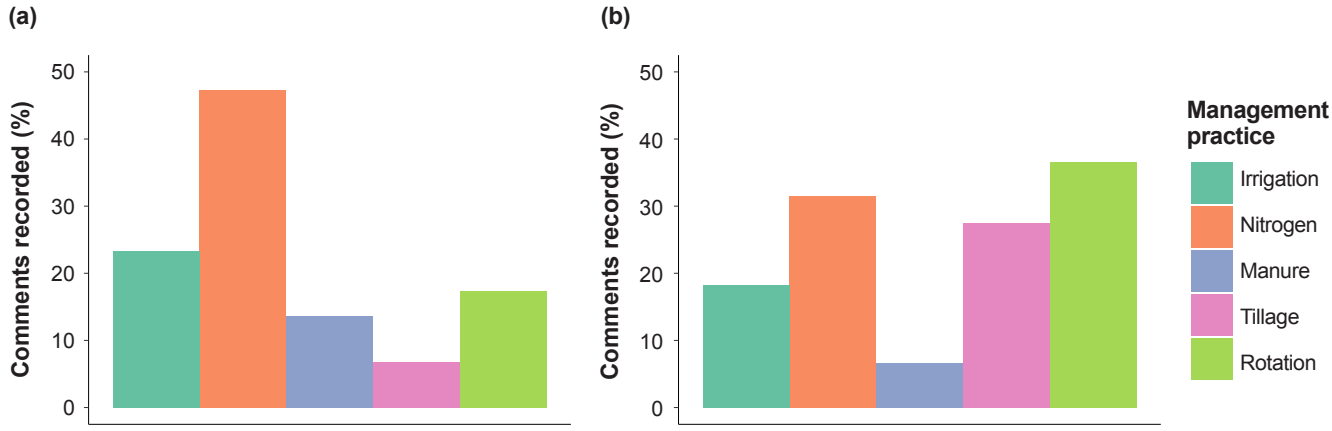
BARRIERS TO PROGRESS

In these meetings, farmers identified the structural barriers that prevent them from doing more good work on their fields to protect groundwater and improve the sustainability of their farms. Some of these barriers are obvious (i.e., time and money), while other less obvious barriers exist. However, addressing all existing barriers is important to achieving the vision farmers have for their fields in the future.

Negative Public Perception. The general understanding shared by farmers is that the public believes that farmers don't care about the environment and aren't working to protect groundwater. This is evidenced by media reports over the past few years painting farmers in a negative light with respect to groundwater and the environment. While this characterization is itself inaccurate and in need of correction, this misperception also impedes the adoption of more good work by farmers when success stories that could help inform policy decisions are not shared. If the public believes that the solution to our groundwater problems is educating farmers on the basic principles of conservation, they

Figure 3

Summary of comments received across all meetings categorized by management practices for (a) Question 1, practices that are currently working, and (b)Question 2, future practices.



are only creating another barrier for farmers to overcome. Farmers are not asking for education as to why protecting groundwater is important or on the basic strategies that can be used to protect groundwater. They already understand that they have a responsibility to protect groundwater and many have been working hard for years to adopt more environmentally friendly practices. Incorrect public perception of farming was the issue most commonly mentioned by participants.

Locally Appropriate Knowledge. Farmers make decisions on which management practices to use based on locally appropriate information of the benefits and tradeoffs associated with a given practice. Because changes in management practices, whether major or minor, carry some level of risk, farmers are not likely to make changes without evidence that the practice will be beneficial on their fields. University research is often conducted under soil and climate conditions that are not directly transferable to local conditions. Similarly, there is no simple way for a farmer to get access to a centralized information database on all the research conducted that would be appropriate for their fields. Farmers trust management practices that have been demonstrated on fields they know and by peers they trust. However, there is currently no formal way for farmers to share information with other farmers on which practices are working in their fields. The lack of locally appropriate knowledge was one of the most significant barriers identified in this process.

Long Return on Investment Period for New Practices. Both changes in tillage and rotation management practices, as well as adoption of precision irrigation and N management, have high upfront costs and a long return on investment (ROI) period. While these practices make sense in the long term, the transition period and costs in the short term make them difficult to adopt. The environmental benefits of these practices may also have a shorter ROI period compared to the ROI for the economic benefits. For example, upgrading an irrigation system with GPS nozzles for variable-rate irrigation is an expensive investment that will take years to pay off with the modest decreases in the total volume of water applied. However, it may have immediate environmental benefits by limiting irrigation applications in areas that are highly vulnerable to NO_3 leaching. In a similar way, cover crops can immediately reduce NO_3 leaching once planted but may take many years to improve soil health to the point that cover crops are an economically beneficial practice.

Lack of Technical Expertise and Actionable Information. While there is an abundance of new precision management technologies, which generate massive amounts of on-farm data, farmers lack the resources needed to use this technology to its full potential. On-farm technology is changing very rapidly. While farmers with lower technological literacy may be challenged, even the savviest producers could have a hard time keeping up with the rapid pace of change. At the same time, the data generated by these tools is almost useless without accompanying support systems to interpret the data or provide actionable information. Without the knowledge to operate new technologies or the ability to make decisions based on the data generated, farmers will be spending time and money on technology that is not fully useful to them.

Absence of Markets for Alternative Crops and Improved Inputs. In some cases, the management practices that farmers want to use are not aligned with existing markets. Without markets aligned to farmer needs, certain practices will not be feasible. For example, some farmers expressed interest in growing alternative crops such as canola (*Brassica napus* L.), oats, peas (*Pisum sativum* L.), hemp (*Cannabis sativa* L.), alfalfa, or anything besides corn and soybeans; however, they also identified that there is no market to sell these crops. Other inputs, such as advanced precision agriculture technologies, have either not yet been developed or are not yet commercially available for farmers in this area.

Unpredictable and Variable Environmental Conditions. Farmers work in systems that are defined by their unpredictable and variable conditions. Unexpected or extreme weather events, volatility in crop prices, and soil conditions that change dramati-

cally over just a few feet can impede or even derail the best-laid plans. Farmers are largely unable to control major factors that determine whether their farm is financially viable or if negative environmental impacts will occur. This lack of control means that farmers are limited in their choices of management practices because of the need to mitigate and manage the risk of unexpected events happening and account for the variability in their fields.

Restrictions from Landowners, Bankers, and Government. Farmer decisions on which management practices to use are limited by outside interest groups such as landowners, bankers, and government agencies. A landlord may restrict a farmer's ability to change their tillage or rotation management practices. A banker may limit financing options on farmers when crop prices are low. Government agencies have restrictions and regulations for conservation programs, crop insurance, and water-appropriation permits. There is also a maze of paperwork required for the different government programs and permitting. Together, these three groups currently limit the flexibility of farmers to implement new practices that could have a positive impact on groundwater.

The adoption of more groundwater-friendly management practices is limited primarily by systemic barriers rather than by a lack of knowledge or interest on the part of farmers. Farmers are already adopting many management practices with the goal to protect groundwater. Additionally, farmers have a vision of the management practices they want to implement in their fields in the next five years. In order to accomplish their goals of decreasing their environmental impact and increasing the sustainability of their operations, farmers are asking for help from the SWCD to overcome the barriers they have identified.

STRATEGIES FOR SUCCESS

To overcome the identified barriers to progress and adopt more practices that protect groundwater, workshop participants suggested shifting the public narrative, promoting improved regulations, facilitating local information exchange, developing assistance programs, fostering financial support, and encouraging the development of local markets.

The public narrative does not accurately reflect the work farmers are doing to protect groundwater. Better stories demonstrating how farmers are working to protect groundwater need to be told. Education on agricultural systems should be provided to those outside of the agriculture community. Similarly, members of the public also need to be connected to farmers to build relationships and understanding.

Common sense regulations would let farmers do more good work to protect groundwater and improve their bottom line. This would include regulations that are rooted in common sense and are locally controlled. Government conservation programs should have increased flexibility and reduced paperwork. At the same time, all levels of government involved in agriculture should be working together.

Additional sources of locally relevant information to evaluate the performance of management practices are needed. Regular publication of locally appropriate research results should be provided to farmers. Programs to arrange peer-to-peer sharing of information between farmers on practices that are working in their fields are effective methods to share information. Additionally, the number of local field days and on-farm demonstrations should be expanded.

In some situations, there are certain resources or areas of expertise that, when provided by someone else, can overcome a time, cost, or expertise barrier faced by a farmer. An in-season N management program, including tissue and soil NO_3 testing, could be provided to farmers at low or no cost by a SWCD. Training in new technologies, including how to use sensors and software, could be provide by retailers when equipment is purchased. Application assistance for conservation programs should also be provided by government agencies.

Targeted financial assistance could increase the adoption rate of management practices with a long-term ROI or high upfront cost. Financial incentives for adopting costly management practices with strong environmental benefits, such as cover crops, could be provided. Cost-sharing for investments with long-term ROI or high upfront cost, such as variable-rate irrigation, would allow more farmers to upgrade equipment. Opportunity to "try out" or rent equipment, such as equipment for reduced tillage, before buying would help farmers get the right equipment to meet their needs.

Developing new markets is a large task; however, farmers are asking for the option to grow alternative crops beyond the small set of currently marketable crops. Investments in local mills and end producers would support markets for alternative cropping systems. Access to inputs such as climate-hardy cover crops and precision agriculture technologies would also increase the adoption of these practices.

MOVING FORWARD

This series of workshops provided important insights into the work farmers are already doing to protect groundwater and the role SWCDs and other stakeholders can play in helping farmers adopt more environmentally beneficial management practices. Based on these conversations, farmers strongly feel a responsibility to protect groundwater and want to do more. Although there is more work still to be done, it appears that this region is on the right track to protect groundwater.

While addressing the systemic barriers facing farmers will be an uphill challenge, there are opportunities for a SWCD to help the farmers they serve. Assistance programs, local information exchanges, and help reframing the public perception of agriculture are all within the reach of a SWCD, and accomplishing them could help farmers get more good work done. Other approaches such as improving regulations, developing local markets, and providing financial support are outside of the direct control of a SWCD; however, using these findings as a guide, a SWCD could advocate for the action of other stakeholders to make changes in these areas.

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REFERENCES

Adams, R. 2016. Pollution Sensitivity of Near-Surface Materials. St. Paul, MN: Minnesota Department of Natural Resources.

Gunderson, D. 2014. Irrigation boosts potatoes, but Park Rapids pays more for water. MPR News, February 13, 2014.

Haugen, D. 2014. Big rise in irrigation pumping draws DNR attention to Minnesota's 'Bonanza Valley'. MPR News, February 19, 2014.

Hennink, M., I. Hutter, and A. Bailey. 2011. Qualitative Research Methods. London: SAGE.

Keeler, B.L., J.D. Gourevitch, S. Polasky, F. Isbell, C.W. Tessum, J.D. Hill, and J.D. Marshall. 2016. The social costs of nitrogen. Science Advances 2(10):e1600219, doi:10.1126/sciadv.1600219.

Kennedy, T. 2015a. In farm country, tainted water is 'just the way it is'. Star Tribune, July 4, 2015.

Kennedy, T. 2015b. Tainted drinking water is costing Minnesota taxpayers millions. Star Tribune, April 29, 2015.

Marcotty, J. 2012. Minnesotans pay a price for crop fertilizer at faucet. Star Tribune, December 24, 2012.

Marcotty, J. 2013. In central Minnesota, potatoes are pushing out forest land. Star Tribune, October 26, 2013.

Marcotty, J. 2018a. Minnesota's big water ambitions yield benefits, no simple answers. Star Tribune, May 24, 2018.

Marcotty, J. 2018b. Overuse of farm fertilizer drives state's first effort to regulate it. Star Tribune, April 25, 2018.

MDA (Minnesota Department of Agriculture). 2015a. Minnesota Agricultural Water Quality Certification Program. St. Paul, MN: Minnesota Department of Agriculture.

MDA. 2015b. Minnesota Nitrogen Fertilizer Management Plan. St. Paul, MN: Minnesota Department of Agriculture.

MDA. 2018a. Proposed Permanent Rules Relating to Groundwater Protection. St. Paul, MN: Minnesota Department of Agriculture.

MDA. 2018b. Township Testing Program Update – March 2018. St. Paul, MN: Minnesota Department of Agriculture.

MDH (Minnesota Department of Health). 2018. Community Public Water Systems with Elevated Source Water Nitrate, 2015-2016. St. Paul, MN: Minnesota Department of Health.

MN DNR (Minnesota Department of Natural Resources). 2017. MN DNR Permitting and Reporting System. St. Paul, MN: Minnesota Department of Natural Resources

MN EQB (Minnesota Environmental Quality Board). 2015. Beyond the Status Quo: 2015 EQB Water Policy Report. St. Paul, MN: Minnesota Environmental Quality Board.

MN EQB. 2017. Minnesota Environment and Energy Report Card. St. Paul, MN: Minnesota Environmental Quality Board.

Minnesota Pollution Control Agency, Department of Natural Resources, Minnesota Department of Agriculture, Minnesota Department of Health, Minnesota Board of Soil and Water Resources, Minnesota Public Facilities Authority, Met Council, and Minnesota Environmental Quality Board. 2018. Clean Water Fund Performance Report. St. Paul, MN: Legislative Coordinating Commission on Minnesota's Resources.

Robertson, T. 2009. Farm runoff blamed for town's contaminated water. MPR News, June 29, 2009.

USDA NASS (National Agricultural Statistics Service). 2013. Farm and Ranch Irrigation Survey. Washington, DC: United States Department of Agriculture National Agricultural Statistics Service.

USDA NASS. 2014. Minnesota State and County Data – 2012 Census of Agriculture. Washington, DC: United States Department of Agriculture National Agricultural Statistics Service.

USDA NASS. 2017. Cropland Data Layer. Washington, DC: United States Department of Agriculture National Agricultural Statistics Service.

USDA NRCS (Natural Resources Conservation Service). 2018. Soil Survey Geographic (SSURGO) Database. Washington, DC: United States Department of Agriculture Natural Resources Conservation Service.

Vogel, J. 2014a. Getting water to crops when they're thirstiest pays off. MPR News, October 2, 2014.

Vogel, J. 2014b. In Cold Spring, it's trout vs Lost Trout in tension over water and beer. MPR News, March 24, 2014.