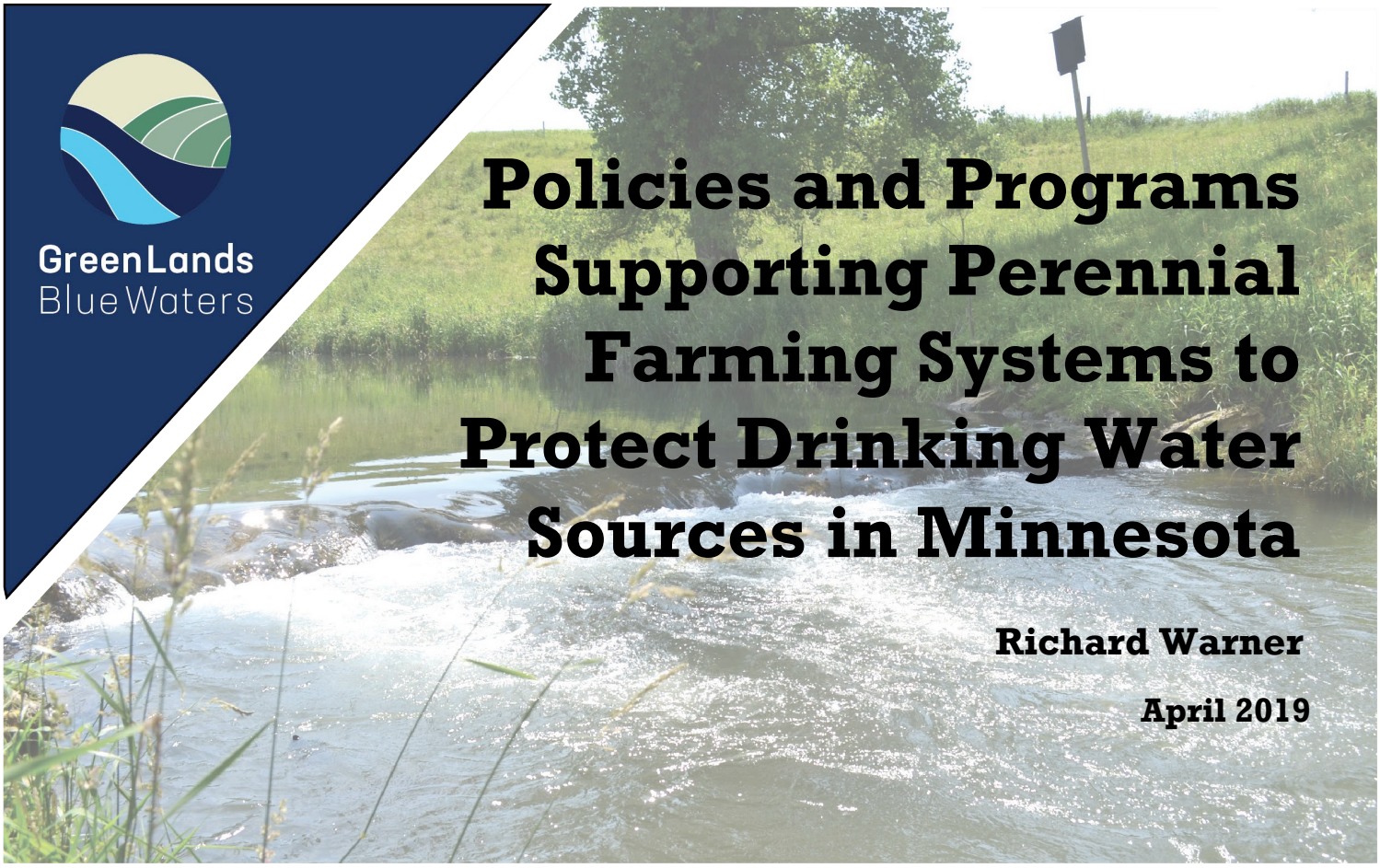

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Policies and Programs Supporting Perennial Farming Systems to Protect Drinking Water Sources in Minnesota

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Summary

Groundwater-based community water supplies can be protected from agricultural nitrate contamination by growing perennial crops, pastures, and agroforestry systems over wellhead protection areas (WHPA). In the U.S. Upper Midwest, nitrate contamination of groundwater supplies is most acute over glacial outwash and other alluvial soils, when nitrogen fertilizers are applied in the fall and spring to mostly bare farm fields and then followed by rain or irrigation. Under these conditions, part of the nitrogen is converted to water-soluble nitrate, which can be leached from the soil and concentrated in shallow aquifers that supply public water systems and private wells. Strategies to address agricultural contamination of groundwater have focused on: 1) removing nitrate from contaminated water (denitrification); 2) finding new water sources by installing new wells or new infrastructure to use surface water; 3) taking farmland in a WHPA out of production, returning the land to native vegetation; or 4) changing how nitrogen fertilizer is managed in the WHPA. While the first three strategies are effective, they are expensive, with the costs paid from local water user fees and state and federal programs. The fourth strategy has had limited success to date but shows promise as a component of a comprehensive WHPA management strategy.

An additional way to fix the problem of agricultural nitrates in well water is to convert farmland in the WHPA from annual crops to perennial farming systems, which significantly reduces nitrate leaching, keeps farmland in production, and leaves the solution in the hands of farmers. This paper describes federal and state policies and programs available in Minnesota to support conversion of farmland in WHPA to perennial farming systems. Corporate sustainability programs and markets for perennial crop products provide additional, essential incentives to increase perennial crops in WHPA. The perennial grain Kernza® is winning public and private support as a tool to remediate nitrate pollution in WHPA.

Four strategies are recommended here for increasing use of perennial farming systems to reduce agricultural nitrate contamination of groundwater sources for community water supplies:

1. Include perennial farming solutions in source water management plans;
2. Increase public and private funding for perennial farming solutions in WHPA;
3. Concentrate acreage of perennial farming in WHPA to show that perennial crops can reduce nitrates in community drinking water supplies; and
4. Increase funding for research to improve understanding of the environmental and economic impacts of perennial farming systems in protecting community water supplies.

Safe drinking water is a necessity, not an option

Nitrate is among the most prevalent contaminants of public and private water systems in rural agricultural areas of the U.S. Upper Midwest. In Minnesota, approximately 75% of residents (about 4 million), including most living in rural communities and small towns, get their drinking water from groundwater. Figures 1a and 1b show the distribution of private wells and community water supplies in Minnesota with nitrate concentrations of concern for public health.

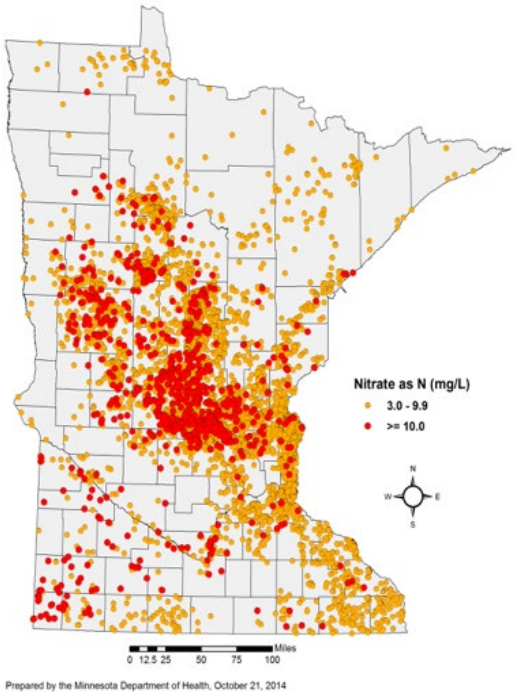

Figure 1a. Private wells at risk of nitrate contamination in Minnesota.
Credit: Minnesota Department of Health

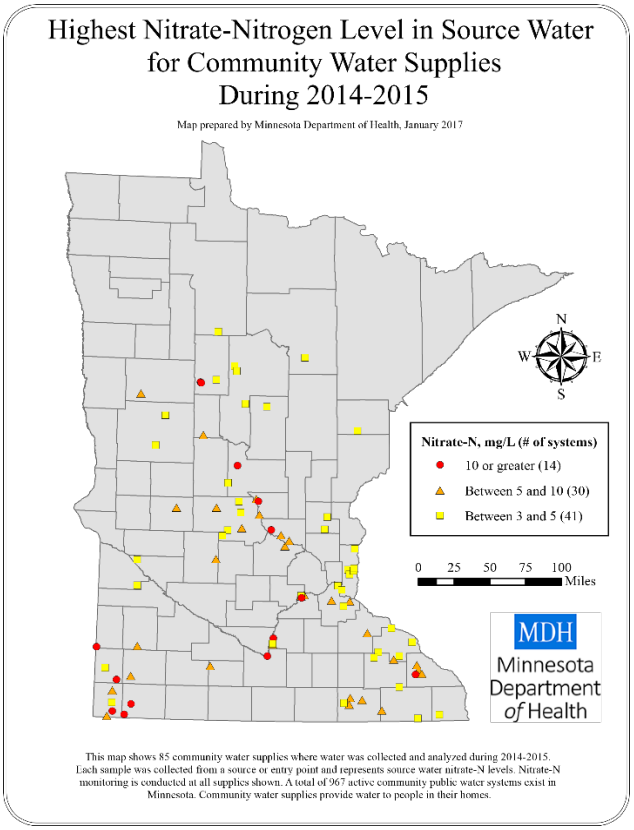

Figure 1b. Community wells at risk of nitrate contamination in Minnesota.
Credit: Minnesota Department of Health

The potential health risks of exposure to nitrate is particularly high for pregnant women and infants. Children below the age of six months who drink water containing nitrate above 10 mg/L could become seriously ill and, if untreated, may die. In view of these risks, federal and state government agencies protect the public from water containing too much nitrate. The US Environmental Protection Agency (EPA), under the Safe Drinking Water Act (SDWA), sets nitrate maximum contamination level (MCL) for water supplies at 10 mg/L. Background nitrate levels in Minnesota groundwater are generally below 3 mg/L. Thus, groundwater sources testing above 3 mg/L are assumed to be contaminated by one or more human activities.

Implementation of drinking water regulations falls to water utilities and owners of private wells. Water utilities are responsible for meeting water quality standards, including the MCL for nitrate, in the water delivered to their customers. To comply with the regulation, when a well nears or exceeds the MCL for nitrate, utilities might blend water from two or more water sources, which may require drilling additional wells or building infrastructure for capturing surface water. Where high levels of nitrate in groundwater and

surface water sources are widespread and persistent, a utility might install denitrification equipment, which removes nitrate before the water is distributed to customers. Alternatively, utilities may purchase or rent farmland over wellhead protection areas and manage the land to reduce groundwater contamination; this may include removing the land from agricultural production. Water user fees and tax-supported federal and state programs pay for the new infrastructure, land acquisition or rental, and for the ongoing costs of keeping the public water supplies free of agricultural nitrate.

Individual private wells are required to be tested for nitrate and other contaminants at the time of construction. While private wells must be free of bacteria before a home can be occupied, there are few regulatory mandates regarding nitrate or other contaminants in private wells.

The process of groundwater contamination with nitrogen from agriculture

Geology, climate, and choice of farming systems converge in the U.S. Upper Midwest to contaminate groundwater with nitrate and other agrochemicals. Glacial geology in much of this region strongly influences the distribution and availability of groundwater sources for drinking water, and the vulnerability of groundwater to contamination with agrochemicals, including nitrate. Before the mid-1900s when much of the land was converted to industrial agriculture, drinking water was accessed with relatively shallow wells in areas of glacial outwash and alluvial soils. The same soils are often susceptible to leaching of nitrate when the land is used to grow annual crops with synthetic fertilizer applied. In Minnesota, the most vulnerable groundwater supplies are in the central sand plains and southwestern glacial outwash areas, as well as the karst region in the southeastern corner of the state. Contamination of groundwater with agricultural nitrogen, its path to public water supplies, and the financial drivers of this system are represented in Figure 2.

Agriculture is primarily rainfed in the U.S. Upper Midwest. While there is a rainfall gradient through our region, from the drier West to wetter East, rainfall in most years can support corn, soybeans, sugar beets, other annual grains, oilseed, and root crops. Conventional farming with annual crops results in farm fields that are mostly bare from about November through May. Nitrogen fertilizers are often applied in April or early May, which coincides with plentiful spring rains, while the fields are bare or growing young crops with low demand for nitrogen (Figure 3). Fall application of nitrogen fertilizers, also practiced in the region, can result in increased nitrate leaching when soil temperatures exceed 50 degrees F and crops are absent. Hence, agricultural nitrogen is easily leached into groundwater, carried off the field to surface water, and lost to the atmosphere as greenhouse gasses.

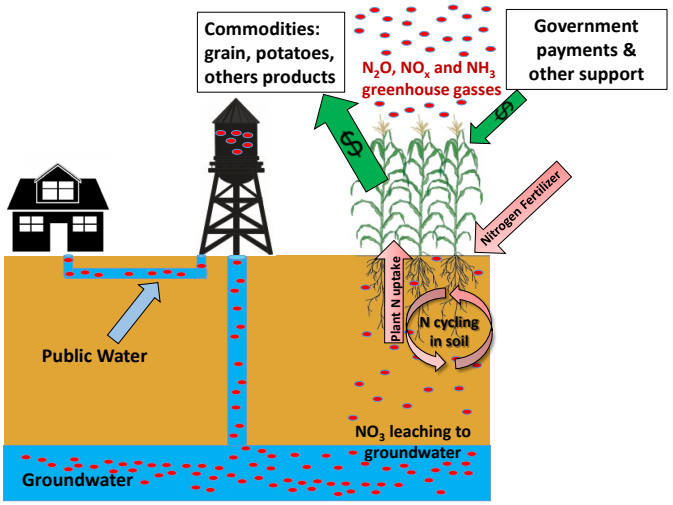

Figure 2. Nitrogen path from farmland in annual crops to groundwater supplies. Nitrogen applied to annual crops is 1) used by the crops, 2) cycled in the soil, 3) emitted to atmosphere as greenhouse gasses, 4) leached to groundwater, and 5) runoff to surface water (not shown). Nitrate-nitrogen (NO_3-N) is concentrated over time in groundwater that is used by public water utilities and private wells. The economic drivers of this system are the crops produced and government payments.
Credit: Dr. Jacob M. Jungers, University of Minnesota.

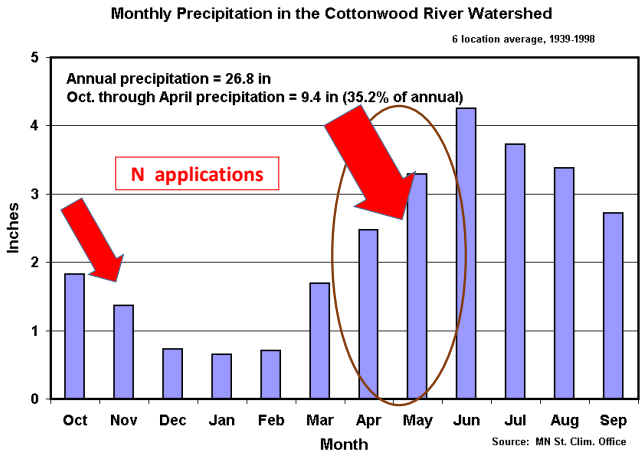

Figure 3. Monthly rainfall averages over 60 years for Cottonwood River Watershed in southern Minnesota where more than 70% of the land is in production of annual crops, primarily corn and soybeans. Red arrows show approximate times that most agricultural nitrogen is applied. Brown oval shows convergence of nitrogen application, mostly to bare farm fields, and rainfall that allows significant nitrogen to runoff to surface waters and leach into groundwater.
Credit: Minnesota State Climatology Office.

Conventional Strategies to Protect Groundwater Sources from Agricultural Nitrate Contamination

Agricultural nitrate contamination of drinking water from groundwater supplies can be corrected by: 1) removing nitrate from groundwater already contaminated; 2) installing infrastructure for new water supplies; 3) removing farmland from production, thereby eliminating the need for nitrogen fertilizer; or 4) change to farming methods that lower nitrate contamination of groundwater to acceptable levels. While the discussion here focuses on public water supplies, the science is the same for private wells. Unfortunately, the governmental programs and policies available for public water supplies seldom apply to private wells.

It is expensive to build and maintain infrastructure that removes nitrate from groundwater already contaminated or to access new water supplies. A study of public water supplies in Minnesota (Lewandowski et al, 2008) found that a new well can cost a community $75,000 to $500,000 (2006 dollars) which can double the cost of water to the customers. Moreover, a new well may face the same nitrate threats or may introduce new water quality problems associated with different aquifers. The same study found that nitrate treatment (removal) systems can quadruple the cost of water to the customers. Minnesota communities where the public water systems went above 10 mg/L nitrate have spent more than $3000 per household to fix the problem (see Appendix A). The community members bearing the costs for cleaning their water are not necessarily the same people who benefit from use of agricultural nitrogen. Furthermore, neither nitrate removal from water of an existing well nor drilling a new well protects groundwater supplies from ongoing contamination.

Ending or reducing contamination of the groundwater supply begins with management of land, vegetation, water, and potential contaminants. For some types of public water supplies, the federal Safe Drinking Water Act requires states to delineate WHPA. The surface of a WHPA is delineated to guide management of land, water, and potential contaminants that can impact the water supplied by that well (Figure 4). The shape of a WHPA is influenced by the configuration and properties of geologic strata (e.g., sand, gravel, clay, bedrock) and how they influence the direction and rate of groundwater flow.

In Minnesota, the typical WHPA map is based on a 10-year travel time; water and soluble contaminants will take approximately 10 years to travel from the surface at the outer edge of the WHPA to the well. The actual rate of flow can vary considerably with changes in precipitation, land management in the WHPA, surface water and groundwater management in and near the WHPA, including the rate of pumping water from the aquifer. To further guide management decisions, drinking water supply management areas (DWSMA) are delineated using major landmarks, roads, and property lines that are recognizable by land owners and natural resource managers. Figure 4 highlights croplands, because farming with annual crops in the WHPA is a major cause of nitrogen contamination of groundwater supplies. Land in WHPA is mainly in private ownership and frequently outside of the boundaries and regulatory authority of the community using the groundwater.

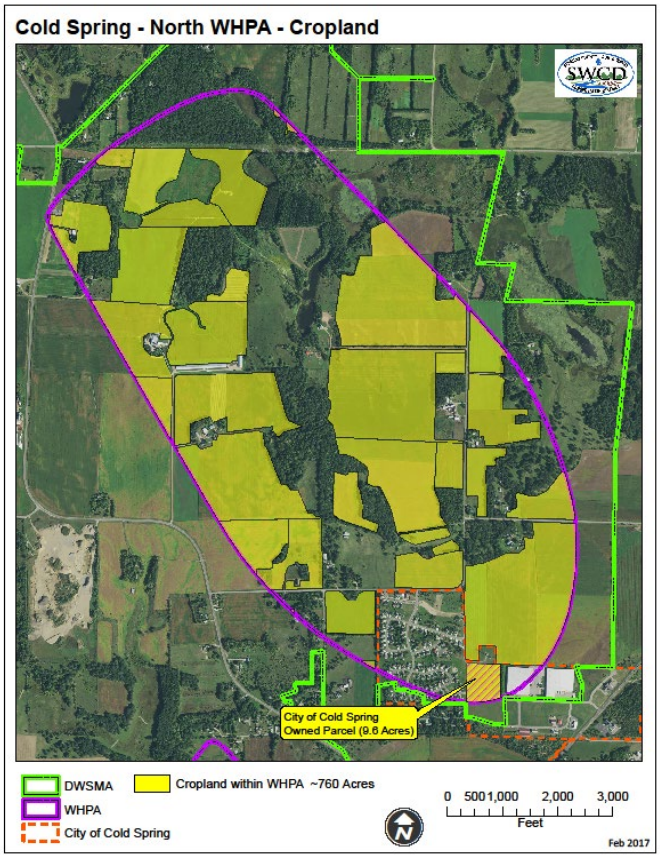

Figure 4. Map showing the Wellhead Protection Area (WHPA) and cropland within the WHPA for a well serving the City of Cold Spring, Minnesota.
Credit: Stearns County Soil and Water Conservation District.

Returning the cropland to prairie, wetlands, and forest would solve the problem by eliminating the application of nitrogen and other agrochemicals. Public water suppliers use a variety of programs that pay farmers to enroll farmland in the WHPA in the Conservation Reserve Program (CRP), management easements, or other set-aside programs that convert cropland to native vegetation. Unless the change is made permanent, when contracts end, farmers are free to return the land to production, with potential recontamination of groundwater. Some utilities have purchased cropland in their WHPA to permanently convert the land to native perennial vegetation or to direct farming choices to systems that minimize impacts to groundwater supplies. Cropland set-aside programs are expensive, with

the high costs on-going, potentially forever. Furthermore, taking farmland out of production reduces agricultural productivity, which negatively impacts jobs and businesses locally and along multiple value chains; and reduces the tax base at all levels of government.

Changing farming methods to reduce nitrate leaching to acceptable levels in groundwater place the burden of remediation primarily on farmers who create the pollution and the markets that benefit from the resulting crops. One approach is to continue growing the same annual crops (corn, soybean, wheat, beets, and others), but change how much nitrogen fertilizer is applied and when; reduce tillage; or add a winter cover crop; or a combination of these practices. Each of these practices has been shown to reduce nitrate leaching under some conditions. While government programs incentivize use of these practices, adoption by farmers is inconsistent, including in WHPA. Adoption of these practices has not yet been shown to control rising nitrate levels in vulnerable WHPA.

Using perennial farming systems to protect groundwater sources

An alternative way to protect groundwater supplies is to convert farmland from annual crops to perennial crops, pasture, and agroforestry systems. Relative to many annual crops, perennial farming systems nearly always require much less added synthetic nitrogen fertilizer and make better use of fertilizer that is applied, resulting in less contamination of groundwater. Soil nitrate levels were two-fold lower in fields with the perennial grain Kernza relative to maize even with high levels of fertilizers added to both crops (Jungers, et.al. 2019). Extensive root systems occupy the soil year-round, and extended plant growth into fall and beginning in early spring allow for efficient use of nutrients by perennial crops during these seasons, thereby minimizing leaching of nutrients to groundwater supplies. In addition to clean water, perennial farming systems provide other environmental benefits relative to annual crops, including improved soil health and reduced emissions of greenhouse gasses that contribute to climate change (Crews, et.al. 2018).

Keeping the land in production with perennial farming systems engages agricultural businesses in fixing the problem of nitrate in groundwater supplies. These crops, like other crops, require farm inputs and produce agricultural outputs, thereby supporting businesses, creating jobs, and generating taxes at the local, state, and federal levels. Subsidies may still be required, but perhaps at less cost to tax payers and water users than other groundwater protection strategies.

Perennial farming systems that can help resolve groundwater supply problems include the following.

- IWG / Kernza: The cool season grass intermediate wheatgrass (IWG) is a new dual-purpose perennial crop that provides the edible grain Kernza and high-quality forage. Figure 5 compares the environmental and economic inputs and impacts of an annual crop (corn) with IWG / Kernza. Approximately 120 acres of IWG/Kernza are planted in WHPA in Minnesota, where researchers from the University of Minnesota, Minnesota Department of Agriculture, and the water utilities are evaluating the crop's impact on groundwater.
    - Economic drivers: edible grain used in bread, pasta, beer, and much more; hay, livestock, meat, and dairy.

- Pastures and forage crops: Perennial grasses, legumes, and other forbs in pastures and hay fields. To prioritize protection of groundwater supplies, pastures and fields should be managed to maintain moderate above ground biomass and healthy root systems year-round. Care must be taken to follow regulations designed to protect wells from contamination from manure.
    - Economic drivers: forage and hay crops; livestock, meat, and dairy.

- Biomass and bioenergy crops: Switchgrass, Miscanthus, poplar, willows, and other fast growing perennial species that can be repeatedly harvested for plant biomass.
    - Economic drivers: biomass as fuel for energy production; emerging technologies may result in conversion of biomass to livestock feed, building materials, and other uses.

- Agroforestry: This is a diverse group of tree and shrub crops, including fruits, nuts, berries, syrup, and timber. Woody crops may be grown mixed with perennial grasses and forbs (alley cropping) and might include livestock (silvopasture).
    - Economic drivers: The economics of agroforestry are as diverse as the crops and management systems, including fruits, berries, nuts, wood, livestock, meat, and dairy.

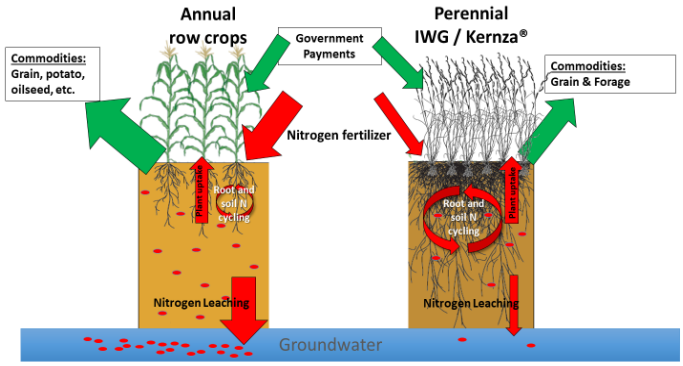

Figure 5. This graphic compares a conventional annual crop (left) with a perennial crop (right). Relative to most annual cropping systems, the perennial crop (intermediate wheatgrass IWG and the grain Kernza®) requires less added nitrogen fertilizer and makes better use of available nitrogen, resulting in less nitrogen leaching to groundwater. While the per area volume of production of grain and hay from the perennial crop is less than for the annual crop, input costs for the perennial crop are lower and the value of environmental benefits, including groundwater protection, are significant. Government subsidies are assumed to be the same for either crop. Credit: Dr. Jacob M. Jungers, University of Minnesota.

Federal policies and programs for protecting groundwater with perennial farming systems

Optimizing support for perennial farming systems that protect groundwater sources starts with understanding the policies, regulations, and agencies working to protect water supplies, and the opportunities for markets to support perennial farming solutions to agricultural contamination of groundwater sources. This section describes how federal policies and programs can optimize support for perennial cropping systems to protect groundwater sources from contamination with nitrate and other agro-chemicals.

As authorized by the Safe Drinking Water Act (SDWA) of 1974 and amendments, the US Environmental Protection Agency (EPA) sets water quality standards for public drinking water and works with states to implement drinking water protection programs. As defined by the EPA, a public water system must serve at least 15 connections or 25 people for at least 60 days of the year. The EPA distinguishes between Community Water Systems that serve the same users year-round (e.g., most cities, towns, mobile home parks), and Non-Community Water Systems that are either Non-Transient (serve the same people, but not all year: e.g., school and churches with their own wells) or are Transient (serve different people through the year; e.g., campgrounds, rest stops). Regulations and government services are different for these sorts of public water systems. The SDWA does not cover private wells.

The EPA oversees the Drinking Water State Revolving Fund (DWSRF) program that provides financial assistance to state water management agencies that, in turn, support water utilities to improve infrastructure and management of public water systems. The EPA provides grants to states and states provide a 20% match to capitalize the DWSRF. States are responsible for management of their DWSRF. These are "revolving funds," where loan repayments are returned to the fund and used to support subsequent loans. Loans from the DWSRF can have low-interest rates or be interest-free to small utilities (less than 10,000 users) and disadvantaged water suppliers and may be further subsidized with grants. Other forms of financial support (e.g., loan guarantees, refinancing) are also possible with the DWSRF. States use set-asides (money taken from the fund) to cover costs of managing the DWSRF and providing technical assistance to water utilities, and for special programs. The fund supports infrastructure improvements, including equipment for treatment (removal) of nitrate. DWSRF loans can also be used to improve the water source, including purchase of land or land rights in a WHPA. With the right loan terms, grant subsidies, and profits from sale of perennial crop harvests and pasture leases, the DWSRF can, in theory, support conversion of farmland in the WHPA from annual crops to perennial crops.

In our region, state agencies responsible for ensuring compliance with the federal regulations for safe drinking water and administration of DWSRF are:

- Illinois Environmental Protection Agency
- Iowa Department of Natural Resource
- Minnesota Department of Health
- Missouri Department of Natural Resources
- Wisconsin Department of Natural Resources

Tribes may have a public water authority independent of the state authority. In Minnesota, the Mille Lacs Band of Ojibwe has requested regulatory authority under the federal SDWA.

Two programs from the federal Farm Bill have potential to support perennial farming in WHPA. The Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP) are US Department of Agriculture - Natural Resources Conservation Service (NRCS) programs that improve water quality, soil health, and address many other agricultural resource concerns. There is significant potential to protect groundwater supplies, if more of these funds are invested in perennial farming systems over WHPA. Appendices B (EQIP) and C (CSP) list

the practices and enhancements that do or can potentially support perennial farming systems over WHPA.

Minnesota policies and programs for groundwater source protection with perennial farming systems

About 80% of Minnesotans receive their drinking water from public water systems, mostly from groundwater sources. There are about 6700 public water suppliers in Minnesota, including 968 community water suppliers (Minnesota Department of Health, 2017).

Minnesota, "Land of 10,000 Lakes," has a deep commitment to water, including the quality and quantity of groundwater sources of drinking water. In 2017, with leadership from Governor Dayton, Minnesota launched an ambitious program to improve water quality by 25% by 2025. The 25x25 program description begins with drinking water and the problem of source water contamination with nitrate (Minnesota Pollution Control Agency, 2017). The 25x25 regional information package for West Central Minnesota states: "Living cover is a key strategy for protecting drinking water, especially within lands surrounding a public water supply well, to keep contaminants from reaching the well or well field. Living cover holds water, filters contaminants, and reduces runoff." That report and equivalent reports for other regions of the state give examples of perennial crops and pastures as strategies for preventing nitrate contamination of drinking water supplies, including groundwater sources.

The major state policies and regulatory and implementation programs supporting water quality are summarized below, highlighting how these programs do or could support use of perennial farming systems to protect groundwater resources from agricultural nitrate contamination.

Roughly 115,000 to 120,000 acres of annual crops are grown in vulnerable WHPA each year in Minnesota (Steve Robertson, pers. comm., 2018). That is less than 0.5% of approximately 25,000,000 acres farmed in the state and less than 1% of more than 17,000,000 acres in annual crops planted in recent years (USDA, 2018). While that is not a lot of farmland on a statewide scale, the impact to individual farmers with land in vulnerable WHPA can be significant.

Minnesota Statutes, Chapter 103H: Groundwater Protection describes the responsibilities and authorities of Minnesota state agencies to protect groundwater resources, including the designation of sensitive areas for protecting groundwater, and use of easements and other tools for managing land, water, and contaminants to protect groundwater supplies. State statute also describes the responsibilities, liabilities, and protections of landowners in designated sensitive areas. Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Agriculture (MDA) have considerable authority under these statutes. Minnesota Statutes, Chapter 103H, Section 275, state that, "The Pollution Control Agency, or for agricultural chemicals and practices, the commissioner of agriculture shall adopt by rule water resource protection requirements that are consistent with the goals of section 103H.001 to prevent and minimize pollution to the extent practicable." MPCA is charged with protection of groundwater from non-agriculture contaminants and from contamination with nitrate from manure. MPCA is also the state authority for protecting surface water from contamination from synthetic fertilizers and manure. MDA is the state authority for protecting groundwater from agricultural chemicals, including nitrate from synthetic fertilizer.

Under Minnesota Statute 103H, the Board of Water and Soil Resources (BWSR) is charged with overseeing and supporting water management plans, in collaboration with local soil and water conservation districts. The statue also charges the Department of Natural Resources (DNR) with identifying sensitive groundwater areas and notifying other agencies and the public where the sensitive areas are located and the types of risks to groundwater in these areas.

Minnesota state agencies use a variety funding sources to provide technical and financial assistance to protect groundwater source for drinking water, including General Fund allocations, the Minnesota Clean Water Fund, and the federal allocations to the DWSRF. Local governments, non-profits, foundations, corporations, and associations provide additional technical and financial support to these programs.

The Minnesota Clean Water Fund is the principal channel for new groundwater protection funding in the state. The Fund receives 33% of the revenue generated by the Clean Water, Land and Legacy Amendment, which was approved in 2008 to provide 25 years of dedicated funding by increasing state sales and use tax by three-eighths of one percent. The Clean Water Fund allocated $228 million in 2016-2017. At least 5% of Clean Water Fund must be directed to protection of drinking water sources.

The Minnesota Board of Water and Soil Resources (BWSR) is the state's administrative agency for soil and water conservation districts (SWCDs), watershed districts, and county water managers. They direct much of the water planning in Minnesota and provide technical and financial support for implementing those plans. The following BWSR programs support groundwater protection.

- Under the Comprehensive Local Water Management Act (Minnesota Statutes 103B.301 to 355) BWSR provides grants and technical assistance for county-scale water management plans, which include protection of groundwater resources. There are opportunities to include in the plans strategies to use perennial farming systems for groundwater protection and targeting that protection to vulnerable WHPA.

- One Watershed One Plan is a BWSR managed Clean Water Fund program that is ramping up across the state. Groundwater resources are included in these plans. There are opportunities to include perennial farming in these watershed plans as a strategy for protecting groundwater resources.

- BWSR Clean Water Fund grants provide support for implementing county water management plans and other water protection activities. For example, Rock and Pipestone County SWCDs received grants in 2017 to protect vulnerable WHPA from nitrogen contamination by, in part, replacing row crops with the perennial crop Kernza. There are opportunities for other local programs to use BWSR Clean Water Fund grants to support use of perennial farming systems to protect vulnerable WHPA.

- The Erosion Control and Water Management Program, also call the State Cost-Share Program, provides grants to local offices to cost-share with land occupier to implement conservation practices that address priority soil erosion or water quality as established by BWSR. Groundwater quality is one of the priorities for this program. There are opportunities to use Cost-Share Program funding to implement perennial farming practices in vulnerable WHPA.

- The annual BWSR Academy provides opportunities to train federal, state, county, and private sector personnel in the use of perennial farming systems for protecting groundwater sources.

The Minnesota Department of Agriculture (MDA) is charged under the state statutes for groundwater protection with protecting groundwater in sensitive areas from contamination from agricultural chemicals and practices. The following MDA programs support groundwater protection.

- The Nitrogen Fertilizer Management Plan (NFMP) is the state's plan to protect groundwater supplies from agricultural nitrogen fertilizer contamination (Minnesota Department of Agriculture, 2015). The plan focuses on fertilizer use and the 4 Rs of fertilizer management: use the Right kind of fertilizer, in the Right place, in the Right amount, at the Right time. Implementation of the plan is based on Best Management Practices recommended by the University of Minnesota Extension (UMN Extension: https://www.extension.umn.edu/agriculture/nutrient-management/nitrogen/). Following the NFMP, MDA has proposed a groundwater protection rule that has been approved by an Administrative Law Judge and is proposed to become effective January 1, 2020, even though the formal adoption process will not happen until after the 2019 legislative session. The rule includes perennial crops among the "alternative management tools" for regulatory use when public wells reach 9 mg/L of nitrate or are predicted to surpass 10 mg/L in the next decade. There is an opportunity to expand the description of perennial farming practices in the implementation guidelines for MDA's groundwater protection rule.

- The Agricultural Water Quality Certification Program had $5 million Clean Water Funds for FY 18-19 and other resources to support voluntary conservation measures where the whole farm participates in the program (Minnesota Department of Agriculture, 2018). There may be opportunities for farmers with cropland in vulnerable WHPA to enroll in the certification program and use grant money to help implement perennial cropping systems to protect groundwater resources.

- Vegetative Cover and Soil Health: $150,000 Clean Water Funds FY 18-19 to evaluate market-driven viability of crops that provide vegetative cover. There may be opportunities to include perennial crops in this program.

- Technical assistance and on-farm demonstrations were awarded $2.25 million FY 18-19 Clean Water Funds to support five long-term projects, including evaluating the effectiveness of Best Management Practices (Minnesota Department of Agriculture,

2018). There may be opportunities to test and evaluate the effectiveness of perennial farming systems on groundwater resources in several of these projects.

- The Clean Water fund supports the partnerships that promote groundwater nitrogen monitoring and reduction activities, primarily through education and outreach to farmers and farm advisors. The program reaches farmers on a regional scale; it does not target WHPA. A component of this program supports nutrient management BMP (the 4 Rs) outreach in the southeastern part of the state in collaboration with UMN Extension. A parallel program could be created to support perennial farming education and outreach in parts of the state with high risk to groundwater and where perennial farming is likely to improve quality of groundwater.

- A Social Measures Monitoring System is being piloted as part of the Clean Water Fund. The program conducts surveys, provides training, and does follow-up monitoring of the capacity of individuals and local advisory teams. The program was initiated with a focus around the Nitrogen Fertilizer Management Plan and implementation. In 2014, the program was expanded to include Soil Water Conservation District staff members understanding of local groundwater quality and quantity issues; training from DNR and UMN Extension; and ongoing monitoring. There is an opportunity to further expand this social monitoring program to include team members supporting perennial farming solutions to groundwater quality.

- Agricultural Research and Evaluation were granted $1.325 million Clean Water Funds in FY 18-19 (Minnesota Department of Agriculture, 2018). This program has funded 35 projects since 2008. These funds are awarded through a competitive request for proposals. There are opportunities to expand research on the environmental and economic benefits of perennial farming systems planted in WHPA to protect groundwater resources.

- Forever Green Initiative at the University of Minnesota was awarded $1.5 million Clean Water Funds FY 18-19 for this long-term program that is developing new perennial crops and evaluating their environmental and economic impacts (Minnesota Department of Agriculture, 2018). Perennial crops being developed and tested include Kernza, hazelnuts, and a perennial relative of sunflowers. The Forever Green Program receives additional funding from federal research grants, foundations, and corporations. There are opportunities to expand research on these new crops to specifically evaluate the potential for new perennial crops to protect groundwater resources in vulnerable WHPA and to understand the economics of perennial farming systems in the context of source water protection.

The Minnesota Department of Health (MDH) is the state authority for ensuring safe and adequate drinking water supplies. The following MDH programs support groundwater protection.

- Developing plans for WHPA: Supported by the DWSRF, with EPA and MN Clean Water Funds, by 2020, source water protection plans will be developed for all vulnerable community and some non-community, non-transient systems that use groundwater. As of 2017, plans were developed for 331 of 590 vulnerable systems. These plans, with their periodic amendments, delineate the WHPA, assess vulnerabilities, and identify actions to reduce risks to these systems. There is an opportunity to incorporate perennial farming recommendations for communities where the combinations of agriculture practices and hydrogeology make it likely that perennial crops are a viable method to protect groundwater resources from agricultural nitrate.

- MDH grants for source water protection: From 2010 through 2017, MDH used Clean Water Fund to make more than 1,000 source water protection action grants, totaling $4.1 million. There are three types of grants: Plan Implementation grants for implementation of approved wellhead protection plans; Competitive grants for source water protection in communities and non-transient systems, regardless having an approved wellhead protection plan; and Transient grants for protecting source water in transient systems. The annual ceiling is $10,000 and the latter two grant types require 1:1 matching funds. These grants support diverse source water protection programs,

including education, analysis, monitoring, planting of cover crops (winter annuals) in WHPA, sealing old wells and new infrastructure, and treatment, including nitrate removal systems. There are opportunities to fund conversion of cropland from annuals to perennial systems, particularly if that strategy is included in the wellhead protection plan.

- MDH provides technical management for the MN DWSRF - approximately $38 million available in 2018. The fund provides low cost, long-term loans for communities and other public water providers for drinking water infrastructure projects. The two highest ranked projects for this fund in 2018 were for nitrate treatment. There may be opportunities to use these loan funds to more economically address the same nitrate problem through purchase or permanent easements of croplands in vulnerable WHPA, converting the land to perennial farming systems, with revenue from the harvested crops applied toward loan repayment.

- MDH is testing source water quality of community water systems. The Safe Drinking Water Act only requires testing of community water after it is treated; there is no federal requirement to test source water prior to treatment. Between 2010 and 2014 MDH tested for 25 contaminants, including nitrate, in source water of 919 community water systems and 23 surface water systems. These data provide a baseline for source water quality for more than 2300 community water system wells; many community systems mix water from multiple wells and some also include surface water.

USDA NRCS in Minnesota obligated more than $29,000,000 and $84,000,000 from EQIP and CSP, respectively, in 2017. There is an opportunity to work with NRCS Minnesota to increase use of these programs for source water protection. NRCS Minnesota recently added IWG/Kernza planted in pure stands to three practice standards typically used in buffers to protect surface water; these changes were made, in part, to support farmers working to comply with Minnesota's new buffer law. A similar approach could be made to revision of practice standards to expand EQIP and CSP opportunities with Kernza and other perennial systems for farmers working to protect groundwater sources in WHPA. The revised practice standards might also be highlighted in future editions of the NRCS Minnesota brochure that describes EQIP practices for protecting groundwater, "Cropland Conservation Practices for Protecting Groundwater."

Figure 6 summarizes the major government and university programs that support perennial farming for source water protection in Minnesota.

Figure 6. Government programs supporting perennial farming in WHPA in Minnesota.

Program / Fund	Lead Agency
Planning	
One Watershed One Plan	BWSR
County Water Plans	BWSR
WHPA Plans	MDH
Farm-scale conservation planning	NRCS
Farm Plans (AWQC)	MDA
Implementation	
EQIP and CSP funding to farmers	NRCS
Clean Water Fund grants to local agencies	BWSR
State Cost-Share Program for contracts with farmers	BWSR
CWF Source Water Protection Grants	MDH
DWSRF loans and grants	MDH
Research	
Forever Green	MDA
Ag research & evaluation	MDA
On-farm demonstrations	MDA
Federal research grants	USDA/NIFA and others

Market support for source water protection with perennial farming systems – Kernza® example

Ongoing development of the perennial edible grain Kernza illustrates the challenges and opportunities for government agencies, businesses, and researchers supporting use of perennial farming systems to protect source water. While development of Kernza as a crop is still in early stages, extraordinary progress is being made by plant breeders, agronomists, and food scientists (DeHaan & Ismail, 2017) and interest is growing among food and beverage businesses using the grain. The Land Institute in Salina, Kansas leads the international team developing Kernza as the first commercial, perennial grain crop, and they hold the trademark for Kernza. The Land Institute has engaged a global network of over 100 researchers supporting development of Kernza as a crop and businesses developing Kernza products. The University of Minnesota, primarily under the Forever Green Initiative, has been a principal partner in developing Kernza, documenting the environmental impacts of farming with Kernza, and promoting markets for the grain. Green Lands Blue Waters, with offices in the Minnesota Institute for Sustainable

Agriculture, is coordinating the development of a Kernza Growers' Guide (available soon at http://greenlandsbluewaters.org and http://kernza.org) and has helped develop Kernza markets, particularly in Minnesota. Scores of other universities and government laboratories across the U.S. are part of the Kernza research and development team. Outside the U.S., significant research programs with advanced breeding populations of Kernza are ongoing in Canada, Australia, Sweden, and France (Jungers et al., 2019).

Corporate sustainability goals are providing important incentives for increasing Kernza acreage in competition with conventional annual crops, which have higher yields and are often subsidized by government programs that reduce risk to farmers. Patagonia Provisions cites their commitment to regenerative agriculture, healthy soil, water conservation, and carbon sequestration for their investments in Kernza. In addition to supporting Kernza research, Patagonia Provisions contracted farmers for the first commercial-scale acreage of Kernza and released the first commercial Kernza product, Long Root Ale, produced in partnership with Hopworks Urban Brewery of Portland, Oregon. General Mills cites their commitment to reduce greenhouse gas emissions among their reasons for funding Kernza research. They too have invested in commercial-scale Kernza farming and the General Mills brand Cascadian Farms has a limited-release organic Kernza cereal product as of Spring 2019. Likewise, retailer Askov Finlayson is investing in Kernza to address global warming. Their Kernza ale called "Keep the North Cold" is produced in Minnesota by Fair State Brewing Company.

Minnesota has become a hub for small businesses using Kernza. The Birchwood Cafe in Minneapolis has had Kernza on their menu since 2013. Kernza is a great fit for the social and environmental goals of the Cafe's owner, staff, suppliers, and customers. Examples of other Kernza products produced by Minnesota businesses include an ale produced by Bang Brewing, noodles produced by Dumpling and Strand, and whole grain Kernza tabouli served from the Foxy Falafel food truck. Kernza regularly appeared on the menu of The Perennial restaurant in San Francisco (now closed) and has been served at Bien Cuit in New York City and in dozens of other restaurants, breweries, and pubs across the country.

The Forever Green Initiative, Green Lands Blue Waters, Minnesota Rural Water Association, state and local agencies, and local water utilities are organizing collaborative efforts to use Kernza and other perennial crops for groundwater protection of drinking water supplies in Minnesota. Kernza was planted on two vulnerable WHPA in 2017 and expanded to three more in 2018, totaling about 120 acres across five WHPA. A Fact Sheet and two Case Studies will soon be available on http://greenlandsbluewaters.org. These WHPA range in size from roughly 800 acres to several thousand acres, and so, far less than 10% of the farmland in any WHPA has been converted to Kernza. While researchers are documenting reductions in the concentration of nitrate in soil and groundwater directly below Kernza fields (Jungers, et al. 2019), more than these few fields of cropland in a WHPA must be converted to Kernza and other perennial farming systems to remedy the problem of nitrate in source water.

Conclusions and recommendations

Over the past three decades, much of the discussion about agriculture and water quality in the U.S. Upper Midwest has focused on surface water, including how cumulative impacts of agricultural contaminants are causing the hypoxic zone - The Dead Zone - in the Gulf of Mexico (Rabotyagov et al. 2014). Unfortunately, agricultural solutions to surface water problems require land use transformation over many thousands, or tens of thousands, or millions of acres of farmland and the results might not be evident for decades. By contrast, a community's drinking water supplied from groundwater that is contaminated by agricultural nitrate might be made healthy by changing farm systems over 1,000 acres or less, with the results evident in five or ten years. While farmers are hard-pressed to take on new financial risks to adopt experimental farming systems, they may be more motivated to help ensure clean drinking water in the communities where they and their children and grandchildren live and attend schools and churches served by the community water system.

The challenge – and opportunity - is to build coalitions of farmers, community leaders, businesses, government agencies, and researchers working together in vulnerable WHPA to convert annual cropland to perennial farming systems at a scale that will eliminate agricultural nitrate contamination of the communities' water supplies. Implementing the following four strategies can expand long-term use of perennial farming systems in WHPA, reduce agricultural nitrate pollution of the communities' sources of water, and document the resulting environmental and economic benefits.

1) Include perennial farming solutions in source water management plans: Including perennial farming systems among the solutions in the county-scale water plans, WHPA plans, and plans for individual farms in WHPA will increase the likelihood that perennial farming will be adopted to protect groundwater sources. Changes to funding program guidelines may be needed, specifically including the addition of perennial farming solutions among the ranking criteria used for selecting planned actions.

2) Increase investments for perennial farming solutions in WHPA: Administer government programs described above for increased funding of perennial farming in WHPA. While government support will reduce farmers' risk, the key to long-term success will be more companies buying greater volumes of products harvested from perennial farming systems. Markets for the harvested crops are the single most essential investment for getting farmers to switch to new, unfamiliar crops. For new perennial crops, farmers need contractual commitments for purchase of two or more years of future harvests. Farmers also need technical advice about how to plant and manage new perennial crops, including harvest and post-harvest storage of grain, nuts, berries, etc. Financial assistance may also be needed for farmers and local businesses to acquire or rent specialized equipment for harvesting, cleaning, storage and otherwise preparing harvested perennial crops for market, at least until the volume of acres planted and harvested justifies greater private sector investments.

3) Concentrate acreage of perennial farming in a few WHPA to demonstrate the reduction of nitrate in drinking water supplies: Picture residents of a small town standing in front of their freshly painted water tower, all smiling and holding up glasses of clean drinking water, crediting the company and agencies that supported the successful transition to Kernza fields in their WHPA. The location of the next few thousand acres planted to Kernza and other perennial crops might be left to chance, thereby having little impact on water quality, or those acres could be directed to a few WHPA where their collective benefits can restore clean drinking water for a few communities. Such demonstration projects should target WHPA where: a) contamination with agricultural nitrate is a problem; b) hydrogeology suggests that source water nitrate will be measurably reduced by transforming < 1,000 acres of farmland from annual to perennial crops; and c) the farmers, community and water utility endorse a WHPA plan to transform most of the cropland to perennial farming systems. Businesses large and small can measurably contribute to their sustainability goals by guaranteeing markets and prices for harvests resulting from perennial crops that result in clean water from participating communities. Likewise, government agencies can incentivize and complement private sector investments that result in communities enjoying clean water at a reasonable cost.

4) Increase funding for development of perennial crops and to improve understanding of the environmental and economic impacts of perennial farming systems in WHPA: Increase support to develop improved varieties of perennial crops, learn how to grow them, and demonstrate their use in food and industry. Expand research on the impacts of perennial crops on soils, water, and climate, and on the economic impacts on farms and businesses. Long-term research should track the impacts resulting from perennial and annual crop rotations that are likely to occur on WHPA.

Other states in the U.S. Upper Midwest, elsewhere in the U.S., and other countries have similar opportunities to use perennial farming systems to protect groundwater sources in WHPA from nitrate and other agrochemicals.

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Appendix A - Minnesota community water systems' remediation actions and cost for exceedance of Nitrate Maximum Contaminant Level, 2011 through 2017. (Adopted from Minnesota Department of Health, 2018; Table 1)

Community Public Water Supply	Population (2016)	Past and Potential Future Actions	Estimated Capital Cost per Household (2016 dollars)
Adrian	1211	Wells sealed and treatment plant built.	$3,400
Brookhaven Development, Scott County	45	Potential future new well.	$3,400
Chandler	270	Future hookup to LPRWS (see below).	Unknown
Clear Lake	525	Treatment plant to be replaced.	$7,900
Cold Spring	4,053	Potential new wells.	$1,100
Edgerton	1,171	Treatment plant built.	$3,500
Ellsworth	456	Well sealed and treatment plant built.	$3,600
Hastings	22,335	Treatment plant built.	$430
Leota	209	Interconnect to LPRWS (see below) installed.	Unknown
Lincoln-Pipestone Rural Water System (LPRWS)	13,010	Potential blending wells and treatment plant improvements.	$180
Park Rapids	3,808	Wells sealed, new well constructed, and treatment plant built.	$3,100
Randall	650	Future potential treatment plant.	$7,400
Rock County Rural Water System	2,256	Transmission main built to blend wells.	$46
Saint Peter	11,758	Treatment plant built.	$1,700
Sundsruds Court, Wadena County	40	Treatment installed.	$450

Appendix B - EQIP conservation practices as of 2017 that can support perennial farming in vulnerable WHPA in the Upper Midwest. * = practices approved by NRCS MN to include Kernza.

Practice Number	Practice Name	CLC strategies			
		Forage	Biomass	Perennial Grains	Agro-forestry
311	Alley Cropping	X	X	X	X
327	Conservation Cover				X
328	Conservation Crop Rotation	X	X	X	
332*	Contour Buffer Strips	X	X	X	
331	Contour Orchard & Other Perennial Crops	X	X	X	X
342	Critical Area Planting	X	X	X	X
512	Forage and Biomass Planting	X	X	X	
511	Forage Harvest Management	X	X	X	
422	Hedgerow Planting				X
595	Integrated Pest Management	X	X	X	X
379	Multi-Story Cropping		X	X	X
528	Prescribed Grazing	X		X	
550	Range Planting	X		X	
391	Riparian Forest Buffer				X
390	Riparian Herbaceous Cover	X	X	X	
381	Silvopasture Establishment	X		X	X
612	Tree & Shrub Establishment	X	X		X
490	Tree & Shrub Site Preparation			X	X
645	Upland Wildlife Habitat Management	X		X	X

Appendix C - CSP enhancements as of FY2018 that can support perennial farming in vulnerable WHPA in the Upper Midwest.

Activity Code	Enhancement Name	CLC Strategies			
		Forage	Biomass	Perennial Grains	Agro-forestry
E381133Z	Silvopasture for wildlife habitat (structure and composition) Conservation Practice 381: Silvopasture Establishment	X	X	X	X
E381137Z	Silvopasture for wildlife habitat (cover and shelter) Conservation Practice 381: Silvopasture Establishment	X	X	X	X
E390118Z	Increase riparian herbaceous cover width for nutrient reduction Conservation Practice 390: Riparian Herbaceous Cover	X	X	X	
E391118Z	Increase riparian forest buffer width for nutrient reduction Conservation Practice 391: Riparian Forest Buffer	X	X	X	X
E391126Z	Increase riparian forest buffer width to reduce sediment loading Conservation Practice 391: Riparian Forest Buffer	X	X	X	X
E391136Z	Increase riparian forest buffer width to enhance wildlife habitat Conservation Practice 391: Riparian Forest Buffer	X	X	X	X
E393118Z	Extend existing filter strip to reduce excess nutrients in surface water. Conservation Practice 393: Filter Strip	X	X	X	
E393122Z	Extend filter strip to reduce excess pathogens and chemicals in surface water. Conservation Practice 393: Filter Strip	X	X	X	
E393126Z	Extend existing filter strip to reduce excess sediment in surface water. Conservation Practice 393: Filter Strip	X	X	X	
E511137Z2	Forage harvest management that helps maintain or improve wildlife habitat (cover and shelter) Conservation Practice 511: Forage Harvest Management	X	X	X	
E511139Z2	Forage harvest management that helps maintain wildlife habitat continuity (space) Conservation Practice 511: Forage Harvest Management	X	X	X	
E512101Z1	Cropland conversion to grass-based agriculture to reduce water erosion Conservation Practice 512 - Conservation Forage and Biomass Planting	X	X	X	

E512101Z2	Forage and biomass planting for water erosion control to improve soil health Conservation Practice 512: Forage and Biomass Planting	X	X	X	
E512132Z1	Forage and biomass planting that produces feedstock for biofuels or energy production Conservation Practice 512: Forage and Biomass Planting	X	X	X	
E512139Z1	Establish wildlife corridors to provide habitat continuity Conservation Practice 512: Forage and Biomass Planting	X	X	X	X
E528132Z2	Stockpiling cool season forage to improve plant productivity and health Conservation Practice 528: Prescribed Grazing	X		X	
E528133Z1	Stockpiling cool season forage to improve structure and composition Conservation Practice 528: Prescribed Grazing	X		X	
E528133Z2	Grazing management for improving quantity and quality of plant structure and composition for wildlife Conservation Practice 528: Prescribed Grazing	X			
E528140Z1	Maintaining quantity and quality of forage for animal health and productivity Conservation Practice 528: Prescribed Grazing	X		X	
E550106Z	Range planting for increasing/maintaining organic matter Conservation Practice 550: Range Planting	X	X	X	X
E612126Z	Cropland conversion to trees or shrubs for long term improvement of water quality Conservation Practice 612: Trees/shrub Establishment				X
E612130Z	Planting for high carbon sequestration rate Conservation Practice 612: Tree/Shrub Establishment				X
E612133X2	Cultural plantings. Conservation Practice 612: Tree/Shrub Establishment				X
E612133X3	Sugarbush Management. Conservation Practice 612: Tree/Shrub Establishment				X
E612133X1	Adding food-producing trees and shrubs to existing agroforestry plantings Conservation Practice 612: Tree/Shrub Establishment				X