Chris Steller

From: Haga, Celi (BWSR) <celi.haga@state.mn.us>
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To: Chris Steller
Subject: Working Lands Watershed Restoration Program Interim Report to the Legislature
Attachments: Final Working Lands Interim Report 10-15-17.pdf

The Minnesota Board of Water and Soil Resources (BWSR) is pleased to deliver an electronic copy of its Working Lands Watershed Restoration Program Interim Report to the Legislature, as required by Laws of Minnesota 2016, Chapter 189, Article 3. Two hard copies are in the mail.

Please don't hesitate to contact me if you would like additional information.

Best,

Celi

Celi Haga | Legislative Coordinator
Minnesota Board of Water and Soil Resources (BWSR)
123 520 Lafayette Road North
Saint Paul, MN 55155
C: 651-315-5082
Web | Twitter | Facebook

BOARD OF WATER AND SOIL RESOURCES

Working Lands Watershed Restoration Program

Interim Report to the Minnesota Legislature
October 15, 2017

Prepared by:

- Suzanne Rhees, Conservation Projects Coordinator, Minnesota Board of Water and Soil Resources, St. Paul
- David Weirens, Assistant Director for Programs and Policy, Minnesota Board of Water and Soil Resources, St. Paul

Consultants

- University of Minnesota Water Resources Center: Dr. Jeffrey Peterson, Ann Lewandowski, Dr. William Lazarus, Dr. Amit Pradhananga
- Environmental Initiative: Greg Bohrer, Meleah Houseknecht, Erin Neihoff

Agency Consultants

- Minnesota Pollution Control Agency: Chuck Regan, Ted Fuller, Water Quality Modeling

Stakeholder and Interagency Advisory Group

- Amanda Bilek, Minnesota Corn Growers Association
- Tanner Bruse, Pheaseants Forever
- Whitney Clark, Trevor Russell, Friends of the Mississippi River
- Jason Garms, Greg Hoch, Minnesota Department of Natural Resources
- Scott Hanson, Minnesota Rural Water Association
- Brendan Jordan, Great Plains Institute
- Nicholas Jordan, Forever Green Initiative, University of Minnesota
- Ashley Kohls, Minnesota Cattlemen's Association
- Rod Larkins, Agricultural Utilization Resource Institute
- Terri McDill, Minnesota Pollution Control Agency
- Michelle Medina, Minnesota Farmers' Union
- Steve Morse, Minnesota Environmental Partnership
- Bob Patton, Bill Fitzgerald, Minnesota Department of Agriculture
- Cole Rupprecht, Minnesota Farm Bureau
- Shawn Schottler, St. Croix Research Station, Science Museum of Minnesota
- Carissa Slotterback, University of Minnesota Humphrey Institute
- Joe Smentek, Minnesota Soybean Growers
- Karen Voz, Minnesota Department of Health
- John Voz, Minnesota Board of Water and Soil Resources

The estimated cost of preparing this report (as required by Minn. Stat. 3.197) was $2,480.

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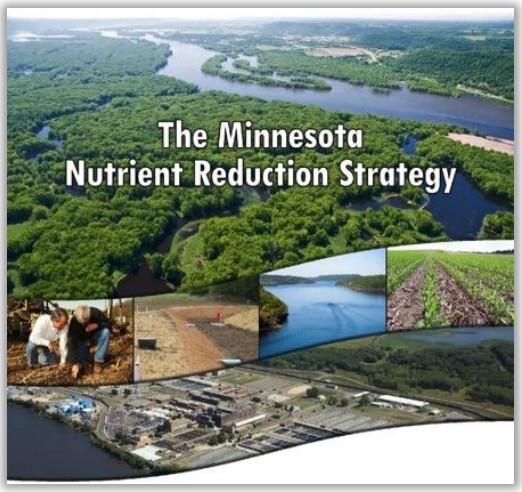
I. Introduction



Minnesota has made a significant commitment to clean water and habitat through the Clean Water, Land and Legacy Amendment and decades of investment in conservation programs. While the quality of Minnesota's lakes, rivers, streams, and groundwater is improving, the pace of progress is not as fast as hoped. The Minnesota Nutrient Reduction Strategy and numerous other studies show that excess phosphorous, nitrogen, and sediment are impairing water quality. Runoff from agricultural and urban land and lakeshore development raises the amount of phosphorus in Minnesota lakes, which in turn causes algae to grow. Nitrate pollution from septic systems, fertilizers, and manure threatens public and private water supplies.

Changes in agricultural practices have resulted in conversion of small grains and hay, once common parts of the farming system, to corn and soybeans, and subsurface tiling has altered hydrologic systems. Both corn and soybeans leave farmland essentially bare for much of the year, making it vulnerable to wind and water erosion and nutrient leaching. The timing and intensity of precipitation are changing, increasing the risks of destructive flooding and soil loss. In spite of improvements in agricultural practices, such as conservation tillage, improved manure and nutrient management, and land set-aside programs, water quality is increasingly threatened by these forces.

There is growing recognition among conservation professionals, researchers, farmers and other engaged citizens that in order to increase the pace of progress on water quality, more vegetation is needed on the land for longer periods of time. But is it possible to increase this 'conservation footprint' on the landscape without taking additional land out of production?

One possible solution, discussed for over a decade, is to increase production of perennial crops as energy feedstocks for multiple uses, including advanced biofuels that could supplement or replace ethanol. In 2015 and 2016, a coalition of renewable energy, environmental and agricultural organizations promoted a bill that would incentivize planting of perennial crops to improve water quality, and in 2016 the Minnesota Legislature directed the Board of Water and Soil Resources (BWSR) to prepare a plan and feasibility study for a Working Lands Watershed Restoration Program. Table 1 lists the elements of the legislation and the progress made by BWSR and partners to date.

Table 1. Summary of Working Lands Legislation and Project Activities

Elements of the Legislation	Project Activities
Develop a detailed plan to implement a working lands watershed restoration program to incentivize the establishment and maintenance of perennial crops, including:	Detailed below
• a process for selecting **pilot watersheds** that are expected to result in the greatest water quality improvements and exhibit readiness to participate in the program;	Six major watersheds selected for study based on defined criteria; minor watersheds within each major watersheds selected for more detailed modeling based on local partner recommendations.
• an assessment of the **quantity of agricultural land** that is expected to be eligible for the program in each watershed;	Being assessed in terms of predominant crops and soil productivity, with a focus on identifying lands less suitable for row crop production.
• an assessment of **landowner interest** in participating in the program;	Being assessed through landowner surveys as well as selected meetings with local partners.
• an assessment of the **contract terms** and any recommendations for changes to the terms, including consideration of variable payment rates for lands of different priority or type;	Being assessed through development of a spreadsheet tool that generates comparisons of farm income and expenses of current annual row crop systems compared to alternative crops, for different locations within each watershed that vary by soil productivity.
• an assessment of the opportunity to **leverage federal funds** through the program and recommendations on how to maximize the use of federal funds for assistance to establish perennial crops;	Being assessed through discussions with federal agricultural agencies and evaluation of federal farm bill programs. Additional outreach in late 2017 will focus on agency and stakeholder farm bill priorities.
• an assessment of how **other state programs** could complement the program;	Being assessed through discussions with state agencies that manage easement programs, incentive programs, cost-share programs, and wildlife habitat management programs.
• an estimate of **water quality improvements** expected to result from implementation in pilot watersheds;	To be determined through modeling of water quality impacts of land use/land cover changes in selected watersheds.
• an assessment of how to best integrate program implementation with **existing conservation requirements** and develop recommendations on harvest practices and timing to benefit **wildlife production**;	Being assessed through discussions with state wildlife and biomass managers.
• an assessment of the potential viability and water quality benefit of **cover crops** used in biomass processing facilities;	Due to the growing level of interest among producers and potential end users, cover crops have been integrated into the suite of potential alternative crops being assessed. There is a particularly high level of interest in cover crops for managed grazing and for relay or double cropping with row crops.

Elements of the Legislation	Project Activities
• a **timeline for implementation**, coordinated to the extent possible with proposed biomass processing facilities;	To be developed for the final report.
• a projection of **funding sources** needed to complete implementation.	To be developed for the final report.

Multiple Solutions

While the original legislation was based on the expectation of biofuel development, to be deployed in conjunction with existing ethanol plants, it became apparent that there are technical and policy barriers to widespread production of ethanol from perennials, termed "cellulosic ethanol" or "advanced biofuel." These range from the falling prices of conventional fuels to difficulties in processing the tougher plant fibers of perennial grasses for ethanol.

> "In the face of low petroleum prices, continuing policy support and investment in research and development will be needed to allow biofuels to reach their full potential." *Dovetail Partners, Global Production of Second Generation Biofuels: Trends and Influences. January 2017.*

BWSR and project partners are therefore looking beyond ethanol production to other potential uses for perennials, as well as for winter annual crops that hold the soil in place. New technologies for interseeding row crops into annual cover crops such as winter rye and oilseeds are making it more feasible to maintain living cover outside of the relatively short growing season. Innovations in crop breeding and production methods by the University of Minnesota's Forever Green Initiative are improving the yield and hardiness of many perennial crops.

Potential end uses for these alternative crops include bio-jet (biodiesel) fuel, combustion for heat and power, products such as animal bedding and plant-derived packaging material, animal feed and forage for beef and dairy cattle, and even food products such as those made from Kernza® wheat. Not all crops can feasibly be grown in all watersheds, but each of the initial pilot watersheds has conditions appropriate for some crops. Potential crops and their end uses are discussed further in Section V of this report.

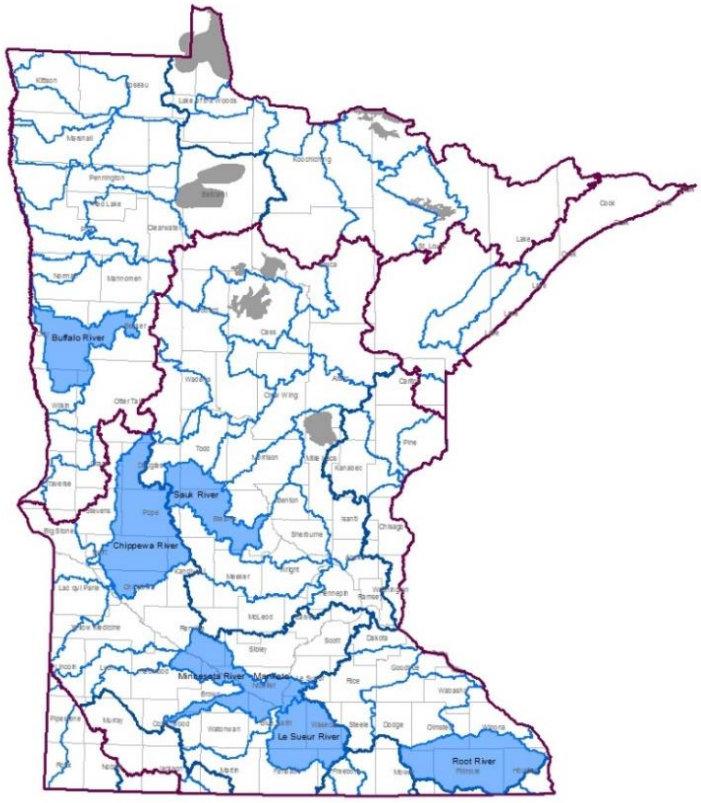
Project Design and Schedule

BWSR has worked closely with other state agencies, University of Minnesota researchers, agricultural and commodity groups, environmental organizations, local governments, and other groups engaged in water resource management. A stakeholder group that includes these interests has met four times as of October 2017. Meetings included a half-day workshop on grazing, forage, and animal feed as strategies

for encouraging establishment of perennials and cover crops. An upcoming half-day workshop in November will focus on emerging end uses of biomass, including biofuels, biothermal energy, and food products.

A project web page was established and is regularly updated with meeting notes and presentations, at http://www.bwsr.state.mn.us/planning/WLWRP/wlwrp.html .

Sample watersheds were selected for study based on their geographic and physical diversity, diversity of cropping systems, previous planning efforts and level of community engagement. Given the high level of engagement in watershed-scale planning across Minnesota, many other watersheds could have been selected, but the scale and time frame of this study limited it to six. Within each major watershed, one or more minor watersheds were selected for water quality modeling, based on recommendations from watershed districts, soil and water conservation districts, and other local partners. Major and minor watersheds are:



Major watersheds for study

- Minnesota River – Mankato Watershed (Nicollet County) – Rogers Creek and Saint Peter area
- Le Sueur River Watershed – Upper Cobb River and Cobb Creek
- Chippewa River Watershed – Shakopee Creek Headwaters
- Sauk River Watershed – Getchell Creek / County Ditch 9
- Root River Watershed – Watson Creek
- Buffalo–Red River Watershed – Whiskey Creek

BWSR contracted with the University of Minnesota's Water Resources Center (WRC) to identify and quantify the economic and social factors affecting farmers' willingness to grow alternative crops on lands currently in annual row crops. The WRC's research efforts include:

- A survey of up to 500 landowners in each of the six major watersheds, beginning in late August, 2017.
- A literature review of research on potential perennial and cover crops.
- Development of a spreadsheet decision tool that addresses what financial incentives would be required to induce agricultural producers to convert cropland in selected Minnesota watersheds to perennial crops or to add cover crops.

Other major elements of the project include:

- Modeling of impacts to water quality that would result from conversion of land in the selected watersheds from conventionally-farmed row crops to perennial grasses, cover crops, or managed grazing. Modeling is being conducted by MPCA staff.
- Assessment of existing federal Farm Bill programs that relate to working lands and perennial cropping systems, including conservation title programs and other policies that impact farm decision-making and present opportunities and/or barriers to establishment of perennials and other living cover crops. The Environmental Initiative is conducting this assessment, which includes outreach to agricultural interests, non-profits, and state agencies.

These work tasks, and initial results, where available, are discussed in Sections II and III.

Previous Planning Efforts and Related Programs

The Working Lands initiative is not the first effort to examine the potential for biomass crops to provide clean energy and environmental benefits. Both previous pilot studies and existing state programs have advanced Minnesota's interest in promoting renewable energy from biomass. State initiatives have also evolved in response to changes in related federal programs and in economic and market conditions for biofuels.

The RIM-Clean Energy Program (2008)

In 2007 the Minnesota Legislature directed BWSR to prepare a Reinvest in Minnesota (RIM) – Clean Energy Program – a working lands conservation program for growing native perennial crops for bioenergy. The legislative directive, Minnesota Statutes, Section 103F.518, stipulates that selection of land for the program must be "based on its potential benefits for bioenergy crop production, water quality, soil health, reduction of chemical inputs, soil carbon storage, biodiversity, and wildlife habitat."

Elements of the proposed RIM-clean energy easement program included:

- A competitive allocation process for project area selection, targeting acres in proximity to an energy facility. The assumption was that a bioenergy facility would be able to use multiple feedstocks, with an emphasis on native perennial plants.
- An easement period of at least 20 years.
- A tiered payment system structured to encourage landowners to grow native perennial plants, both herbaceous and woody. The payment rate would be based on the estimated market value of the land, with the highest per-acre payments for lands producing the greatest diversity of species.

Program guidelines and standards were developed and submitted to the legislature in January, 2008, but the program did not receive funding for implementation, although the authorizing legislation remains in place.

The AGRI Bioincentive Program (2015)

In 2015, the Minnesota Legislature established a Bioeconomy Production Incentive Program to encourage commercial-scale production of advanced biofuels, renewable chemicals, and thermal energy production from biomass (Minnesota Statutes, sections 41A.15 to 41A.18). The new program replaced the NextGen Energy Board, which provided grants to bioenergy projects between 2008 and 2014.

The production incentive program, now known as the AGRI Bioincentive Program, is administered by the Minnesota Department of Agriculture. Program requirements include the following:

- For the advanced biofuels program, eligible producers must meet a specified production level of 23,750 MMBtu per quarter. Advanced biofuel must meet the definition of the national Renewable Fuel Standard (RFS) program to be eligible for the production incentive. (The RFS program states that renewable fuel, other than ethanol made from cornstarch, must improve greenhouse gas emissions over the petroleum-based fuel it replaces by at least 50%.) Biofuels using agriculture biomass must include a minimum percentage of perennial or cover crop source material: 10 percent in years one and two, 30 percent during years three and four, and 50 percent in years five through ten. Responsible biomass sourcing provision apply to ensure sustainable harvest of crop residues.
- For the renewable chemicals program, content of the product must be at least 51% bio-based, and may be derived from agricultural, forestry, or solid waste sources. Production must constitute at least 750,000 pounds per quarter. Payments are higher for cellulosic biomass than for sugar and starch-based sources.
- For the biomass thermal energy program, facilities must produce at least 250 MMBtu per quarter. Payments are higher for perennial or cover crop biomass.

The program has received appropriations in subsequent fiscal years and a number of facilities using forestry sources are receiving payments, which are in the form of rebates following proof of output.

II. Interim Work Products

The Working Lands initiative includes a number of major tasks currently in progress. While the final results are not yet available, this section summarizes progress to date and anticipated next steps. The first three tasks listed below are being performed under the auspices of the University of Minnesota's Water Resources Center, led by WRC director Dr. Jeffrey Peterson. The fourth task, water quality modeling, is being performed by MPCA staff.

Literature Review

The Water Resources Center team have reviewed the extensive body of literature on alternative perennial and annual cover crops suitable for Minnesota watersheds, together with their economic feasibility and the social/behavioral factors influencing crop changes through contracts. Studies relying on farmer surveys are particularly relevant. The literature review also includes research on producer willingness to produce biomass at different prices and under different contractual terms.

Previous technical analyses have been reviewed to inform the current analysis. For example, a web tool was developed in 2011 for calculating an Environmental Benefits Index (EBI) for more effectively pricing land to be enrolled in the Conservation Reserve Program. This information was adapted for the One Watershed One Plan prioritization process and was used to guide selection of major watersheds for this study.

Literature review is an iterative task, with new information being added continually.

Survey of Farmers and Landowners in Major Watersheds

A survey was developed and is being administered by the Department of Forest Resources, led by Dr. Amit Pradhananga. The survey is a mailed questionnaire that assesses socio-economic factors influencing landowner conservation behavior, including local capacity of private and public entities. It inquires about landowner sociodemographics (e.g., age, income), property characteristics (e.g., size, tenure), motivations (e.g., information sources, efficacy, social influences, beliefs, norms) for conservation practice adoption and program participation, and current and future conservation behaviors. The survey also assesses landowner awareness of perennial and cover crops and their interest in and support for a potential working lands program. The questionnaire was developed based on a review of existing research on community capacity and landowner conservation decision making conducted in Minnesota's watersheds, previously tested instruments, and insights from project partners.

In August, 2017, 500 surveys were sent to owners of agricultural property (identified based on property tax codes) in each of the six major watersheds, for a total of 3,000 surveys. As of early October, the response rate was 10%, which is low but not uncommon for surveys of farmers and landowners of farmland. Property tax records indicate ownership, not land use, so the survey goes to many landowners who do not farm their own land (although some have passed the survey along to their renters). The fall harvest season also impacts farmers' availability to answer surveys. A second wave of surveys was sent in early October to non-respondents, and a third and final wave will be sent in early November.

Preliminary results are summarized in Appendix A. On average, respondents are most familiar with alfalfa, followed by annual cover crops and small grains. In contrast, a majority of respondents reported that they are not at all familiar with Kernza® and winter-hardy oilseeds such as camelina and field pennycress. Financial incentives appear to be the most important motivation for future use of perennial or cover crops, including cost-share payments and tax benefits as well as markets to sell the crops and simpler conservation program requirements.

Survey data will be analyzed using basic descriptive statistics to assess individual variables and inferential statistics to assess relationships between variables. Regression-based models (logit, structural equation modeling) will be used to determine the influence of sociodemographic and property characteristics, landowner motivations, and economic factors on practice adoption.

Spreadsheet Decision Tool

A major component of the Working Lands initiative is a quantitative assessment of biomass supply and farm economics. Dr. William Lazarus, of the University of Minnesota's Department of Applied Economics, has led the effort to develop a spreadsheet tool to generate quantitative outputs for each of the six sample watersheds. The spreadsheet includes:

(a) Comparisons of farm income and expenses of current annual row crop systems compared to alternative crops, for different locations within in each watershed that vary by soil productivity
(b) Predictions of the number of acres that could be converted from annual row crops to an alternative cropping system grown under contract, for varying contract prices and contractual terms

Output (a) is generated from enterprise (cost-return) budgets using FINBIN[1] and other available data from the literature review. Budgeted net incomes are calculated for different locations in a watershed based on available index values such as the Crop Productivity Index (CPI). Default values of grain commodity prices (e.g., based on recent trends) are entered to reflect expected future price conditions, although these values can be changed by users of the tool.

Output (b) will rely on the budget-generated net incomes for different values of the appropriate index. For example, for crops where CPI is the appropriate index, the difference in net income between the base system (e.g., corn-soy rotation) and an alternative system (e.g. switchgrass) is a break-even payment – that is, the minimum contract price needed for a farmer to be willing to switch to the alternative system. These breakeven payments across the CPI values in a watershed can be visualized as supply curves – a plot showing the relationship between price paid for biomass and acres converted.

The spreadsheet has been developed and is being tested and refined based on input from project partners and stakeholders. For example, budgets for grass-fed dairy, both organic and non-organic, were recently added to the spreadsheet.

Results from the spreadsheet tool will be reported for several predefined scenarios in each of the study watersheds based on local conditions and the feasibility of different cropping systems. The scenario will reveal estimated biomass supply, farmer income, contract payments, biomass buyer payments, and onsite/offsite environmental impacts, for different combinations of

- Biomass/perennial crop type
- Economic conditions (commodity grain prices)
- Contract terms (contract length etc.)

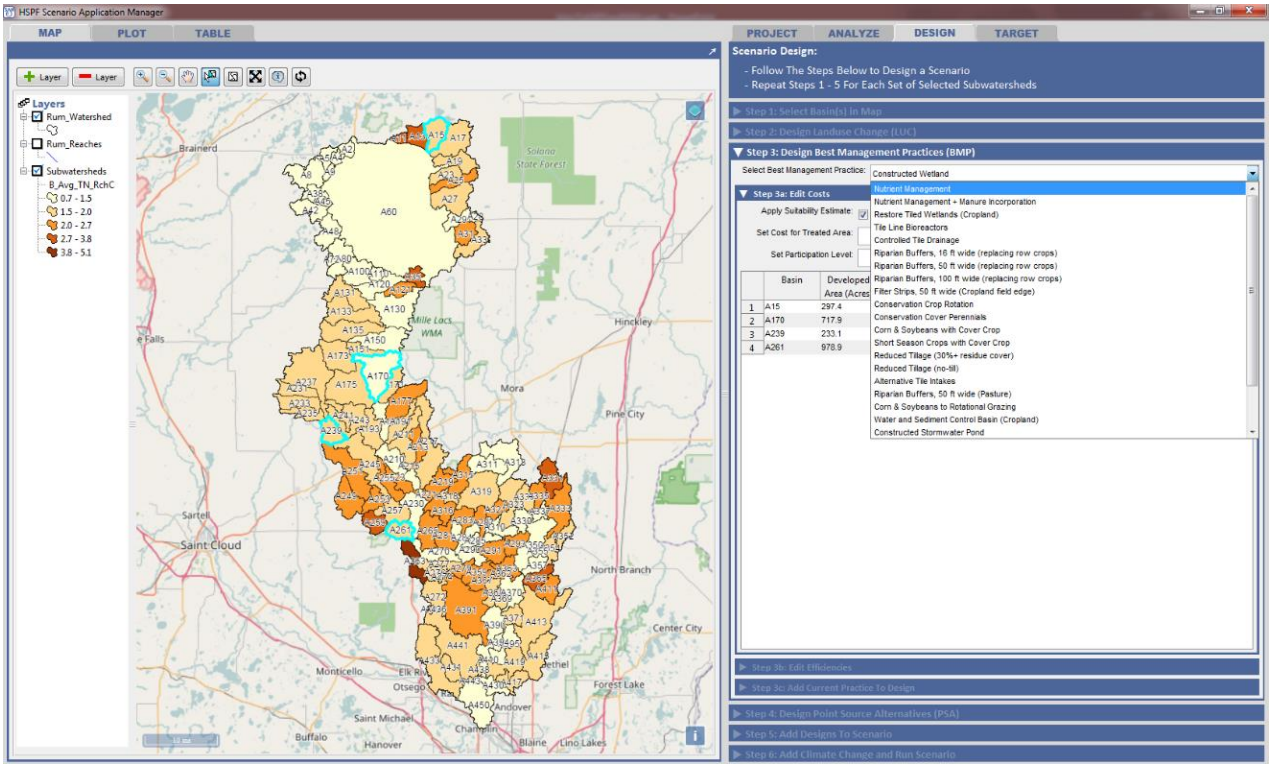
[1] FINBIN is a farm financial database that summarizes actual farm data from thousands of agricultural producers who use FINPACK for farm business analysis. FINPACK is a comprehensive farm financial planning and analysis software system used by agricultural producers, professionals, educators and lenders to help over 50,000 producers analyze their farm business each year. FINPACK is developed and supported by the Center for Farm Financial Management at the University of Minnesota.

Water Quality Modeling

A variety of models for water quality and quantity are available to assess the impacts of changes in land cover and defined best management practices (BMPs). The MPCA uses the Hydrological Simulation Program – FORTRAN (HSPF) model for this purpose. (FORTRAN is the computer language used by the model.) HSPF can simulate water flow rates as well as sediment (including sand, silt, and clay), nutrients, and other substances found in a water body. The model uses real-world historic meteorological data as input to the hydraulic and biogeochemical equations used to represent the interconnected processes at work within a watershed. After confirming the model's accuracy with a process called calibration, agency scientists and local partners can use it to model different scenarios of land-use change and how those changes might affect water quality.

HSPF models currently simulate data from 1995 – 2009 or 1995 – 2012. Water quality is calibrated and validated by using observed data from multiple stream gauges spread throughout the watershed. The quality of the calibration can be viewed in terms of model performance during "wet" or "dry" years or on a seasonal basis.

Sediment and nutrient loading rates, including those coming from agricultural acres, are simulated by a set of process-based equations and the interaction of meteorological inputs with land characteristics. Simulated per acre loading rates are compared to the range of values reported in scientific literature for reasonableness. Types of tillage are simulated not by one tillage parameter but by changing model terms relating to infiltration, surface roughness, and other land-cover factors that mirror the effects of a tillage type. Tile drainage, stormwater, and other artificial drainage features are simulated by



parameters that determine the speed water enters shallow groundwater and the amount of time those water inputs are maintained in the shallow groundwater after a storm event.

The MPCA now combines the HSPF model with a Scenario Application Manager (SAM) – a decision support tool that uses a GIS interface, enabling the modelers to assess the impacts of land use changes at the catchment scale, as shown in the sample screenshot below.

As of October, 2017, the HSPF – SAM model is being developed and tested in several of the sample watersheds. Essentially, conversion of land in row crops to a perennial crop or pasture for grazing, or addition of a cover crop, results in a change in the amount of surface runoff and subsurface drainage, with resulting changes in sediment, total phosphorus, and total nitrogen entering the adjacent stream or lake segment, and with effects on water quality further downstream.

III. Next Steps

The central objective of the Working Lands Watershed Restoration Program is to define the parameters of a contract program that will, as specified in the enabling legislation, "incentivize the establishment and maintenance of perennial crops." The spreadsheet tool will help define the terms of the program. As currently envisioned and mentioned in the legislation, such a program would likely offer "variable payment rates for lands of different priority or type." For example, more productive cropland would typically receive a higher payment, since the loss of production value if converted to a perennial crop would be greater than the loss for marginal land. Rates for cover crops would presumably be lower, since the land would remain in "cash crop" production. Similarly, managed grazing systems or crop rotations that include grazing could also be calibrated based on the likely returns. Another criteria in setting payment rates would, of course, be the effects of the proposed perennial or cover crop on water quality and related ecosystem benefits. These parameters will be defined and tested through dialogue with stakeholders and project partners.

The project team will also examine other policies that could contribute to a future working lands program. These may include tax incentives for producers, sourcing requirements for biofuels, recruitment of biomass processors, and existing but underutilized programs such as water quality trading between point sources and nonpoint sources.

Soil health practices are another area where progress directly benefits water quality. BWSR will make a supplemental assessment of how accelerated adoption of soil health practices on traditional commodity cropland could be accomplished.

Additional tasks to be completed prior to completion of this project include the following:

Federal conservation program analysis

This task, led by the Environmental Initiative, includes an assessment of:

- Existing federal Farm Bill programs that relate to working lands and perennial cropping systems including conservation title programs and policies that impact farm decision-making

- Ability to leverage existing Farm Bill Programs to support a working lands program in Minnesota, including any barriers in the current federal Farm Bill that discourage establishment of perennials and other living cover crops.

- Potential changes to existing Farm Bill programs that would increase their ability to support a Minnesota working lands program (as identified by stakeholders in public position statements, through personal correspondence, in stakeholder meetings, and/or at the Governor's 2015 Water Summit and subsequent water quality meetings).

Biomass end uses case studies

Similar to the half-day forum held in April 2017 on grazing, forage and animal feed, a half-day session is planned for mid-November focusing on the most promising end uses for biomass, including biothermal combustion, biojet fuel, food products, and bio-based packaging.

Assessment of conservation requirements and wildlife production

This task involves an evaluation of the potential effects of biomass production on wildlife habitat, including pollinator habitat. Effects can be beneficial when row crops are converted to more diverse crops or crop rotations, but negative effects can occur if biomass harvesting occurs during the nesting season, for example. Sustainable sourcing requirements for biomass crops can be established to avoid such negative impacts.

IV. Overview of Sample Watersheds

Sample watersheds were selected to meet the requirements of several elements of the Working Lands initiative's enabling legislation:

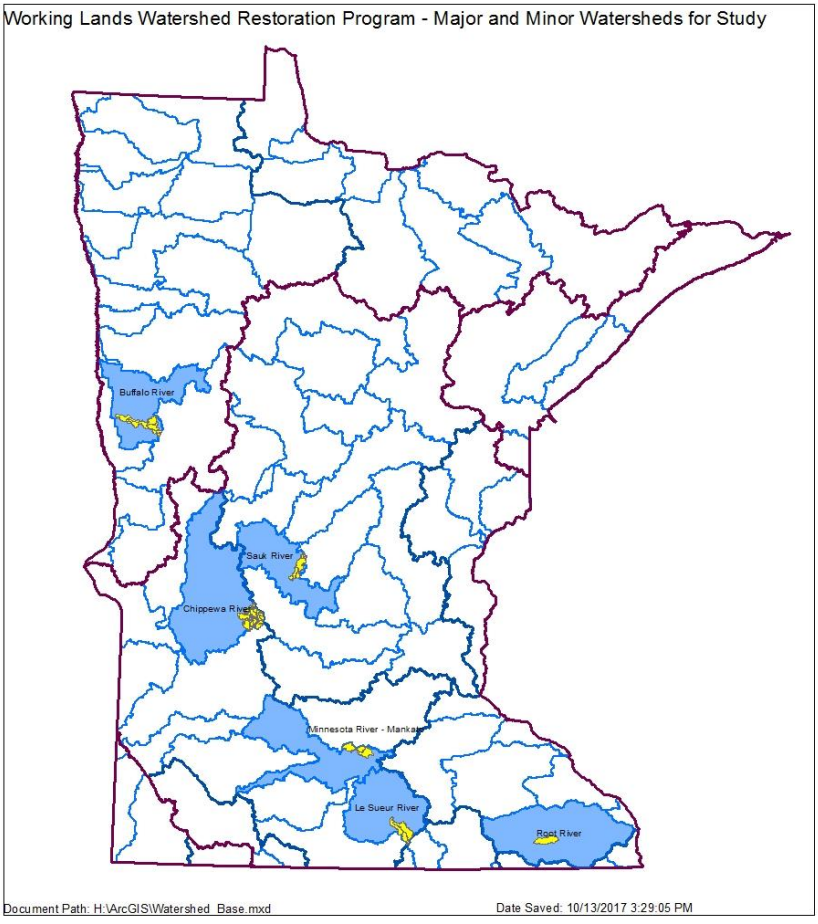
- a process for selecting pilot watersheds that are expected to result in the greatest water quality improvements and exhibit readiness to participate in the program;
- an assessment of the quantity of agricultural land that is expected to be eligible for the program in each watershed; and
- an estimate of water quality improvements expected to result from implementation in pilot watersheds.

These elements call for a two-level process: "readiness" is a quality best measured at the major watershed scale (8-digit hydrologic unit codes or "HUC8"), where most assessment, intergovernmental coordination, and planning take place. Estimating water quality improvements, however, is most practical at the minor watershed scale – in most cases, the "HUC10" or "HUC12" scale, where changes in land use and addition of best management practices can be modeled more precisely.

The project team developed a set of preliminary criteria to be used in selecting watersheds from among Minnesota's delineated major watersheds for analysis.

- Broad geographic distribution across Minnesota's agricultural regions, extending from northwest to southeast.
- Landscape-scale diversity representing Minnesota's varied agricultural ecoregions, including those with beef and dairy cattle, those with steep slopes and other types of marginal land, those subject to frequent flooding, and those with the highest percentage of row crop agriculture and the highest land values.
- Proximity to refiners, processors, and other potential end-users – including a full range of biomass processing options beyond ethanol. Processing options range from grazing and animal feed to biothermal energy (heat and power) to biofuels. Proximity to campus-scale or small-community power plants is of particular interest.
- Prior planning efforts, through development of Watershed Restoration and Protection Strategies (WRAPS), watershed plans (1W1P), county water plans, and related studies.
- Demonstrated interest, social capacity, and local leadership, as demonstrated through evaluations by state and regional partners and/or community engagement studies.
- Availability of adequate data and models to assess potential water quality improvements (such models are widely available in most major watersheds).
- Opportunities to achieve multiple benefits identified in other environmental or economic studies or plans, such as wellhead and groundwater protection, wildlife benefits, pollinator benefits, economic diversification, etc.
- Opportunities to achieve results in "borderline" watersheds – those exhibiting a downward trend or close to the "tipping point" of impairment.

Some of these criteria are fairly subjective, and not all can be maximized in the same locations. BWSR used an evaluation tool originally produced by the University of Minnesota in 2013 for the MDA's Sentinel Watersheds Project. The evaluation tool provides watershed-scale assessments within major river basins based on user-selected attributes. The tool was recently



Major and minor watersheds identified for study

updated for One Watershed One Plan using the current publicly available GIS data layers.

For each major basin, a variety of criteria can be prioritized as a way to rank the HUC-8 scale watersheds. The three primary criteria for this analysis were the risks of soil erosion, wildlife habitat, and water quality, plus additional criteria designed to assess the degree of runoff, nitrogen and phosphorus yield, and steam impairment. Other criteria were added based on basin characteristics, including dominance of row crops and/or animal units, land use conversion to row crops, and drinking water supply vulnerability, depending on the location. In each case, the selected watersheds fell into the "top three" within the river basin. The team also considered additional information on previous and ongoing watershed studies and planning efforts. Each of the selected watersheds has either a completed Watershed Restoration and Protection Strategy (WRAPS) or extensive water quality monitoring and assessment reports, to be used in preparation of WRAPS and Total Maximum Daily Load (TMDL) reports.

Within each major watershed, one or more minor watersheds were selected for water quality modeling based on recommendations from watershed districts, soil and water conservation districts, and other local partners. Each of the minor watersheds was identified for various reasons: as a source of specific impairments, a focus area for potential improvements, an area where local governments and the agricultural community are particularly engaged, or an area considered to have potential for biomass crops. All the selected watersheds are located within 50 miles of one or more ethanol plants, and many are close to institutions such as college campuses that offer potential for localized bioenergy initiatives.

Conditions and issues in the major and minor watersheds are summarized below.

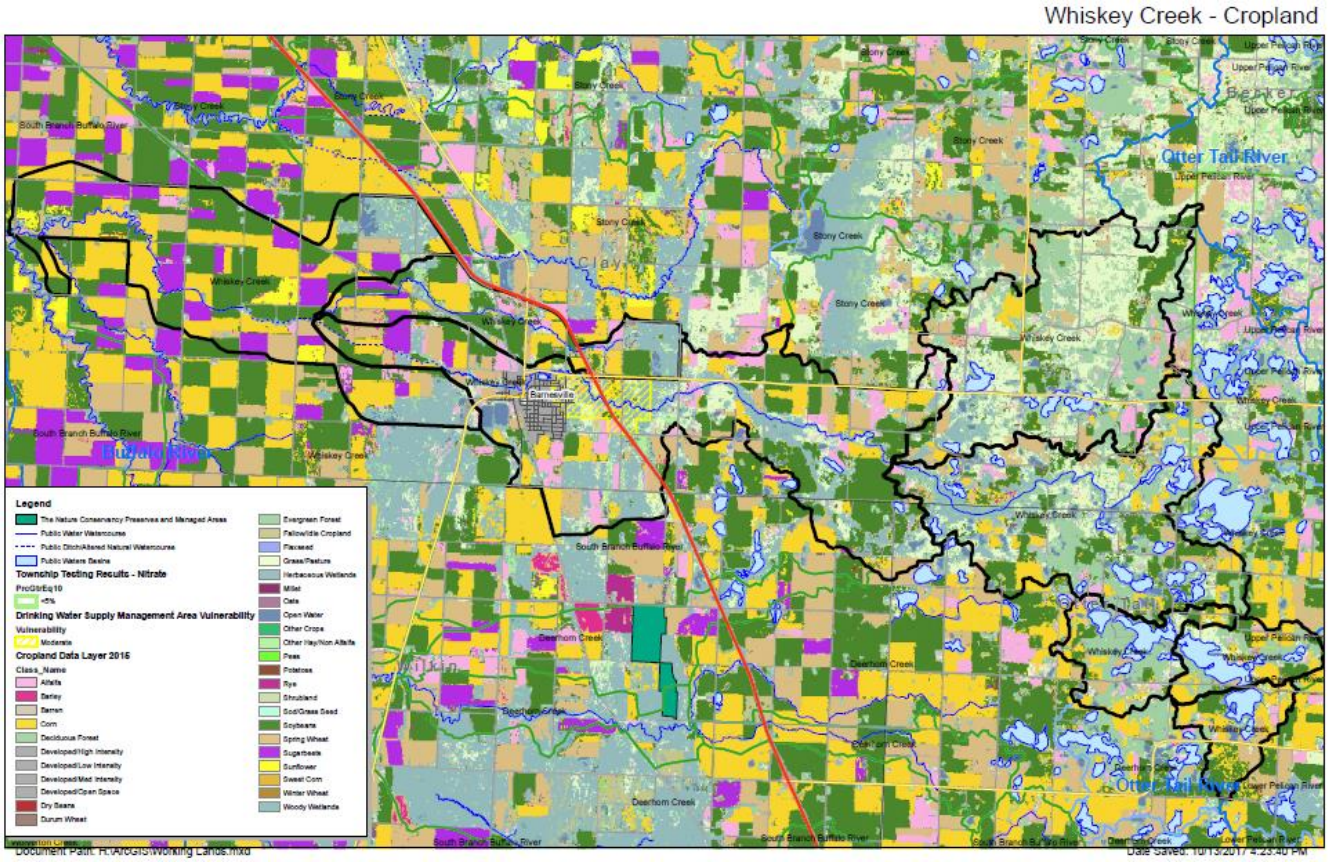
Buffalo River – Whiskey Creek

The Buffalo River watershed covers more than 1,100 square miles in portions of Clay, Becker, Wilkin and Otter Tail counties. The watershed is located in the Red River Basin and spans three ecoregions: the Lake Agassiz Plain, the North Central Hardwood Forests, and the Northern Lakes and Forests. Land use in the west and central portions – mainly the Lake Agassiz Plain – is predominantly agricultural. The eastern portion of the watershed is mostly forested, with more rugged topography; this area is shaped by the Lake Agassiz beach ridges, ancient shorelines shaped by the receding waters of the glacial lake. Corn, soybeans and sugar beets are the primary crops. There is still some grazing on the beach ridges.

Water quality problems in this area include excess nutrient levels, bacteria levels, and sediment. According to the 2015 WRAPS, "The poor water quality conditions reflect the intensely farmed landscape, human changes to hydrology, intensive drainage, and lack of buffers around lakes and streams. Restoration strategies will need to focus on reducing phosphorus, sediment, and bacteria through livestock management, nutrient management, wind breaks, buffers, and other best management practices." A One Watershed One Plan initiative is beginning in the watershed in 2017.

The Whiskey Creek watershed (one of several "Whiskey Creeks" in this area) is located to the east and west of the City of Barnesville. It spans an area extending downstream from the beach ridge, where

soils are rocky and less productive, to the south branch of the Buffalo River. This area is part of the Minnesota Prairie Plan corridor, and landowners have expressed interest in perennial cultivation. Barnesville's drinking water supply management area extends outside the city limits in the Whiskey Creek watershed; it is considered moderately vulnerable to contamination. Whiskey Creek itself is impaired for aquatic life (turbidity) and aquatic recreation (E. coli).



Whiskey Creek Watershed - Buffalo River

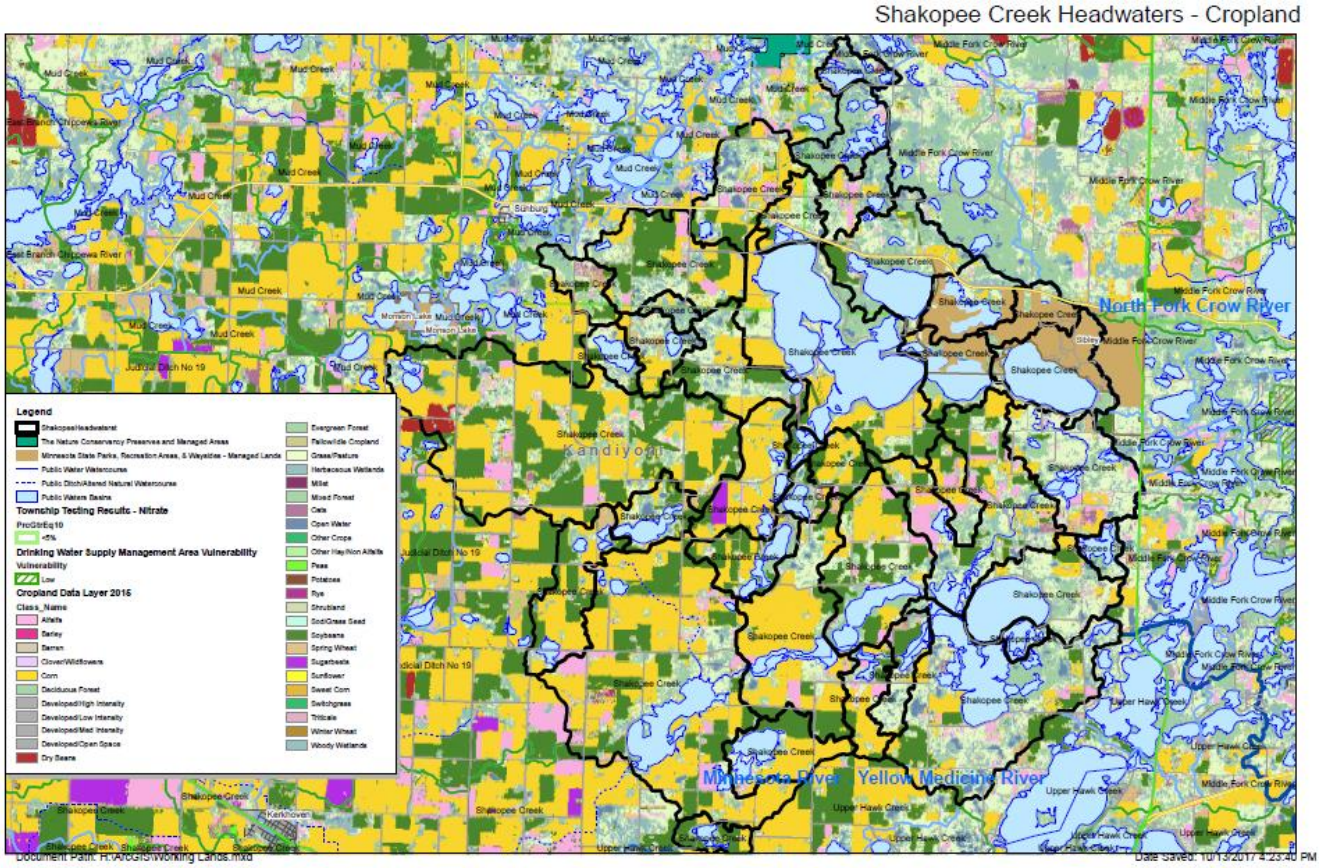
Chippewa River – Upper Shakopee Creek

The Chippewa River is the largest tributary to the Minnesota River. Its watershed covers 2,085 square miles and drains portions of eight counties in west central Minnesota extending from the southern part of Otter Tail County to Montevideo, where the Chippewa joins the Minnesota River. The northeast part of the watershed tends to be hillier, wooded, and more easily eroded, while the southwest portion tends to be flatter with more agricultural land. About 80 percent of the land is in agricultural use. Corn and soybeans are the primary crops, with small grains, hay, and grasslands making up the balance. Crops are more diverse in the upper reaches of the watershed, which includes multiple lakes and Sibley State Park.

The geology of the Chippewa River watershed includes a complex mixture of moraines and till, lake deposits, and outwash plains. The hilly moraines result in a high potential for erosion of sediment into streams.

The watershed is the site of the Chippewa 10% Project, developed by the Chippewa River Partnership and the Land Stewardship Project, which has involved extensive monitoring, modeling, and outreach to farmers and landowners. The concept behind the project is that changing farming practices on just an additional 10 percent of the watershed's sensitive agricultural land can be enough to correct water quality impairments, reduce flood potential, restore wildlife habitat, and potentially produce energy crops. Project tools include a 10% Cropping Systems Calculator that allows farmers to explore the financial implications of various alternatives, including more diversified rotations, covering fields beyond the growing season of the main cash crops, integrating perennials and establishing grazing systems.

The minor watershed of Upper Shakopee Creek is actually a cluster of over thirty small catchments that form the creek's headwaters. Several of these watersheds have been extensively modeled by the DNR using the Gridded Surface Subsurface Hydrologic Analysis (GSSHA) method, which models surface water and groundwater hydrology, erosion, and sediment transport. Additional modeling in HSPF was completed in three minor watersheds as part of the Chippewa 10% Project: the East Branch, Middle Mainstem, and Shakopee Creek in its entirety. Several scenarios were modeled, including five that involved an increase in perennial cover.



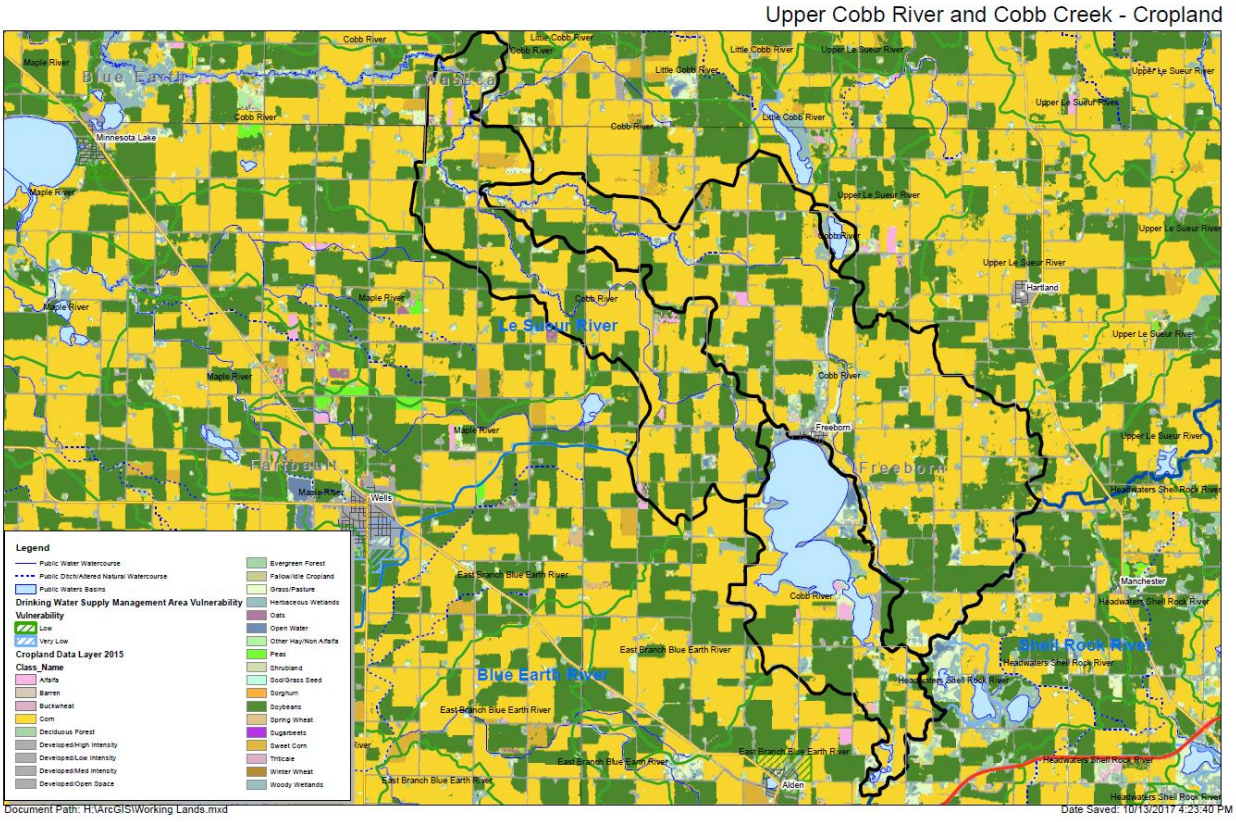
Upper Shakopee Creek Watershed - Chippewa River

Because of its mix of land uses and terrain, the Chippewa River watershed includes many lakes and stream segments that are not impaired, or have not yet been assessed. However, Shakopee Creek directly south of the selected headwaters area is impaired for aquatic life based on aquatic macroinvertebrate and fish bioassessments, turbidity and fecal coliform, and some of the lakes in the watershed, including Norway Lake, are impaired for aquatic life and aquatic recreation due to excess nutrients.

Le Sueur River: Freeborn Lake – Cobb River – Cobb Creek

The Le Sueur River major watershed is located in south central Minnesota and drains approximately 711,000 acres (1,110 square miles), joining the Blue Earth River west of Mankato. The watershed is largely rural with 84% of the land in agricultural use, of which approximately 93% is planted in corn and soybeans. Lakes and wetlands currently comprise 3% of the watershed. About 89% of the wetlands have been drained since European settlement. Many of the lakes are shallow and provide wildlife habitat while others are deeper and popular for recreation. Soils in the watershed are fertile but poorly drained, and much of the farmland is now drain tiled.

The Le Sueur watershed is a major source of sediment and nutrients to the Minnesota River. The topography of the river valley, which was carved during the massive drainage of glacial Lake Agassiz, has created steep ravines with knick points that contribute to the erosive qualities of the streams, increasing



Cobb River, Cobb Creek and Freeborn Lake - Le Sueur River

river flows and sediment loading. Water monitoring shows some modest improvements in water quality in the Le Sueur River over the past 10 years though several sections of the river and its streams continue to suffer from turbidity, low dissolved oxygen, and excess nutrients.

The Cobb River and Cobb Creek watersheds were selected for study based on the recommendations of the Le Sueur Watershed Network, a farmer-led effort coordinated by the Water Resources Center at Minnesota State University -Mankato. The group identified issues with phosphorus impairment of Freeborn Lake, which is impaired for aquatic recreation. The Cobb River is impaired for aquatic life based on aquatic macroinvertebrate bioassessments, fish bioassessments, and turbidity; it is also impaired for aquatic recreation (E. coli).

Sauk River – Getchell Creek Area

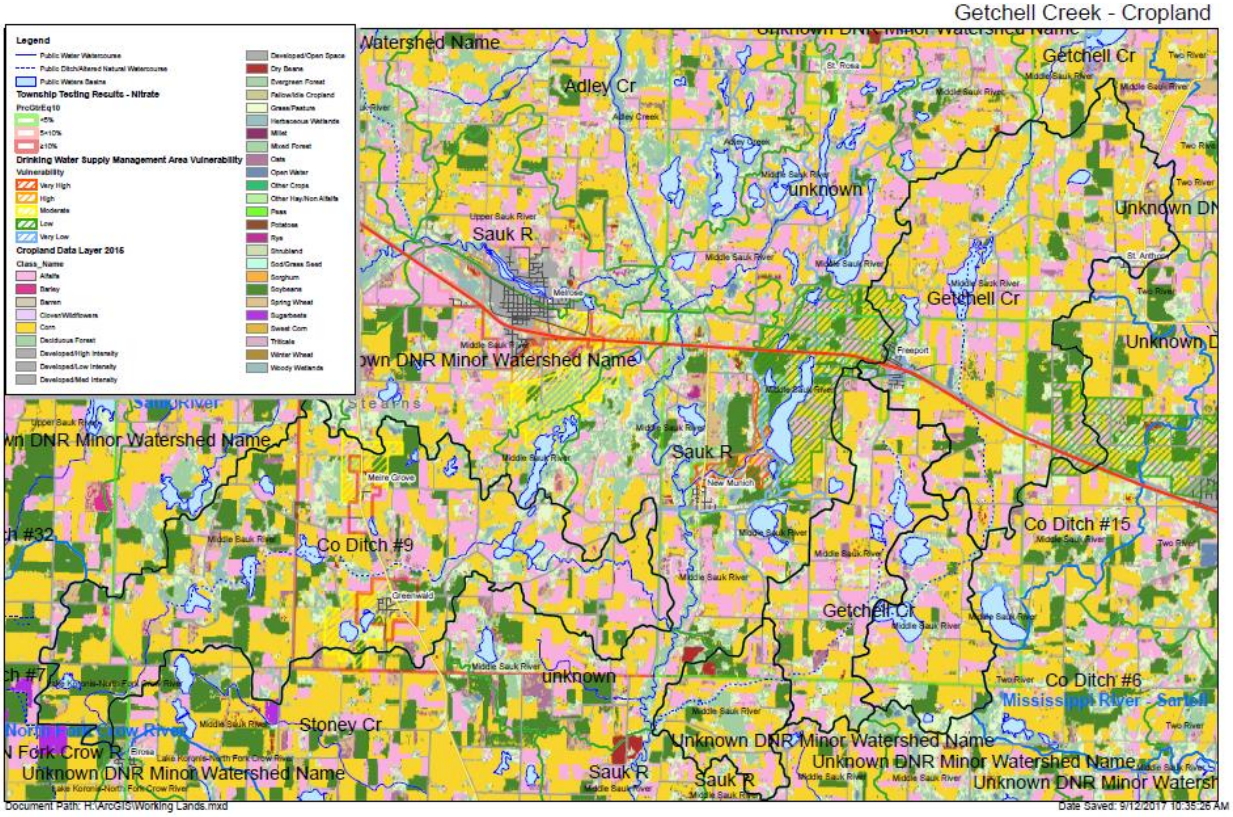
The Sauk River watershed covers 667,200 acres (1,043 square miles) and extends from the Mississippi River near St. Cloud to within three miles of Alexandria. The overall watershed is about 75 miles in length. The Sauk River itself meanders for 120 miles in a northwest to southeast direction.

The watershed is located in the north central forest ecoregion, the transitional zone between the state's northern forestlands and southern agricultural lands. It contains 371 established lake basins and 586 perennial and intermittent streams. The watershed is affected by agriculture and urban development with phosphorus and sediment as the primary stressors. It is the only one of the sample watersheds where a significant amount of alfalfa is being grown and sold for hay. Stearns County is a major center of dairying, however, larger dairies are shifting away from alfalfa to corn silage as feed, while the number of smaller dairies still using alfalfa is declining. The Sauk River Watershed District encourages establishment of riparian buffers for haying through a program offering cost share funds for hayed buffers. Groundwater-surface water interaction has been identified as a factor within the Sauk River watershed. A pattern of decreasing average summer flows in the river's main stem indicate groundwater-surface water interaction – that is, surface flows are being affected by groundwater withdrawals for irrigation and drinking water supplies.

The Getchell Creek watershed was recommended for study by the Sauk River Watershed District staff based on the high nutrient volumes it contributes to the Sauk River. The creek is channelized along almost its entire course; first dug in 1907, it has since been maintained by local landowners periodically and is classified in part as public water and in part as public ditch. The adjacent watershed of County Ditch 9, west of the Sauk River mainstem, was included in the analysis in order to include the drinking water supply management areas for the cities of Meire Grove and Greenwald, both of which show moderate levels of vulnerability. Additionally, results of the MDA township nitrate testing program indicate that in Grove

Township, where County Ditch 9 is located, over 10% of the private wells tested show nitrate levels above 10 milligrams/litre, which is the established health risk limit.[2]

Getchell Creek is impaired for aquatic life, based on aquatic macroinvertebrate bioassessments, and for aquatic recreation (E. coli).



Getchell Creek and County Ditch 9 - Sauk River

[2] http://www.mda.state.mn.us/~/media/Files/chemicals/nfmp/stearnsfinal201415.pdf

Minnesota River – Mankato – Rogers Creek and St. Peter Area

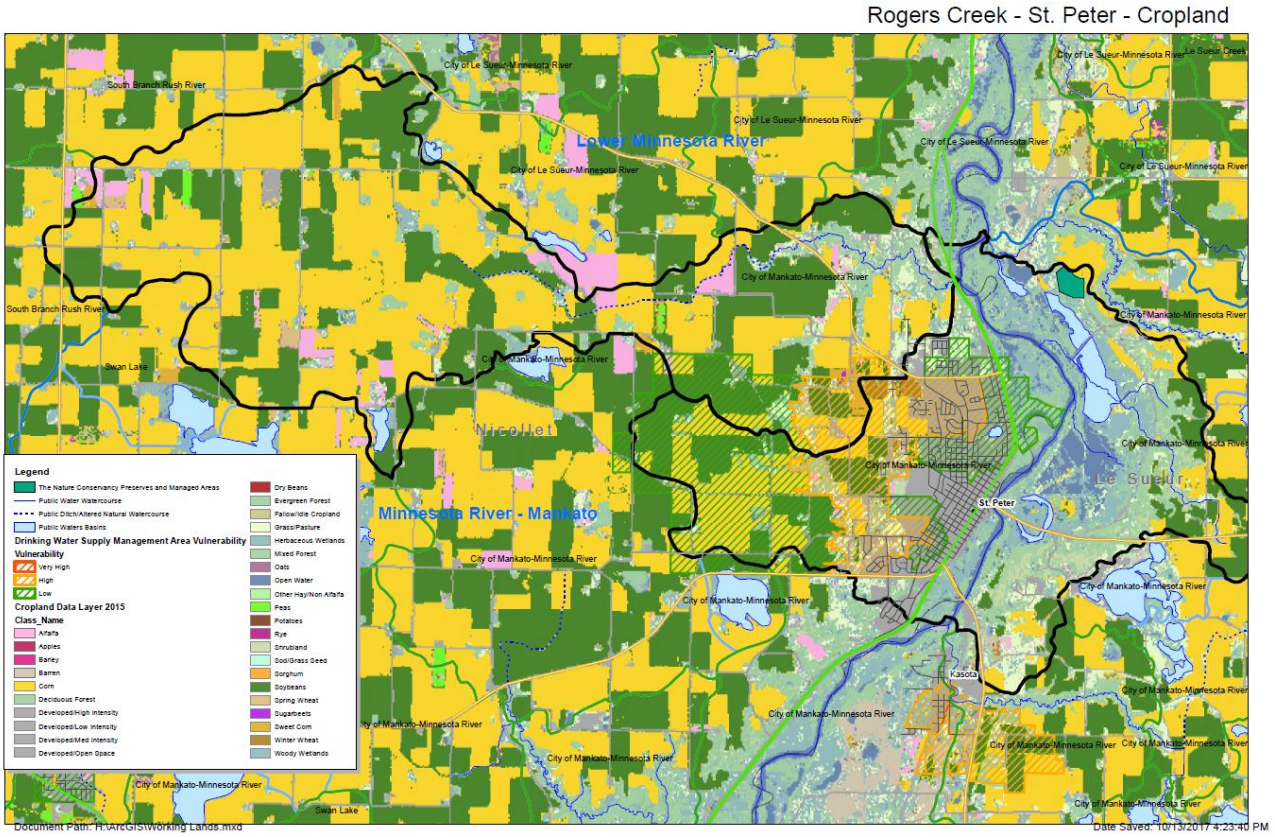
The Minnesota River - Mankato watershed covers 861,886 acres across Cottonwood, Brown, Redwood, Renville, Sibley, Nicollet, Blue Earth, and Le Sueur counties in south-central Minnesota. The watershed's landscape is diverse, with flat cropland in the west and bluffs and lakes in the east. As in the Le Sueur watershed, steep slopes and bluffs bordering the valley of the historic Glacial River Warren contribute to significant erosion. Land use is dominated by row crop agriculture, which occupies about 76% of the watershed, with corn and soybean production accounting for about 90% of cropped lands. County Soil and Water Conservation Districts have identified the primary resource concerns to be sediment and erosion control, stormwater management, drinking water and source water protection, drainage management, waste management, nutrient management, surface water quality and wetland management.

The Rogers Creek watershed was selected for study based in part on local knowledge and interest. Extensive outreach and engagement efforts in the nearby Seven Mile Creek watershed were organized through the University of Minnesota's Humphrey Institute in 2014-2016, in partnership with the Nicollet County SWCD and Great River Greening. This effort, termed the New Ag Bioeconomy Project, included research on potential biomass crops and modeling of different crop scenarios through an interactive GeoDesign web-based tool. Additionally, the Nicollet County SWCD received a Targeted Watershed grant from BWSR in 2015 for expanded outreach and conservation practices, including promotion of cover crops.

The NRCS identified Seven Mile Creek as one of three priority watersheds in Minnesota to receive technical assistance under the National Water Quality Initiative (NWQI). In priority watersheds with impaired streams. NRCS is helping producers implement conservation and management practices through a systems approach to control and trap nutrient and manure runoff. Qualified producers receive assistance for installing conservation practices such as cover crops, filter strips and terraces.

Rather than continuing to focus on the relatively small and heavily-studied Seven Mile Creek watershed, the project team identified the nearby Rogers Creek watershed as having similar conditions. Rogers Creek is also located adjacent to the City of St. Peter, where the vulnerability of drinking water supplies has been a continuing challenge. The small Minnesota River watershed that encompasses the city is also included.

Opportunities in the area include several large dairies that currently import their hay from western states. Obstacles include the high productivity and high prices of cropland, making conversion to alternative crops difficult.



Rogers Creek and St. Peter area - Middle Minnesota River

Root River – Watson Creek

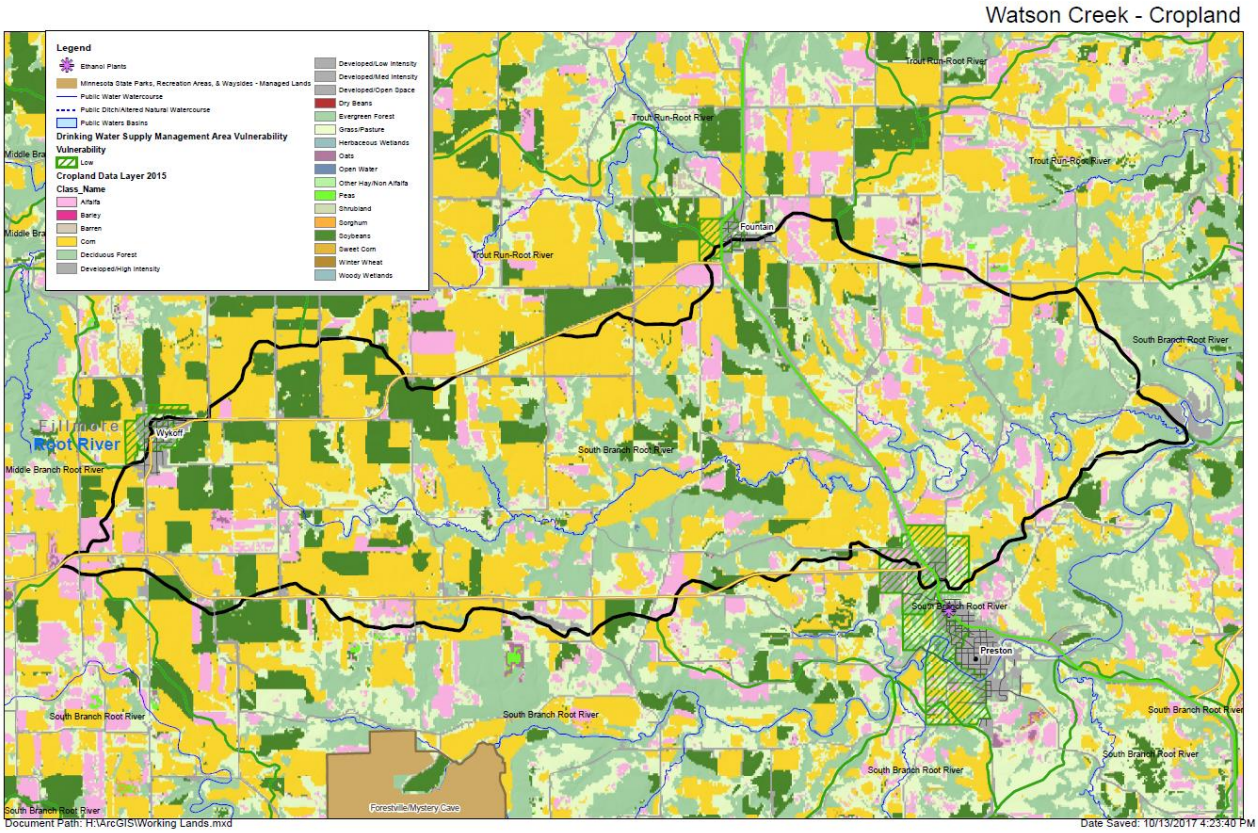
The Root River watershed covers 1,064,961 acres in southeast Minnesota within the Lower Mississippi River Basin. The watershed drains west to east before joining the Mississippi River approximately five miles east of the small town of Hokah. The watershed primarily lies within the Driftless Area ecoregion with a small portion of its headwaters in part of the Western Corn Belt Plains ecoregion. The distinctive karst (limestone) topography of the region gives the land limited capacity to retain water.

Cropland generally occupies the fertile plains area in the western portion of the watershed, but also the river valleys located throughout the driftless area, comprising about 41% of the watershed. Pasture (31%) and forest/shrubland (22%) are found primarily in the rolling hills and bluff regions located in the eastern half of the watershed. However, in the past decade, high prices for row crops have led to conversion of land has been converted from pasture to cropland, while cattle have become more scarce.

The Root River contributes substantial amounts of nitrogen and phosphorus to the Mississippi River. County SWCDs have identified sediment and erosion control as a primary threat to area waters. Drinking water/source water protection is also a key concern. The Root River region is particularly susceptible to groundwater contamination as a result of its permeable soils and karst features.

The Watson Creek watershed (HUC-12) is part of the South Branch Root River HUC-10. Watson Creek is impaired for aquatic life (through fish and aquatic macroinvertebrate bioassessments), aquatic recreation (E. coli), and drinking water (nitrates).

The Fillmore County SWCD has a long history of working with landowners in the Watson Creek watershed to address pollution problems. The watershed was one of three pilot study areas for the Minnesota Nutrient Reduction Strategy, developed as part of the statewide effort in 2013-2015, so considerable modeling of impairments and potential BMPs has been completed. The SWCD staff have identified a need for cover crops and perennial crop establishment. The watershed is also home to a large ethanol refiner, POET Biorefining in Preston, which has expressed interest in working with the SWCD on some type of environmental initiative.



Watson Creek area - Root River

V. Overview of Biomass Crops

An assessment of the market potential and environmental benefits of perennial and cover crops and cropping systems includes a number of factors: the cost and effort involved in establishing these crops, the benefits they provide to water quality and soil health, any disadvantages or obstacles to their establishment, current research initiatives, and current and potential uses. This section includes brief profiles of selected crops. More detailed data on costs of establishment and potential revenue are incorporated into the spreadsheet decision tool.

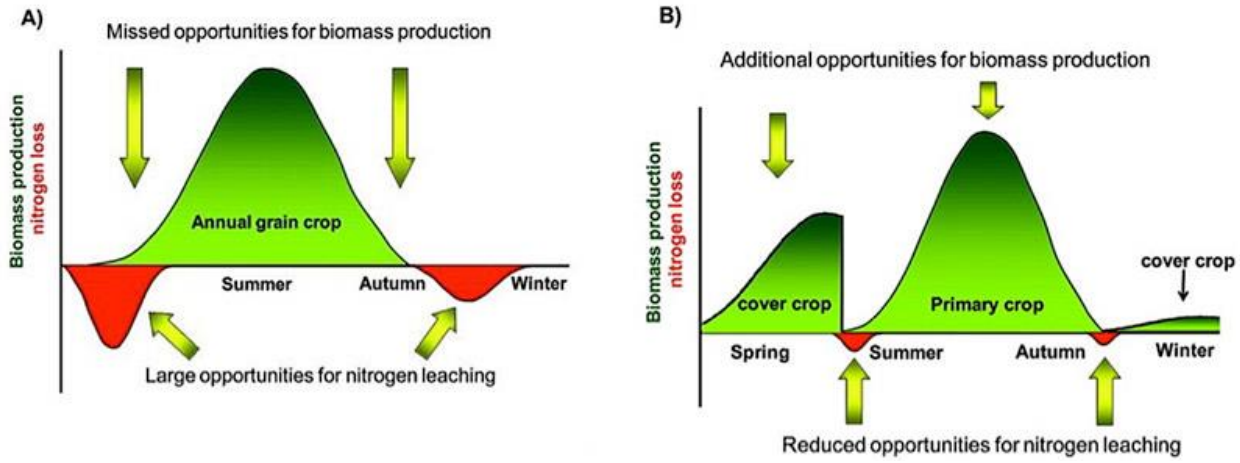
Definitions of Terms

The crops discussed below include those commonly termed “perennial” as well as a number of “annual cover crops.” These terms often overlap. Minnesota Statutes section 41A.15, which established the Bioeconomy Production Incentive Program, includes definitions of both terms:

- "Perennial crops" means agriculturally produced plants that are known to be noninvasive and not listed as a noxious weed in Minnesota and that have a life cycle of at least three years at the location where the plants are being cultivated. Biomass from alfalfa produced in a two-year rotation shall be considered a perennial crop.
- "Cover crops" means grasses, legumes, forbs, or other herbaceous plants that are known to be noninvasive and not listed as a noxious weed in Minnesota and that are either interseeded into living cash crops or planted on agricultural fields during fallow periods for seasonal cover and conservation purposes.

In practice, these definitions overlap, since many perennials are grown as cover crops – for example, alfalfa can be used as an annual cover crop, as can winter (cereal) rye and some clover species. Both types of crops provide “living cover,” a term frequently used in discussions of agriculture and water quality. The amount of “cover” provided varies depending on when and how the crops are grazed or harvested. As with perennials, cover crops can produce biomass when soils are typically base, as shown in Figure 1.

Figure 1. Opportunities for biomass production with cover crops. From Chopra et. al., 2017.



Perennial Grasses

Switchgrass

Switchgrass (*Panicum virgatum L*.) is a North American native perennial warm-season grass. Along with big bluestem and Indiangrass, it is one of the three dominant species of the North American tallgrass prairie. In its native habitat, switchgrass is generally found in the more humid zones of the tallgrass prairie. Switchgrass has attracted perhaps the greatest attention among the grasses and crops evaluated as potential biofuel feedstocks, because of its high productivity and broad adaptability. In studies funded by the US Department of Energy, switchgrass emerged as the lead perennial herbaceous candidate for biomass production. Therefore, its characteristics are well documented.

Switchgrass is well-suited to marginal sites, but also flourishes on more productive land. Other benefits include its ability to capture excess nitrogen, reduce erosion, increase soil carbon sequestration, and provide wildlife habitat, as switchgrass stands tend to become more diverse over time.

According to *Switchgrass Agronomy,* a guidebook by the Ontario Biomass Producers Cooperative, "Switchgrass is a farmer-friendly crop with exciting market opportunities. It requires low investment and minimal labor. In Ontario, switchgrass has been successfully grown on both prime agricultural land and on more marginal class 3 soils that are stony, gravelly or relatively shallow. It is relatively easy and inexpensive to establish from seed, and can be grown and harvested using conventional farm equipment. Switchgrass is cut once per year, and is harvested off-season from other baling activities."

Switchgrass yields are improving as new varieties are developed. In Minnesota, yields vary depending on the quality of the soil and the amount of fertilizer used, but 3 to 5 dry tons per acre appear feasible.

Switchgrass

Switchgrass for biofuel

Switchgrass has been used as a biofuel in several pilot programs. It was grown on about 5,000 acres in Eastern Tennessee to supply a pilot biofuel refinery in Vonore from 2010-2015. The refinery was closed in 2015 by DuPont; the company is now focused on corn stover as a feedstock for cellulosic ethanol at its plant in Nevada, Iowa.

An earlier demonstration project in Iowa, the Chariton Valley Biomass Project, used locally grown switchgrass co-fired with coal to generate electricity at the Ottumwa Generating Station over a ten-year period from 2001 through 2010, with funding from the U.S. Department of Energy.

Other uses for switchgrass

- Switchgrass is currently being grown in eastern Ontario for animal bedding and as a constituent of dairy cattle feed.
- Research at the University of Nebraska indicates that switchgrass and other perennial grasses can be used as forage for beef cattle, particularly if energy density and digestibility are improved.
- Researchers at Pennsylvania State University report that animal bedding is a well-established market for grass material, with farm gate prices for bedding straw ranging from $80 to $100 per dry ton. The University of Delaware is testing switchgrass as a chopped bedding for poultry farms.
- AURI is researching treatment of switchgrass and other perennial grasses with calcium hydroxide to increase nutrient content and sugar extraction, increasing suitability as livestock feed.
- Switchgrass can be co-fired, usually with coal, to produce steam for heating. However, its combustion can create slag in boilers.
- Emerging uses for switchgrass include biochar, a byproduct of pyrolysis (heating in the absence of oxygen). Biochar can be used as a soil amendment and is currently being used in a new cat litter product (OurPets' Switchgrass Natural Cat Litter with BioChar).

Research indicates switchgrass is not currently being grown in Minnesota for biomass, bioenergy, animal bedding, or other uses discussed here, although it may be in use as a forage crop. The perennial spreadsheet decision tool treats it as equivalent to small grain straw, such as wheat straw.

Miscanthus

Giant Miscanthus *(Miscanthus x giganteus)* has been widely studied as a highly productive bioenergy crop. Like switchgrass, it requires very little nitrogen fertilizer, captures excess nitrogen; sequesters carbon, prevents erosion; and performs well on marginal lands. Originally an Asian grass, it has been used in Europe for biomass and in North America as a horticultural specimen plant. The bioenergy variety of the plant is a sterile triploid hybrid, planted via rhizomes rather than seed. Miscanthus yields range from 12 to 15 dry tons per acre. Characteristics such as low moisture at harvest, low free sugar content, low nitrogen content and high lignin content make it better suited for thermochemical conversion (combustion) than switchgrass. Unlike switchgrass, it is not suitable for animal feed or forage, although it can be used for animal bedding.

Concerns as to its potential invasive qualities in North America have not been borne out by research. However, limited plant material and limited planting equipment have slowed its use. Since miscanthus is a sterile hybrid, the crop cannot be planted from seeds, but instead must be established with vegetative materials such as rhizomes or plugs. There are currently few if any sources for miscanthus rhizomes.

Miscanthus for biofuel

The primary example of miscanthus use for biofuel is the partnership between the University of Iowa (UI) and Iowa State University (ISU) to grow miscanthus as a renewable feedstock for the UI power

plant. The project's goal is to establish the crop on 2,500 acres in Southeast Iowa to produce 22,500 tons of the feedstock. As of 2016, 300 acres had been established through 10-year contracts with farmers, at a rate of approximately $200/acre, similar to Conservation Reserve Program payments.

Other uses for miscanthus

Miscanthus is being grown and processed for animal bedding, particularly for poultry bedding, in Ontario, Pennsylvania and Illinois. Green Flame Energy, an Illinois biomass-sourcing company, reports that the best market for miscanthus in that area is currently turkey bedding, but suggests that heating of livestock barns with miscanthus fuel chips can be competitive with propane. Like switchgrass, miscanthus is not currently being grown in Minnesota for biomass.

Kernza® Wheat (Intermediate wheatgrass)

Kernza wheat (*Thinopyrum intermedium)* was developed by the University of Minnesota's Forever Green Initiative and the Kansas-based Land Institute as a perennial grass that could provide food products, biofuel, and forage. Intermediate wheatgrass was already in use as a winter-hardy perennial forage. Its domestication as a grain crop was begun by the Rodale Institute in 1989 and continued by the Land Institute and Forever Green. Because of its extremely dense and deep root system and rapid regrowth after harvest, crop residue can be harvested for biofuel or forage use while the plant continues to build soil carbon and control soil erosion.

Like the other perennial grasses, Kernza removes excess nitrogen from the soil. Studies have shown that nitrate in soil water under Kernza is about four times lower than that found under corn. This characteristic has stimulated a great deal of interest in Kernza as a suitable crop for wellhead protection areas in Minnesota, especially for those that are vulnerable to nitrate leaching.

Limitations of Kernza in its current state include its small seed size, challenges in harvesting and processing, and the fact that yield declines rapidly in the second and third year after planting. Research at the University of Minnesota showed declines from as much as 900 kilograms of grain per hectare (about 800 lbs./acre) to as little as 200-300 kilograms (180 - 270 lbs./acre). Alternatives being explored include planting in rows perpendicular to the flow of water and tilling between the rows – however, the effect of tilling on carbon sequestration benefits needs to be quantified. Breeding initiatives are also focusing on shatter resistance, seed size, and grain quality.

Kernza wheat at University of Minnesota, St. Paul

Uses for Kernza

Kernza is attracting a high level of interest as a niche-level food crop. It can be blended with annual wheat flour to make bread and used on its own to make quick breads. It is also being processed for pasta and beer. The supply of seed is being limited to ensure that potential growers are adequately trained and equipped and to avoid a "boom-and-bust" scenario. General Mills, through its Cascadian Farms enterprise, is working with the Land Institute to gradually increase Kernza production to commercial scale, and has committed to incorporating the grain in a snack products or cereal in 2018.

Kernza also has potential as a bioenergy crop, but this aspect has received relatively less attention than its food potential. A cropping system could incorporate all these uses: grain would be harvested in late July- mid August. Right after harvest farmers would remove the residue, which could be used as low-quality hay, but would be better suited for a biofuel scenario. Regrowth could be grazed on by November or April.

The logistics of Kernza distribution are handled by Plovgh (pronounced "plough"), a company that connects farmers, buyers and producers. As of July, 2017, Plovgh reported that Kernza is being grown on seven sites in Minnesota, as well as on test plots; demand greatly exceeds supply. The slow-growth strategy employed by the Land Institute and Plovgh means that the crop is unlikely to occupy significant acreage in the short term, but it may be particularly well-suited to vulnerable locations such as wellhead protection areas.

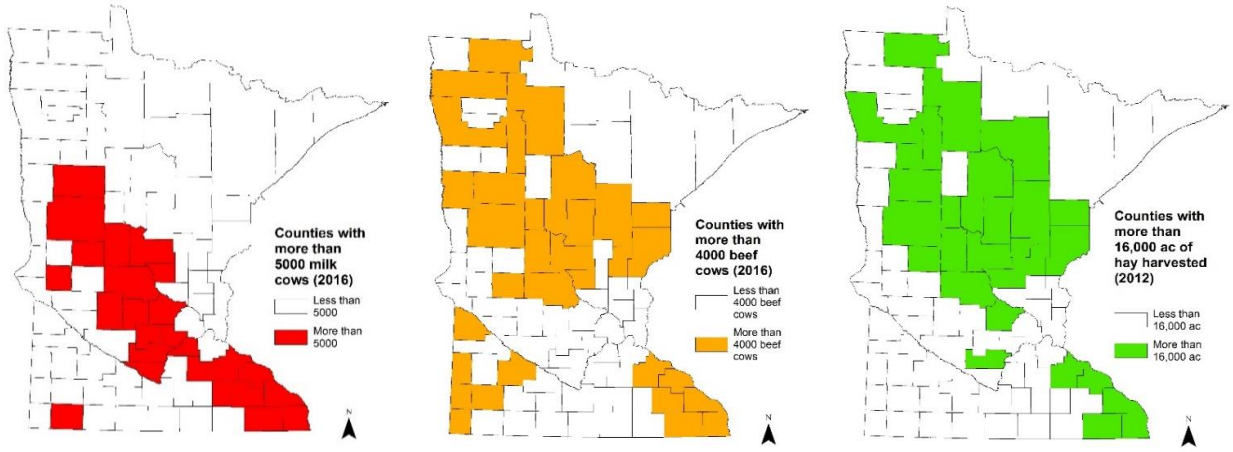
Alfalfa

Alfalfa is typically grown in a two- to three-year rotation, and is defined in statute (see Definition of Terms above) as a perennial crop. Its primary use is for livestock feed. High-quality alfalfa is considered "the cornerstone of any dairy farm forage ration," according to the University of Minnesota Extension. Of 1.8 million acres of hay produced in Minnesota, about 70% consists of alfalfa, and over three-quarters of the alfalfa crop is baled as dry hay.

Alfalfa fixes substantial amounts of nitrogen in its crown and roots, and scavenges nitrogen in the soil. It can be highly productive, with an average yield of 3.4 tons per acre, and requires little if any fertilizer. Its benefits include erosion control, reduction in the population of annual weeds, and an increase in the yield of crops that follow in a rotation, as the stored nitrogen is released into the soil. Use of alfalfa in a corn rotation has been shown to lower production costs, since less fertilizer is needed.

However, the amount of alfalfa grown in Minnesota is declining. As shown in Figure 2 below, alfalfa supply is localized to demand, and fewer cattle on the landscape mean that less hay is being grown. Other challenges can come with wet weather (as in 2017) resulting in lower-quality hay and a decline in hay prices. Transportation costs make it impractical to ship hay long distances. Moreover, alfalfa production simply requires more labor and more equipment than corn and soybean production.

Figure 2: Relationship of Milk Cows, Beef Cows, and Hay Production. From Goplen, 2017



Potential Uses of Alfalfa

The Forever Green Initiative is working on development of more winter-hardy versions of alfalfa. Cultivating alfalfa in mixed stands with grasses produces hay that is more suitable for horse consumption, since pure alfalfa hay is too high in protein; horses represent an underutilized market for alfalfa.

AURI is researching methods for extracting the soluble protein from alfalfa, which could present opportunities for livestock and poultry feed. Alfalfa is also a key constituent of pasture-based grazing systems for livestock.

Alfalfa-grass forage mixture. Photo: U of MN Extension

Annual Cover Crops

Oilseeds: Camelina

Camelina plot at U of MN - Morris

Camelina (Camelina sativa) is a short-season annual crop native to parts of Asia and Europe, now being recognized in North America as an oilseed crop. According to the Forever Green Initiative, "camelina has great potential for use as a cash cover crop that can provide both ecosystem services and economic benefits to farmers in the Upper Midwest." Research shows that winter camelina can feasibly be double- and relay-cropped with traditional food and forage crops such as soybean and spring wheat. These cropping systems require little fertilizer and water, remove excess nitrogen from the soil, prevent soil erosion, and provide needed early spring forage for pollinators.

Camelina is grown in the Pacific Northwest primarily as an early summer annual oilseed crop. Research in Minnesota and the Dakotas focuses on its use as a winter annual suitable for northern climates. The winter camelina currently grown at Morris is integrated into a three-year rotation of corn grain, spring wheat and soybeans that is typical of western Minnesota. The camelina is planted after spring wheat harvest using a prairie grass drill. Soybean is planted the next spring into the camelina in 30 inch rows. The camelina is harvested using a combine over the tops of the young soybean plants. It is not yet clear whether camelina can be established successfully between soybean crops (that is, planted following soybean harvest) since much depends on when the ground freezes in any given year. Breeding initiatives are focused on reducing seed pod shatter, increasing seed size, and achieving earlier maturity.

In the Pacific Northwest, the average yield of spring camelina is 1,600 pounds of seeds per acre. Tests of winter camelina at Morris showed somewhat lower yields of 1,300 – 1,400 pounds per acre, but seeds have a higher oil content.

Winter camelina harvest. Photo: Forever Green

Camelina for biojet fuel

The Commercial Aviation Alternative Fuels Initiative (CAAFI) is a coalition of airlines, aircraft and engine manufacturers, energy producers, researchers, international participants and U.S. government agencies seeking to promote the development of alternative jet fuel options are comparable to petroleum-based jet fuel in safety and cost, while also offering environmental

improvement and security of energy supplies. There are many different production methods; camelina and other plant oil crops are most suitable for hydro-processing. Hydro-processed renewable jet fuels (HFJ's) are typically blended at about a 50:50 ratio with traditional petroleum fuels. They are resistant to microbial growth and able to be stored effectively. No engine modifications are needed to conventional aircraft engines.

CAAFI's director, Steve Csonka, reports that there is clear interest in camelina as an alternative jet fuel, especially the winter varieties. Studies indicate that camelina-based biojet fuel reduces CO2 emissions by 75 percent compared to traditional petroleum-based jet fuel, as well as reducing particle emissions in engine exhaust. The primary obstacle to widespread adoption, as with other biofuels, is the low price of conventional jet fuels. A recent study at Oregon State University found that a gallon of camelina-based jet fuel would cost about 60 cents more than conventional jet fuel.

Other uses for camelina

- Camelina oil was used historically for food, medicinal use, and lamp oil. It is being marketed in Europe in salad dressing and cooking oil, and is used in skin care products and detergents.
- Camelina feed is approved for salmon and trout feed in Canada, comparing favorably to canola. It is farmed in Saskatchewan; the oil sells for around $2,200 a ton.
- Camelina shows promise as an early spring food for pollinators, particularly for honeybees, since it flowers from late April through early May when there is little other food available. Camelina planted at Morris produced 100 pounds of nectar sugar and 60 pounds of pollen per acre, enough to meet the annual needs of one beehive.
- Camelina meal can be used as a constituent of beef cattle protein source, similar to distiller's dried grains with solubles (DDGS), a byproduct of ethanol production.
- There is interest in camelina as a constituent of bio-based plastics, with ongoing research at AURI.

Oilseeds: Pennycress

Field pennycress (*Thlaspi arvense* L.) is a winter annual oilseed similar to camelina, with similar benefits for erosion control and nitrate removal. It provides good weed control, reducing herbicide inputs by up to two-thirds. At the University of Minnesota - Morris the most productive lines are producing around 1,500 lbs/acre (25 bu/acre) of seed with 40% oil by weight.

Based on research in Illinois and Missouri, pennycress' shorter growing season makes it suitable for a corn and soybean rotation – it can be aerially seeded over standing corn in August to September, then harvested in late May. The applicability of this rotation in Minnesota has yet to be determined.

The University of Minnesota, Department of Agronomy and Plant Genetics, has initiated a breeding program to develop early maturing varieties of pennycress and is collaborating with USDA-ARS on a breeding program.

Pennycress oil is not yet approved as an edible oil. The most likely market for pennycress is biodiesel fuel, since it is comparable in viscosity and other characteristics to soy-based biodiesel and may perform

better in colder climates. Like camelina, pennycress is also being researched as a constituent of bio-based plastics.

Winter Rye (Cereal Rye)

Winter rye (*Secale cereal*) is a common winter annual cover crop in Minnesota, particularly in conjunction with sugar beets, reducing their vulnerability to wind erosion.[3] It is the only small grain that meets the standards for winter hardiness to overwinter in Minnesota. Winter rye can be interseeded into corn or planted after small grain harvest and can be grazed in fall as a forage crop. It requires termination in the spring prior to planting corn. Its decomposition leads to chemicals being released that suppress weeds. However, winter rye currently doesn't fit well into a soybean rotation, since all commercial varieties mature in late June nearly a month later than the recommended soybean planting dates.

Breeding efforts are focused on developing varieties that increase early season biomass and allow for easier seeding of the subsequent crop varieties. There is demonstrated market interest in malting rye for distilling and craft brewing. North Dakota State University is testing new varieties to meet these demands.

Cover Crop Mixtures for Soil Health

Conventional wisdom regarding cover crops in Minnesota was that the short growing season made cover crops too difficult to establish. However, there is increasing interest in cover crops for seasonal grazing and for soil health and improved yield of associated row crops. Potential benefits of cover crops include reduced soil compaction, additional soil water holding capacity due to greater soil organic matter, nitrogen fertilizer savings from mineralized soil organic matter, cooler soil temperatures during the growing season, and herbicide cost savings.

Cover crops require some trial and error to establish, but seem to be the most successful when a mixture of crops is planted, including brassicas (e.g., radishes, turnips), legumes (e.g., clovers), and annual grasses (e.g., oats or annual ryegrass). The spreadsheet decision tool factors in several types of cover crops, including legumes and oilseeds.

[3] The words rye and ryegrass cause much confusion. Rye (*Secale cereale*) typically refers to the cereal or small grain plant. It produces a grain with strong flavors and colors. Flour made from it is used to make rye breads, and it is distilled to make rye whiskey. Ryegrasses (*Lolium multiflorum*) are very palatable, high quality forage grasses. There are several types of ryegrass cultivars with varietal differences within each type. https://www.agweb.com/article/rye_and_ryegrass_whats_the_difference_naa_university_news_release/

Forage Crops for Managed Grazing

There is increasing interest in managed grazing, also known as rotational grazing, for beef cattle production and, to some degree, for dairy cattle. As described on the MDA website, "Rotational grazing is a livestock production system where livestock graze in one portion (a paddock) of a pasture that has been divided into several paddocks.
Livestock are systematically moved from paddock to paddock based on the stage of growth of the forages and on the objectives of the grazing system. While one paddock is being grazed, the rest of the pasture rests. This rest and recovery time maintains forage plants in a healthy and vigorous condition." The trampling and fertilization of the soil through managed grazing mimics the ecosystem processes historically present on bison-grazed native prairie.

Dairy grazing herd walks to pasture. Photo: Dairy Grazing Apprenticeship Program

Beef cattle can be moved around the landscape, allowing them to graze for short periods on different tracts of land. The Cropland Grazing Exchange, developed by MDA with partners from NRCS and Sustainable Farming Association have developed a website which is intended to match up livestock farmers with crop farmers who have forage to harvest. Grazing is increasingly being used as a management tool on Wildlife Management Areas and other conservation lands, since it offers many of the same benefits as controlled burning but is less weather-dependent.

The economics of dairy grazing are somewhat limited by the distance that cows can be expected to travel to pasture. However, organizations such as the Dairy Grazing Apprenticeship Program are promoting a small-scale dairying model that relies on pasture for much of the year. Most dairy grazing operations in Minnesota are organic, which makes it difficult to generalize to all operations.

The spreadsheet decision tool includes models for grass-fed beef, cow-calf operations using grazing, and dairy grazing, both organic and conventional.

Other Biomass Crops

A number of other biomass crops were reviewed as part of this study but are not explored in detail in this report. In many cases research into the potential end uses of the crop is lacking, while in other cases the economics of production appear unfavorable.

- **Short-rotation woody biomass crops** – there has been considerable research into the use of poplar and willow species for biofuel. However, the current status of the forest products sector in Minnesota means that there is a declining market for woody biomass in general.
- **Cattails** – there have been some promising efforts to harvest invasive cattail species for biomass in Manitoba and in the Red River Basin in Minnesota. Specifically, Manitoba has actively pursued harvesting of cattail from Lake Winnipeg and other nutrient-stressed waters, pelletizing of the cattails, and supplying them as biofuel for residential pellet stoves and industrial uses. However the province's energy mix (phasing out coal stoves) and available subsidies make these uses uniquely feasible. Likewise, the North Ottawa flood control project in the Bois de Sioux watershed of the Red River Basin successfully harvests cattail after seasonal drawdowns of water in part of the impoundment and uses it as green manure. As yet, this project is unique and highly localized, although the process is worth exploring for other flood control projects.
- **Other warm-season grasses**, such as prairie cordgrass and little bluestem, may be appropriate for use in combination with a perennial biomass crop such as switchgrass. Research at South Dakota State University indicates that higher yields of biomass are obtained by planting cordgrass at the foot of a slope, little bluestem at the highest point, and switchgrass everywhere else. Greater diversity will yield greater habitat benefits, similar to native tallgrass prairie communities. This is another topic deserving of further research.

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Appendix A: Preliminary Survey Findings

Economic and Social Capacity Analysis of the Working Lands Watershed Restoration Program

Preliminary Survey Findings

Prepared for the Minnesota Board of Soil and Water Resources

October 04, 2017

Amit K Pradhananga

Center for Changing Landscapes

University of Minnesota

Summary of findings

After one wave of mailing, we have received 260 completed surveys for a response rate of 10% (Table 1). Two more waves of mailing are scheduled in the next two months.

1. **Sociodemographic and property characteristics**

- Most respondents were male (92%), and white (100%) with a median age of 37 (Table 2).
- About half of the respondents have at least an associate or vocational degree (51%), and a majority (60%) reported total household income of over $75,000 (Table 2).
- Farming experience, in years of farming, ranged between 0 and 82 (Table 2).
- About half of the respondents (49%) farmed over 200 acres in 2016 (Table 3).
- Almost two-thirds of respondents (64%) make their own decisions on their farm, and close to one-half of respondents (48%) reported that over 50% of their income is dependent on agricultural production (Table 3).

2. **Perspectives on perennial or cover crops**

- Less than a quarter of respondents reported that they have converted any portion of their farm from single annual row crops to perennial crops (23%) or added cover crops (20%) to their row crop acreage in the past 10 years (Table 4).
- On average, respondents are most familiar with alfalfa (Mean = 2.26), followed by annual cover crops and small grains (Mean = 1.49). Over three-fourths of respondents reported that they are moderately to very familiar with alfalfa (77%). In contrast, a majority of respondents reported that they are not at all familiar with kernza (66%) and winter-hardy oilseeds such as camelina and field pennycress (74%) (Table 5).
- A majority of respondents reported that they have not planted any of the six types of perennial or cover crops on their farm in the past 10 years (Table 6).
- Over one-third of respondents (35%) are somewhat to very likely to plant alfalfa on their farm in the next five years. Most respondents reported that they are somewhat to very unlikely to plant perennial or cover crops such as annual cover crops and small grains (59%), perennial grasses (64%), kernza (73%), and winter-hardy oilseeds (73%) on their farm in the next five years (Table 7).
- On average, financial incentives appear to be the most important motivation for future use of perennial or cover crops. A majority of respondents reported that they are somewhat to very likely to plant perennial or cover crops if they could get higher payments (63%) and tax benefits (58%) for planting the crops, and if they were compensated for lost crop production (58%). Most respondents were also more likely to plant perennial or cover crops if there were markets available to sell the crops (53%), and if conservation program requirements were less complex (52%) (Table 8).

Table 1. Response rate by watershed

	No. of completed surveys	Response rate
Buffalo River	40	8.7%
Chippewa River	50	11.0%
LeSueur River	52	11.4%
Minnesota River-Mankato	51	10.9%
Root River	36	7.8%
Sauk River	31	8.6%
Total	**260**	**9.8%**

Table 2. Respondents' sociodemographic characteristics

Socio-Demographic Characteristics		N	Percent
Gender	Male	165	91.7
	Female	15	8.3
Race	White	179	100.0
	Non-white	0	0.0
Age	Median	64	-
	Minimum	33	-
	Maximum	95	-
Years farming	Median	37	-
	Minimum	0	-
	Maximum	82	-
Formal education	Did not finish high school	6	3.4
	Completed high school	54	30.3
	Some college but no degree	28	15.7
	Associate or vocational degree	36	20.2
	College bachelor's degree	27	15.2
	Some college graduate work	9	5.1
	Completed graduate degree (MS or PhD)	18	10.1
Household income	Under $20,000	5	3.3
	$20,000-$49,999	25	16.7
	$50,000-$74,999	30	20.0
	$75,000-$99,999	25	16.7
	$100,000-$149,999	30	20.0
	$150,000-$199,999	12	8.0
	$200,000-$249,999	8	5.3
	$250,000-$299,999	1	.7
	$300,000 or more	14	9.3

Source: A study of farming practices in Minnesota, Questions 5, 29, 30, 31, 32, and 33

Table 3. Respondents' property characteristics

Property Characteristics		N	Percent
Acres farmed in 2016	Mean	518.2	-
	Median	200.0	-
	Minimum	0.0	-
	Maximum	5750.0	-
	0-100 acres	48	28.4
	>100-200 acres	39	23.1
	>200-500 acres	28	16.6
	>500-1000 acres	26	15.4
	>1000 acres	28	16.6
Percent income dependent on agricultural production	0% - 25%	65	35.7
	26% - 50%	30	16.5
	51% - 75%	17	9.3
	76% - 100%	70	38.5
Management decisions on farm	I make my own decisions	121	64.4
	I leave it up to the landlord	2	1.1
	I leave it up to my renter	39	20.7
	I hired a land manager	1	0.5
	I work together with the renter/landlord to make decisions	25	13.3

Source: A study of farming practices in Minnesota, Questions 1, 4, and 6

Table 4. Percent of respondents who have converted any portion of their farm from single annual row crops to perennial crops or added cover crops to their row crop acreage in the past 10 years

	N	Yes	No
Perennial crops	168	23.2	76.8
Cover crops	159	19.5	80.5

[a]Percent

Source: A study of farming practices in Minnesota, Question 13

Table 5. Respondents' familiarity with perennial or cover crops

	N	Mean[a]	SD	Not at all familiar[b]	Slightly familiar	Moderately familiar	Very familiar
Alfalfa	184	2.26	1.03	9.8	13.6	17.9	58.7
Annual cover crops and small grains (e.g., winter rye, oats, winter wheat) for soil health or grazing	180	1.49	1.11	24.4	26.1	25.6	23.9
Mixed grazing and forage crops (e.g., grasses, brassicas, legumes)	182	1.25	1.03	29.1	31.9	24.2	14.8
Perennial grasses (e.g., switchgrass, miscanthus, mixed species prairie)	180	1.19	1.12	36.1	27.2	18.3	18.3
Kernza (perennial, "intermediate wheatgrass")	178	0.52	0.83	66.3	18.5	11.8	3.4
Winter-hardy oilseeds as cover or relay crop (e.g., camelina, field pennycress)	181	0.32	0.60	74.0	21.0	3.9	1.1

[a]Responses on a four-point scale from not at all familiar(0) to very familiar (4)
[b]Percent
Source: A study of farming practices in Minnesota, Question 14
SD = Standard Deviation

Table 6. Percent of respondents who have planted perennial or cover crops on their farm in the past 10 years

	N	Yes[a]	No
Alfalfa	182	46.2	53.8
Annual cover crops and small grains (e.g., winter rye, oats, winter wheat) for soil health or grazing	171	29.2	70.8
Mixed grazing and forage crops (e.g., grasses, brassicas, legumes)	165	25.5	74.5
Perennial grasses (e.g., switchgrass, miscanthus, mixed species prairie)	166	24.1	75.9
Kernza (perennial, "intermediate wheatgrass")	139	2.2	97.8
Winter-hardy oilseeds as cover or relay crop (e.g., camelina, field pennycress)	144	0.7	99.3

[a]Percent
Source: A study of farming practices in Minnesota, Question 15

Table 7. Respondents' likelihood of planting perennial or cover crops on their farm in the next five years

	N	Mean[a]	SD	Very unlikely[b]	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Very likely
Alfalfa	181	-0.29	1.64	38.7	11.6	14.4	11.0	24.3
Annual cover crops and small grains (e.g., winter rye, oats, winter wheat) for soil health or grazing	179	-0.68	1.49	47.5	11.2	15.6	12.8	12.8
Mixed grazing and forage crops (e.g., grasses, brassicas, legumes)	177	-0.77	1.45	48.6	14.1	16.4	7.9	13.0
Perennial grasses (e.g., switchgrass, miscanthus, mixed species prairie)	176	-0.88	1.38	51.7	11.9	19.3	6.8	10.2
Kernza (perennial, "intermediate wheatgrass")	177	-1.24	1.02	58.2	14.7	22.0	3.4	1.7
Winter-hardy oilseeds as cover or relay crop (e.g., camelina, field pennycress)	178	-1.26	1.03	60.7	11.8	23.0	2.2	2.2

[a]Responses on a five-point scale from very unlikely (-2) to very likely (2)
[b]Percent
Source: A study of farming practices in Minnesota, Question 17
SD = Standard Deviation

Table 8. Respondents' likelihood of planting perennial or cover crops under various conditions

	N	Mean[a]	SD	Very unlikely[b]	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Very likely
I could get higher payments for planting the crops	168	0.64	1.31	12.5	5.4	19.0	32.1	31.0
I could get tax benefits for planting the crops	166	0.54	1.35	14.5	4.8	22.3	28.9	29.5
I was compensated for lost crop production	166	0.54	1.31	12.7	6.6	22.9	30.1	27.7
There were markets available to sell the crops	165	0.47	1.21	11.5	4.8	30.3	32.1	21.2
Conservation program requirements were less complex.	165	0.44	1.21	10.3	8.5	29.7	30.3	21.2
Conservation programs were more flexible.	167	0.40	1.17	10.8	6.6	32.3	32.9	17.4
I had evidence that planting the crops improved water resources.	166	0.33	1.22	12.7	7.2	33.1	28.9	18.1
I had financial assistance to plant and maintain the crops.	168	0.27	1.33	17.3	8.3	22.6	33.3	18.5
Equipment was made available to plant the crops	167	0.26	1.30	16.8	5.4	31.7	26.9	19.2
I could enroll in a government program providing technical or financial assistance	166	0.26	1.29	15.7	9.0	25.9	32.5	16.9
I had evidence that the perennial/cover crops did not reduce yield of conventional crops (i.e., corn and soybeans).	167	0.22	1.23	14.4	7.2	37.7	24.0	16.8
There was local infrastructure to store crops	163	0.21	1.20	14.1	6.7	36.8	28.2	14.1
I could learn how to maintain the crops for soil conservation	165	0.19	1.25	16.4	7.9	29.1	33.9	12.7
I could learn how to maintain the crops for erosion control	165	0.17	1.27	16.4	9.7	28.5	31.5	13.9
Trusted agricultural advisers helped me with crop management	165	0.16	1.19	15.2	5.5	40.6	26.1	12.7
I could talk to other landowners or farmers who have planted the crops	167	0.02	1.25	18.0	10.2	35.3	24.6	12.0
I had help with the physical labor of planting and maintaining the crops	165	-0.04	1.25	20.0	9.1	36.4	23.6	10.9
I could attend a workshop or field day about perennial/cover crops	166	-0.07	1.20	18.7	10.8	38.6	22.9	9.0
I knew more about how to plant and maintain the crops	167	-0.11	1.32	23.4	12.6	26.9	26.3	10.8
I knew more about the wildlife benefits of the crops	167	-0.22	1.32	26.3	9.6	34.1	19.2	10.8
I could be enrolled in a registry program that recognizes local conservation stewards.	166	-0.33	1.16	24.1	10.8	44.0	15.7	5.4

[a]Responses on a five-point scale from very unlikely (-2) to very likely (2)

[b]Percent

Source: A study of farming practices in Minnesota, Question 21; SD = Standard Deviation


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