Farmer-Led Expansion of Alfalfa Production to Increase Water Protection" (M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 04i)).

Project Abstract
For the Period Ending June 30, 2022

PROJECT TITLE: Farmer-Led Expansion of Alfalfa Production to Increase Water Protection

PROJECT MANAGER: Nicholas R. Jordan
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 04i as extended by M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18

APPROPRIATION AMOUNT: $500,000
AMOUNT SPENT: $386,514
AMOUNT REMAINING: $113,486

Sound bite of Project Outcomes and Results
Farmers working together in watersheds can build the base of supply chains for new crops that provide continuous living cover of farmland, thereby providing healthy soil, clean water, and abundant wildlife. These supply chains will meet demand for sustainably produced commodities, providing a market-driven pathway to clean water.

Overall Project Outcome and Results
We advanced a novel prevention-based strategy for protecting water resources, based on market-driven integration of alfalfa—and other perennial and annual crops that provide continuous living cover (CLC) of farmland—into corn/soybean-based farming operations. Integration of CLC crops will protect water resources, improve soil health, support wildlife, and enhance agricultural production and profit. Specifically, we **1) tested a farmer-led working lands approach for using alfalfa and other CLC crops to improve agricultural effects on water**, and **2) did R&D to open new markets for alfalfa**. Under 1), we worked with farmers in the Rogers Creek watershed near St. Peter, MN to develop and implement a watershed-scale protection plan based on adoption of alfalfa and other CLC crops, including on-farm implementation plans, and supported pilot-scale production of several novel CLC crops. We monitored water quality, showing that current farming systems are releasing relatively high levels of nutrients. Simulation modeling showed that increased production of alfalfa and other CLC crops can efficiently produce significant improvements in water quality. Economic analyses showed that integrating alfalfa and other CLC crops had good potential to support profitable production. Under 2), we assessed advanced processing and storage practices to reduce moisture-related spoilage and nutrient leaching of alfalfa, identifying eviable practices that reduce these historical impediments to profitable alfalfa production; we developed and assessed new applications for alfalfa, which revealed multiple promising options: biochemicals, nutraceuticals, and high-value sustainably-produced animal and aquaculture feeds; and developed supply-chain connections and identified market opportunities, via development of pilot projects, outreach and knowledge sharing, and novel collaborations. Overall, the project illuminated methods for building new production systems and supply chains needed to support increased production of alfalfa and other CLC crops as a scalable, non-regulatory approach for improving agricultural effects on water resources.

Project Results Use and Dissemination

We have disseminated results in reports, provided as appendices to the final project report (available in the Research Reports section here), and many presentations as detailed in the project's reports. These include the 2019 Minnesota River Congress meeting on "Profitable Farming in Time of Climate Change" meeting, a February 2020 industry meeting on alfalfa utilization, a February 2021 exhibition on value-added alfalfa applications at the Midwest Forage Association's Symposium, a July 2021 field day at a Kernza® field attended by 75 industry stakeholders, and a June 2022 "Fields of Opportunity" webinar in June that presented an overview of project findings to a large internet audience.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2018 ENRTF Work Plan Final Report

Today's Date: September 14, 2022

Date of Next Status Update Report: Final Report

Date of Work Plan Approval:

Project Completion Date: 6/30/22

Does this submission include an amendment request? No

PROJECT TITLE: Farmer-Led Expansion of Alfalfa Production to Increase Water Protection

Project Manager: Nicholas R. Jordan

Organization: University of Minnesota

College/Department/Division: CFANS/Agronomy & Plant Genetics

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Location: Region: Southwest, Southeast **Counties:** Nicollet

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Total Project Budget: $500,000

Amount Spent: $386, 514

Balance: $113,486

Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 04i as extended by M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18

Appropriation Language: $500,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to develop a farmer-led, market-based working-lands approach to increase water protection in agricultural areas by targeted expansion of alfalfa production and development of methods to convert alfalfa to high-value bioproducts. This appropriation is available until June 30, 2021, by which time the project must be completed and final products delivered.

M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18. ENVIRONMENT AND NATURAL RESOURCES TRUST FUND; EXTENSIONS. [to June 30, 2022]

I. PROJECT STATEMENT:

We are developing a novel prevention-based strategy for protecting water resources, based on a farmer-led, market-based working lands approach to enhancing protection of water in agricultural regions. Our project is based on targeted integration of the perennial crop alfalfa into corn/soybean-based farming operations. If carefully targeted, adding alfalfa to these operations will provide multiple benefits: protecting water resources by reducing soil erosion and loss of nutrients from farms, reducing need for pesticides, improving soil health, supporting wildlife (such as pollinators), and enhancing production and profit for farmers and the agricultural industry. Our project results will help enable application of this prevention-based strategy across most agricultural regions of Minnesota. Therefore, our project will advance a highly feasible, widely applicable, and sustainable solution to major water resource conservation challenges that have resisted solution for decades. Our project will innovate by developing new and widely-replicable methods for farmer-led protection of water resources, and by helping to develop extensive new markets for alfalfa. Beneficiaries include Minnesota farmers and the broader agricultural economy, and rural and urban communities that will benefit from improved water resources and from enhancements to the agricultural economy. Our specific objectives are **1) to test a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water**, and **2) to do focused research & development work to open new markets for alfalfa**. Under 1), we will develop a replicable working lands implementation approach, doing pilot work in the Seven Mile Creek watershed near St. Peter, MN, where there is substantial and growing demand for alfalfa. Our goals are to develop and implement a watershed-scale protection plan, involving 10-15 farmers in the watershed; develop on-farm implementation plans for 10-15 farm operations; provide advice and support to these operations on profitable production of alfalfa in corn-soybean systems while also efficiently producing environmental benefits; produce a water quality monitoring report on effects of integrating alfalfa in corn-soybean production systems in this watershed; produce an economic report on integrating alfalfa in corn-soybean production systems. Under 2), we will advance emerging technologies for utilizing alfalfa that are opening up new large markets for the crop; these markets include sustainably-produced aquaculture feed for farming high-value fish and shellfish in Minnesota, and other high-value bio-products from alfalfa. Our goals are to identify “rescue” strategies to protect alfalfa from moisture-related decay; optimize process to extract cellulose sugars from alfalfa for conversion into high-value bio-products such as biochemicals and nutraceuticals; upgrade alfalfa leaf extract for aquaculture feeds. Our project uses new scientific capabilities to target alfalfa in places where it will provide large improvements in water resources, and to produce high-value bio-products from alfalfa. Our project is supported by a wide range of preparatory efforts, an experienced project team, and leverages multiple collaborative partnerships, each of which will contribute additional efforts, resources, and substantial cost-share funds to the project.

II. OVERALL PROJECT STATUS UPDATES:

First Update January 31, 2019

Project efforts have focused, during the project ramp-up period, on Activity 1 (Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water), and Activity 3 (Develop value-added processes and products for profitable alfalfa marketing). For Activity 1, we have conducted strategic and implementation planning, which have positioned us for current activities, which focus on recruiting farmer participants in the watershed. For Activity 3, we have developed analytical methods and processes to reduce antinutrients that are hypothesized to be harmful to non-ruminants. This preliminary work was required due to new insights into processing that may enable new marketing opportunities for sustainable animal feeds for non-ruminant animals. These activities position the project to evaluate different harvesting methods, cutting mechanisms and storage integrity as the spring harvest commences.

Second Update June 30, 2019

During the first half of 2019, project efforts have **continued to emphasize** Activity 1 (Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water), and Activity 3

(Develop value-added processes and products for profitable alfalfa marketing). For Activity 1, we have carried extensive discussions with key participants in the project, including farmers, conservation professionals in state agencies and non-profit groups, and scientists in universities and agencies. We have also developed materials for informing potential farmer participants about the project and recruiting their participation. Progress for this activity was somewhat impeded by the resignation of both participating staff members of our key partner in Activity 1, the non-profit group Great River Greening. For Activity 3, project part AURI has taken the lead on development of value-added processes and products for that will enable profitable marketing. During the reporting period from Jan-2019 to Jun-2019, AURI built on the foundation we established previously on analytical methods and processes to reduce antinutrients that are hypothesized to be harmful to non-ruminants; while also conducting some outreach activities.

Third Update January 31, 2020

During the second half of 2019, project efforts have advanced Activity 1 (Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water), and Activity 3 (Develop value-added processes and products for profitable alfalfa marketing). For Activity 1, we have done a round of one-on-one meetings with potential farmer participants in our farmer-led working lands approach, explaining the approach that our project is piloting and testing. We have also done a wide range of outreach to potential market opportunities for agricultural products produced in the watershed. In addition, we have identified an opportunity to leverage the efforts with our project with a related effort in the Cannon River Watershed, and are working to enhance incentives for participation in our project by collaboration with the related effort. We are also seeking additional grant support to enable more robust evaluation of our approach. Finally, we have discussed possible cost-sharing for farmers participating in the pilot project from various State agricultural conservation programs with a range of personnel in relevant State agencies, including BWSR and MDA. Activity 2 work remains pending, as particular plans for changes in agricultural land-use in the project area develop. For Activity 3, project partner AURI has continued to lead on development of value-added processes and products for that will enable profitable marketing. During the reporting period from July 2019 to January 2020, AURI advanced two aspects within this activity: a) developing harvesting and storage mechanisms to minimize humidity-related spoilage; and b) expanding the uses of alfalfa extract to be amenable as a non-ruminant feed ingredient.

Fourth Update June 30, 2020

During the first half of 2020, project efforts have focused on advancing Activity 1 (Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water), and Activity 3 (Develop value-added processes and products for profitable alfalfa marketing), as well as several outreach activities. Despite a range of impediments related to the covid-19 situation, we were able to significantly progress toward Activity 1 goals, via a range of activities with participating farmers in our target watershed. We have also embedded our project efforts in a larger regional effort organized by the University of Minnesota's Forever Green Project. This regional effort is striving to create new market channels and other economic opportunities for alfalfa production, all of which will bolster the key outcome goals of this project. Alfalfa utilization R&D under Activity 3 are also key to creating new market channels and opportunities, and these also activities progressed during this reporting period.

Fifth Update January 31, 2021

During the second half of 2020, we continued to advance Activity 1 (Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water), and Activity 3 (Develop value-added processes and products for profitable alfalfa marketing), while also initiating planned water sampling activities as part of Activity 2. Additionally, we continued to engage with farmers in our project around their interests in adding new crops in their rotations, in addition to alfalfa, to provide additional market-driven pathways to water conservation. Specifically, we are working with several growers to demonstrate winter camelina integrated with overwintering "cash cover crops", and the perennial grain Kernza®. Each of these crops complement alfalfa as options to enable farmer-led, market-based working lands approach to increase water protection in agricultural

areas. There continues to be significant promise for developing markets for the new crop rotations in local bakeries, breweries, school districts, and grocery stores. The 44-acre winter Camelina pilot planting was delayed one year in order to better fit the crop rotation the farmer was targeting, but several smaller pilot plantings were established in the vicinity of the project area.

Amendment Request as of 05/05/2021

We wish to rebudget funds for the support of the planned water quality sampling. Instead of utilizing a UMN technician to conduct this water quality sampling, as originally planned and budgeted, we wish to add to our existing contract with project partner Great River Greening (GRG) for this same work, including necessary travel and supplies. GRG has the technical skills and also has established relationships with local landowners, which are important to getting permission to sample key locations. More broadly, GRG personnel are highly familiar with the watershed and its hydrology. To this end, we would rebudget funds for the associated labor (Total $24,975) from Civil Service salary and fringe to a Professional Services contract. We would also rebudget funds from Travel ($2,985) and Lab Services ($90), as these expenses associated with the water sampling would be included in a contract as needed to perform the service work itself. This leads to a total of $28,050 being moved into the contract with GRG.

Amendment approved by LCCMR 6/1/2021

Project extended to June 30, 2022 by LCCMR 7/1/21 as a result of M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18, legislative extension criteria being met.

Sixth Update June 30, 2021
During the first half of 2021, we began to overcome the delays in Activity 1 (Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water) that resulted from Covid-19. Specifically, it again became possible to hold one-on-one meetings with farmers in the project area, enabling key discussions and engagement activities to proceed. Also, as noted below, the project has advanced to the point where watershed-scale modeling of implementation scenarios for targeted adoption of alfalfa and other crops with particular water-quality benefits is warranted. During the reporting period, a baseline SWAT model was developed for the Rogers Creek watershed, setting the stage for modeling implementation scenarios, which is now underway. Water sampling activities under Activity 2, have continued, providing locally-meaningful monitoring data that are being shared with farmers under Activity 1. In work under Activity 3 (Develop value-added processes and products for profitable alfalfa marketing), project partner AURI has focused productively on R&D to develop protein products isolated from alfalfa juice. These proteins have promising market applications as sustainably-sourced animal feeds, and for direct human consumption, as a novel and sustainable-source plant protein ingredient that could be used in many food products. These novel market opportunities, which could enable significant expansion of alfalfa production – and hence water conservation – on Minnesota farms, are being broadly communicated by AURI in a variety of outreach forums.

Seventh Update January 31, 2022
During the second half of 2021, we continued to gain momentum, moving past delays in Activity 1 (Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water) that resulted from Covid-19. Specifically, we continued to hold one-on-one meetings with farmers in the project area, enabling key discussions and engagement activities to proceed. We continued and have largely completed watershed-scale modeling of implementation scenarios for targeted adoption of alfalfa and other crops with particular water-quality benefits, which we are now using in group discussions with farmers in the project area, to help these farmers in a group consideration of whether increased adoption of these crop is warranted. Water sampling activities under Activity 2 have also continued, with certain insights emerging because of very dry conditions that occurred during the main growing season in this period. In work under Activity 3 (Develop value-added processes and products for profitable alfalfa marketing), project partner AURI has focused on R&D to

develop protein products isolated from alfalfa juice for both sustainably-sourced animal feeds, and for direct human consumption. These studies advanced to the point where some results are in hand, as detailed below. Finally, AURI continued to face limitations on its outreach work from pandemic-related delays and restrictions during the second half of 2021, but some efforts were able to continue.

Final Update June 30, 2022

During the final months of the project period (the first six months of 2022), effort focused on continuing, finalizing, and developing deliverables relevant to project activities. Specifically, in Activity 1 work, we continued a range of activities to provide final inputs needed for both deliverables, and completed materials for these. We also developed a report describing lessons learned as we carried out the Activity 1 workplan, which presented us with a number of unexpected challenges and changes in circumstances, requiring a variety of adaptations on our part. We also developed a report, based on extensive simulation modeling, describing effects of diversification via alfalfa and other continuous-living-cover crops of current farming operations in the project's target watershed on water resources. For Activity 2, we developed several reports that supported our Activity 1 workflow, including a report on current water quality in the target watershed, and an extensive assessment of the economic opportunities associated with diversification of current farming operations with alfalfa and other and other continuous-living-cover crops. We also developed a report evaluating the replicable watershed planning and implementation process model we used, and identifying needs for scaling-up. This report describes lessons learned as we carried out the workplans for Activities 1 and 2, which as noted presented us with a number of challenges requiring adaptations on our part. Work on Activity 3 was led by project partner AURI. During the most recent project period, AURI's technical and value-chain development team focused on completing project deliverables, focusing on three primary areas of activity: 1) Assessment and implementation of advanced processing and storage practices to reduce moisture-related spoilage and nutrient leaching of alfalfa; 1) Development and assessment of new, value-added applications for alfalfa, and 3) Development of supply chain connections and identification of market opportunities, with a focus on development of pilot projects, outreach and knowledge sharing.

Overall Project Outcome and Results

We advanced a novel prevention-based strategy for protecting water resources, based on market-driven integration of alfalfa—and other perennial and annual crops that provide continuous living cover (CLC) of farmland—into corn/soybean-based farming operations. Integration of CLC crops will protect water resources, improve soil health, support wildlife, and enhance agricultural production and profit. Specifically, we **I) tested a farmer-led working lands approach for using alfalfa and other CLC crops to improve agricultural effects on water**, and **II) did R&D to open new markets for alfalfa**. Under I), we worked with farmers in the Rogers Creek watershed near St. Peter, MN to develop and implement a watershed-scale protection plan based on adoption of alfalfa and other CLC crops, including on-farm implementation plans, and supported pilot-scale production of several novel CLC crops. We monitored water quality, showing that current farming systems are releasing relatively high levels of nutrients. Simulation modeling showed that increased production of alfalfa and other CLC crops can efficiently produce significant improvements in water quality. Economic analyses showed that integrating alfalfa and other CLC crops had good potential to support profitable production. Under II), we assessed advanced processing and storage practices to reduce moisture-related spoilage and nutrient leaching of alfalfa, identifying eviable practices that reduce these historical impediments to profitable alfalfa production; we developed and assessed new applications for alfalfa, which revealed multiple promising options: biochemicals, nutraceuticals, and high-value sustainably-produced animal and aquaculture feeds; and developed supply-chain connections and identified market opportunities, via development of pilot projects, outreach and knowledge sharing, and novel collaborations. Overall, the project illuminated methods for building new production systems and supply chains needed to support increased production of alfalfa and other CLC crops as a scalable, non-regulatory approach for improving agricultural effects on water resources.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Develop a farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water.

Description: Support a core group of watershed farmers (initially organized by Nicollet County Soil and Water Conservation District), to design a farmer-led working lands plan by which these farmers take charge of preventive protection of water resources. The plan will be based on targeted expansion of alfalfa production in the Seven Mile Creek watershed within the 3-mile radius area surrounding Northern Plains dairy, and/or on relocation of existing alfalfa cultivation areas to other areas where they are more effective and efficient in protection of water resources. The UMN Collaborative Geodesign process will be used to identify specific on-farm locations for alfalfa cultivation that are economically advantageous for farmers while effectively and efficiently protecting water. This watershed-scale plan provides an overall scheme for water protection but is not sufficiently detailed to guide farm-scale implementation. Therefore, an expert consultant will assist individual farming operations in identifying on-farm locations for producing alfalfa to enhance crop production, profit, and water protection. To proceed, we will hold both one-on-one and group meetings with participating farmers, including those who are currently producing alfalfa and others who may wish to begin production. The project watershed coordinator will conduct and facilitate these activities. The coordinator will hold at least two individual meetings with each farmer, to explain and discuss options for producing alfalfa and participating in a watershed-scale plan to protect water. If a farmer is interested in expansion or improvement of alfalfa production, the expert consultant will help each farmer produce "*individual intent plans*" that identify how alfalfa production can be cost-effectively integrated with the current farming operation. At least two watershed group meetings will be held per year. These meetings will be used for discussion and implementation planning for expanding and improving alfalfa production to improve both farm revenue and water resources. The UMN Collaborative Geodesign tool will be used to develop a watershed plan for the 3-mile radius area, by knitting individual-intent plans together.

ENRTF BUDGET: $186,460; matching funds were provided, in the form of in-kind services contributed by University of Minnesota personnel Jordan to Activity 1, valued at $12,000.

Outcome	Completion Date
1. Develop and implement watershed-scale protection plan.	*June 30, 2021*
2. Develop on-farm implementation plans for 15 farm operations.	*January 31, 2021*

First Update January 31, 2019

Project efforts related to Activity 1 focused on strategic and implementation planning, including identifying key individuals and developing talking points for networking and recruiting activities to build a base of support among key influencers in the watershed, meeting with key stakeholders (e.g. City of St. Peter, Conservation Marketplace Minnesota), and updating plans for provision of decision support to participating farmers. These efforts positioned us for current activities, which focus on recruiting farmer participants in the watershed.

Second Update June 30, 2019

During this project period, project personnel from UMN and Great River Greening participated in numerous meetings with the Nicollet Co. Soil and Water Conservation District, local farmers, and scientists from local universities. These Scientists included faculty from the University of Minnesota, Gustavus Adolphus, and presenters at the 2019 Minnesota River Congress meeting and "Profitable Farming in Time of Climate Change" meeting in St. Peter. The meetings with SWCD staff, farmers, and scientists focused on preparations for farmer interviews. Landowner contact information and interview preparations were focused on the Seven Mile Creek Watershed. It was through these strategic meetings that partners agreed the project would be more effective if Rogers Creek were made the primary watershed. From early May through June, Great River Greening refocused their strategic planning for the Rogers Creek Watershed. Project progress was somewhat slowed by resignation

of both of the Great River Green personnel that had been advancing the project. However, at this writing, successors to both these individuals have been hired and are at work on the project.

Third Update January 31, 2020

Personnel from the University of Minnesota and Great River Greening (GRG) made extensive progress during this project period. GRG connected with more partners in the Rogers Creek area and contracted Aestiv LLC to assist with outreach and communication within the Rogers Creek area. GRG and Aestiv met with over a dozen farmers in the area to discuss their interest in establishing a core group of farmers who would pursue new opportunities for new markets at the local level. They also met with local dairy operations, bakeries, and grain storage facilities to discuss the potential for markets for new crops in the area. Additionally, project personnel met with a number of state agency personnel to discuss connecting participating farmers to State ag-conservation cost-share and other supporting resources. The project period ended with GRG and Aestiv planning for the first core group meeting at one of the farmer's homes inside the Rogers Creek watershed. Feedback from farmers has been positive and interest is high for pursuing new opportunities in the watershed.

Fourth Update June 30, 2020

Significant progress was made during this period of the project despite the unprecedented difficulties. Due to COVID-19, Great River Greening lost momentum in March with farmer outreach. Meetings were scheduled in March to discuss crops that the group of farmers would be most interested in learning more about and strategize the next steps. Not only was the meeting canceled, but the uncertainties of that time lost the interest of many partners to discuss any new crops or practices. GRG took a break from outreach for about 1.5 months while the farmers focused on planting their crops. By late April and early May, we returned to one-on-one discussions including farmers and local agronomists. We received a commitment from one farmer to plant 44 acres of Camelina this fall as a pilot demonstration field for other members of the group to observe and learn from. Another 12 acres of Kernza® were planted last fall inside the watershed that will also be used as a demonstration site. Outreach and communication moving forward will focus primarily on these two sites, but GRG is continuing to reach out to more growers in the watershed who are interested in these efforts.

Fifth Update January 31, 2021

Adjustments were made to outreach strategies during this period due to continued difficulties presented by COVID-19. Great River Greening continued to keep in touch with farmers throughout the watershed. Farmers remain interested in pursuing new crops in their rotations and changing rotations for more sustainable markets and decreasing environmental impacts. There continues to be significant promise for developing markets for the new crop rotations in local bakeries, breweries, school districts, and grocery stores. The 44-acre winter Camelina planting was delayed one year in order to better fit the crop rotation the farmer was targeting. The farmer growing 12 acres of Kernza® on the edge of the watershed allowed a group of farmers and buyers to attend socially-distant pre-harvest and harvest gatherings at the field. GRG videoed the consultations and conversations at these gatherings, interviewed attendees (including state representative Jeff Brand), and recorded a nearby Kernza® planting. They are compiling the videos into promotional and educational material for farmers in the area who are interested in growing Kernza® and other new crops. Due to the shift in outreach strategies, GRG continues to develop better online resources to compensate for the inability to host as many in-person gatherings as planned.

Sixth Update June 30, 2021

Great River Greening continued to make good progress in recruiting farmers and other partners within the supply chain to join the farmer-led group interested in pursuing increased acreage in new crop rotations. They met with members of multiple agencies, University Extension, and other non-profits to discuss other incentives for the new crops as well. GRG was able to publish articles in local newspapers, newsletters, and partner websites about the local interest in the new crops. The farmer who was planning on planting 44 acres of winter camelina last year had to delay their piloting of the crop, but they plan on planting 15 acres this fall where the field can be a demonstration for other farmers in the area. Individual conversations have continued to build a

stronger commitment from those who are interested. The water sampling portion of the project has also led to conversations with other farmers in the watershed who wanted to learn more about the project. GRG plans on hosting two or three field days this fall where farmers will be able to observe the community support. Finally, the project has advanced to the point where spatial modeling can be used to test scenarios for implementation of targeted planting of alfalfa and other perennial and continuous-living-cover crops in the Roger Creek watershed. The SWAT model was used instead of the UMN Collaborative Geodesign process; the latter was originally planned but is not available for the Rogers Creek watershed that has become the project's focus. During the reporting period, the initial stages of SWAT modeling were accomplished, enabling the development of modeled implementation scenarios, which are now in preparation.

Seventh Update January 31, 2022

Great River Greening continued making progress recruiting farmers and partners. Conversations became more frequent with local agency staff and University Extension about the role of marketable continuous living cover crops in improving drinking water and surface water quality. The city of St. Peter is interested in how effective these crops are in the DWSMA which overlaps the Rogers Creek watershed. GRG hosted a field day at a Kernza® field in which they invited 25 farmers, market representatives, and agency staff, but 75 people attended. This event was a testament to the community interest and support of these crops. A farmer also planted 15 acres of winter camelina into a rye field as the first pilot of the marketable cover crop in Nicollet County. Other local farmers stopped by to watch and ask questions. GRG and partners are planning a farmer meeting for February 24th where approximately 15 farmers are likely to attend out of interest in continuous living cover crops. COVID prevented a couple of gatherings from taking place, but conversations continued to increase interest.

Final Update June 30, 2022

Great River Greening hosted a farmer dinner on March 2, 2022 (rescheduled due to weather). It was exciting to see farmers discussing the logistics and real possibility of growing continuous living cover crops. A couple of farmers expressed serious interest in trying a new crop within the next few years. There were 13 total attendees with 3 of those being Forever Green and Great River Greening representatives and the rest being farmers or landowners. The spring experienced an unfortunate setback when the landowner of the winter camelina pilot field sold it to someone who proceeded to kill the crop. Other farmers who were interested in piloting their own fields of winter camelina in Fall 2022 decided to wait until someone else has successfully grown the crop in the area. The original winter camelina grower has committed to piloting it again. Great River Greening also produced a video about the piloting of new crops like winter camelina. The video is available on Great River Greening's YouTube channel and 7-milecreek.org. Great River Greening has also secured further funding to continue the momentum through events and field days in the area as more farmers are expressing interest.

Final Report Summary

By the end of the project partners on this project had met with 48 farmers, landowners, and operations affiliates in the area. Of those 23 were interested and active in the project. The farmers collectively farm 5,000 acres in the area and 2,900 acres in the Rogers Creek watershed. The watershed protection plan is provided as Appendix I. On-farm implementation plans could be developed on only a limited basis. The forced relocation of the project to an adjacent smaller watershed (i.e., Roger Creek watershed) reduced the total number of farm operations that might potentially participate and only a fraction of these operations were open to considering implementation plans. We also found that much more extensive and protracted initial discussions were needed before farmers will were open to detail planning discussions re. integration of additional alfalfa and other CRC crops in their farm operations. We were able to hold such discussions with 6 farm operations (farmed acreage totaled about 4000 or 28% of the watershed). These discussions involved detailed analysis of each farm operations in terms of current cropping systems, rotations, and placement of crops across the spatial extent of each farm, seeking to identify opportunities to improve the farmability, profitability, and environmental footprint of the farm operations. As appropriate to each operation and each farmer's willingness to discuss particular aspects of their operations, these analyses involved field visits, GIS precision ag analysis, and financial

improvement/ROI analysis. Results of this planning work for individual operations is not included in this report to respect confidentiality of farmer's business information discussed in the course of planning.

Activity 2: Implementation Support for Alfalfa Integration in Corn/Soybean Production Systems.
Description: Communicate available information to support targeted integration of alfalfa into the prevalent corn/soybean production systems in this region, so that farmers can profitably produce abundant yields of quality alfalfa while maximizing water-quality and other resource protection benefits of alfalfa production. This will be done by providing advice and support to farmers within the Seven Mile Creek watershed and in adjacent watersheds. Monitor water quality impacts (including nutrients, soil sediments, and pesticide residues, among other parameters) by a flexible, adaptive strategy, in collaboration with the Federal Clean Water Act Section 319 Project ***Seven Mile Creek Assessment and Implementation*** (Gustavus Adolphus College), and determine economics of alfalfa production when integrated into corn/soybean production systems for production and resource protection.

ENRTF BUDGET: $126,940, matching funds were provided, in the form of in-kind services contributed by University of Minnesota personnel Mulla, valued at $13,340. Original proposal planned matching funds from Federal Clean Water Act Section 319 Project Seven Mile Creek Assessment and Implementation (Gustavus Adolphus College) to support Activity 2 water quality monitoring during all project years. These funds were not expended, due to relocation of project to a different watershed, for which no Section 319 project funds were available.

Outcome	Completion Date
1. Advice and support for profitable production of alfalfa in corn-soybean systems while also efficiently producing environmental benefits.	*January 31, 2021*
2. Water quality monitoring report on effects of integrating alfalfa in corn-soybean production systems.	*June 30, 2021*
3. Economic report on alfalfa on integrating alfalfa in corn-soybean production systems.	*June 30, 2021*
4. Evaluate replicable implementation process model and identify needs for scaling-up.	*June 30, 2021*

First Update January 31, 2019
Project work on Activity 2, Implementation Support for Alfalfa Integration in Corn/Soybean Production Systems have not yet been initiated, as these activities are contingent on Activity 1.

Second Update June 30, 2019
As was the case at the first update, above, activities under Activity 2, Implementation Support for Alfalfa Integration in Corn/Soybean Production Systems, have not yet been initiated, as these activities are contingent on Activity 1. We anticipate that these activities, particularly Advice and support for profitable production of alfalfa in corn-soybean systems while also efficiently producing environmental benefits, will commence in first quarter 2020.

Third Update January 31, 2020
Activities under Activity 2, Implementation Support for Alfalfa Integration in Corn/Soybean Production Systems, remain pending, but related support has begun regarding other perennial crop integration, specifically for the perennial grain crop Kernza® (intermediate wheatgrass), and participating farmers will be establishing 110 new acres of Kernza® within the project area in 2020.

Fourth Update June 30, 2020
Great River Greening developed a scope of work for water sampling throughout the watershed in coordination with the MPCA to build on their previous sampling efforts. First samples were collected at the end of June and will continue at least monthly through the end of the project. These samples will serve as baseline samples for

nutrients in the creek and drainage systems before new crops are planted in order to determine the impact from using more cover crops and perennial crops in the watershed. At present, three farmers are willing to allow GRG staff to collect samples directly from their drainage systems in order to study the change in nutrient concentrations before and after new crops are added to their rotations.

Fifth Update January 31, 2021
Great River Greening began a monthly sampling routine throughout the Rogers Creek watershed. Samples were taken from the creek channel near the outlet, ditches, and tile drains throughout the watershed. Each sample was submitted to the Minnesota Department of Health environmental laboratory for nutrient analyses. Three farmers are allowing samples to be taken from their tile drains and nearby ditches. One farmer decided to start researching agricultural best management practice ideas as a result of seeing the nitrate concentrations coming from their field. The results will be reviewed this winter and shared with the farmers to help them better understand the nutrient efficiencies of their crops.

Sixth Update June 30, 2021
Water sampling has continued throughout the watershed. GRG and the U of M have decided to grab samples for another year. Three farmers have given GRG permission to grab samples from their tile drains across eleven drainage systems, and GRG is grabbing samples from two ditch sites and three stream sites. The Kernza® sites are showing the lowest concentrations of nutrients in their discharge, and the grain rotations and alfalfa sites are also yielding promising concentrations in this watershed. The nitrate concentration has been decreasing over the course of the past year, but this seems to follow a similar trend in other waterways across southern Minnesota rather than being a result of practices in the watershed.

Seventh Update January 31, 2022
Great River Greening continued to collect water samples from throughout the watershed. One family requested more samples from some of their fields that contain higher levels of organic matter. Sampling needed to stop on two fields due to conflict between the landowner and renter. GRG recruited a local crop consultant who started having meetings with farmers to discuss the economic and agronomic viability of continuous living cover crops on their respective fields. GRG also continues to partner with the University of Minnesota to model the water quality impacts of larger-scale land conversion in the Rogers Creek watershed. Summaries of these results will be shared at a farmer meeting in February.

Final Update June 30, 2022
Great River Greening finished collecting water samples in May 2022. They organized the data for an appendix to the final report. Results from the private landowners' drainage tiles will be shared with those farmers individually and an in-person explanation and follow up with occur in the winter after the farmers' busy harvest season is complete. Students from a University of Minnesota hydrology class join GRG staff on a couple of sampling days to learn more about the process and to take cross-section measurements in a couple of locations along the creek. They also estimated flow at one of the locations. Results from the sampling period are included as an appendix to the final report.

Final Report Summary
We describe outputs and outcomes from Activity 2 under the headings of the main deliverables for this activity.
1. Advice and support for profitable production of alfalfa in corn-soybean systems while also efficiently producing environmental benefits. This deliverable was not produced, and budgeted funds for its production were not expended. The increases in local demand for alfalfa that were anticipated at the outset of the project did not materialize, partly because of changes in the business circumstances and plans of several large dairy farms in the project region. In the absence of increased demand, no farmers decided to increase production of alfalfa in their farming operations. Several farmers in the project watershed did decide to begin pilot production of several other continuous-living-cover crops (specifically, the perennial grain Kernza® and the winter-hardy

oilseed winter camelina), but these farmers obtained technical support through other channels, avoiding the need to spend project funds for that purpose.

2. Water quality monitoring report on effects of integrating alfalfa in corn-soybean production systems.
The monitoring report is provided as Appendix II. Our water sampling during the project period revealed nutrient concentrations that were generally comparable to other nearby watersheds with similar levels of row-crop agriculture. During the project water-sampling period, conditions were relatively dry, reducing Nitrate-N loss relative to more typical years, but many of our samples still exceeded surface water quality standards for Nitrate-N. Total phosphorus samples showed that most of the ditch and creek sites exceeded the state standard for total phosphorus (0.15 mg/L), with samples exceeding 1.0 mg/L observed in some cases; these levels occurred immediately after rain events. The two sampled Kernza® fields had lower concentrations of nitrate/nitrite-N, and one Kernza® field averaged under 0.5 mg/L nitrate/nitrite-N, a very low level, demonstrating the potential of this perennial grain crop to address nitrate contamination issues in the watershed and nearby drinking water source areas. There are areas of highly-organic soils in the watershed, which may be contributing a disproportionate amount of nitrogen to the creek. Targeting those acres with CLC crops could be beneficial for water quality, but those acres are also likely wetter and may not support many CLC crops. Targeting acres with high nutrient losses and soils that could grow CLC crops may be beneficial, and restoring wetlands or other cover to wet soils high in organic matter may be better for those acres.

3. Assessment of effects of diversification via alfalfa and other CLC crops on water resources.
We also developed a report, based on extensive simulation modeling, describing effects of diversification via alfalfa and other continuous-living-cover crops of current farming operations (principally, annual row-crop systems based on corn and soybean production) in the project's target watershed on water resources. This report is provided as Appendix III. In this modeling work, nitrate-N, total phosphorus, and sediment losses for the Rogers Creek watershed were predicted using the Soil and Water, Assessment Tool (SWAT) model. A comparison was made between predicted nutrient losses given current cropping practices (corn-soybean rotation), and for alternative cropping systems which incorporated alfalfa and other perennial or cover crops. The alternative cropping systems included an alfalfa rotation (alfalfa in rotation with corn), a Kernza® rotation (intermediate wheatgrass grown in rotation with soybean), and a winter camelina rotation (soybean grown in rotation with winter rye, and winter camelina used as a cover crop). Model simulation of these rotations required creation of new crop files for Kernza® and winter camelina within SWAT, which were validated using measured yield, biomass, and nitrate-N data. Simulated average annual nitrate-N losses given the current corn-soybean cropping system were 29 kg/ha. Model results show that conversion of corn-soybean acreages to the alfalfa and Kernza® rotations were particularly effective at reducing nitrate-N losses from agricultural areas in the watersheds, but reductions in nitrate-N were also achieved with the winter camelina rotation. From model predictions, achieving a 10% reduction in nitrate-N in the watershed required converting approximately 4% of current corn-soybean area to the alfalfa, winter camelina, or Kernza® rotations. Larger areas of land were needed to achieve greater reductions in nitrate-N, in particular for the winter camelina rotation. A 50% reduction in nitrate-N in the watershed required converting 61% of current corn-soybean area to the alfalfa rotation, 54% of those areas to the Kernza rotation, or all of the area to the winter camelina rotation. Average annual sediment and total phosphorus losses for current land-use were predicted to be 4.47 tons/ha and 3.26 kg/ha, respectively. A small area of land cropped with corn and soybean on areas of high slope was responsible for the majority of the sediment and phosphorus losses; 3.9% of the land cropped in the corn-soybean rotation was responsible for 98% of sediment losses and 94% of phosphorus losses. The Kernza®, alfalfa, and winter camelina rotations were all effective at reducing sediment and phosphorus losses when targeted to those areas contributing the highest loads. A 10% reduction in sediment was achieved converting 0.7% of the corn-soybean acreage to the alfalfa rotation, 0.5% of the area to the Kernza® rotation, or 1.4% of the area to the winter camelina rotation. In order to achieve a 10% reduction in phosphorus, 0.4% of the land needed to be converted to the alfalfa or Kernza® rotation, or 0.8% of the land to the winter camelina rotation.

4. Economic report on alfalfa on integrating alfalfa in corn-soybean production systems.
The economic report is provided as Appendix IV. As noted above, the scope of the report including additional continuous-living-cover crops, such as Kernza and winter camelina, to respond to farmer interest. The report concludes that many of these crops could be produced profitably in the project region, but profit levels were often less than obtainable through conventional corn-soybean production systems. This analysis shows that additional revenue will be necessary to support production of these crops in the region, e.g., via payments for production of environmental benefits related to water resources. However, these analyses are conservative as they do not take into account the value of agronomic benefits resulting from diversification of farming operations by production of these crops. These benefits include increased soil health and quality, and control of pests such as herbicide resistant weeds.
5. Evaluate replicable implementation process model and identify needs for scaling-up. This deliverable is included in Appendix I. In general, we found that our implementation process model was promising. Implementation efforts in the project region have created considerable interest in working together to develop market opportunities for production of continuous-living-cover crops that protect water resources, as well soil and wildlife, while opening new economic opportunities for regional farmers. However, we found that a number of particular factors impeded progress, including the Covid-19 pandemic, uncertain market demand for these crops, and the complexity of exploring diversification options for farmers within the region, even on pilot scales.

Activity 3: Develop value-added processes and products for profitable alfalfa marketing.
Description: We will target three primary areas for improving the profitability. First, we will focus on implementing advanced chopping and sealing mechanisms to reduce moisture-related spoilage and nutrient leaching of alfalfa due to rain. These operations include innovation in post-harvest processing combined with optimizing the timeline from harvest to sealing as well as evaluating the efficacy of naturally occurring anti-microbials in preventing spoilage. Successful implementation of these strategies will not only help alfalfa use but also decrease water pollution by nutrients. Second, we will develop new applications for alfalfa. The leaf extract is naturally rich in protein and contains anti-nutrients, which restrict its use as feed to ruminants. Specifically, we will work on de-toxifying the leaf extract such that alfalfa protein can be utilized by non-ruminants as well as inclusion in aquaculture feed, which will significantly increase the demand and value. We will use a hybrid enzymatic and chemical treatment to detoxify alfalfa extract for it to be amenable for digestion by non-ruminants and fish. Furthermore, we will also refine methods for extracting cellulosic sugars from alfalfa residue for further conversion into high-value bio-products such as nutraceuticals and biofuels. The underlying goal is to establish a diverse portfolio of high-value products from the entire alfalfa plant. Third, we will develop supply chain connections and identify new market opportunities through exploration, development and management of pilot scale projects with private businesses to commercialize new products and technologies. The outreach component will include organizing 1-2 Innovation Network Program Forums to further awareness, knowledge-sharing and action planning related to innovative opportunities for products, markets and technologies from traditional and emerging alfalfa varieties. The primary theme of the outreach effort will be to communicate the new uses of alfalfa that will be developed within this project.

ENRTF BUDGET: $186,600

Outcome	**Completion Date**
1. Implement preventions strategies to prevent moisture-related decay of alfalfa and nutrient leaching	*June 2019*
2. Optimize process to extract cellulose sugars from alfalfa for conversion into high-value bio-products such as biochemicals and nutraceuticals. 3. Identify at least one market opportunity in nutraceutical and cellulosic sugars sectors by validating supply chain connections.	*June 2020*

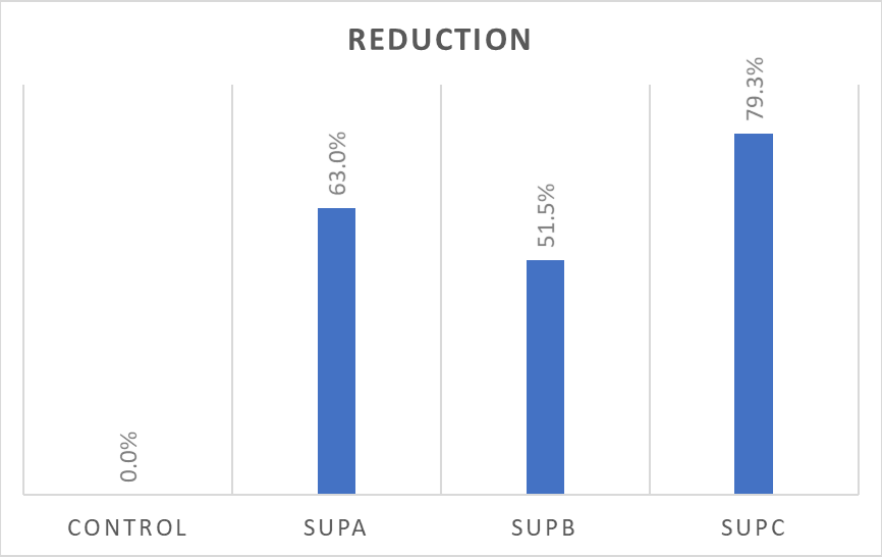
4. Upgrade alfalfa leaf extract for aquaculture feeds and identify and capture value-added opportunities in aquaculture sector.	*Dec 2020*
5. Disseminate the results from this project – new value-added applications of alfalfa using Network Forums, publications and other outreach avenues	*June 2021*

First Update January 31, 2019

In pursuit of the outcomes of Activity 3, we have initiated work toward two aspects within this activity: first is developing harvesting and storage mechanisms to minimize humidity-related spoilage and the second is expanding the uses of alfalfa extract to be amenable as a non-ruminant feed ingredient. For the second aspect, the analytical methods and processes have been developed to reduce antinutrients that are hypothesized to be harmful to non-ruminants. These activities position the project to evaluate different harvesting methods, cutting mechanisms and storage integrity as the spring harvest commences. The preliminary method and process development is to ensure that LCCMR funds will be used in the most impactful manner.

Second Update June 30, 2019

Technical progress was mainly focused on developing a process for reducing/eliminating antinutrients in alfalfa press extract (juice). Towards this objective, several different Unit Operations are being evaluated – boiling, solvent extraction, enzymatic hydrolysis and chemical pretreatment. We have completed the process design for each of these processes and established analytical methods based on chromatography and mass spectrometry. We also completed preliminary implementation of the design using enzymatic hydrolysis and the results show strong promise of reducing the anti-nutrients in alfalfa juice extract. As the figure below indicates, which shows reductions in anti-nutrient levels in juice extract samples, three treatments resulted in substantial reduction compared to the control (no treatment). In the coming reporting period, AURI intends to build on these results and capture any intellectual property.



Third Update January 31, 2020

In effort pursuant to Activity 3: Develop value-added processes and products for profitable alfalfa marketing, AURI made progress toward two aspects within this activity: first was developing harvesting and storage mechanisms to minimize humidity-related spoilage and the second was expanding the uses of alfalfa extract to

be amenable as a non-ruminant feed ingredient. The outcome from these two aspects will be the focus of outreach and commercialization efforts, organizing Forums to disseminate the findings. In this reporting period, AURI established processing and storage methods for alfalfa that could be easily opted by processors. Fresh alfalfa was collected at day of, 24 hrs, and 48 hrs after cutting and passed through a haylage chopper. Samples were then split for liquid extraction and ensiling. Ensiling and processing trials were then conducted for 21 days after haylage. At the end of ensiling, samples were split, and half were placed in a freezer for storage until chemical analysis could be performed. The remain sample was pressed, and juice was collected and frozen until further testing could be conducted. This protocol was followed for alfalfa samples 24 hrs and 48 hrs after cutting. Utilizing the juice samples, a protein isolate protocol was being developed and protein content was determined. Future work will be focused on removal of the anti-nutrients and cellulosic sugar analysis in juice from ensiling trials along with additional extraction tests for protein isolates.

Fourth Update June 30, 2020

Work conducted by project partner AURI made progress toward two aspects of the workplan: first was developing pressing conditions for alfalfa and the second was expanding the uses of alfalfa extract to be amenable as a non-ruminant feed ingredient and cellulosic sugar extraction for further conversion to high-value bioproducts. Microbial biomass studies were conducted to investigate options for adding value to alfalfa by using the extracted cellulosic sugars to create higher value chemicals. Outcomes from these two aspects will be the focus of outreach and commercialization efforts; specifically, AURI will organize forums to disseminate the findings. In this reporting period, AURI established nutritional analysis of pressed and ensiled alfalfa, started additional alfalfa trials, and investigated the cellulosic sugar availability in alfalfa. Steve Olson (an independent contractor) convened a stakeholder meeting for potential alfalfa utilization with researchers and industry representatives on February 3, 2020. From this meeting, additional work to investigate nutritional components of pressed and ensiled alfalfa juice was conducted from the previous year for information to evaluate the potential value-added characteristics of the juice. Additionally, cellulosic sugar availability and protein concentrate work was performed on the pressed juice. Conversations with the Plaint Protein Innovation Center at UofM were held for discussions on creating protein isolates from alfalfa juice and work will begin in later 2020. Lastly, the first cutting of alfalfa in 2020 was collected and pressed following the same protocols as last year. Future work will be focused on spray drying the alfalfa juice, analytical analysis of meal and dried cake, and continued pressing of additional alfalfa cuts.

Fifth Update January 31, 2021

Work conducted by project partner AURI made progress toward two areas within this activity during the second half of 2020: first was extracting sugar from alfalfa juice and the second was expanding use of alfalfa by developing a feed product. AURI also identified ideal cellulosic sugar extraction conditions from alfalfa and ensiled juice to improve sugar availability for fermentation. Additionally, the research team developed a protocol and conditions for spray drying alfalfa juice and a chemical nutritional and digestibility analysis was performed on the spray dried material. Researchers are examining this material for potential commercial use by the AURI supply chain team.

Conversations with the Plant Protein Innovation Center (PPIC) at the University of Minnesota regarding protein isolates from alfalfa juice continued during the second half of 2020. While Covid-19 restrictions delayed progress on lab activities, AURI has been able to work with the PPIC over the last six months to review literature on human consumption of alfalfa-based materials which will provide a foundation for future work. The AURI technical team has also identified an opportunity to pursue a swine feed trial to examine the use of alfalfa protein-concentrates in animal nutrition products. While the team identified a potential partner to conduct the trials, lab delays occurred, and the trial is tentatively scheduled for February 2021. Continued AURI work will focus on bio-product fermentation of alfalfa, protein extraction with PPIC, and animal nutrition applications as part of its continued efforts to develop value- added products from Minnesota alfalfa.

While COVID-19 restrictions on travel and meetings created challenges for stakeholder engagement and potential pilot project identification, groundwork by AURI's supply chain and business development team continued over the past several months to explore potential supply chain opportunities and identify potential future partners. Efforts to engage private business will increase during the first half of 2021. This work will include continued support from an independent contractor who will focus on outreach to potential industry partners and evaluation of markets for alfalfa protein products.

Covid-19 restrictions on travel and events also created delays in AURI's outreach and dissemination efforts. Faced with the inability to stage in-person events, the AURI Connects team focused on shifting much of its work to the development of online forums and virtual events as part of its "Fields of Innovation" initiative. AURI is planning to share the results of this project through events (virtual if necessary, in-person if possible), publications, and other outreach avenues as the project progresses during 2021.

Sixth Update June 30, 2021
AURI's research team continued its efforts to identify new, value-added applications, building on its previous work ensiling and pressing alfalfa to extract juice and sugars and for potential use in high-value products. AURI collaborated with an outside research lab to perform small batch fermentation trials, utilizing this sugar-rich juice to assess its potential value as a feedstock for biofuels. High levels of organic acid in the juice, a byproduct of the ensiling process, led to limited success in fermentation, which may limit opportunities for use of ensiled alfalfa in such applications. Work has also continued to identify value-added applications for alfalfa protein. AURI has continued to collaborate with the Plant Protein Innovation Center (PPIC) at the University of Minnesota to examine potential uses for protein isolates from alfalfa juice, with a particular focus on use in products intended for human consumption. While Covid-19 restrictions delayed progress on lab activities, PPIC was able to begin work on protein characterization and functionalization during the first half of 2021, and a final report on their findings will be completed in fall, 2021.

In addition to exploring potential uses for alfalfa protein for human consumption, AURI researchers have also continued to examine potential high-value animal nutrition applications. As part of this work, AURI has partnered with researchers at the University of Minnesota's Southern Research & Outreach Center (SROC) to conduct swine feeding trials using spray-dried alfalfa protein concentrates developed by AURI's research team. SROC conducted the feed trial in June, with a final report on the data and findings due in September 2021.

AURI's planned outreach, stakeholder engagement, and supply chain development activities continued to face pandemic-related delays and restrictions during the first half of 2021. While there were limited opportunities for in-person outreach and meetings due to the pandemic, AURI has continued its efforts to engage key stakeholders. In February, AURI was an exhibitor at the Midwest Forage Association's 2021 Symposium, sharing information on the value-added applications under exploration as part of this project. Wider outreach and engagement efforts aimed at industry stakeholders are being planned for the second half of 2021 and will be guided by results of the research being conducted in coordination with PPIC and SROC. AURI's research and commercialization teams also held meetings with USDA-ARS alfalfa researchers during the first half of 2021 to share updates about the project and examine opportunities for future collaboration on alfalfa product development.

Seventh Update January 31, 2022:
AURI's research team continued its efforts to identify new, value-added applications, building on its previous work ensiling and pressing alfalfa to extract juices and sugars for potential use in high-value products. AURI collaborated with the University of Minnesota's Southern Research & Outreach Center (SROC) to conduct swine feeding trials using spray-dried alfalfa protein concentrates developed by AURI researchers. The study evaluated the efficacy of spray-dried alfalfa in ileal digestibility in young pigs. The team then introduced sprayed alfalfa at zero, three, six and nine percent of the diet. Digestibility coefficients for all the amino acids indicated the optimum inclusion rate of spray dried alfalfa was six percent. The overall ileal digestibility results of the study

show inclusion of nine percent spray-dried alfalfa in young pig diets may influence performance. A pig nursery performance study is able to confirm the inclusion rate. Spray-dried alfalfa could be equally as effective as spray-dried plasma, since the pigs' performance was not affected when the experimental diets when formulated with non-sprayed plasma. A nursery growth performance study to compare the aforementioned elements will justify the replacement of spray-dried plasma with spray-dried alfalfa. Further nursery swine trials will aid in identifying economics associated with utilizing spray-dried alfalfa solubles as a highly digestible feedstuff.

Work also continues to identify value-added applications for alfalfa protein, and AURI continues to collaborate with the Plant Protein Innovation Center (PPIC) at the University of Minnesota to examine potential uses for protein isolates from dried alfalfa with a particular focus on use in products intended for human consumption. While Covid-19 restrictions delayed the progress of lab activities, the PPIC was able to begin work on protein extraction from alfalfa. Initial extraction was slow due to low levels of soluble protein extracted, but work continues to optimize conditions to extract protein from dried alfalfa.

AURI's planned outreach, stakeholder engagement and supply chain development activities faced ongoing pandemic-related delays and restrictions during the second half of 2021. While there were limited opportunities for in-person outreach and meetings due to the pandemic, AURI continued its efforts to engage key stakeholders. In January 2022, AURI staff attended the Midwest Forage Association's Symposium, sharing information on value-added applications under exploration as part of this project. Wider outreach and engagement efforts aimed at industry stakeholders are planned for 2022, guided by results of the research conducted in coordination with the PPIC and SROC. AURI's research and commercialization teams also held meetings with the University of Minnesota and USDA-Agricultural Research Service alfalfa researchers during the second half of last year to share updates about the project and examine opportunities for future collaboration on alfalfa product development.

Final Update June 30, 2022

AURI's research team continued its efforts to identify new, value-added applications, addressing opportunities to use ensiling and other alternative processing methods to identify new uses for alfalfa based both on extracted juices and sugars and on various novel and emerging uses for protein isolates. In particular, further work continued, investigating the quality of protein isolates from alfalfa harvested by current methods. In addition to these activities, analysis, interpretation, and report-writing activities were carried out. AURI's planned outreach, stakeholder engagement and supply chain development activities were also brought to a conclusion with several events and engagement efforts during this period as detailed in the final report (Appendix V).

Final Report Summary

Project R&D and outreach/engagement under Activity 3 advanced development of value-added processes and products for profitable alfalfa marketing. This work focused on three primary areas of activity:

1. Assessment and implementation of advanced processing and storage practices to reduce moisture-related spoilage and nutrient leaching of alfalfa. Our goal was to identify best alfalfa processing and storage methods to efficiently enable producers to exploit value-added opportunities for expanding the adoption of alfalfa production. Rapid ensiling methods were used, providing the high moisture level required to conduct mechanical pressing to remove alfalfa solubles (in liquid form) to identify greater value opportunities for alfalfa. Pressed, fermented alfalfa juice was found to have high sugar content and may be a base for development of other high-value alfalfa applications. Re-ensiled haylage maintained nutrient quality during continued storage.
2. Development and assessment of new, value-added applications for alfalfa. A number of potential high-value use cases for alfalfa were investigated. Enzymatic hydrolysis was found to be is a far superior process for reducing saponin content and improving protein quality in alfalfa that any other method in the public domain. Good potential was found for high-value use of spray dried alfalfa solubles in the animal nutrition sector, using the protein and amino acid profile as replacements for animal-based feed ingredients. Economic feasibility and cost of producing spray-dried alfalfa solubles is required to identify market potential. Utilization of spray-dried alfalfa solubles does not eliminate further utilization of the remaining alfalfa fiber as haylage or dried hay as a

forage for livestock. We investigated potential of extracted alfalfa protein for direct human consumption; results indicated that current technology for extracting hydrolyzed alfalfa proteins cannot meet two key technical criteria: high protein yields and high isolate purity. This research highlighted an important future consideration re. alfalfa protein for direct human consumption. Hydrolysis of the protein, which proved to be the primary barrier to producing a protein isolate, is linked to traditional methods of harvesting alfalfa. Therefore, development of a functional alfalfa protein isolate for food applications requires further R&D to develop a method for deactivate hydrolytic enzymes (such as immediate drying post-harvest).
3. Development of supply chain connections and identification of market opportunities, with a focus on development of pilot projects, outreach, and knowledge sharing.

Our project team identified, communicated, and collaborated with multiple key stakeholders in Minnesota's alfalfa sector. This collaboration, coupled with guidance and support from industry experts, researchers, and producers, served as the foundation for AURI's assessment of multiple potential high-value use cases.

IV. DISSEMINATION:

***Description*:** Our project will disseminate results via a range of approaches. First, the project will produce a range of reports, all of which will be made available via web sites of the University of Minnesota or AURI (e.g, http://greenlandsbluewaters.net/; http://www.auri.org/). These reports will include the watershed plan for alfalfa integration in Seven Mile Creek, the water-monitoring report, and the economic report, and technical reports on "rescue" strategies to protect alfalfa from moisture-related decay; an optimized process to extract cellulose sugars from alfalfa for conversion into high-value bio-products; and upgrading alfalfa leaf extract for aquaculture feeds. Second, we will store archive water-quality monitoring data in facilities of the Department of Soil, Water, and Climate at the University of Minnesota. Third, we will make presentations on the project's farmer-led, market-based working lands approach for using alfalfa to reduce agricultural effects on water to at least three conferences, focusing on events that attract broad audiences, such as the Minnesota Waters Conference. Fourth, to disseminate knowledge on opportunities for expanding production of alfalfa, we will organize 1-2 Innovation Network Program Forums to further awareness, knowledge-sharing and action planning related to innovative opportunities for products, markets and technologies from traditional and emerging alfalfa varieties. The primary theme of these outreach efforts will be to communicate the new uses of alfalfa that will be developed within this project. Finally, we will proactively engage with print, broadcast, and internet media to seek coverage of the project as a farmer-led, market-based working lands approach to enhancing protection of water in agricultural regions.

First Update January 31, 2019
Dissemination activities are in a ramp-up phase; the project manager has presented the project in a quarterly meeting of the Bioeconomy Coalition of Minnesota, a high-impact dissemination audience regarding emerging market opportunities for alfalfa, beyond the current major market as feed for dairy cows.

Second Update June 30, 2019
For the outreach activities, project partner AURI has initiated a discussion to launch a large, holistic platform to bring the growers, co-ops, researchers and end-users to identify current challenges in commercializing cover crops. The networking event(s) will be held in conjunction with UMN outreach/extension team. It is intended to organize a forum to address these issues. The scope of each forum, timeline, participants and other logistics are still under development. A specific focus of the forum will be alfalfa upgrading and expanded use. In addition to exploring possibilities in non-ruminant feed and aquaculture, issues with drying and storage, potential applications of alfalfa extract in food and pharmaceuticals will also be addressed.

Third Update January 31, 2020
Planning and scheduling for outreach activities is advancing, but these have not yet been implemented. Outreach project partner AURI is preparing for several outreach forum activities in 2020.

Fourth Update June 30, 2020
As noted above, outreach activities organized and delivered by project partner AURI were initiated during this reporting period.

Fifth Update June 30, 2021
As noted above, several different outreach, dissemination, and communication activities were carried out during the reporting period by project partners Great River Greening and AURI.

Sixth Update January 31, 2022
Dissemination activities were again carried out through a range of events, gatherings, and presentations, as noted in above reports for this project period by project partners Great River Greening and AURI.

Final Update June 30, 2022
We have disseminated results in appendices to the project report (available in the Research Reports section here), and in public presentations (total of 13), as detailed in reports, e.g., the 2019 Minnesota River Congress, a February 2020 industry meeting on alfalfa utilization, a February 2021 exhibition on value-added alfalfa applications at the Midwest Forage Association's Symposium, a July 2021 field day at a Kernza® field attended by 75 stakeholders, and a June 2022 "Fields of Opportunity" webinar that presented an overview of project findings to a large internet audience. Additionally, we hosted more than 100 individual/small-group meetings with key stakeholders.

V. PROJECT BUDGET SUMMARY:

Explanation of Capital Expenditures Greater Than $5,000: N/A

Explanation of Use of Classified Staff: N/A

Total Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours: 2392	Divide by 2,080 = TOTAL FTE: 1.15

Total Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation:

Enter Total Estimated Personnel Hours: 3400	Divide by 2,080 = TOTAL FTE: 1.63

B. Other Funds:

SOURCE OF AND USE OF OTHER FUNDS	Amount Proposed	Amount Spent	Status and Timeframe
Other Non-State $ To Be Applied To Project During Project Period:			
	$ 419,137	$ 0	Secured; available 6/1/18

Other State $ To Be Applied To Project During Project Period:			
	$ 25,340	$ 0	Secured; available upon demand.
Past and Current ENRTF Appropriation:			
	$ N/A	$ N/A	
Other Funding History:			
	$ N/A	$ N/A	

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Great River Greening	N/A	Non-profit group	Watershed coordination
AURI	N/A	Non-profit group	Alfalfa R&D
TBD after procurement	N/A	TBD after procurement	Agronomy advising

B. Partners NOT receiving ENRTF funding

Name	Title	Affiliation	Role
N/A			

VII. LONG-TERM IMPLEMENTATION AND FUNDING:

Project results will develop a replicable farmer-led working lands approach for expanding alfalfa production to improve wellhead protection and meet other water management needs, and accomplish critical research and outreach activities to expand markets for alfalfa beyond those available from dairies. Both results are essential to achieving benefits from expanded alfalfa production for water, farm and rural economies, and all Minnesotans. Ultimately, we aim to develop farmer-led, market-based working lands approaches for meeting critical water resource needs. Our project will strongly complement other efforts to develop working lands approaches in Minnesota. This research and demonstration project is designed to meet its goals in three years. We anticipate that our project will produce a workable farmer-led working lands implementation approach, and expand interest in new market opportunities for alfalfa, e.g., for Minnesota's emerging high-value aquaculture industry. If we are successful, then subsequent efforts—beyond the period of this project—will focus on building capacity for widespread application of farmer-led, market-based approaches for meeting water resources needs, and further expansion of emerging alfalfa marketing opportunities.

VIII. REPORTING REQUIREMENTS:

- **The project is for 4 years, will begin on 7/1/18, and end on 6/30/22.**
- **Periodic project status update reports will be submitted 1/31 and 6/30 of each year.**
- **A final report and associated products will be submitted between June 30 and August 15, 2022.**

IX. SEE ADDITIONAL WORK PLAN COMPONENTS:

A. Budget Spreadsheet
B. Visual Component or Map
C. Parcel List Spreadsheet

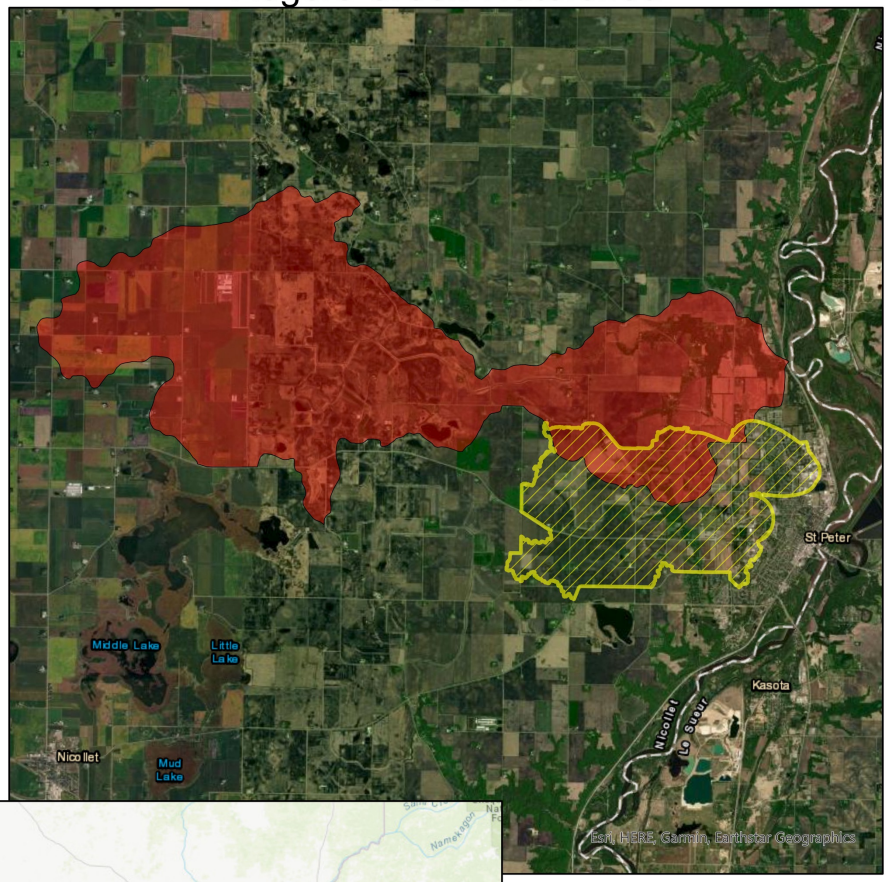
D. Acquisition, Easements, and Restoration Requirements
E. Research Addendum

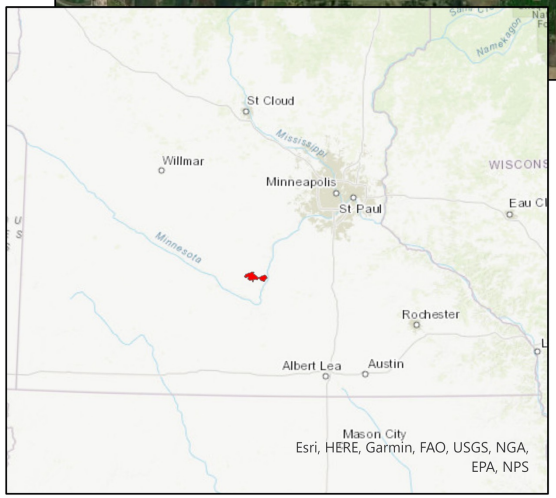
Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 Budget Spreadsheet Final
Project Title: Farmer-Led Expansion of Alfalfa Production to Increase Water Protection
Legal Citation:M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 04i
Project Manager: Nicholas R. Jordan
Organization: University of Minnesota
College/Department/Division: CFANS/Agronomy & Plant Genetics
M.L. 2018 ENRTF Appropriation:
Project Length and Completion Date: 4 years - 6/30/22
Date of Report: September 15, 2022

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	AMENDED BUDGET 6/1/21	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)			
Agronomy & soil science technicians (yr 1: 160 hours/yr (8%FTE), $50/hr; yr2: 710 hours/yr (34%FTE), $50/hr; yr 3:710 hours/yr (34%FTE), $50/hr, (Total estimated amount $79,000)	$54,025	$7,903	$46,122
Applied economics faculty (1, year 3 only, 1 week (2.0% FTE); $3,000) (Total estimated amount $3,000)	$3,000	$499	$2,501
Applied economics graduate research assistant (1, year 3 only (25% FTE); $22,000). (Total estimated amount $22,000)	$22,000	$22,000	$0
Geodesign programmer, 250 hours (12%FTE), $80/hour; year one only. (Total estimated amount $20,000)	$20,000	$0	$20,000
Professional/Technical/Service Contracts			
Watershed coordinator with GRG, 600 hours/year (30% FTE); $60 hour, 3 years (Total estimated amount $108,000)	$108,000	$108,000	$0
Additional Professional Services Contract for Great River Greening: $24,975 salary, $2,985 travel, $90 supplies	$28,050	$28,050	$0
Contract with consultant to provide partial support for assistance to individual farming operations in identifying on-farm locations for producing alfalfa to efficiently enhance crop production, profit, and water protection. RFP will be issued according to University of Minnesota procedures. (Total estimated amount $32,710)	$32,710	$32,710	$0
Process Engineer/Organic and analytical scientist will work on assessing alfalfa materials for conversion them into fishmeal supplements and protein-based food-based applications. Total team effort is 20% FTE/yr at $55/hr, all years) (Total estimated amount $68,640)	$68,640	$56,637	$12,003
Food Scientist) will work on extracting cellulosic sugars and high-value nutraceuticals Total team effort is 20% FTE/yr at $55/hr, all years) (Total estimated amount $68,640)	$68,640	$65,335	$3,305

Activity 3 supply chain team will establish supply chain connections and lay foundation for new market opportunities through exploration, development and management of pilot scale projects with private businesses to commercialize new products and technologies. Total team effort is 8% FTE/yr at $55/hr), all years. (Total estimated amount $27,450)	$27,450	$23,953	$3,497
Activity 3 outreach team will organize 1-2 Innovation Network Program forums over the course of the grant period to further awareness, knowledge sharing and action planning related to innovative opportunities in alfalfa-based food, feed and fuel applications and products, markets and technologies. Total team effort is 5% of FTE/yr at $55/hr, all years).(Total estimated amount $17,160)	$17,160	$16,182	$978
Equipment/Tools/Supplies			
Water-quality monitoring supplies and sample analysis; $227.76 per sampling week x 34 sampling weeks/yr x 2 years).	$15,398	$11,516	$3,882
Process equipment (one new High temperature/pressure reactor) for processing alfalfa plant residue and conversion into cellulosic sugars.	$15,000	$8,944	$6,056
Travel expenses in Minnesota			
Activity 1 travel for collaborative geodesign team (6 Minneapolis-St. Peter round trips x $1,272/trip for vehicle rental, fuel, per diem) and project director (9 Minneapolis-St. Peter round trips x $92 trip for mileage, per diem) to support working lands design process.	$8,460	$365	$8,095
Activity 2 travel for collection of water samples (yr 2: 25 Minneapolis-St. Peter round trips x $92/trip for mileage, per diem;; yr 3: 26 Minneapolis-St. Peter round trips x $92/trip for mileage, per diem, and extension educator (10 Minneapolis-St. Peter round trips/yr, all years x $92 trip for mileage, per diem).	$4,467	$2,795	$1,673
Activity 3 Travel by the technical team, supply chain team, and outreach team. Travel by Technical team to collect samples and conferences, to partner labs, various locations = $2,000; Travel by Innovation and Commercialization Team to private businesses and investors, various MN locations = $3,000; Travel by the Outreach and Communications team to Forums (various MN locations) ,costs of hosting Forum speakers = $2,000.	$7,000	$1,625	$5,375
COLUMN TOTAL	**$500,000**	**$386,514**	$113,486

Rogers Creek Watershed





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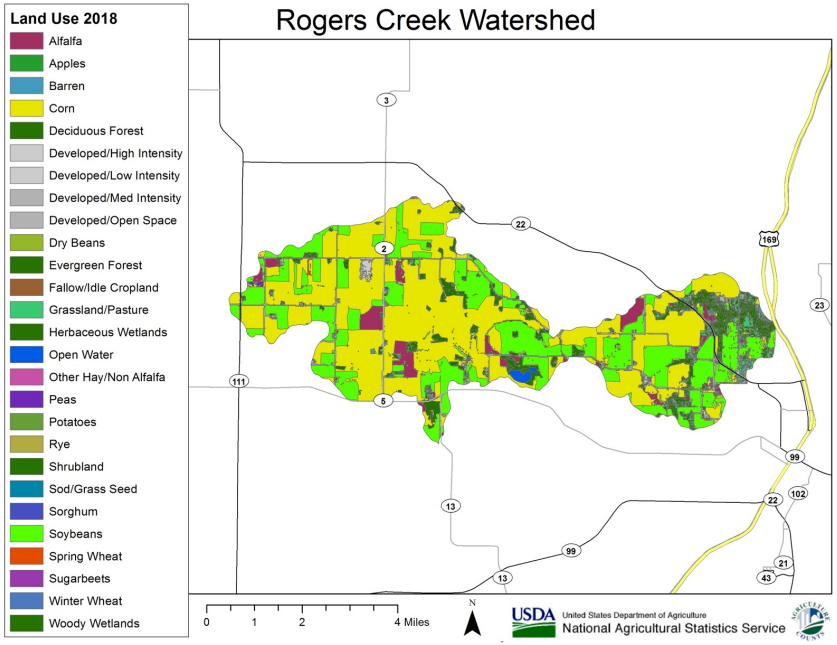
St Peter Drinking Water Supply Management Area
Rogers Creek Watershed

N



Project Map: Rogers Creek Watershed

"Farmer-Led Expansion of Alfalfa Production to Increase Water Protection" / M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 04i

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND