2018 Project Abstract
For the Period Ending June 30, 2022

PROJECT TITLE: Develop Market-Based Alternatives for Perennial Crops to Benefit Water Quality and Wildlife
PROJECT MANAGER: Jason Ulrich
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 08c as extended by as extended by M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18

APPROPRIATION AMOUNT: $ 150,000
AMOUNT SPENT: $ 150,000
AMOUNT REMAINING: $ 0

Sound bite of Project Outcomes and Results
The project researched using different types of market incentives to develop policies and programs to fund putting more perennial lands in Minnesota's agricultural areas to benefit water quality and wildlife habitat.

Overall Project Outcome and Results
Although as a state we've spent millions of dollars on conservation, the health of our streams and lakes has not improved in most of Minnesota's agricultural areas. At the same time, populations of songbirds, pheasants, bees, and monarch butterflies have continued to decline because of a loss of grassland habitat. The main reason for these issues is the continued loss of grassland to planting row crops like corn and soybeans. Reversing this loss is very difficult because of the high cost required to take profitable cropland out of production without affecting a farmer's bottom-line. In this project we researched new ways to restore our waterways and habitat by economically replacing typical row crops with grass and perennial crops by creating new market incentives. For example, what if a solar company could be paid an incentive by a publicly funded program to place solar arrays on small areas of corn fields near the edges of streams? A subsidy would be paid to the solar companies to install the array and the farmer could grow forage grass for grazing sheep underneath them. This way the farmer gets paid a fair rental rate for having the array on their property and could collect additional income from the livestock, while the solar company has an incentive to spend more to install and maintain the array. Our objective in this project was to research solutions such as these, estimating how much they would cost, and how a program or a policy would have to be structured to pay for them. We investigated several incentive programs and found that economically practical programs are possible right now with the right policies to support them. Our research provides a valuable starting point for policy makers to start thinking about new creative, economical ways to help restore the health of our waterways and grassland habitats.

Project Results Use and Dissemination
The work has been presented to agencies such as the Minnesota DNR and at several Science Museum member events. Finally, the project team was instrumental in organizing and leading the highly successful AgroEcology Summit in Windom, MN in August 2019, where the project work was presented over several hours to more than one hundred attendees. The concepts of using markets to drive adoption of perennial crops/cropping systems generated considerable interest, and follow-up meetings have been scheduled with several environmental advocacy groups to discuss next steps.

Following the completion of the project, the fact sheet created for this project and link to LCCMR and the final report will be shared via Science Museum social media platforms.

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

Today's Date: July 31, 2022

Final Report

Project Completion Date: June 30, 2022

PROJECT TITLE: Develop Market-Based Alternatives for Perennial Crops to Benefit Water Quality and Wildlife

Project Manager: Jason Ulrich

Organization: Science Museum of Minnesota

College/Department/Division: St. Croix Watershed Research Station

Mailing Address: 16910 152nd St. North

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Location: Statewide. Results are applicable statewide, but we will model the market scenarios in two watersheds, (one in the western part of the state and one in eastern part, e.g. Cottonwood and Whitewater) to provide real world estimates of water quality and wildlife habitat benefits.

Total Project Budget:	$150,000
Amount Spent:	$150,000
Balance:	$ 0

Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 08c as extended by as extended by M.L. 2021, First Special Session, Chp. 6, Art. 6, Sec. 2, Subd. 18

Appropriation Language: $150,000 the second year is from the trust fund to the Science Museum of Minnesota for the St. Croix Watershed Research Station to design and evaluate at least six market-based scenarios for perennial cropping systems in Minnesota, including technological and economic feasibility, and estimate their potential to improve water quality and provide wildlife habitat. 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:

If we are going to make meaningful improvements to degraded waters and habitat for pollinators and grassland wildlife species, Minnesota must find a way to make perennial cropping systems profitable. This will require creating markets and incentives that stimulate farmers to put land into perennial vegetation/crops.

Despite millions of dollars spent on conservation practices, water quality has not improved in most agricultural watersheds, and grassland-dependent species continue to decline. The common denominator that benefits water quality and habitat are practices that incorporate perennial vegetation such as filter strips, wetlands, prairies, pastures, hay land, and grassed waterways. However, the cost of implementing these practices to a level that would create substantial improvements is estimated to exceed $1 billion per year. This is because the vast majority of conservation practices, including perennial vegetation, are simply not profitable—they require funding for implementation. Measurable improvements to water quality and habitat hinge on reshaping the discussion about affordable ways to implement perennial vegetation/crops. Instead of thinking about solving our water quality and habitat challenges by funding one conservation practice at a time, we need to think about how we can stimulate entire cropping systems that utilize large acreages of perennial crops. We need to think about products such as electricity, fuel, meat, and industrial chemicals as markets that can be developed and modified to utilize large quantities of perennial feedstocks and thereby create a landscape that benefits water quality and habitat. In other words, use markets as conservation best management practices.

We will design six market-based approaches that could stimulate the incorporation of perennial vegetation into cropping systems. While the technological aspects of some markets for perennials have been shown, minimal analysis has been done of the costs and benefits, nor the policy and economic incentives necessary to create demand for these cropping systems. An outcome from each of the six designed market approaches will be an estimate of the number of acres of the perennial crop necessary to satisfy the product demand. These acres of perennial crop (and the management techniques such as fertilizer and harvest dates) will be input to existing, calibrated watershed models to estimate the reduction in sediment, phosphorus and nitrate from each of the perennial cropping systems. The acres of perennial crop will be applied in various configurations (e.g. as buffer strips, or whole fields) to compare their efficacy. Equally important to cost-benefit analysis is the wildlife habitat value of the perennial cropping systems. To quantify the wildlife benefits, a habitat score based on number of acres, plant diversity, harvest timing and phenology will be calculated. This habitat score and the calculated water quality improvements will be combined with the cost estimate from the market evaluations to offer a cost-benefits analysis of each scenario. From these, recommendations of the requirements and feasibility of using market demand to stimulate perennial cropping systems will be offered.

Specific outcomes are:

a) Design and cost analysis of six market scenarios to stimulate adoption of perennial cropping systems.
b) Comparison of mandates, incentives and consumer promotion as drivers to create demand for perennial crops.
c) Estimation of reductions in sediment, phosphorus and nitrate in representative watersheds resulting from each market scenario and the associated perennial cropping system.
d) Development of a habitat score to provide a quantitative metric of benefits to wildlife created by the markets for the perennial crops.
e) Cost-benefit analysis of each market scenario and perennial crop.
f) Recommendations on using market drivers as the key to stimulating implementation of perennial cropping systems.

II. OVERALL PROJECT STATUS UPDATES:

Project Status as of: January 31, 2019
The main objective of this project was to demonstrate how market levers could be used to stimulate perennial cropping systems---and the benefit to water and wildlife. Central to this objective is choosing and outlining reasonable market scenarios that display the role of mandates, incentives/subsidies, or consumer labeling to this endeavor. We have spent the first part of this project researching and refining potential market scenarios that are relevant to Minnesota, reasonably feasible, and showcase either a mandate, incentive or consumer labeling approach. We have settled on markets for three cropping systems and a combination of economic drivers.

- Home heating with switchgrass pellets, that uses a subsidy program to stimulate farmers to produce pellets, coupled with a consumer labeling and tax rebate (incentive) to get home owners to purchase pellet stoves and pellets.

- A subsidy/incentive program for local meat producers who use Kernza (intermediate wheatgrass) as livestock feed, coupled with a State sponsored consumer labeling campaign to promote the water and wildlife benefits of the meat products --with the intention that this would be a pilot program, scalable to large commercial meat processing companies.

- Using a mandate that requires a certain percentage of annual electric production to come from solar arrays that are placed in riparian areas managed with rotational grazing.

- Using a subsidy provided to large electric companies to incentivize them to combine solar arrays with rotational grazing of sheep.

- Public funding for a consumer promotional campaign to get businesses and homeowners to voluntarily pay a 1-5% increase for electricity generated from riparian solar arrays managed with rotational grazing.

In the original workplan we had suggested a market scenario centered on using grass-fed crickets as a source of protein in pet foods. After researching this scenario, we determined it is unlikely that crickets would be reared cost-effectively on grass/alfalfa and thus dropped this scenario. In the workplan we had also suggested that we would demonstrate a single market driver for each scenario and would present 6 scenarios in all. As we refined the details for each scenario, we determined that for several of them it would be better to combine two market levers (i.e. an incentive program along with a consumer promotional campaign). Thus, we think that the five scenarios listed above, with multiple drivers, offer a more reasonable demonstration of how markets can be used to create perennial cropping systems.

We are just beginning with the effort to model the water and wildlife benefits resulting from each scenario. We have realized that each scenario needs to include parameters that identify how, where and the potential acreage of each new perennial system. To shape this, we are defining a simple parameter called the “riparian ratio” (riparian length divided by project area) that can be tied to the market driver to define the placement and size of the mandated or subsidized perennial system. For example, the subsidy provided to farmers to produce switchgrass pellets would only be offered on enrolled lands that had a riparian ratio exceeding a certain value. This “restriction” on the eligibility is critical to making sure the program provides significant water quality benefits as well as a constraint to estimating and managing costs.

Project Status as of: August 31, 2019

Five market scenarios to generate perennial cropping systems have been developed and scaled to a pilot watershed. These scenarios center on using Kernza (a perennial grain) as livestock feed, home heating with switchgrass pellets, and solar arrays coupled with conservation grazing. In concert, the scenarios demonstrate the use of mandates, incentives/subsidies and consumer promotion as levers to create market demand for perennials. Full descriptions of the scenarios are presented below. In order to conduct a cost-benefit analysis, each market scenario was scaled to a 5 million dollar "pilot project" targeted at a HUC-12 watershed---the upper south fork of the Watonwan River. Based on the estimated costs to implement each scenario and the $5 million available in funds, it was possible to calculate the amount of perennial vegetation/crop acres necessary to satisfy each market. Our market scenarios, with 5 million dollars available in start-up funds, generated between 1000 and 2500 acres of perennial vegetation in a HUC-12 watershed---representing a 4 to 9% conversion of row-crops to perennials. These acres were placed either randomly or adjacent to waterways in the HUC-12 and water quality and habitat benefits were modeled. Preliminary modeling results of water and habitat benefits have been completed. All market scenarios resulted in a combined reduction in sediment, phosphorus and nitrate of at least 60%. Habitat scores ranged from 20 to 45—which means the perennial vegetation created by our market scenarios are 20 to 45 percent as valuable as converting 10% of the watershed to high quality prairie. These water quality and habitat scores are significant and demonstrate the cost-effectiveness of using markets to drive land use changes that benefit water and wildlife. Markets scenarios and associated water quality and habitat benefits were presented at the AgroEcology Summit in Windom, MN in August 2019. The concepts of using markets to drive adoption of perennial crops/cropping systems spawned considerable interest and follow-up meetings have been scheduled with several environmental advocacy groups to discuss next steps.

Project Status as of: January 31, 2020

Market scenarios are being refined and finalize. One of the outcomes from evaluating the market scenarios and feedback from the Agroecology summit, was that consumer promotion of perennial products was a key component of nearly all market based methods to stimulate perennial cropping systems. Since there is currently a shortage of perennial products to promote, we decided to transform the concept somewhat, and explore the idea of promoting existing products (not made from perennials) and use the proceeds to fund the purchase or adoption of perennial lands. To demonstrate this alternative method of consumer promotion, we opted to trial it in a real world setting. St. Croix Valley Trees, a small choose-and-cut Christmas tree farm in the Metro area (that also sells hot food), agreed to test the idea of labeling food products "*Water Wildlife and Weather Friendly*", and use proceeds from the sale of these products to fund the subsequent purchase of perennial filter strips on a nearby row-crop farm. Brats and hot dogs with the label "*Water Wildlife and Weather Friendly*" (*W3Friendly*) were priced at 50-cents more than equivalent non-labeled brats and hot dogs. Customers could voluntarily choose between the *W3Friendly* or non-*W3Friendly* labeled items. Seventy-five percent of customers chose to spend the extra 50-cents and purchase the *W3Friendly* labeled items. The proceeds from this extra charge, will now be used to establish a 50-foot wide prairie filter strip around a wetland on a neighboring farm. This trial run of the consumer promotion model to fund the placement of perennials on agricultural lands using proceeds from *W3Friendly* products was viewed by ~7000 adult visitors over a 7-day period on the Christmas tree farm. While this demonstration of the *W3Friendly* consumer promotion concept on St. Croix Valley Tree farm was very encouraging, it is a single test with limited scope and representation, but it does allow us to present the concept as a whole to future interested parties in a more clear and engaging manner. We are currently working with Science Museum personnel to see if we can do a larger demonstration of the *W3Friendly* consumer promotion idea tied to food and gift items sold at the Science Museum.

Water quality and habitat benefits resulting from each of the scenarios has been modeled for one HUC-12 watershed, and in progress for a second HUC-12. A HUC-12 in the South Fork of the Watonwan river (25,000 acres) has been modeled to estimate the water quality benefits of converting select areas to perennial vegetation resulting from each market scenario (i.e., switchgrass, intermediate wheat grass, prairie+solar); further, the modeling was used to examine potential differences in benefits between placing perennial vegetation in relatively small parcels located in riparian corridors (portions of row-crop fields bordering perennial water sources such as streams, rivers and lakes) versus whole-field sized, randomly located parcels. Further detail on the current methodology and results are presented below.

Modeling results for environmental benefits show significant reductions across all three scenarios – switchgrass pellets, intermediate wheat grass livestock feed, solar+pasture -- when replacing corn and soybean in riparian areas. In particular, particulate phosphorus and sediment were predicted to decrease watershed-wide by 27-60% and 30-80%, respectively, while nitrogen showed more modest reductions of 3-8%. In all cases, reductions were dictated by total land converted to perennials based on the cost per acre for each scenario (i.e. not surprisingly, the more land that was able to be converted for the same amount of funding the greater the benefit). However, when putting the same total acres from each scenario into random fields (not near riparian areas), significantly less water quality benefit was realized for the same cost. Randomly placed fields of perennials had both particulate phosphorus and sediment reductions of only 5-13%. Overall, these results show the substantial cost-benefit advantage to targeting placement of perennial vegetation into small portions of existing row-crop fields in riparian areas versus fewer, larger blocks placed randomly in a watershed. These results also predict that if funding were directed toward promoting markets for perennial crops, significant cost-effective environment benefits could be gained.

Project Status as of: February 1, 2021

Due to Covid19 no work has been done on this project since the previous reporting period of February 2020. The project manager, Shawn Schottler, was furloughed from the Science Museum in late March 2020 and just returned to work in January 2021. Jason Ulrich, who is doing much of the cost-benefit analysis, was also furloughed during this period. The project was requested a one year extension in the fall of 2020, however we still hope to complete the project in the next 6 to 8 months. Work has resumed and we are continuing with finalizing estimates of water quality and habitat benefits for the different market scenarios, and relating these to the costs for each. We will also continue to further define the attributes of the W3Friendly paradigm as a consumer promotional driven method to implement perennial vegetation in critical landscapes. Depending on our ability to coordinate our efforts while working remotely, we hope to finish the project by mid-summer and have a final report submitted in the fall of 2021. Completion dates in the Activity matrix below were changed to reflect our new timeline estimates.

Amendment request: due to delays and furloughs from COVID-19, this project has requested an additional year extension.

As of 2/16/2021 LCCCMR has added this project to a list of projects seeking COVID-19 related extensions, but further action is dependent on legislative action.

Project extended to June 30, 2022 by LCCMR 7/7/21 as a result of 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], legislative extension criteria being met.

Amendment Request: Project Status **Special Update as of:** May 15, 2021

Jason Ulrich has replaced Shawn Schottler as Project Manager. Relevant changes have been made in the first section of this Workplan as well as the Budget spreadsheet.

Amendment approved by LCCMR 7/7/21

Project Status Update August 31, 2021:

Since returning from Covid-19 furlough, work has resumed on finishing the remaining Outcomes. Work in progress includes selecting the second (and final) project watershed to repeat the water quality and habitat benefits modeling and analysis. In addition, the final report and fact-sheet are roughed out and will be completed after the benefits modeling and analysis.

Project Status as of January 31, 2022:

Project is nearing completion with remaining modeling tasks (water quality and habitat benefits of proposed scenarios) and cost-benefit analyses mostly completed. Final report writing and fact-sheet development will continue through the remaining project term.

Note: Budget balance remaining $28,674 is the same as reported in the last project update, and reflects that the Science Museum has not invoiced for any further funds as of yet although project activities have continued.

Overall Project Outcomes and Results

Although as a state, we've spent millions of dollars on conservation, the health of our streams and lakes has not improved in most of Minnesota's agricultural areas, while at the same time, populations of songbirds, pheasants, bees and monarch butterflies have continued to decline. The main reason for these issues is the continued loss of grassland for planting corn and soybeans. Reversing this loss is very difficult because of the high cost required to take profitable cropland out of production without affecting a farmer's bottom-line. In this project we researched new ways to economically replace corn/soybeans with perennial grasses by creating new market incentives. For example, what if a solar company could be paid an incentive to place solar arrays on small areas of farm fields near the edges of streams? The farmer would replace corn/soybeans with forage grass for grazing sheep around and underneath the solar arrays, could collect income from the livestock, and rent for having the solar array on their property. Our project explored five market scenarios like this example, estimating how much they would cost, how a policy would have to be structured to pay for them, and the extent of their environmental benefits. We found that economically practical programs for replacing corn/soybeans that improve water quality and habitat are possible right now with the right policies to support them. These include solar arrays with pastures, growing perennial wheatgrass for feeding hogs, and growing switchgrass for use in pellet burning stoves. However, our research also revealed limitations to these scenarios that would prevent them from making substantial environmental improvements statewide. Nevertheless, the project provides a valuable starting point for policy makers to start thinking about new economical ways to help restore the health of Minnesota's waterways and grassland habitats while also supporting its farm economy.

III. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Define and Evaluate Six Market-Based Scenarios for Perennial Vegetation

Summary Budget Information for Activity 1:		
	ENRTF Budget:	**$ 150,000**
	Amount Spent:	**$ 150,000**
	Balance:	**$ 0**

Market Scenarios and Cost Analysis

The technology and desire to grow perennial crops (create supply) such as switchgrass or intermediate wheatgrass has progressed greatly in recent years. What has been missing is an understanding of how to make these crops profitable. Unless proactive efforts are instituted to create demand for the perennial crops they will remain unprofitable and non-viable alternatives, i.e. no farmer is going to make the change to a perennial crop unless they can be assured there is market that will buy it. The underlying principle of this project is that market demand, more so than product supply, is a driver for increasing perennial cropping systems. This project will demonstrate three principle drivers or levers that can be manipulated to increase the market equilibrium quantity for perennial crops: production subsidies (incentives); mandates; and consumer promotion/eco-labelling.

Incentives or subsidies are payments made to either producers or consumers of a product. They effectively lower the cost of production (in the case of producers) or lower the price of the product (consumers). Mandates are edicts requiring or restricting certain production methods, materials, or outputs. In the short run, mandates can increase the cost of production. Consumer promotion is often labelling on the final product that indicate a differentiating factor between the product in question and its substitutes. Eco-labels are consumer labels that indicate the product is environmentally friendly, and can increase the price consumers are willing to pay for a product. All of these levers have the effect of increasing the equilibrium quantity of the product produced and sold.

To examine these levers, and their potential to stimulate changes in agriculture, six market scenarios for perennial cropping systems will be identified. Three will focus on the same product, perennial grass/alfalfa fed to crickets to create protein for pet rood, and while comparing the three market levers. The other three will each focus on a novel perennial cropping system created by either a subsidy, mandate, or consumer promotion. The potential scenarios likely to be considered are:

<u>Scenario 1: Alfalfa/grass fed to cricket as protein for pet food: **Subsidy**</u>
Crickets could be raised on alfalfa or perennial grasses. The dried and ground crickets would then be used in pet food to provide protein. A policy centered on creating a subsidy that would lower the cost of production by providing a payment to the pet food producer will be evaluated and a cost analysis will be completed.

<u>Scenario 2: Alfalfa/grass fed to crickets as protein for pet food: **Mandate**</u>
Similar market as Scenario 1 but a mandate would be used to require that a certain percentage of perennial grasses be used to feed the crickets. The production cost analysis will be similar to Scenario 1 but the differences in socio-political efforts will be evaluated

<u>Scenario 3: Alfalfa/grass fed to crickets as protein for pet food: **Consumer Promotion**</u>
This scenario will offer a comparison of consumer promotion/eco-labeling for the same product evaluated using subsidies and mandates in Scenarios 1 and 2. Consumer labels will be used to indicate that the final product was produced in a more environmentally friendly. Eco-labels, such as these, have been shown to increase consumer demand. A cost evaluation of how much more the consumer would have to pay for the “eco-friendly” product will be done.

<u>Scenario 4: Intermediate wheatgrass grain as hog feed: **Subsidy**</u>
An alternative subsidy/incentive for another product requiring perennial grasses/grain will be examined. An example would be a subsidy for hogs fed a certain percentage of grain from perennial intermediate wheatgrass instead of corn. A cost analysis of how large the subsidy would need to be for producer to use intermediate wheatgrass grain versus corn will be completed.

<u>Scenario 5: Pastures with solar arrays: **Mandate**</u>
A mandate for another product requiring perennial grasses will be examined. An example would be a mandate requiring a percentage of solar arrays to be placed in pastures used for grazing cattle. This scenario provides for dual-use of a field--- production of ‘grass fed’ beef and electricity. The socio-technological factors and start-up costs necessary to create this type of scenario will be evaluated.

<u>Scenario 6: Small business/home heating with switchgrass pellets: **Consumer Promotion**</u>
An alternative consumer labelling scheme for another product requiring perennial grasses will be examined. An example would be consumer promotion efforts to encourage home and small business heating with pellets made from switchgrass. A cost analysis of switchgrass pellet production will be evaluated and compared to traditional heating methods.

For each scenario, a cost and return calculation (budget analysis) will be performed. This will compare the costs of production with market prices for the product in question. The production costs will be as comprehensive as possible, including any land, labor, fuel, transportation, processing, and/or other input costs. This will provide us with enough information to determine what price would be required to make the product attractive to a farmer. Once this information is calculated, for a given scenario, we will use existing literature on the appropriate driver to determine viability. For example, in Scenario 3 and Scenario 6, we will be focused on subsidies. We can determine what level of subsidy, directed at a certain point in the production process. This may look something like a subsidy of so many dollars per mass of perennial grass-fed crickets used in pet food. Or, it may be a subsidy of so many dollars per area of perennial grass grown that is used to feed the crickets. For mandates, Scenarios 2 and 5, we will determine the effects of different types of mandates, such as requiring 50% of the cricket food being perennial grass and not corn, or requiring a certain percent of crickets in the pet food. In Scenarios 3 and 6, which deal with consumer labels, we can estimate potential increases in willingness to pay based on documented examples, and compare this with what we calculate the increased costs of production to be.

These market estimates will provide a range of compared and contrasted products and market factors, which will result in different levels of shifts from corn to perennial grasses. An outcome from this analysis is that each scenario requires a certain amount of alternative perennial crop to satisfy the new market demand. This amount of a new crop can be translated into a number of acres required. This acreage is then input to the modeling efforts below to estimate water and wildlife benefits of the perennial cropping system.

Water Quality and Habitat Benefits

Creation of the market scenarios and perennial cropping system will result in a number of acres needed to fulfill each market's estimated demand. A watershed modeling framework will then estimate water quality benefits of each perennial crop scenario based of the designated number of market acres. Water quality benefits will be quantitatively represented by modeling flow, nitrate, total phosphorus (TP) and suspended sediment (SS). The framework is composed of the watershed model SWAT coupled with field-scale GIS analyses that will include metrics such as distance and travel time to perennial streams, field slope, likelihood of artificial drainage and land use history. SWAT is a very effective model for agronomic focused scenarios because of its explicit support for different agricultural cropping systems and management operations. However, SWAT is a watershed scale model while the scale of the perennial crop implementations is on an individual field or portion of a field. Therefore, field-scale GIS analyses will enable a watershed scale model like SWAT to perform more effectively at the smaller scales consistent with the crop implementations. Examples of utilizing these types of GIS analyses include modifying SWAT's output to consider more realistic distribution of sediment and phosphorus erosion as well as buffer strip effectiveness based on GIS calculated (actual) distances to the nearest streams, and the field slope characteristics.

The current plan entails simulating baseline conditions and then comparing results when acreage of perennial crops from the market scenarios are substituted (See list below). However, as the project progresses and intermediate results are generated, changes to these scenarios are possible:

(1) Baseline using current cropping and management practices.
(2) Cultivation and fall harvest of switchgrass for biomass combustion.
(3) Cultivation and three annual cuttings of alfalfa for cricket feed to make pet food.
(4) Cultivation and fall harvest of intermediate wheat grass (IWG) as hog feed.
(5) Pasture land with solar panels.

Placement and field configuration of the perennial crop implementations are important; as such, scenarios 2 through 5 will be simulated using at least two configurations including, but not limited to, the following:

A. Field buffer strips with a width of 240 feet (Buffer widths of 240 feet conform to multiples of typical farm machinery widths)
B. Rectangular 80-acre blocks (generally encompassing an entire field)

These configurations will be randomly placed in the modeled watersheds. The Cottonwood River and Whitewater River watersheds will serve as the modeled study watersheds. Both watersheds are heavily agricultural and collectively provide a wide range of soil, topographic and climate conditions. Both watersheds have flow and water quality data available for model calibration. The models will be calibrated at the watershed outlets for a period of approximately 20 years (preferably, the most recent 20 years). Field-scale predictions of flow, nitrate, TP and SS will be constrained by current literature from the agricultural regions of the upper Midwest.

Results will consist of modeled comparisons between the baseline scenario and each of the cropping scenarios on an average annual basis. As such, these will comprise relative changes in average flow volume and nitrate, total phosphorus and sediment mass per acre, per year over the calibration period. In addition, a weighted water quality index will be utilized similar to that implemented in BWSR's PTMapp ("Prioritize, Target, Measurable" application) project approach:

$$\text{Water Quality Score} = 0.5 \times \text{SS reduction} + (0.25 \times \text{nitrate reduction} + 0.25 \times \text{TP reduction}) \quad \text{eq. 1}$$

Lastly, the Habitat Score (outlined in following section) will be combined with modeled water quality scores and normalized by watershed area to get one pair of scores (Water Quality and Habitat) for each scenario.

Development of Habitat Score

Frequently, when perennial cropping systems are being promoted the water quality benefits are given primary, if not sole, consideration. However, from a natural resource perspective and value to the public, the benefits of these cropping systems as potential wildlife habitat are of equal importance. This project seeks to give equal weight to water quality and wildlife benefits and emphasize how perennial cropping systems that offer significant improvements to both should receive greater consideration. What is lacking in many water quality modeling efforts is an easy way to calculate a habitat value of the crops and management practices implemented. We will refine a method for generating a "habitat score" based on vegetation type, acreage and farming practices and will apply it to the watershed models used in this project.

The habitat score is not based on benefits to any particular fauna, but rather founded in the premise that size, floristic diversity and minimal disturbance are basic attributes of good habitat.

$$HS = \sum(\text{Area}_i \times C_i \times D_i \times M_i) \times 100 / WA \qquad \text{eq. 2}$$

HS = the combined Habitat Score for perennial crops or vegetation added to a watershed.
Area = the total acreage of any particular perennial crop/vegetation (i)
WA = watershed area in acres

C_i, D_i and M_i are modifiers related to floristic diversity and management of the perennial crop:

C_i is a modifier for the configuration of how the perennial crop is implemented. For example,
C_i for 200 foot buffers = 0.85
C_i for 80 acre fields = 1.0
C_i for 40-foot-wide strips/waterways = 0.75

C_i for whole field implementation such as inter-row cover crops = 1.0

D_i is the modifier for floristic diversity of the crop or cropping system:
D_i for grass monocultures = 0.75
D_i for mixed grass planting = 0.9
D_i for single species forb crop (e.g. alfalfa or camelina) = 0.8
D_i for multiple species of forb = 0.9
D_i for mixed plantings (forbs+grasses, e.g. prairie) = 1.0

M_i is the modifier related to how the crop is managed:
M_i for undisturbed = 1.0
M_i for fall harvest = 0.9
M_i for harvest during nesting season = 0.5
M_i for termination in the spring (e.g. for rye inter-row cover crop) = 0.1
M_i for low intensity grazing = 0.7
M_i for high intensity grazing = 0.6

This habitat score provides a simple, quantitative and comparative measure of the potential wildlife benefits of the perennial crops/vegetation added to a watershed. While the specifics of what is good habitat can be somewhat nebulous, the appreciation that there is a continuum of habitat value ranging from annually plowed fields, to seasonally harvested perennial vegetation, to blocks of undisturbed, highly diverse grasslands is almost obvious---the essence of which is captured by the habitat score. The habitat score along with the water quality score give a simple summary of the water and wildlife benefits of the perennial cropping systems created by each market scenario. Putting both of these, side-by-side in a simple table, facilitates the discussion about which market scenarios offer the best benefits per implementation cost.

Cost-benefit summary and socio-political recommendations.

The budget analysis (part 1 above) provides a cost estimate for adoption of each market scenario, and the watershed modeling results provide an estimate of the resulting water and wildlife benefits. The habitat score and water quality benefits (score and actual pollutant reductions) will be divided by the respective cost estimate of each market scenario to give a dollar per benefit estimate. This cost-benefit summary can be used to evaluate which of the market scenarios offer the most cost-effective means for achieving our natural resource objectives—but more importantly, the summary provides a demonstration of the financial dynamics and environmental magnitude of creating markets for perennial cropping systems. The markets scenarios presented in this project are mostly intended to serve as examples to stimulate and augment the discussion about how we can pay for land use practices that benefit water and wildlife. Using the scenarios developed for this project we will compare and contrast the effectiveness of using incentives, mandates or consumer promotion as drivers of perennial cropping systems and provide recommendation on the socio-political changes necessary to bring these markets to reality. Results from this project will be summarized in a final report and a concise four-page fact sheet. The fact sheet will highlight the necessity of creating markets for perennial crops, present the six market scenarios along with their associated cost-benefit analysis as examples, and offer a summary of the recommendations on the socio-political efforts required to create cost-effective markets for perennial cropping systems.

Summary Budget Information for Activity 1: **ENRTF Budget: $ 150,000**

Amount Spent: $ 150,000

Balance: $ 0

Outcome	Completion Date
1. Define and research scenarios (Five- with multiple levers for two of the scenarios) for perennial cropping systems	June, 2020
2. Estimate water quality improvement and habitat value relative to market costs	June 2021
3. Summarize cost-benefit comparison and provide recommendations	August 2021

First Update: January 31, 2019

We have spent the past couple months researching and evaluating different scenarios for stimulating markets for perennial cropping systems. We have settled on the scenarios briefly described in the Summary section above. These scenarios are currently being refined and expanded in detail by our partners in the Water Resource Dept- U of MN. Specifics about how a particular market lever would be created, who would implement it, and how it would be managed are currently be distilled. A full description of each market scenario will be completed by June of 2019.

Modeling of water and wildlife benefits resulting from each market scenario is just beginning. We are still working on incorporating details into each scenario that will define the number of eligible acres and restrictions about placement on the landscape. For example, in the solar + pasture scenarios, we will ultimately define the number of kWhr that will be subsidized. And, since we know the number of acres needed per kWhr, we can calculate the amount of perennial land potentially added by creating this market. If we couple this with criteria for placement on the land, then we can also shape and increase the water quality benefits. Modeling efforts will accelerate once these parameters are defined for each scenario. To this end, we have recognized that it would very helpful to have a simple parameter tied to each scenario that could be used to constrain where and how much land is eligible in each program. We have a created the "Riparian Ratio" for this purpose. The riparian ration (RR) is the length of riparian feature abutting the project land, divided by the total project area. We are still working on the ideal RR for each scenario. RR could easily be calculated by any land owner or manger using Google Earth or similar free software. Linking this RR to each market driver/policy ensures that the perennial lands created will be in places that benefit water quality yet still large enough to be economically viable. We will have RR characteristics defined and linked to each scenario by June 2019.

Second Update: August 31, 2019

Summary of Market Scenarios

The following describes the three scenarios (plus sub-scenarios) tested in the project. For each scenario, a program of market incentives is developed to facilitate replacement of corn/soybeans with a perennial vegetation/crop. The scenarios will be tested and compared using a pilot watershed of approximately 25,000 acres. Scenarios are tested assuming a market incentive of $5 million is available to support each scenario's program within the pilot watershed.

Scenario 1: Switchgrass Pellets for Home Heating

Introduction

Wood pellets for home heating has been promoted as a renewable energy source. Using combustion stoves as a heat source is controversial due to potential air quality and human health concerns—however, these are more of a problem with older, less efficient stoves. Newer stoves, which only make up about a quarter of American wood stoves are cleaner and less likely to contribute to indoor particulate matter. (Alliance for Green Heat, 2011; Wyss et al., 2016)

Most home heating pellets use wood as a source material. However, pellets can be made from grasses, such as switchgrass, or from a blend of grasses and wood. Pellets made from 100% switchgrass are similar in combustion efficiency (ratio of heat output to energy content of source material) to wood pellets—somewhat less when burned at a low heat, while surpassing wood when burned under high heat (Vermont Grass Energy Partnership, 2011). Switchgrass pellet stoves could also replace propane stoves as a heat source. While stoves using propane emit lower particulate matter emissions (Environmental Protection Agency, n.d.), pellet stoves use a renewable energy source that performs carbon capture. Using perennial grasses to produce pellets would have an additional environmental benefit when grown as a replacement for annual row crops, particularly in riparian areas. Pellet stoves can be a cheaper option compared to furnace heat, though they are more labor intensive (Table 1). Here we describe the costs and benefits of a perennial grass pellet home heating system and outline a potential program to drive their use.

Program Need

While the system may appear viable from a producer and consumer standpoint, opportunity cost may affect participation, thus creating the need for a program incentives. The farmer could make money growing switchgrass for pellets, but if the alternative—traditional corn/soy rotation – is more attractive, from a profit, risk, and/or social perspective, then the farmer must be motivated away from the standard system. And for the consumer, the heating may be potentially less costly than alternative forms, but there is a substantial time cost that we have not addressed.

System description

As shown in Figure 1, a co-operative program could use switchgrass that was grown on-farm. The perennial grass would be purchased from the growers, and baled and dried in a storage phase. Once the grass has dried sufficiently, the pellets can be manufactured off-farm in a centralized facility, and sold to stove owners who are members of the co-op. The pellets would have a special label indicating their source and environmental benefits. Stove owners would also receive a rebate for the purchase of a pellet stove that replaces their older, propane stove.

Proposed Program

To address both the opportunity costs of the farmer and consumer, we propose a multi-prong program approach for spending the $5 million. For the farmer, a subsidy in the form of a guaranteed price, for the consumer, a rebate, for the pellet producer, a startup subsidy**.**

Farmer Subsidy

Corn prices are relatively low currently, with average profits per acre negative. However, a subsidy to shift away from corn production may still be needed, even though with off farm production, substantial start-up costs would not be required. We recommend a guaranteed price of $100/ton for switchgrass delivered to the pelletizing facility. See Table 2 for farmer cost and return information.

Industry Subsidy
To incentivize construction of palletization facilities, we propose a subsidy of $120,000 to pay for the pelletizing equipment. The policy will also pay for the farmer's switchgrass. See Table 3 for industry cost and return information. The program will also pay for the co-op startup costs and potentially some of the pelletizing labor costs.

Consumer Rebate

In Minnesota, about 2.4 percent, or about 50,000 homes are heated with wood stoves (Eleff, 2017). Because of the human health and environmental damages associated with older, less efficient wood stoves, swapping out old stoves with new is a recommendation of the Minnesota Pollution Control Agency (Minnesota Pollution Control Agency, 2019). The Environmental Initiative, a nonprofit, administers Project Stove Swap, which assists certain people in need with replacing their older, dirtier stoves (The Environmental Initiative, 2019). However, we will not require that only old stoves be replaced, and instead offer a rebate of $1,000 for the purchase of a new pellet stove for 1,000 people who agree to purchase pellets from the co-op for a guaranteed rate of $250/ton. See Table 4 for stove owner information. The program will also pay for a promotional campaign.

Program Cost Breakdown

The program would pay for the pelletizing line, three years of pellet purchases, stove rebates, and a fund for the creation of the pellet co-op and branding/promotion. See Table 5 for detailed cost information.

Long Term Prospects

Because the pelletizing facility could potentially be profitable without the farmer subsidy, this program could exist on its own, provided the promotion insures consumers remain pellet stove users.

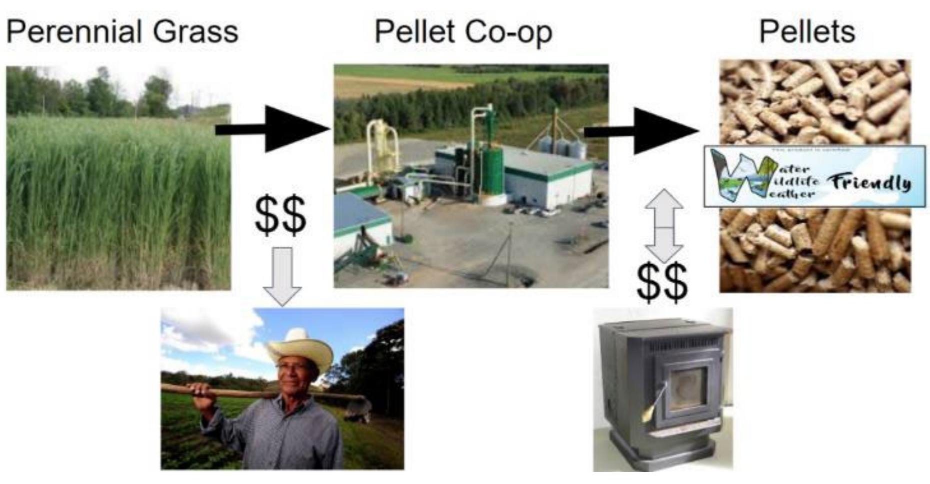

Figure 1: Pellet System Overview

Table 1: Home Heating Energy Source Comparison [1]

	Pellet Stove	Furnaces		
		Natural gas	**Oil**	**Propane**
Annual Total Cost	$1,200	$1,155	$2,093	$2,888

[1] Values adapted from (Energy Pellets of America, 2019; Energy Services Group, 2019; Gillespie, 2019). Assumes home size of 2,000 sq. feet, annual pellet need of 3.6 tons, annual pellet stove cost of $300, pellet cost of $250 per ton, and stove lifespan of 20 years. Includes electricity cost.

Table 2: Farmer Cost and Return. Italicized items are paid by the program.[1]

Establishment[3]	$16/ac
Harvest[3]	$44/ac
Yield[4]	4 tons/ac
Co-op Payment	*$100/ton*
Total Profit	$340/ac

[1]Values adapted from (Heil & Ciolkosz, 2014) and personal communication.

Table 3: Pellet Production Facility Costs and Return. Italicized items are paid by the program.[1]

Production	
Fixed Equipment Costs	$120,000
Additional Costs (building, etc.)	$100,000
Subsidy	*$120,000*
Total Annual Cost	$8,024
Inputs	
Annual Pelletizing Capacity	3,600 tons
Storage Loss	10 %
Co-op Payment	*$100/ton*
Annual Cost for Switchgrass	*$400,000*
Income	
Price for Co-op Pellets	$250/ton
Annual income	**$900,000**
Total Profit	$891,976

[1]Values adapted from personal communication, and (Heil & Ciolkosz, 2014). Assumes 5% interest rate and twenty year loan time period. Does not account for labor or land rental. After three years, the program would no longer reimburse for switchgrass. Does not account for labor or land rental.

Table 4: Stove Owner Cost and Return. Italicized items are paid by the program.[1]

Stove Purchase	
Stove Cost Low	$1,700
Stove Cost High	$3,000
Rebate	*$1,000*
Annual Cost	$221
Pellet Cost	
Price for Co-op Pellets	$250/ton
Annual Pellets Needed	3.6 tons
Annual Cost	$900
Total Annual Cost	$1121

[1] Values adapted from (Gillespie, 2019). [1]Mean value between high and low stove costs. Assumes 5% interest rate, 20 year lifespan.

Table 5: Switchgrass for Home Heating Program Cost Breakdown.

Farmer Subsidy	
Tons Needed	4000
Price	$100/ton
Years	10
Total Cost	$4,000,000
Industry Subsidy	
Pelletizing Equipment	$120,000
Total Cost	$120,000
Consumer Rebate	
Rebate per consumer	$1,000
Number of consumers	1,000
Total Cost	$1,000,000
Total Cost	$5,120,000

Scenario 2: Intermediate Wheatgrass for Animal Feed

Introduction

The state of Minnesota is home to almost 9 million hogs, about 12 percent of all hogs in the United States (Barrett, 2018; Belz, 2019; Minnesota Department of Agriculture, 2016; Ye, 2017). (*Note: here we refer to both hogs and pigs as hogs.*) For comparison, Minnesota is home to less than 2 percent of the U.S human population. The vast majority of U.S. corn grown is used for animal feed and ethanol, with only a small amount directly consumed by humans. Most of the corn fed to Minnesota hogs comes from corn grown in Minnesota (Minnesota Pork Producers Association, 2019). To focus in on the animal feed sector of corn production, we have developed this scenario to replace a portion of the corn used to feed hogs with intermediate wheatgrass, a perennial that produces a kernel similar to wheat.

Program Need

To determine program need (i.e., the amount of market incentive required), we must estimate the impact on consumer prices for pork products. An average slaughtered hog (live weight 250 lb.) has 150 lb. of human edible meat (0.6 / lb.), and is sold at wholesale for $150, or a dollar per lb. The additional cost of per hog of feeding intermediate wheatgrass could increase the wholesale price. According to a report by the Sustainable Agriculture Research Council, many consumers would be willing to pay $1.50 (in 2019 dollars) more per package of porkchops if the hogs were raised in a way that resulted in 80 to 90 percent odor abatement and 40 to 50 percent water pollution reduction (Sustainable Agriculture Research & Education, 2003). Consumers may be willing to pay a premium with a labelling program in place for animal products raised on intermediate wheatgrass (Kernza).

System Description

Intermediate wheatgrass is similar nutritionally to wheat. For hogs, wheat has 95% of the feed value of corn, which implies that corn will require about 105% of its weight replaced by intermediate wheatgrass. We assume that up to 10% of the corn portion of a hog's diet can be replaced with intermediate wheatgrass, with no nutritional detriment to the animal. 10% of the corn portion is 66.7 lb., or 1.2 bushels, of corn; 105% percent of this is 70 lb., or 1.25 bushels of grass (See Table 6 for hog food requirements). If we assume that intermediate wheatgrass' price would be the same as that of corn, and that the other components of a hog's diet are the same per weight cost as corn, then the overall cost of purchasing food for hogs, with 10% of the corn replaced, would be less than 1% higher. However, if we assume farmers will need to make as much money with perennial grass as they did with corn, perennial grass will have to earn the same profit per acre as corn, which would be about $23 per bushel, this is using the means of the assumption ranges in the assumptions in Table 7. At this price, the cost to feed hogs would increase by $28 per hog, which we will use in the rest of this scenario. This is, effectively, 17 cents more per lb. We propose that all pork not produced under this program be taxed 17 cents per lb. to make the intermediate wheatgrass fed pork more attractive.

Proposed Program

We propose a consumer labelling program approach, an intermediate wheatgrass subsidy, and a pork tax.

Farmer Subsidy

We recommend a guaranteed price of $10/bushel for intermediate wheatgrass. The remaining $13/bushel would be paid by the hog farmer.

Product Surcharge
All pork not under the program would be assessed a 17 cents per lb. surcharge (pork tax). If this surcharge were passed onto the consumer, and the same amount of pork was purchased, this is the equivalent of $47.6 million per year, or $8.50 per Minnesotan per year.

Consumer Labelling:
The label will appear on the end product and indicate that it is "Water and Wildlife Friendly: This animal was fed perennial grasses." In order to label a product, the animal involved must have 10% of its corn feed replaced with intermediate wheatgrass. The producer must pay the farmer involved a $13/bushel for intermediate wheatgrass.

Program Cost Breakdown
The program would pay for 500,000 bushels per year, enough for 33,000 hogs.

Scope

Pork is not contained within the state of Minnesota. As such, there are supply and demand implications not discussed here. However, Minnesotans' meat consumption is likely on the higher end of the U.S. (Lusk, 2017), and there already exists a market for sustainable and humanely raised pork in the state.

Table 6: Average Feed Needed for the Lifespan of One Hog[1]

Feed	Weight (lb.)
Corn	667
Soybean Meal	143
Distiller Grains (dried)	32.5

[1]Values adapted from (Lawrence & Ellis, 2008).

Table 7: Intermediate Wheatgrass for Animal Feed Assumptions [1]

Average Corn Profit	$161/ac
Corn Price	$3.44/bushel
Intermediate Wheatgrass Production costs	$250 to 400/ac
Intermediate Wheatgrass Yield	24 bushels/ac

[1]Esimate from FINBIN. Range of yields is 15 to 30 bushels/acre.

Scenario 3: Solar Arrays with Conservation Pastures

Introduction

Solar energy capture has been expanding rapidly in the United States over the past decade, with enough current solar production to power over 12 million homes (Office of Efficiency and Renewable Energy, 2019; Solar Energy Industries Association, 2019c). While a northern state, Minnesota has the solar potential equivalent to Florida or Texas (MN Commerce Department, 2019), and in fact, solar energy in Minnesota has been increasing, with 2016 through 2018 seeing substantial installations (Figure 2), resulting in 2 percent of Minnesota electricity now coming from solar energy (Solar Energy Industries Association, 2019b). Solar energy at a commercial level currently has a 30% federal tax credit, which will decrease over time, eventually becoming 10% permanently in 2022 (Solar Energy Industries Association, 2019a) To increase solar energy production, while at the same time retaining land for agricultural use, solar panels can be used in conjunction with agricultural systems (Dupraz et al., 2011). Commercial solar producers have a 10% tax break. Xcel Energy, the main electric utility in Minnesota has committed to increase solar energy production by 4,000 MW.

Here we describe several scenarios where solar panels are installed on riparian land.

System description

Solar panels can be installed in land previously used to grow row crops. The photovoltaic panels can be arranged in various configurations with different sized gaps between panels, and different heights of the mounting poles. For agricultural purposes, the gaps become important as crops essentially compete with solar panels for sunlight when placed on the same plot of land. The height and gaps between the panels are important as equipment or animals may need to fit underneath or in between (Dupraz et al., 2011). To avoid issues with large scale harvesting, we assume the land under the panels will be used as grazing ground for animals. The larger the animal, the higher the panels need to be, increasing the cost, and decreasing the amount a solar company is willing to pay per acre, which ranges from $600 to $1200 per acre. Currently, 85% of Minnesota's energy is produced in state (Energy Information Administration, 2019).

Proposed Program

We propose to increase solar production by 150MW for our pilot watershed**,** (if this were for ten watersheds, this would be less than half of what Xcel has committed). We discuss 3 variations on the scenario a-c: a subsidy, a mandate and a rider (adder fee).

3a. Solar Company Subsidy

The additional costs generated by the increase in energy production costs could be borne by the solar energy companies. Here we propose a one-time subsidy payment of $6,000 per MW of solar capability installation in program eligible riparian zones. This would be a total cost of $900,000. It is possible solar energy production will not actually be any more expensive for the consumer (Mahajan, 2018).

3b. Mandate Scenario

Here, we propose to mandate the solar energy increase. Participating farmers must agree to maintain agricultural production under the solar panels, but the specifics will be up to them. If agricultural production is not required for solar panel production, it is possible that land will just be removed from agricultural production. Given the high prices offered by solar panel companies, as compared to the potential profits for row crops, it is unlikely there will not be enough participants to meet the mandate. This solution would let the market determine energy prices and could have unintended consequences.

3c. Rider (adder fee) Scenario

If we allowed the utility to charge a rider, or energy price increase of 0.5 cents per kwh, this would increase consumer energy costs, the costs would be borne by the consumers. We are waiting in additional advice from colleagues at private solar firms to provide additional information to complete this cost analysis.

Table 8: Solar Production Parameters and Costs[1]

Additional Array Installation Cost	6,000 $/MW
Energy Potential	0.15 MW/ac
Additional Array Installation Cost	$923/ac
Acres Needed	900
Total Cost	$900,000

[1]Adapted from (Energy Information Administration, 2019). Fixed tilt is typically $3,500/MW, however, we have assumed an additional cost of $2,500/MW due to the non-uniform shapes of riparian zones. [15]Process developed as part of this project.

Environmental Benefits Estimation

Water Quality Benefits

Benefits to water quality were defined as the percent reduction of watershed-wide sediment, particulate phosphorus, and nitrate amounts of each scenario's cover and management regimen when compared with conventional corn/soybean agriculture. Particulate phosphorus is primarily associated with sediment and comprises most of the total phosphorus load; the remainder – dissolved/soluble reactive phosphorus -- was not considered at this stage in the project as it is significantly more difficult to evaluate.

Reductions in sediment and particulate phosphorus were simulated using GIS tools that (1) implemented the RUSLE erosion model (Revised Universal Soil Loss Equation) which estimates sediment/particulate phosphorus erosion at the field-slope scale, and (2) used simplified sediment transport routines to estimate the proportion of eroded sediment that reaches the nearest perennial stream. Nitrate reductions were estimated using published nitrate yields (e.g., lb.s per acre per year) for each cover and management scenario in comparison nitrate yields from typical corn/soybean agriculture.

A major objective of the water quality benefits analysis was to determine the effectiveness of placing converted perennial areas in riparian corridors versus placing them randomly throughout the watershed. We defined riparian corridors as existing corn/soybean areas adjacent to perennial channels. Placing converted areas in riparian corridors is optimal for water quality benefit because these areas are recognized as exporting a disproportionately high amount of non-point source pollutants to downstream resources. The modeling approach, thus, was also designed to quantify the difference in water quality benefits between riparian- and randomly placed perennial areas.

Because of the complexities of the modeling approach, a single watershed was selected to model water quality benefits at this stage of the project: the headwaters of the South Fork of the Watonwan River. The watershed is designated as a HUC-12 watershed (USGS Hydrologic-Unit-Code 12) and consists of approximately 25,000 acres of predominantly corn/soybean agriculture. Future stages of the project will include an increase in the areas evaluated for scenario benefits. The modeling process described above will be refined and applied to a second HUC-12 watershed in the Blue Earth or Cottonwood basins---thus representing a different geography. Preliminary water scores (e.g. combined percentage reductions of sediment, phosphorus and nitrate) are shown in Table 9. For all markets scenarios the water quality benefits are significant and could represent an important water quality tool.

Habitat Benefits

Scenario habitat benefits were defined using a *normalized* habitat score specifically developed for the project. Calculating the normalized habitat score for each converted area entailed first calculating a *raw* habitat score and then dividing it by the raw habitat score given to an area whose size, species composition and management are presumed to be of optimal habitat quality.

In our watershed example, optimal habitat quality was designated as an area composed of 10% of the watershed area (2,500 acres) covered with undisturbed, diverse prairie.
The raw habitat score was calculated with the following equation:

Raw Habitat Score = sum($Area$ x C x D x M x R x W)   eqn 2   where:

Area = area of perennial conversion (acres)
C = Configuration modifier = fractional coefficient that lowers the raw habitat score if converted areas are less square-like and more rectangular
D = Diversity modifier = fractional coefficient that lowers the raw habitat score if converted areas are less diverse in terms of grass and forb species
M = Management modifier = fractional coefficient that lowers the raw habitat score if converted areas are harvested or grazed
R = Habitat Connectivity modifier = fractional coefficient that lowers the raw habitat score if converted areas are not near other converted or existing perennial habitat areas.
W = Water Proximity modifier = fractional coefficient that lowers the raw habitat score if converted areas are not near perennial water sources

The normalized habitat score for each converted area was calculated by dividing the raw habitat score by the optimal raw habitat score resulting in a decimal score from 0 to 1; this value was then multiplied by 100 to create a more interpretable index from 0 to 100. For example, a habitat score of "25', means the perennial crops associated with that scenario is 25% as good as putting 10% of the watershed in high quality, diverse prairie.

Preliminary habitat scores for each of the scenarios based on the acres generated in our modeled HUC-12 watershed are shown in Table 9. Habitat scores range from 20 to 45—which means the perennial vegetation created by our market scenarios are 20 to 45 percent as valuable as converting 10% of the watershed to high quality prairie. Given the cost to simply purchase and restore land to prairie, these habitat scores demonstrate the cost-effectiveness of using markets to create benefits for pollinators, songbirds, and gamebirds.

Third Update: January 31, 2020

Water Quality Assessment of Each Scenario

Thus far in the project, a single HUC-12 watershed, has been modeled to estimate the water quality benefits of converting select areas to perennial vegetation resulting from each market scenario (i.e., switchgrass, intermediate wheat grass, prairie+solar); further, the modeling was used to examine potential differences in benefits between placing perennial vegetation in relatively small parcels located in riparian corridors (portions of row-crop fields bordering perennial water sources such as streams, rivers and lakes) versus whole-field sized, randomly located parcels. Further detail on the current methodology and results are presented below.

The South Fork of Watonwan River HUC-12 watershed comprising about 25,000 acres was selected. This headwaters watershed of the Watonwan River has a single perennial mainstem stream channel (the South Fork Watonwan), several ephemeral channels flowing into the mainstem, and two lakes listed on DNR's public waters list. Topographic relief in the watershed is very low with mostly flat farm fields and slightly increased slopes in the proximity of its shallow stream/river valleys. The watershed area is over 90% corn/soybean agriculture. The South Fork Watonwan River and Fish Lake are listed by MPCA as impaired for aquatic life indicating the health of fish populations is low due to non-point source pollution from agricultural row-crops. See Figure 2

The second watershed modeled is Rush Creek, a tributary of the Straight River within the Cannon River HUC-8 watershed. It comprises about 15,000 acres and is over 90% corn/soybean. The main perennial channel is designated impaired by the MPCA. [This description was added later for the final report]

Methodology for Estimating Environmental Benefits

The first step in the current approach was to manually delineate portions of existing corn or soybean fields bordering streams, rivers and lakes in the project watershed. These delineated riparian areas were named Potential Perennial Areas (hereafter, PPA's). The aim with this step was to construct sub-field PPA's from 1 to 50 acres in size such that the resulting area would "square-off" the fields containing the PPAs thereby providing easier tractor operations on the remaining row-cropped field portions. The resulting 66 PPA polygons were drawn using Google Earth and imported into ArcGIS 10.4. PPAs totaled 956 acres watershed-wide (See Figure 3)

Next, predicting and quantifying benefits of PPA's requires a modeling approach that can simulate hydrology and water quality at the relatively small scales, e.g. modeling sediment erosion and transport from an individual PPA to the nearest water source; however, whole-watershed models such as SWAT and HSPF are not able to simulate hydrological and water quality processes at this scale. For this reason, we changed our planned approach to use the SWAT model, and instead developed a GIS modeling approach (based on BWSR's PTMapp model) that predicts sediment, phosphorus and nitrogen export from each 3 x 3 meter LiDAR grid cell in the watershed to the nearest perennial water source. The GIS modeling approach is summarized in the following steps:

1. Calculate sediment and associated (particulate) phosphorus erosion (mass) from each LiDAR grid cell using RUSLE (Revised Universal Soil Loss Equation) based on soils, land cover type and slope; nitrogen generated in each grid cell was handled separately based on land cover types reported in the USDA MANAGE database.
2. Calculate travel time from each grid cell to the nearest perennial stream, river or lake using manning's equation (based on vegetation-roughness and slope in each grid cell). This calculation estimates how long it takes for flowing water to travel across each grid cell in the watershed.
3. Calculate eroded sediment and particulate phosphorus mass reaching nearest perennial water source from each grid size using a relationship based on travel time and estimated median eroded sediment diameter. All nitrogen generated was assumed to reach nearest water source regardless of travel time.

The three steps above was repeated for three configurations:

1. *Baseline (current) condition*. Project watershed is covered with vegetation as per 2018 Crop Data Layer from USDA National Agricultural Statistics Service.
2. *Riparian PPA*. Corn and soybeans in delineated riparian areas are replaced by perennial grasses (to simulate effects of switchgrass, intermediate wheat grass and prairie).
3. *Random PPA*. Corn and soybeans in randomly placed whole fields (comprising the same area as the total area of riparian PPAs) are replaced by perennial grasses (to simulate effects of switchgrass, intermediate wheat grass and prairie).

In the case of the Riparian PPA configuration, an additional step was taken to estimate trapping of sediment and particulate phosphorus within each PPA from any row-cropped drainage area upstream (i.e., corn/soybean fields whose water flows across the PPA, enabling PPA to act as a very wide filter strip). Trapping efficiency of PPA's was assumed to be 95% and 75% for sediment and phosphorus, respectively. No nitrogen was assumed to be trapped by PPA's.

Environmental Benefit Results

Results of the modeling outlined above are composed of watershed-wide sediment, phosphorus and nitrogen mass exports -- i.e., the total amount of pollutants either reaching a lake or flowing out of the watershed via the perennial stream network -- for each configuration. The differences between configurations (Baseline Configuration 1 pollutant masses minus Configurations 2 and 3 pollutant masses) reflect water quality benefits of each PPA configuration. Results were reported in percent reduction of watershed-wide pollutant mass per acre of PPA; this was necessary as each of the three market scenarios had different PPA sizes owing to the different costs per acre of scenario implementation. Thus, the modeled percent reductions could be scaled by area for any number of scenarios in which PPA sizes were smaller or larger than those modeling above (i.e., larger or smaller than 956 acres) without having to re-run the model for each potential scenario. Water quality and habitat benefits for each scenario are shown in Table 1 below.

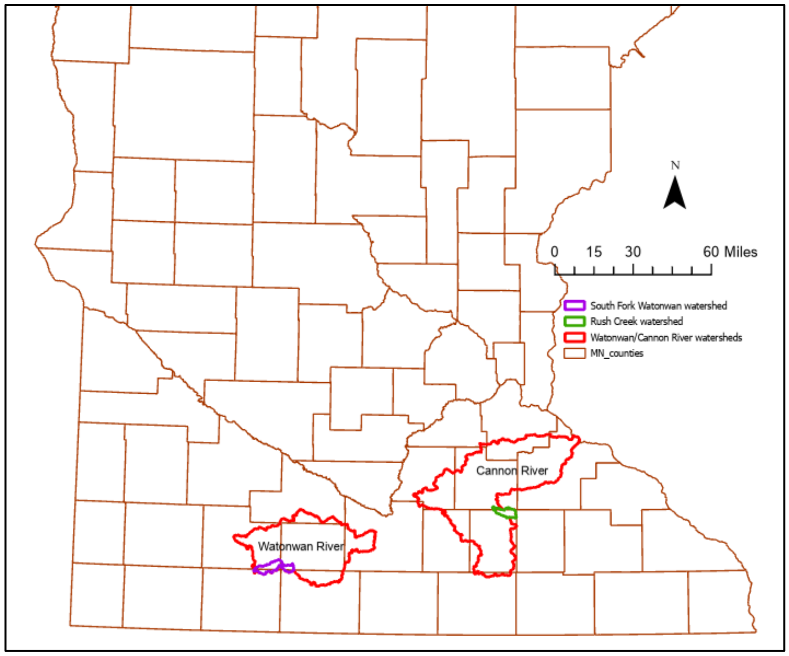

Figure 2. Pilot watersheds modeled to test the environmental benefits of the market scenarios. The South Fork of the Watonwan (~25,000 acres) lies within the Watonwan major watershed; Rush Creek (~15,000 acres) lies with the Cannon River Major watershed.

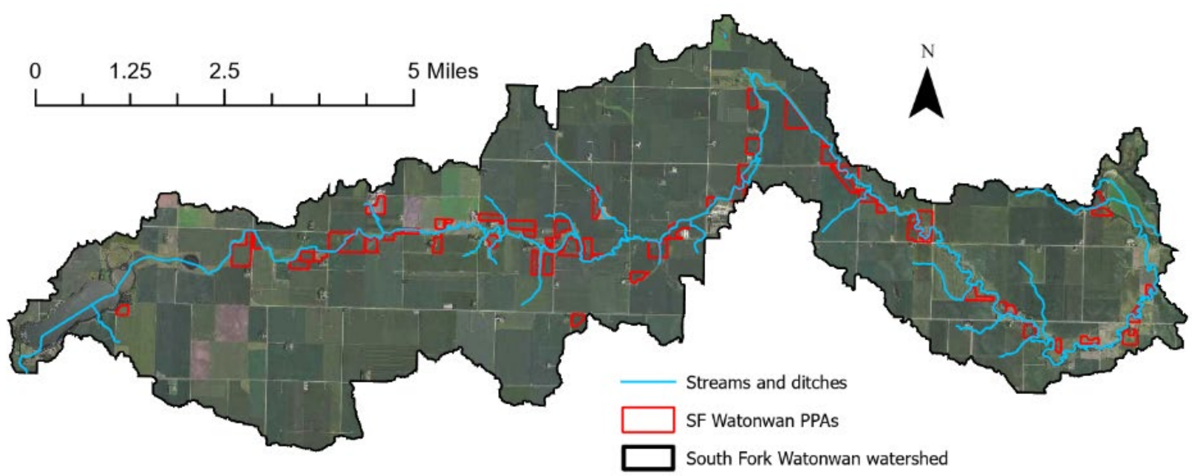

Figure 3. Primary pilot watershed: South Fork of the Watonwan River. Potential perennial areas (PPAs) were placed in riparian areas, squaring off the farm fields as much as possible.

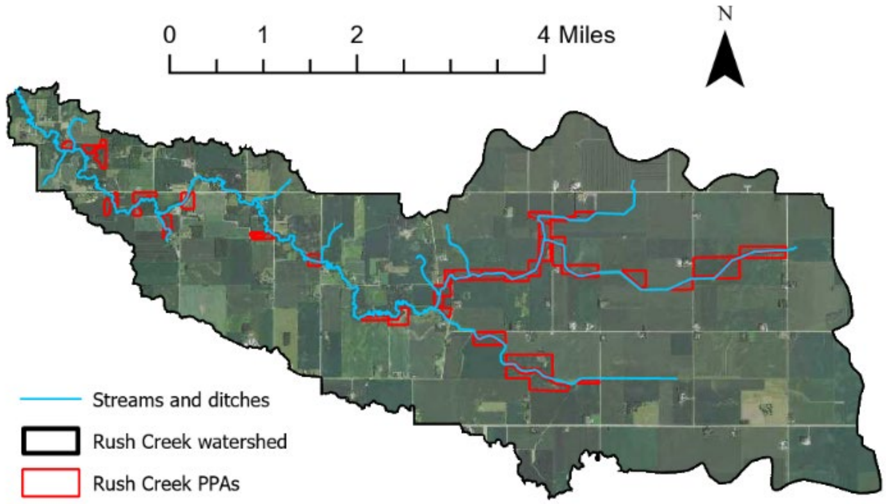

Figure 4. Second pilot watershed: Rush Creek in the Cannon River watershed. Potential perennial areas (PPAs) were placed in riparian areas, squaring off the farm fields as much as possible. Watershed was included in analysis to compare the effects of variations in watershed characteristics on environmental and habitat benefits.

Next Steps

For the next progress update, we will apply the modeling methodology outlined above in a second HUC-12 watershed within the Le Sueur watershed (within the Greater Blue Earth River Basin). The watershed selected will contain a mix of perennial streams/ditches, rivers and publicly accessible lakes. [Final Report Comment: the HUC-12 ultimately selected as the second watershed was the Straight River/Rush Creek HUC-12 in the Cannon HUC-8 watershed]

Demonstration of Consumer Promotion as Market Driver for Perennials

Market scenarios are being refined and finalize. One of the outcomes from evaluating the market scenarios and feedback from the Agroecology summit, was that consumer promotion of perennial products was a key component of nearly all market based methods to stimulate perennial cropping systems. Since there is currently a shortage of perennial products to promote, we decided to transform the concept somewhat, and explore the idea of promoting existing products (not made from perennials) and use the proceeds to fund the purchase or adoption of perennial lands. To demonstrate this alternative method of consumer promotion, we opted to trial it in a real world setting. St. Croix Valley Trees, a small choose-and-cut Christmas tree farm in the Metro area (that also sells hot food), agreed to test the idea of labeling food products "*Water Wildlife and Weather Friendly*", and use proceeds from the sale of these products to fund the subsequent purchase of perennial filter strips on a nearby row-crop farm. Brats and hot dogs with the label "*Water Wildlife and Weather Friendly*" (*W3Friendly*) were priced at 50-cents more than equivalent non-labeled brats and hot dogs. Signage (see Figures 5a-5d) explained the promotion to customers as they waited in line to purchase food items while at the tree farm.

Customers could voluntarily choose between the *W3Friendly* or non-*W3Friendly* labeled items. Seventy-five percent of customers chose to spend the extra 50-cents and purchase the *W3Friendly* labeled items. The proceeds from this extra charge, will now be used to establish a 50-foot wide prairie filter strip around a wetland on a neighboring farm. This trial run of the consumer promotion model to fund the placement of perennials on agricultural lands using proceeds from *W3Friendly* products was viewed by ~7000 adult visitors over a 7-day period on the Christmas tree farm. While this demonstration of the *W3Friendly* consumer promotion concept on St. Croix Valley Tree farm was very encouraging, it is a single test with limited scope and representation, but it does allow us to present the concept as a whole to future interested parties in a more clear and engaging manner.

We are currently working with Science Museum personnel to see if we can do a larger demonstration of the *W3Friendly* consumer promotion idea tied to food and gift items sold at the Science Museum. If we are given permission to go forward, this will also provide a platform to present the science, cost-benefit analysis and social needs behind finding market based solutions for perennial system to create clean water and wildlife habitat.

Figure 5a. Signage for consumer promotion *W3Friendly* demonstration project conducted by project staff.

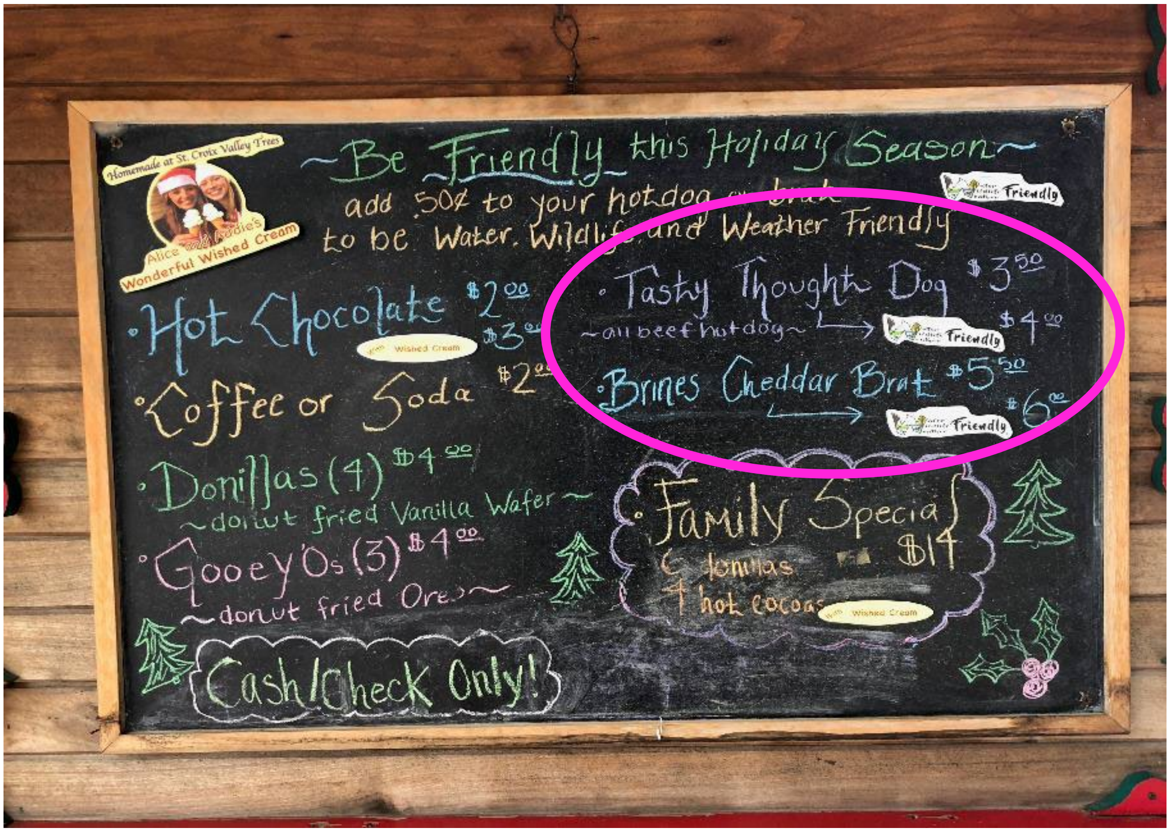

Figure 5b. Signage for consumer promotion *W3Friendly* demonstration project conducted by project staff.

Figure 5c. Signage for consumer promotion *W3Friendly* demonstration project conducted by project staff.

Figure 5d. Signage for consumer promotion *W3Friendly* demonstration project conducted by project staff.

Fourth Update: August 31, 2020

No update: Project manager and St. Croix Research Station staff were on furlough due to Covid19.

Fifth Update: January 31, 2021

Due to Covid19 no work has been done on this project since the previous reporting period of February 2020. The project manager, Shawn Schottler, was furloughed from the Science Museum in late March 2020 and just returned to work in January 2021. Jason Ulrich, who is doing much of the cost-benefit analysis, was also furloughed during this period. The project was granted a one year extension in the fall of 2020, however we still hope to complete the project in the next 6 to 8 months. Work has resumed and we are continuing with finalizing estimates of water quality and habitat benefits for the different market scenarios, and relating these to the costs for each. We will also continue to further define the attributes of the W3Friendly paradigm as a consumer promotional driven method to implement perennial vegetation in critical landscapes. Depending on our ability to coordinate our efforts while working remotely, we hope to finish the project by mid-summer and have a final report submitted in the fall of 2021.

Project Status Update August 31, 2021:

Since returning from Covid-19 furlough, work has resumed on finishing the remaining Outcomes. Work in progress includes selecting the second (and final) project watershed to repeat the water quality and habitat benefits modeling and analysis. In addition, the final report and fact-sheet are roughed out and will be completed after the benefits modeling and analysis.

Project Status as of January 31, 2022:

Project work is near completion with report writing and fact-sheet creation continuing – principal remaining tasks include a cost-benefits summary of the scenarios analyzed as well as a recommendations section to guide LCCMR in understanding the implications of the project findings.

Final Report Summary

Note on Summary

Much of the project's background, approach, methodologies and results sections have been incrementally documented in detail in previous status updates above; however, as our thinking on this research has evolved over the course of this 4-year project, a certain amount of this previous content is inconsistent with the final approach and results. In addition, this summary also serves as the last incremental update of work completed that has not yet been documented, and has additional background information added for better clarification and context. Therefore, this summary seeks to weave all of this information together in most clear, concise way possible, laid out in the following sections:

Overall Approach and Results – Overall summary of project approach and results

Conclusions and Recommendations – Overall project conclusions and recommendations for further work

Expanded Background Information – Additional content written from a policy/economics perspective that supplements information previously documented

References – A list of sources cited across all sections of the report

In some cases, comments have been inserted into the sections above in brackets to clarify meaningful differences between any (now) provisional information presented there, and the finalized information presented here.

Overall Approach and Results

Market Scenarios Approach

We conceived of many different approaches for creating hypothetical markets and incentives that could stimulate farmers to convert corn/soybean land into perennial vegetation/crops for environmental (water quality and habitat) benefits with profitability roughly equivalent to corn/soybean agriculture. Potential market incentives included combinations of mandates, subsidies, surcharges/taxes, and consumer promotion (See page 36 for more information).

Some approaches initially proposed were determined to be not viable or feasible enough to research further, while other new, more promising methods were conceived and developed as the project progressed. Of the six scenarios originally proposed, the three involving growing grass/alfalfa to fed crickets as protein for pet food (see page 8) were abandoned because we determined them not cost-effective enough to consider further. Conversely, the scenario involving solar arrays with pastures was expanded from one to three, resulting in five market scenarios total. (Additionally, a scenario conceptually different than the other scenarios was broadly developed and piloted on a very small, limited scale. See page 35) The five market scenarios are summarized below:

Scenario 1: Switchgrass Pellets for Home Heating

This scenario entails creating a program to incentivize farmers to grow perennial switchgrass which is harvested and sold to a manufacturing facility to be made into burnable pellets, which are then bought by existing pellet stove owners in Minnesota. The program would need to provide incentive funds for (1) a farmer subsidy to grow the switchgrass (to supplement the sale price of the switchgrass to match corn/soybean profitability), (2) an industry subsidy to build a switchgrass pellet manufacturing facility, and (3) a consumer rebate for existing wood-burning stove owners to buy a pellet burning stove (See page 13 for more information).

Scenario 2: Intermediate Wheatgrass (Kernza) for Animal Feed

This scenario entails creating a program to incentivize farmers to grow perennial intermediate wheatgrass – IWG, also called “kernza” -- to replace 10% of the corn based calories in hog diets within Minnesota. The kernza-supplemented pork would be marketed to consumers at a higher price (i.e., a tax/surcharge). The program would provide incentive funds for a farmer subsidy to grow the IWG -- supplementing the sale price of the IWG to match corn/soybean profitability (See page 17 for more information).

Scenarios 3a, 3b, 3c: Solar Arrays with Conservation Pastures

These scenarios entail incentivizing utilities (such as Xcel Energy) to place relatively small solar arrays on existing corn/soybean land parcels rather than in a smaller number of much larger solar farms thereby incurring higher installation and operational costs. Farmers would receive rental income from the utility and would plant perennial grasses for rotational grazing of sheep under and around the solar panels to further generate income (to match that of corn/soybean agriculture). Three different scenario incentives were considered: (3a) a program generating funds for utilities to offset higher solar costs, (3b) an industry mandate that requires the utility to absorb higher solar costs, or (3c) a consumer fee passed on to customers offsetting the utilities' higher solar costs (See page 19 for more information).

Cost-Benefit Analysis of Market Scenarios

To judge potential of the market scenarios, the water quality and habitat benefits vs. the cost of the program incentives were analyzed. Environmental benefits of scenarios were tested assuming a set amount of money - $5 million – that could be spent (according to each scenario's incentive cost per acre) in a pilot agricultural watershed of approximately 25,000 acres containing a stream impaired according to MPCA criteria (South Fork of the Watonwan River HUC-12). Each scenario could consequently "buy" a certain number of perennial acres within the watershed; the more the acres, generally, the better the water quality and habitat benefits.

It was recognized early in the project that the environment benefits of perennial plantings – especially water quality benefits -- would be maximized by placing them in relatively small corn/soybean areas (compared to entire farm fields) adjacent to streams and lakes -- commonly referred to as "riparian" areas -- where most surface water non-point source pollution originates. Thus, all five market scenarios presented here assume perennials would replace corn/soybeans in riparian areas (and this placement necessitates the incentives in the three solar scenarios -- 3a, 3b, 3c). The water quality advantage of riparian vs. random placement was tested in the modeling analysis.

We estimated a hypothetical placement of each scenario's incentivized acres within the pilot watershed. Each scenario's total acres were distributed into parcels, called potential perennial areas (referred to as PPAs), comprising either (1) 40-acre fields randomly located within watershed, or (2) in much smaller areas adjacent to perennial streams, i.e., the riparian areas. These areas were small enough to not drastically reduce the farmers' field acres, and were manually shaped such that they "squared-off" or simplified the field boundary next to the stream-- a presumed benefit to farming operations. Riparian areas are understood to be greater sources of non-point source pollution because of close proximity to the stream (See Figure 6). Further, they have the potential to intercept runoff from upslope parts of the farm field that flow over them before entering the stream, thereby functioning as grass filter strips, with their water quality effectiveness generally increasing as the upslope area draining to them increases. Water quality benefits for all scenarios were estimated using a LiDAR GIS-based modeling approach that differentiates between these placement factors. (See Figure 6; see pages 22-26 for more information). Habitat scores were calculated using a scoring system developed for the project (see pages 21-22). An additional watershed (Cannon River - Rush River HUC-12) was selected and modeled similarly to test the variation of these riparian PPA areas under different topographic, soil and climate conditions.

Figure 6. Riparian and random placement of hypothetical potential perennial areas (PPAs) associated with project market scenarios in project pilot watershed (South Fork Watonwan River) along with modeled sediment/phosphorus export. Map illustrates the water quality advantage of placing PPAs in riparian areas were the export potential is highest.

Table 10. Environmental Benefits of Market Scenarios in two pilot watersheds. Modeled estimates of water quality reduction percentages for the primary pilot watershed (South Fork Watonwan) and secondary pilot watershed (Rush Creek, Cannon River) are on *Wshd* lines 1 and 2, respectively. Water scores are the sum of Riparian-placed TN, TP, & Sed reduction percentages. Randomly-placed TN, TP, & Sed reduction percentages are provided for comparison. Note substantial improvement in reductions from riparian vs. randomly placed perennial vegetation. Higher reductions for Rush Creek scenarios are the result of larger drainage areas flowing to PPAs. Habitat scores are the percent equivalent to each watershed adding 10% of the total area as high-quality, diverse prairie.

Scenario	Wshd	PPA Acres	Water Score	Habitat Score	TN red. %	TP red. %	Sed red. %	TN red. %	TP red. %	Sed red. %
			Riparian Placement					Random Placement		
(1) Switchgrass Pellets for Home Heating	1	1,140	30	20	7	9	14	4	6	6
	2	670	56	18	15	17	24	3	7	8
(2) Intermediate Wheatgrass for Animal Feed	1	2,500	65	45	15	19	31	8	13	13
	2	1,470	92	46	24	26	42	7	10	12
(3abc) Solar Arrays with Conservation Pastures	1	975	25	30	6	7	12	3	5	5
	2	562	47	32	13	14	20	2	6	5

The results of the environmental benefits analysis are presented in Table 10. Results suggest that significant improvements in water quality and habitat in this 25,000 acre pilot watershed (Wshd 1: South Fork Watonwan) could be realized from the $5 million investment if scenario acres (on approximately 0.5-1% of the total watershed acres) were placed in riparian areas. It is important to note that water quality and habitat benefits are roughly equivalent across the scenarios' three perennial vegetation types (switchgrass, intermediate wheatgrass, pasture) *on a per-acre basis*. That is, the main factor driving their environment benefits is the number of acres each scenario was able to "buy" not the vegetation/management type. Thus, the two main considerations for comparing cost-benefit between scenarios are (1) incentives cost required per acre of perennial (i.e., the cheaper the better; the more perennial acres, the more the benefit), and (2) potential scalability -- the practical limit on the number of perennial acres (assuming funding is *not* a limiting factor) based on the maximum market demand. See Table 9. Scalability is important for understanding how a market scenario could benefit water quality and habitat at scales consistent with the scale of water quality and habitat problems in Minnesota. In terms of incentive cost per acre, the solar arrays with conservation pastures scenarios have the best cost-benefit (i.e., lowest cost or no-cost/acre) but are limited from scalability standpoint by current utility commitments for solar power growth (2,500 megawatts by 2032 yields 20,000 acres). Intermediate Wheatgrass (IWG) for Animal Feed has the worse cost-benefit because it requires a yearly investment but could scale as high as 600,000 acres if 100% of the hogs in Minnesota had 10% of dietary requirements met by kernza; however, it is unclear to what extent the consumer market would embrace such an option.

Table 9. Summary of Market Scenarios Incentives, Costs and Scalability

Scenario/Program	Program Incentives Needed ($: provided by program)	Total Incentives Cost per Perennial-acre	Potential Scalability Statewide
1. Switchgrass Pellets for Home Heating	Farmer Subsidy ($), Industry Subsidy ($), Consumer Rebate ($)	One-time $4,400	45,000 acres - If all current MN pellet stove owners switched to switchgrass pellets
2. Intermediate Wheatgrass for Animal Feed	Farmer Subsidy ($), Product Surcharge, Consumer Promotion	$2,000/year	6,000 acres per 1% of MN hogs fed - Dependent on success developing and maintaining consumer market demand for label/brand.
3. Solar Arrays with Conservation Pastures	a) Industry Subsidy ($)	One-time $925	20,000 acres - Dependent on utilities' commitments (or govt mandates): current MN Xcel solar commitment is 2,500 MW by 2032 (= 20,000 acres)
	b) Industry Mandate	$0	
	c) Consumer Fee	$0	

Conclusions and Recommendations

Minnesota's water quality and habitat issues are formidable, particularly in the southern agricultural dominated areas of the state. As such, the goals set to fix these issues are necessarily ambitious and, as a result, prohibitively expensive to achieve under current paradigms of conservation. This study explored alternative ways in which types of potential policy-driven market incentives could be used to help bridge the funding gaps benefiting both water quality and habitat.

The hypothetical scenarios presented here demonstrate well the kinds of market incentive programs that that could accelerate the accumulation of perennial vegetation of the landscape, over and above existing programs such as CREP (Conservation Reserve Enhancement Program), CRP (Conservation Reserve

Program), RIM (Reinvest in Minnesota) and MN DNR's Wildlife Management Areas. Four of the five scenarios (1, 3a, 3b, 3c), assuming the necessary policies could be enacted to create and fund the programs – a challenge in and of itself – would be economically practical when compared to the existing publicly funded programs above. For example, the CREP/CRP/RIM program pays farmers around 90% of the cropland value for permanent easements (current cropland values in Minnesota are around $10,000/acre; Pates, 2022); this is less than a 20-year commitment of Intermediate Wheatgrass for Animal Feed (Scenario 2: $2,000/acre/year = $40,000/acre) but more expensive than Switchgrass Pellets for Home Heating (one-time $4,300/acre) and Solar Arrays with Conservation Pastures (one-time $925/acre or effectively zero with mandate or consumer fee). Water quality and habitat benefits are significant with all five scenarios, reaffirming that focusing conservation in riparian areas gives the greatest bang for the buck; as is coupling water quality and habitat benefits together into a single conservation framework which fosters greater potential for coalition building amongst often siloed citizen, nonprofit and governmental stakeholders groups that can aid politically and financially.

However, given the size of the water quality and habitat issues in Minnesota, spanning across watersheds comprising the roughly 16 million acres of corn and soybeans, the scenarios tested here fall short in terms of their scalability. A look at Table 9 reveals that an optimistic hypothetical level of program adoption (50%, 1% and 50% of potential acres from scenarios 1, 2, and 3, respectively) would result in around 40,000 acres of perennial area (at an estimated one-time cost of approximately $110 million plus $12 million/year) – an impactful amount but not enough to be influential unless placement was limited to a relatively small area. Nevertheless, we recommend pursuing policies for scenarios similar to Solar Arrays with Conservation Pastures and Switchgrass Pellets for Home Heating, bearing in mind that these are starting points and will not provide improvements in environmental benefits at the state-wide scale without changes in federal policies (i.e., the farm bill) or other market forces.

The issue of market limits and scalability is what lead us to research the *W3Friendly* demonstration scenario (see page 26): a business enters into an agreement with the *W3Friendly* program to label or otherwise advertise that the sale of the good or service it sells supports putting perennials on the landscape for environmental benefits, and gives a small fraction of the (presumably) increased price of the good or service to the *W3Friendly* program to be allowed to do so. The program in turn uses the money earned to acquire land as it sees fit. The important distinction with this approach is that the land acquired for perennials is not tied to the money needed to acquire it – it doesn't need to supply a good or service itself (such as wood pellets, livestock feed or solar energy); because of this distinction the program does not have a set ceiling for scale of adoption like the other scenarios tested in this study (other than the consumer market's perception of value for the aims of the program). Thus, an additional recommendation from this study is to continue to research distinct programs such as *W3Friendly,* while continuing to pursue approaches such as the five scenarios tested in this study.

Expanded Background Information
(This supplemental section was included to provide additional background information from a policy/economics perspective.)

Corn/soybean production comprises around 16 millions of acres in Minnesota annually, the majority of which is used for animal feed and ethanol. Replacing these crops with perennial species, particularly in riparian zones (areas bordering water bodies), would decrease nitrogen and phosphorus pollution, decrease sedimentation, increase soil health metrics, and improve wildlife habitat. Implementing more extensive perennial crop growth in riparian zones could have substantial impacts on the landscape, and subsequently, environmental quality.

This report explores potential programs to drive replacement of row crop agriculture in riparian zones with perennial vegetation/crops, while still maintaining farm profitability. We develop scenarios using different economic-based policies such as mandates, subsidies, taxes, consumer promotions and information campaigns.

These different economic tools can motivate perennial crop growth by encouraging or discouraging agronomic practices, and by influencing consumer behavior. All of these can impact the amounts and types of products bought and sold on the market, in an effort to align the private market equilibrium with the true public equilibrium that includes externalities—such as environmental damages from excess nitrogen and wildlife benefits from perennial cropping systems.

Mandates force market output changes via an external action by legally requiring that certain actions be taken. In other words, the market itself is not changed. The best example of mandate related to agriculture in Minnesota is the Renewable Fuel Standard, also called the "ethanol mandate", which requires gasoline to be blended with 10% ethanol, thereby creating additional demand for corn (which is used to make ethanol) over above the normal market demand. Minnesota's Buffer Law, which requires vegetative buffers be in place between waterways and croplands, provides another example of mandates (BSWR, 2021). Tools that employ internal mechanisms to shift the supply include subsidies and taxes—either by making production more or less expensive. Subsidies are given in response to actions perceived to be in the public interest—an example being the federal Conservation Reserve Program, where payments are made to remove environmentally sensitive land from production. In this way, positive externalities, such as ecosystem services, that do not have a traditional market value, are assigned a value through the subsidy program. This effectively internalizes these external benefits. Conversely, taxes or charges are made in response to things deemed against the public good. Taxes on nitrogen fertilizer to reduce pollution and generate funds for water quality have been proposed, but, to the best knowledge of the authors, have not been implemented. The California Water Boards recommended this occur to the legislature, but nothing has been enacted (California Water Boards, 2020).

The demand side of the equation can be addressed as well. Information campaigns, efforts to inform customers (addressing the economic concept of asymmetric information), are widespread and occur at many different levels of government, as well as through non-profits and community outlets. Providing better information can shift demand, making more environmentally beneficial products more desirable. Eco-labels are a type of information campaign where environmental benefits are described on product labels. These have been shown to increase the amount consumers are willing to pay; a review of over 30 experiments found that people were willing to pay over $3 more per kilogram of eco-labeled food product (Bastounis et al., 2021). However, this extra amount is linked to a perception of quality improvement as well (McCluskey & Loureiro, 2003).

The economic tools described in the introduction can be applied in many different ways to target perennial crop production. A program could be designed to specify a particular use of perennial crop (i.e., for habitat, bioenergy, animal feed, etc.). Or a program could allow for multiple uses or allow the grower to decide. Similarly, programs can target specific row crops (i.e. corn over soy beans) or allow different types of crops to be removed (i.e. annuals).

Whatever programs are employed would need to have a thorough analysis to determine how much land (and where) the program would be implemented, how impactful the program would be in Minnesota, and any unintended consequences.

When designing a program, the products of interest should be examined for potential use, as well as the scope of the larger market. As an example, one could imagine a program where row crops are replaced by switchgrass (Panicum virgatum L.), a bunch grass native to North America, which is then used for combustion-based pellets for home heating stoves. While switchgrass provides soil stabilization, wildlife habitat, and has been widely studied for its biofuel potential (Jimmy Carter Plant Materials Center 2011), using combustion stoves as a heat source is controversial due to potential air quality and human health concerns (Alliance for Green Heat, 2011; Wyss et al., 2016). Considering the climate impact, as well as the labor impact (pellet stoves must be fed regularly and cleaned), it is both unlikely many more residents would convert to pellet stoves and concerning to enact a policy promoting such action. Currently, only about 2.4 percent, or about 50,000 homes, are heated with wood stoves in Minnesota (Eleff, 2017). Homes that do use wood pellet stoves burn about 3.6 tons annually (with a comparable cost to other energy sources), which is the equivalent of approximately 45,000 acres of switchgrass (Energy Pellets of America, 2019; Energy Services Group, 2019; Gillespie, 2019). However, commercial facilities to produce pellets from switchgrass do not exist. If they were to exist, they would have to produce pellets that burned as efficiently as wood pellets and offer them at a lower price to encourage purchasing.

One could imagine another scenario that promoted animal feed made from perennial crops, such as intermediate wheatgrass, a perennial grass species native to Eurasia. It was introduced to the United States as a feed stock and provides excellent soil stabilization (Jimmy Carter Plant Materials Center 2003). It can be fed as a corn replacement to hogs being raised for meat consumption. Typically, hogs do not consume any perennial grasses, and while they cannot digest cellulose, they can derive nutrition from intermediate wheatgrass, which is similar nutritionally to wheat. However, with the current agricultural market, corn is a cheaper product to produce. Additionally, there may be some impacts on hog development when fed a non-traditional diet. Pigs are a substantial sector in Minnesota-- the state of Minnesota is home to almost 9 million hogs, about 12 percent of the United States hog population, yet less than 2 percent of the U.S human population (Barrett, 2018; Belz, 2019; Minnesota Department of Agriculture, 2016; Ye, 2017). But, it is important to consider that pork is a global market—meaning that if pork produced in the state of Minnesota had additional costs over out of state pork, consumers could simply purchase the cheaper substitute. Nonetheless, consumers may be willing to pay a premium with a labelling program in place for animal products raised on intermediate wheatgrass; a study found that many consumers would be willing to pay $1.50 (in 2019 dollars) more per package of pork if the hogs were raised in a way that resulted in 80 to 90 percent odor abatement and 40 to 50 percent water reduction (Sustainable Agriculture Research & Education, 2003). As such, they very well may pay more for hogs fed with more sustainable food sources. Regardless, a program to subsidize or mandate alternative feed for pigs would have to be quite thoroughly researched prior to implementation.

These types of programs would differ from a program that did not focus on the end use product of the perennial grass and instead used the land in a different manner—such as a program that supported solar energy production. Solar panels can be installed in land previously used to grow row crops, with perennial pasture grown underneath. Solar energy capture has been expanding rapidly in the United States over the past decade, with enough current solar production to power over 12 million homes (Office of Efficiency and Renewable Energy, 2019; Solar Energy Industries Association, 2019c). While a northern state, Minnesota has the solar potential equivalent to Florida or Texas (MN Commerce Department, 2019), and in fact, solar energy in Minnesota has been increasing, resulting in 4 percent of the energy provided to the upper Midwest by Xcel Energy, the main electric utility in Minnesota. (Solar Energy Industries Association, 2019b).

Solar energy at a commercial level currently has a 26% federal tax credit, which will decrease over time, eventually becoming 10% permanently in 2024 (Solar Energy Industries Association, 2019a) To increase solar energy production, while at the same time retaining land for agricultural use, solar panels can be used in conjunction with agricultural systems (Dupraz et al., 2011). This year, Xcel Energy committed to increase solar energy production by an additional 2,500 MW by 2032 in a bid to become a net zero energy producer by 2050 (Xcel Energy 2022). The photovoltaic panels can be arranged in various configurations with different sized gaps between panels, and different heights of the mounting poles. If land is to be used underneath the panels, the height and gaps between the panels are important as equipment or animals may need to fit underneath or in between (Dupraz et al., 2011). The concern with solar production is that it is quite efficient—each acre can produce 0.15 MW (Energy Information Administration, 2019); Xcel's commitment could potential be generated in less than 20,000 acres.

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IV. DISSEMINATION:

Results from this project will be summarized in a final report and a concise four-page fact sheet. The fact sheet will highlight the necessity of creating markets for perennial crops, present the six market scenarios along with their associated cost-benefit analysis as examples, and offer a summary of the recommendations on the socio-political efforts required to create cost-effective markets for perennial cropping systems. In addition, the concept and objectives of market based solutions to benefit water and wildlife will be presented orally at over 10 venues throughout the State over the duration of the project. Venues will include professional conferences and statewide meeting to audiences of state and federal natural resource managers, policy makers, non-profit advocacy groups, and agricultural producers.

First Update: January 31, 2019

Concepts of this project, especially with regards to the solar + pasture scenarios were presented at the MN-Climate Adaptation Conference in November 2018.

Second Update: August 31, 2019

Markets scenarios and associated water quality and habitat benefits were presented at the AgroEcology Summit in Windom, MN in August 2019. The concepts of using markets to drive adoption of perennial crops/cropping systems generated considerable interest and follow-up meetings have been scheduled with several environmental advocacy groups to discuss next steps.

Third Update: January 31, 2020

We demonstrated the concept of promoting "*W3Friendly*" labeled food products to customers in a real-world setting at a Christmas Tree farm in December (see above summary). This trial run of the consumer promotion model to fund the placement of perennials on agricultural lands using proceeds from *W3Friendly* products was viewed by ~7000 adult visitors over a 7-day period on the Christmas tree farm. Reaction to the idea and consumer preference for products with the *W3Friendly* label was very positive. With this in hand, we are in discussions with the Science Museum of Minnesota to conduct a larger demonstration of promoting *W3Friendly* labeled products to stimulate implementation of perennials on the landscape. We are meeting with SMM supervisors at the end of February to see if we can find a way to promote and sell *W3Friendly* food items in the two cafeterias at the SMM. Any such effort would be accompanied by educational displays about the need to use markets to drive land use changes that benefits water and wildlife.

Fourth Update: August 31, 2020

No update: Project manager and St. Croix Research Station staff were on furlough due to Covid19.

Fifth Update: January 31, 2021

Due to Covid19 no work has been done on this project since the previous reporting period of February 2020.

Project Status Update August 31, 2021:

No dissemination work has been done since returning from covid-19 furlough. We are exploring alternatives to face-to-face presentations because of continued covid-19 in-person restrictions state-wide.

Project Status as of January 31, 2022

Because of continued limitations of covid face-to-face restrictions we are exploring alternatives for sharing the results of the project. In November, the project results were presented to the Museum's members via a dedicated zoom presentation and Q&A. The Science Museum will continue to sponsor opportunities to present the results live to members and the general public, and will create social media content in the form of produced videos that will present and summarize results. These videos will be shared across social media sites representing environmental and farming audiences.

Final Report Summary

The background, goals and provisional and final results have been presented to audiences on numerous occasions since the project got underway. Project content has been presented to agencies such as the Minnesota DNR and at several Science Museum member events. The work has been endorsed and spurred collaboration with groups such as Friends of the Mississippi and Fresh Energy. Finally, the project team was instrumental in organizing and leading the AgroEcology Summit in Windom, MN in August 2019 where the project work was presented over several hours to more than one hundred attendees. The concepts of using markets to drive adoption of perennial crops/cropping systems generated considerable interest and follow-up meetings have been scheduled with several environmental advocacy groups to discuss next steps.

Following the completion of the project, the fact sheet created for this project and link to LCCMR will be shared via Science Museum social media platforms.

V. PROJECT BUDGET SUMMARY:

A. Preliminary ENRTF Budget Overview: See attached budget spread sheet

Explanation of Use of Classified Staff: NA

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

Total Personnel Hours: 1020 hr/yr for 3 yr	0.5 /year, 1.5/project

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

Total Personnel Hours: 208 hr/yr for 2yr	0.1/year, 0.2/project

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:			
NA	$ NA	$ NA	
Other State $ To Be Applied To Project During Project Period:			
NA	$ NA	$ NA	
Past and Current ENRTF Appropriation:			
Funding History: ENRTF M.L. 2016 Chp 76 Sec 3 Subd 08c. $179,000: Establishment of permanent habitat strips within row crops. ENRTF M.L. 2015 Chp 226 Sec 2 Subd 03g. $900,000: Watershed-Scale Monitoring of Long-Term Best-Management Practices	$	$ $ 179,000 $ 900,000	Ends 06/2019 Completed
Other Funding History:			
NA	$ NA	$ NA	

VI. PROJECT PARTNERS:

A. Partners receiving ENRTF funding

Name	Title	Affiliation	Role
Dr. Jeff Peterson	Ag-economist	U of MN, Water Resources Center	Economic and market evaluations
Dr. Lucy Levers	Research Associate	U of MN, Water Resources Center	Economic and market evaluations

VII. LONG-TERM- IMPLEMENTATION AND FUNDING:

The markets scenarios presented in this project are mostly intended to serve as examples to stimulate and augment the discussion about how we can pay for land use practices that benefit water and wildlife. Results from this project are intended to serve as both specific examples of the socio-political changes needed to stimulate perennial cropping systems and as the spark to ignite a larger effort to find ways to create demand for these crops.

VIII. REPORTING REQUIREMENTS:

- The project is for 4 years, beginning July 1, 2018 and ending June 30th, 2022

- Periodic project status update reports will be submitted Jan. 31st and August 31th 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

Attachment A:
Environment and Natural Resources Trust Fund
M.L. 2018 Final Budget Spreadsheet

Project Title: Develop Market-Based Alternatives for Perennial Crops to Benefit Water Quality and Wildlife
Legal Citation: M.L. 2018, Chp. 214, Art. 4, Sec. 02, Subd. 08c
Project Manager: Jason Ulrich
Organization: Science Museum of MN
College/Department/Division: St. Croix Watershed Research Station
M.L. 2018 ENRTF Appropriation: $150,000
Project Length and Completion Date: 4 years. June 30, 2022
Date of Report: August 15, 2022

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits) - Overall	$125,000	$125,000	$0
SCWRS Senior Scientist: Shawn Schottler 37% FTE for 3 years. Salary =70%, Benefits =30% (Total estimate $105,000)			
SCWRS Assistant Scientist: Jason Ulrich 12% FTE for 2 years. Salary =70%, Benefits =30% (Total estimate $20,000)			
Professional/Technical/Service Contracts			
University of Minnesota, Water Resources Center: Research Assistant (or equivalent), to conduct market evaluation and feasibility analysis.	$25,000	$25,000	$0
COLUMN TOTAL	**$150,000**	**$150,000**	**$0**

Environment and Natural Resources Trust Fund (ENRTF)

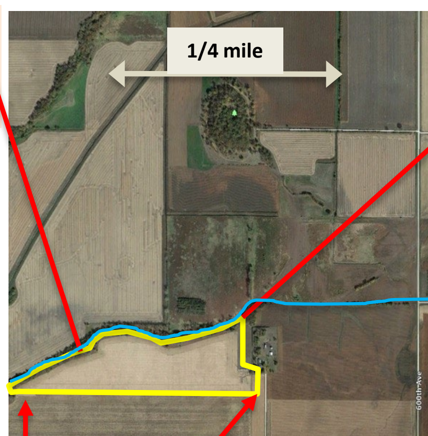
Develop Market-Based Alternatives for Perennial Crops to Benefit Water Quality and Wildlife

Create 5 new market scenarios for placing perennials next to streams in Minnesota's agricultural watersheds…

Estimate their costs and their environmental benefits.

Scenario: Intermediate Wheatgrass for Hog Feed

Scenario: Solar Pastures



Perennial grasses next to streams add grassland habitat and act as filter strips reducing nutrient and sediment runoff