M.L. 2016, **Project Abstract**
For the Period Ending June 30, 2019

PROJECT TITLE: Establishment of Permanent Habitat Strips Within Row Crops

PROJECT MANAGER: Shawn Schottler
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2016, Chp. 186, Sec. 2, Subd. 08c

APPROPRIATION AMOUNT: $ 179,000
AMOUNT SPENT: $ 179,000
AMOUNT REMAINING: $0

Sound bite of Project Outcomes and Results

This project successfully demonstrated the establishment of native perennial plantings within row-crops – without removing land from production. These plantings provided significant habitat value to pollinators and reproduction of monarch butterflies. Adapting this technique to create a strip of milkweeds within the outside row of corn/soy fields could offer substantial benefits to monarchs at minimal cost.

Overall Project Outcome and Results

This project successfully demonstrated three objectives: 1) that perennial vegetation can be established and maintained between rows of corn/soy within a field—without taking land out of production; 2) that the perennial vegetation in the inter-row plantings provides habitat value, and 3) that the plantings can be done in a manner that induces a minimal yield loss to the adjacent corn/soy rows. While establishment of many prairie species in the inter-row strips failed, several did not and are thriving after three years. We have demonstrated that species such as golden alexanders, bottlebrush grass and milkweeds can be established and maintained in a conventional corn/soy rotation. These strips of perennial forbs and grasses were documented to have provided habitat to pollinators and appear to be very good reproduction habitat for monarch butterflies. Perennial strips did induce a 5 to 20 bushel per acre yield loss, but since only 1 out of 24 inter-row strips were planted with perennials, we estimate that the total cost in lost yield for the whole field (80 acres) due the perennial strips is less than $200. Going forward, we think it is possible to plant and maintain just the outside row of a field with a mix of golden alexander, milkweeds, and woodland brome. This mix would provide some early season pollinator habitat and a significant amount of summer Monarch reproduction habitat. And, since only the outside row of a field would be impacted, the total annual cost in lost yield and maintenance of the strip should be under 40 dollars per 80 acres. If implemented on a widespread scale, this could offer a very cost-effective way to provide significant benefit to Monarch populations.

Project Results Use and Dissemination

Results of this project were presented at two farm-day tours as part of the semi-annual Agroecology summit hosted at Willow Lake farm. Combined, there were over 150 participants in the two Agroecology summits with nearly all of these participants given a first-hand tour of the inter-row perennial vegetation strips implemented during this project. Participants included many local farmers testing cover cropping techniques to improve soil health, as well as agency and advocacy professionals and practitioners working to implement perennial cover as habitat or new cropping systems. In addition to the on-site demonstration of the strips, the field days featured presentations and panel discussion by U of MN faculty, Science Museum scientists, MN-DNR biologists, BWSR planners, environmental advocacy groups and local farmers. Both Agroecology summits presented new concepts/methods about existing and emerging cropping systems that incorporate perennial vegetation (including results from the perennial inter-row system of this project); and policies and technology that could be used to stimulate perennial cropping systems. In-depth presentations were given on why perennial systems are needed, how they are critical to improving water quality and wildlife habitat, what future perennial systems could look like, and how manipulating food and energy markets could be a cost-effective method to getting perennial crops/vegetation adopted. The strips project, with its embedded objectives of habitat and water quality, while maintaining ag-profitability, provided a good backdrop to start the conversation about how we are going to modify cropping systems to more cost-effectively meet our natural resources goals.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2016 Work Plan- Final Report

Date of Report: August 1, 2019

Final Report

Project Completion Date: June 30, 2019

PROJECT TITLE: Establishment of Permanent Habitat Strips Within Row Crops

Project Manager: Shawn Schottler

Organization: Science Museum of Minnesota-St. Croix Watershed Research Station

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Location: Demonstration fields at Willow Lake Farm, Windom MN. Cottonwood and Jackson counties

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$ 179,000**
	Amount Spent:	**$ 179,000**
	Balance:	**$ 0**

Legal Citation: M.L. 2016, Chp. 186, Sec. 2, Subd. 08c

Appropriation Language:

$179,000 the second year is from the trust fund to the Science Museum of Minnesota for the St. Croix Watershed Research Station to research the viability of establishing prairie forbs and alfalfa as permanent cover strips in the bare soil between selected rows of corn and soybeans as potential pollinator, monarch, and gamebird habitat. Monitoring of the native plant strips must evaluate the effects of pesticides from adjacent crops on pollinators, including determining whether there is a reduction of pollinators that results in reduced setting of seeds on the native plants. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Establishment of Permanent Habitat Strips Within Row Crops

II. PROJECT STATEMENT:

Grassland species such as native bees, monarch butterflies, meadowlarks, and pheasants continue to decline, and water-quality trends are not improving in many lakes and rivers. The common denominator linking these negative trends is the need for more perennial vegetation/cover crops on the landscape. Annual cover crops such as rye offer promising water-quality benefits but do not provide extended habitat value and require the farmer to incorporate several management steps and costs every year. Perennial cover crops would eliminate the additional management steps and provide full season habitat value. The challenge is to find ways to introduce perennial habitats into the agricultural landscape that do not take land out of production, are economically viable, and result in measurable benefits to water quality and grassland species.

This project will test and demonstrate a new approach to creating perennial habitat for pollinators, monarchs, songbirds and gamebirds within an agricultural landscape without removing land from production. This method will take advantage of precision farming techniques, where equipment drives in the same field rows year after year, and establish strips of permanent vegetation in the bare ground between selected corn/soy rows (Figure 1).

The end product will be a suite of 16, ~30-inch wide strips of perennial prairie species or alfalfa established in the bare space between every 24th row of a 60 acre corn/soy field on the Willow Lake Farm, near Windom Minnesota. This configuration means that no land is taken out of production, yet ~4% of the field is in perennial cover. We will evaluate which individual plant species or combination of species creates the most habitat value, the least crop yield loss, and are the most cost effective to implement. We will develop the techniques necessary for management of these species on a farm scale and provide a cost-benefit summary of the results. The technology tested in this project could ultimately result in thousands of acres of perennial filter strips within a watershed, offering not only an expanded habitat component to the landscape, but also a significant potential water-quality benefit.

This project will be the first phase of what is intended to be a long-term and evolving demonstration of the techniques and advantages of introducing perennial vegetation into row-crops. Because it takes several years to get native prairie species established, this project will focus on the methods and costs associated with implementing the technique and will offer preliminary analysis of the habitat benefits of the perennial strips.

Primary objectives during the 3-year project:

a) Develop methods for seeding and establishing perennial species in the inter-row strips, including techniques to protect the strips from herbicide application to the row-crops.
b) Evaluate which species and combination of species can survive in the inter-row environment.
c) Quantify the cost of implementing this conservation technique, including the corn/soy yield reduction due to the perennial strips.

Secondary objectives:

a) Evaluate habitat value of the strips to songbirds, gamebirds, bumble bees and monarchs.
b) Compare habitat value in fields planted with conventional corn/soy seed to fields planted with non-insecticide treated seed.

These latter objectives are listed as secondary because the perennial strips will only have completed two growing seasons by the third year of the project and will still be maturing. Thus, habitat evaluations at this point offer only the initial glimpse into the faunal value of the strips. Non-treated seed in the above objective refers to corn/soy seed that has not been treated with neonicotinoid insecticides and is a non-GMO variety—

here forth simply called “non-treated” seed. This element was added to the project to allow comparison of faunal response in habitats within treated and non-treated row-crop fields.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of: August 1, 2017

Initial steps to establish and maintain permanent vegetation within row-crops is on track. All strips have been planted on the study site. Eight strips were planted into the residue between corn rows in November of 2016 and an additional eight strips were planted in May of 2017. Strips are 60 feet apart, or one strip per every 24 rows of corn/soy. A custom seed drill (planter) was designed and constructed to plant the prairie seeds into the heavy residue remaining between the corn rows. Custom shields were made and fitted to the chemical sprayer used by the farmer to protect the permanent vegetation strips from seasonal herbicide application. Shielding performed reasonably well during two herbicide applications in May and June of 2017 and minimal injury was observed on the seedlings. Thirteen different species mixes we planted. Initial germination and establishment varies greatly. Fall planted row are generally more advanced than spring planted rows with several savanna grasses and milkweeds doing very well. The first bee and bird nesting surveys were conducted in June and July. Growth of prairie vegetation at this point was still less than 10cm tall, with no species flowering, thus no faunal use was observed. Detailed evaluation of plant establishment and additional faunal surveys will be conducted through September.

Project Status as of February 1, 2018

Prairie strips have completed one growing season. Due to herbicide carry-over problems, less than half of the strips have what we would deem as successful establishment, i.e. there are less than six healthy perennial plants per square foot in the strips between the soybean rows. While this may seem like a disappointing outcome, it is important to note that about half of the strips do have successful establishment of perennial vegetation. Thus, the technique is working—just not for all species. For this demonstration project to be a success, we don’t need all perennial species or mixes to grow, we just some mixes to work. We need to demonstrate that we can establish and maintain permanent vegetation between corn/soy rows, and ideally, we would like a mix grasses and forbs. After one growing season, we have different strips where at least three grass species or forbs have formed healthy, dense, continuous cover between the soy/corn rows, leading us to believe that the technique can work---and can be improved with additional testing. Some strips that “failed” were re-seeded in the fall, and the remainder will be re-seeded in the spring. Initial faunal (bee and butterfly) surveys were conducted during the summer. Due to the fact that the plants were only in the establishment phase, and did not flower, there was minimal insect use during the first year. Faunal surveys will begin again in May 2018. A demonstration field day was hosted at the study site in August 2107. This event was part of the 10th biannual Agro-ecology Summit at Willow Lake Farm. There were about 50 participants, many who were local farmers testing cover crops for soil health. There was a mix of enthusiasm and skepticism regarding the perennial strips demonstrated in this project. Participants are intrigued to see the evolution of this project and are looking forward to the next agro-ecology summit that will be hosted in August 2019.

Project Status as of: August 1, 2018

Inter-row perennial strips are now in their second growing season. The crop field was planted to corn in late-April and inter-row strips were shield from the subsequent herbicide application in May. The corn rows around strips 1 (mixed prairie) and 9 (alfalfa) were planted with non-neonicotinoid treated seed, and can be compared with strips 2 and 10 which have similar inter-row vegetation but the corn was planted with neonicotinoid treated seed. Strips planted in 2017 containing Golden Alexander, savanna grasses, Milkweeds and alfalfa are doing very well (Figure 3). Due to herbicide carry-over problems in 2017, about half of the strips had poor establishment and were thus augmented with additional seed in May 2018. Faunal surveys began the second week of May. Strips were inventoried weekly for bees, songbird nests and monarchs (larva and adults). Four, 500 foot transects were also surveyed in the restored prairie adjacent to the crop field. Strips with Golden Alexander and alfalfa had pollinator densities (native and honeybees) of 1 to 4 bees per 100 lineal feet of vegetation. This density was much higher than in the prairie transects, although this is not unexpected since the density of the flowering plants (forbs) was also much greater in the inter-row strips. As of July 12th, no songbird nests have been found in the strips and only a single red-winged blackbird nest was found in a prairie transect. We think that the amount of nesting habitat available (40 acres of adjacent prairie) is so large compared to the amount of habitat searched (strips plus prairie transects) that we are simply not encountering nesting grassland birds. Strips with two-year old milkweeds were searched for Monarch butterfly larva. Forty-nine monarch larvae were found in the strips (a density of 1.9 larva per 100 feet) compared to five in the prairie transects (a density of 0.25 per 100 feet). While the density of milkweeds in the inter-row strip was much greater than in the prairie transects, it was still impressive to see such high reproductive use in the strip vegetation. The tall, thick corn adjacent to the strips hampered our ability to locate monarch chrysalis, but we did confirm that at least four monarchs successfully pupated to adults—thus confirming that monarchs utilizing milkweed within this neonicotinoid treated cornfield can successfully reproduce. During faunal surveys, we did not note any differences in the strips bordered by corn planted with neonicotinoid treated seeds versus those planted with untreated seed.

In this project are trying to demonstrate three things: 1) that perennial vegetation can be established and maintained with a corn/soy field; 2) that the perennial vegetation in the inter-row plantings would provide some habitat value, and 3) that the plantings would only induce a minimal yield loss to the adjacent corn/soy rows. As of this report, we feel that we have successfully achieved outcomes 1 and 2. While many of the plantings appear to have failed, several did not and are doing very well. We have demonstrated that species such as golden alexanders and milkweeds can be established and maintained in a conventional corn/soy rotation. Secondly, the strips that were successful have been shown to provide habitat for pollinators and appear to be very good habitat for Monarchs. What remains to be shown is how significant the yield drag is on the adjacent corn/soy rows. In some strips such as the milkweed strip, the corn adjacent to the strip does not appear much different than the corn rows distant from the strip. However, the corn adjacent to the Golden Alexander strip and savanna grass strips already appears somewhat stunted compared to the corn further away. We will gather yield data in October to evaluate how big or small the yield losses are.

We are requesting to shift $14,332 from Activity 1 (Capital Expenditures) to Activity 3 (Personnel), to enhance the outreach and dissemination of this project by expanding the scope and content of the Agro-Ecology Summit. The money for this reallocation is available because of cost savings in building the custom seed planter and herbicide shields necessary for installing the habitat strips in Activity 1. The planter was built for a cost of about $10,000 and required very few modifications. The biggest savings was in the design and construction of the herbicide shields that protect the strips during weed control in the crop field. We were able to make very simple but effective shields from readily available parts and installation on the sprayer was easier than expected. Because of these savings, there is over $14,000 of unspent money in capital expenditures. Over the course of the project we have become increasingly aware of how large the interest in perennial vegetation and perennial cropping system is among the conservation and agricultural community. Recognizing this interest, we would like to expand the scope, offerings and attendance of the Agro-Ecology Summit planned for the summer of 2019. The focus on presenting results of this project and implementation of perennial cropping systems in general will remain the same, but with the extra funds we would have the resources to coordinate a much bigger Summit in the following ways:

-Double the number of presentations on perennial cropping systems that benefit water and wildlife
-Expand the 'Summit' to two days
-Invite additional speakers to demonstrate novel ways of implanting perennials on the landscape

-Include an agro-economic session discussing how to make perennial systems profitable.
-Expand the outreach capacity to hopefully increase attendance to 200-300 attendees.

Specially the dollars moved to Activity 3 will be used fund conference coordination. SCWRS Outreach Coordinator, Alaina Fedie, will be added to the project. Her skills and experience in designing, organizing, and creating conference materials, agendas, mailings, and speaker engagement, along with maintaining a website linked to the Science Museums homepage will be invaluable to enrich the offerings and proficiency of the Summit.

Amendment approved by LCCMR December 2018.

Project Status as of: February 1, 2019

All faunal surveys for the 2018 field season were completed as planned. The last task for data collection was to determine yield loss of corn in rows that were adjacent to the inter-row perennial strips. Rather than do individual sampling of sections of the rows, we decided to take advantage of the precision monitoring capabilities of the harvesting equipment (i.e. the combine and grain wagons). Yield in the 12 rows adjacent to the strip of perennial inter-planting was compared to those without any inter-plantings (Figure 4). By assigning a market value to the corn, we translated the yield losses to economic costs. In general, we found that the perennial strips induced minimal yield loss or economic costs. In the few strips with well-established perennial plantings, the yield loss in the two corn rows adjacent to the strips was over 20 bushels per acre. However, only two rows of 24 are impacted, thus the economic cost to the farmer is less than $30 per strip. We estimate that on a whole field (80 acres) scale this would be a cost of less than $200. Surprisingly, a much bigger yield reduction was found in the portions of the field planted with non-neonicotinoid treated seeds (Table 3, strips 1 and 9). Corn yields from the areas planted with non-treated seed were 50 bushels lower than the adjacent areas planted with conventional seed. Yield losses in these rows alone cost the farmer $200 per strip (Table 3). In short, the losses induced by using non-treated seed are much greater than the yield reduction created by not controlling for "weeds" in the inter-row strips. While this is a positive observation for the potential of incorporating the perennial inter-rows strip technique, it is a stark reminder of the risks of using non-treated seed and the genetic enhancements that accompany treated seed.

Organization and planning for the summer Agro-ecology summit are well underway. The conference will have two major focus areas: existing and emerging cropping systems that incorporate perennial vegetation (including results from the perennial inter-row system of this project), and secondly policies and technology that could be used to stimulate perennial cropping systems. We will provide an overview of why perennial systems are needed and how they are critical to improve water quality and wildlife habitat, what future perennial systems could look like and how manipulating food and energy markets could be the cost-effective way to stimulate landscape scale changes. A working title for the conference is: Butterflies, Blue-greens, Kilowatts and Calories.

Overall Project Outcomes and Results: Final Report August 1, 2019

This project successfully demonstrated three objectives: 1) that perennial vegetation can be established and maintained between rows of corn/soy within a field—without taking land out of production; 2) that the perennial vegetation in the inter-row plantings provides habitat value, and 3) that the plantings can be done in a manner that induces a minimal yield loss to the adjacent corn/soy rows. While establishment of many prairie species in the inter-row strips failed, several did not and are thriving after three years. We have demonstrated that species such as golden alexanders, bottlebrush grass and milkweeds can be established and maintained in a conventional corn/soy rotation. These strips of perennial forbs and grasses were documented to have provided habitat to pollinators and appear to be very good reproduction habitat for monarch butterflies. Perennial strips did induce a 5 to 20 bushel per acre yield loss, but since only 1 out of 24 inter-row strips were planted with perennials, we estimate that the total cost in lost yield for the whole field (80 acres) due the perennial strips is less than $200. Going forward, we think it is possible to plant and maintain just the outside row of a field with a mix of golden alexander, milkweeds, and woodland brome. This mix would provide some early season pollinator habitat and a significant amount of summer Monarch reproduction habitat. And, since only the outside row of a field would be impacted, the total annual cost in lost yield and maintenance of the strip should be under 40 dollars per 80 acres. If implemented on a widespread scale, this could offer a very cost-effective way to provide significant benefit to Monarch populations.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Test the establishment and management of ~20 different prairie species and alfalfa as permanent cover strips within row crops

Description:

Site/Field Design

On many farms, corn and soybeans are planted on a 30-inch wide row spacing. The area between the rows (the inter-row, Figure 1) is typically treated with herbicide to keep the soil weed free. Willow Lake farm uses a 24-row planter; meaning 24 rows (60 feet) are planted per pass. Within a 60-acre field, we will establish perennial strips in 1 of every 24 inter-row areas (Figure 2) − in other words, we will plant one inter-row area per pass of the corn planter. Because we are planting the strips in the inter-row area, no corn/soy rows are removed from production.

Willow Lake farm manages its cropland with a technique known as ridge till or strip till. This is a form of no-till, precision farming that is increasing in popularity. In this method, the tractor and equipment drive on the exact same paths each year and the corn (or soy) are planted in the exact same rows each year. This means that only a very narrow band where the corn/soy seed is planted needs to be tilled or disturbed each spring. The remaining ground is left untilled and is covered with corn/soy residue from the previous year. Because of this precision planting method, perennial strips can be established and maintained with no annual disturbance.

Sixteen strips, each about ½ mile long, will be planted in four fields, totaling 60 acres (Figure 2). Depending on Willow Lake Farm's crop rotation at the time of planting, these four fields may be within one 80-acre field as shown in Figure 2, or within two separate, but nearby, 40 acre fields. In either case, half of the strips will be planted into a cornfield and the other half into a soy field (Table 1). This will allow us to compare how well perennial strips establish within corn versus soy. Since most farms rotate between corn and soy, we will have fields rotate similarly in this project. It is currently planned that fields will rotate between corn and soy annually (Table 2).

Currently, nearly all conventional corn and soy seed is treated with neonicotinoid insecticides. It is suggested that fields treated with neonicotinoids pose a threat to non-target fauna such as songbirds and bumblebees. To help assess this risk, we will plant two five-acre fields with non-treated corn/soy seed adjacent to the conventional corn and soy fields (Figure 2, Fields A and D.). Ultimately, we will compare the success of fauna using the perennial strips in the treated versus non-treated fields.

Species Selection

Introducing long-lived native prairie species into row-crops is challenging for two main reasons:

1) We have to find perennial species that can survive the nutrient and water competition within the corn/soy environment, and have the ability to handle the changing light regime (shading) created by the maturing crops.
2) However, the perennial species/strips themselves cannot be overly competitive with the corn/soy and should induce only minimal yield loss to the adjacent corn/soy rows.

Some prairie species may be highly compatible with the lifecycle of corn/soy. Long-lived, short stature species, such as Golden Alexander that have low water and nutrient demands, may thrive in the area between rows with minimal competition to the corn/soy. Perennial nitrogen-fixing legumes, including alfalfa, could offer the additional benefits of reducing fertilizer needs. Glyphosate-tolerant varieties of alfalfa offer particular promise due to the ease of adapting to existing herbicide treatments.

Each of the 16 inter-row strips will be planted with either individual prairie species, a mix of prairie species or alfalfa (Table 2). Many of the strips will be divided into a north and south half, allowing us to test more species or have duplicate treatments. A list of probable species and planting design are shown in Table 2. Historically, row-crop fields with escape milkweeds were shown to be good habitat for Monarch reproduction. We will evaluate milkweed species specifically in certain strips (Table 2) and we will include at least three milkweed species in all strips that use a mix on native forbs. Because of the low light regime (high shade) created by maturing corn and soy, we will focus on using savanna species that are naturally adapted to increased shading throughout the growing season. In addition to the individual species listed in Table 2, candidates for the multiple species strips (e.g. Inter-row 1 in Table 2) will include (but not limited to):

Forbs: Figwort, Butterfly Milkweed, Cream Gentian, Anise Hyssop, Mountain Mint, Beardtongue
Legumes: Cream Indigo, Bush Clover, Purple Prairie Clover, Showy Trefoil,
Grasses: Bottlebrush Grass, Woodland Brome, Fringed Brome, Bicknell Sedge, Oval Sedge

<u>Seeding Method</u>

Seeding these strips into an active no-till, row-crop field has several difficulties. We must restrict the planting to the 30" inter-row area without disturbing the nearby corn/soy rows, and the seeding method needs to create good seed to soil contact through the heavy corn/soy residue present in a no-till field. We will work with a local manufacturing firm to design and fabricate a custom seed drill (using parts from existing equipment) that could be piggybacked onto the 24-row corn planter or pulled separately by an ATV. The intention is to have the seed drill built by the fall of 2016. We will then plant some rows in fall of 2016 by pulling the drill with an ATV and plant other rows in the spring of 2017 by attaching the seed drill to the 24-row corn planter. With either method, 2017 will be the first growing season for all strips. Strips will be planted with a known amount of seeds to facilitate evaluating the "success" of each species. Based on past experience, we will use a total seeding rate of about 80 seeds/ft^2 to promote a high density of seedlings and minimize weed competition.

<u>Herbicide shielding</u>

The corn and soy fields are sprayed at least once each year with a broad-spectrum herbicide to control weeds. A key component of this project is to demonstrate a technique that will protect the perennial strips from this herbicide application, yet still provide weed control in the adjacent corn/soy rows. Herbicide shielding is a well-developed technology and it should be relatively straightforward to adapt an existing shield to the conventional sprayers used today. The shield will likely be a 1.5 x 0.75 meter piece of sheet metal formed into a 90-degree angle along the long-axis. (imagine a long, narrow tin roof). This shield will be attached to the herbicide sprayer boom at a position and spacing equivalent to the perennial strips and will deflect the application of the herbicide away from the plants in the inter-row area.

Evaluating Establishment

A major objective of this project is to evaluate which species or combination of species can be successfully established within a row-crop field. The entire length of all strips will be walked twice each growing season for the duration of the project to provide a qualitative assessment of how well each planting is doing. A list of species present, overall height, density of plants, and presence/absence of flowers will be recorded for each strip.

A quantitative assessment will be conducted on four, 5-meter long representative sections of each strip—two in the north half and two in the south half. We will count and record the number of individuals of each species in the 5-meter section, and calculate both the total plant and individual species density for that strip. Because we will know the number of seeds of each species planted, we can compare the established plant density to the seeded density. This will allow us to estimate the establishment success for both individual species and the overall planting. For an overall seeding rate of 80 seeds/ft^2, an establishment success of 15% (12 plants/ft^2) or greater will be considered very good. (Of course in the mixed plantings with 20 species, any one species will only be planted at 4 seeds/ft^2. At 15% success we will still have a total of 12 plants/ft^2 but the density of any one species will be proportionally less.) Average height, presence/absence of flowering and seed set for each species will also be measured in each 5m section to give an estimate how "robust" the planting is.

Since 2017 will be the first growing season and plants will be in the seedling stage, we will only conduct the two qualitative assessments in this year and won't begin the quantitative assessments until 2018. Quantitative assessments of the 5m sections, along with the additional full strip qualitative assessments, will be conducted in late May and September 2018, and late May of 2019. Funding for this project ends in June of 2019, but we intend to find additional funding and continue these establishment surveys through at least 2020.

Summary Budget Information for Activity 1:	**ENRTF Budget:**	**$ 50,668**
	Amount Spent:	**$ 50,668**
	Balance:	$ 0

Outcome	**Completion Date**
1. *Plant and maintain strips of permanent cover in the bare space between every 24th corn/soy row*	July 2018
2. *Evaluate suitability of species as perennial cover strips, compatible with row crops*	June 2019

Activity Status as of: August 2017

All sixteen inter-row strips have been planted and most are beginning to establish. Strips were planted into heavy corn residue (leaves and stalks) left after the 2016 harvest. To deal with these planting conditions and the narrow area between the corn rows, a custom planter (a.k.a. seed drill) was designed and built by RDHOutdoors of Wilmar Minnesota (Figure 1). The drill was equipped with a 12volt hydraulic system for raising and lowering, and could thus be paired with an ATV rather than a tractor for easier operation. The drill performed well; both in ease of use and properly planting the seeds at the correct depth.

Eight rows were planted in the fall (November 2016) and eight rows were planted in the spring (May 2017). This split planting design was done to both compare fall versus spring establishment and because some species are known to establish better in one season over the other. The biggest challenge with planting was adjusting the seed drill to accommodate the "valley" topography created by the ridge-till farming method used on this farm. Fortunately, among farms using precision planting methods required for the inter-row technique, strip-till is far more common than ridge-till and strip-till farms do not have "valleys" between rows.

The row-crop parts of the overall field were planted to soybeans in June, after all inter-row strips had been planted. Planting of the field crop (soybeans) created very little disturbance to the nearby prairie seedlings germinating in the strips. This may seem trivial but it was crucial to demonstrate that we could physically plant the inter-row area and leave this intact while subsequently planting the field crop. Two herbicide applications were planned for the soybean crop. One application was done immediately prior to planting the soybeans and the second one was done on July 1. A cocktail of broad spectrum contact and pre-emergent herbicides were used. Custom shields were constructed and fastened to the herbicide sprayer to protect the seedlings in the strips from these chemical applications. The shields were relatively simple in design; two arms extending back from the herbicide boom each with a vertical 3 ft x 2 ft rubber barrier protecting the strip from the adjacent spray nozzle. Despite the shielding, there was some herbicide drift that hung in the air after the sprayer and shields had passed. There is some apparent non-target herbicide damage from this delayed drift in most rows, although it appears that most seedlings will recover. However, the bigger herbicide issue is the carry-over effect from pre-emergent herbicide applications in the years preceding our inter-row plantings. Certain species and species mix had little to no germination due to this carryover issue. The short forb and mixed forb mixes had particularly poor germination and these rows will be replanted in the fall of 2017. Despite the "failure" of some mixes, the fact that some species and mixes are establishing is a successful demonstration of the logistics of planting permanent strips into precision no-till fields---the bigger challenge remaining is maintaining these strips and evaluating which species perform the best.

A variety of species and mixes were planted in the 16 strips. Final planning design and mixes used in each strip are shown in figure 1 and table 2 respectively. Part of the experimental design includes comparing faunal use in strips within fields that were planted with corn/soy seed treated with neonicotinoids to strips within portions of the field planted with untreated seed. (see figure 1 and Table 2). It should be noted that the farmer does not use soybean seed treated with neonicotinoids, so the only time the comparison between neonicotinoid treated and non-treated fields will be made is on the years when the study fields are rotated to corn. Species composition and planting density of each species are shown in tables 3 and 4. Mixes were constructed to test several establishment factors including:

a) *Plant height*—both how does plant height effect establishment and how does plant height reduce adjacent crop yield. For example, we have mixes of tall forbs versus short forbs and mixes of tall grasses versus short grasses

b) *Individual species survival*. Over thirty species are represented in the mixes. We will evaluate which species establish best and can compete with the corn/soy.

c) *Seed size*. We grouped mixes according to size of the seed. Establishing prairie into the high corn residue left in a no-till operation presents a challenge for getting seeds planted at a proper depth. Larger seeds tend to do better with deeper planting, whereas small seeds can be inhibited by being planted too deep. To facilitate adjustment of the seed drill, we tried to group species based on the size of their seed and necessary planting depth.

As of this writing, there is wide variation in the germination and growth of the different species and mixes. Some species such as Great Blue Lobelia and Bergamot have shown poor germination in both the spring and fall plantings. As noted earlier, we suspect this is due to herbicide carry-over effects. Other species such as Golden Alexander, Common Milkweed and Coneflower that were fall planted have shown excellent germination and establishment. This is encouraging as it means we could likely construct a mix that is favorable to both the adult and larvae of Monarch butterflies. The mixes that have shown the best establishment thus far are the savanna grass mix (bottlebrush grass and woodland brome) and alfalfa. An establishing strip of savanna grass between soybean rows is shown in figure 1. Success/establishment of each row will be assessed throughout the summer and fall. Rows that are determined to have insufficient plant density will be replanted in the fall with either species that have done well on the site, or with new species we want to test.

Activity Status as of: February 2018

Prairie strips have completed one growing season. Due to herbicide carry-over problems, less than half of the strips would be deemed to have successful establishment, i.e. there are less than six healthy perennial plants per square foot in the strips between the soybean rows. While this may seem like a disappointing outcome, it is important to note that about half of the strips do have successful establishment of perennial vegetation. Thus, the technique is working—just not for all species. For this demonstration project to be a success we don't need all perennial species or mixes to grow, we just need some mixes to work. We need to demonstrate that we can establish and maintain permanent vegetation between corn/soy rows, and ideally, we would like a mix grasses and forbs. After one growing season, we have multiple strips where at least three grass species or forbs have formed healthy, dense, continuous cover between the soy rows; leading us believe that the technique can work---and can be improved with additional testing. Table 5 shows a qualitative description of 'success or failure' of each strip and species survival. In general, the species that had the best establishment were Elymus hystrix (Bottle Brush Grass), Bromus pubescens (Woodland Brome), Muhlenbergia mexicana (Leafy Satin Grass), Zizia aurea (Golden Alexander), Asclepias speciosa (Common Milkweed), Asclepias incarnata (Red Milkweed), Echinacea spp. (Purple Coneflowers) and Medicago sativa (Alfalfa).

Some strips that "failed" were re-seeded in the fall, and the remainder will be re-seeded in the spring. Re-seeding is focused on using species that showed success during the first growing season. Milkweeds (Figure 2), bottlebrush grass and alfalfa in particular established very well, so additional strips, testing different seeding densities (seeds/ft^2), will implemented. Establishing these plants at a variety of densities will allow us to get a better understanding of how plant competition (density) in the inter-row strip affects yield in the adjacent corn/soy row. The farmer who owns the field (study site) has expressed concern about the weeds that will eventually grow with the desired perennial species—especially in the strips that have lower perennial plant density. Milkweed, bottlebrush grass and alfalfa are amendable to low-dosage herbicide treatments that could be used to control the weeds growing among these plants. In the strips with varying densities of milkweeds and alfalfa, we will test a suite of precision herbicide treatments (manually applied), such as glyphosate, clopyrlid, or 2,4D, to control the weeds without hurting the perennial plants or adjacent corn/soy. For example, we will take advantage of the fact that corn and milkweeds are both tolerant of clopyrild and glyphosate (milkweeds are tolerant after mid-summer) and will use a backpack sprayer to apply targeted applications to reduce weeds and foster growth in both the row-crop and strip planting.

Activity Status as of: August 2018

Inter-row strips are now in their second growing season. The following prairie species have established very well—Golden Alexander, Bottle Brush Grass, Woodland Brome (these two grasses are group together and referred to as savanna grasses), Common Milkweed, and Swamp Milkweed. These species have densities of more than 2 plants/ft^2, and will flower and set seed in 2018. Other species that have partial success in getting established include Purple Coneflower, Lance-leaf coneflower, Anise Hyssop, Black-eye Susan, Purple Prairie Clover, Bush Clover, White Beardtongue and Leafy Satin Grass. The remainder of the species planted are either absent or so sparse that their establishment cannot be considered a success at this time. Strips planted with alfalfa are also doing quite well with established plant densities of greater than 2 plants/ft^2.

About half of the strips can be classified as being fully established rows of perennial vegetation. Strips with less well-established vegetation were augmented with seed in May 2018. To avoid disturbing the existing plants, a dropseeder was used for the planting rather than the custom drill. The drop seeder is not an ideal method for spring planting as it does create good seed to soil contract, however it was preferable to the disturbance that would have been created by the seed drill. The dropseeder was a fast and simple planting method and may be an effective technique for fall planting seed when winter freeze/thaw will induce good seed to soil contact. We are planning to test planting one additional strip of Milkweeds in the fall of 2108 with the dropseeder to evaluate this technique.

Seed mixes with species composition similar to what was planted in 2017 were used in the augmented plantings. However, the percentage of species that we know are likely to perform better were increased. The reason that we kept the mixes similar to 2017 was to test if establishing the strips in a year when the crop field is planted to corn is different from a year when the field is in soy. In 2017 the crop field was soybeans and in 2018 it is corn. The herbicides used on soybeans are different than those used on corn, and this is likely to affect which species do or do not establish well. As of July 1, it is too early to tell if establishment is different in 2018 than 2017. In three strips that had very poor establishment we converted the species composition entirely. One strip was planted to alfalfa (we are testing the merit of using the dropseeder to plant alfalfa), the other two were planted with different densities of white dutch clover. White dutch clover is a low growing plant with high pollinator value and we curious to see how it might perform in the inter-row environment.

The corn field was sprayed with a cocktail of four herbicides on May 28th. The same shielding used in 2017 was used to protect the inter-row strips from the herbicide spray and drift. The shields were very effective at protecting the strips from direct spray, but there is some drift that lingers in the air and settles onto the plants. This latent drift caused some spotting and yellowing on the plants—especially the younger plants, but does not seem to induce mortality. The bigger issue with the herbicide application is the pre-emergent components which prevent seeds from germinating. Carryover from these pre-emergent herbicides is likely what is preventing establishment of the species that have failed. We will continue to evaluate establishment to see if the herbicide carryover issues are different in 2018 when corn herbicides were used as compared to the soybean herbicide cocktail used in 2017.

Currently most seed corn is treated with neonicotinoid insecticides. To provide some comparison of the potential effects of the neonicotinoids on the habitat value of the strips, a portion of the crop field was planted with non-treated seed. The 24 corn rows surrounding strips 1 and 9 were planted with non-treated seed. Strips 1 is a mixed prairie species planting and can be compared to strip 2. Strip 9 is an alfalfa planting and can be compared to the alfalfa planting in strip 10. As of July, we have observed no differences in the pollinator abundance or behavior in strips surrounded by corn planted with treated versus untreated seed.

Activity Status as of: February 2019

All plantings and re-plantings have been completed. After two growing seasons, it is pretty clear that only a few of the prairie species planted can handle the chemical and competitive environment within the corn/soybean field. But, the good news is, is that there are some successful plants--and they are good wildlife plants. Golden Alexander and milkweeds did very well and also offered habitat value. Going forward, we think it is possible to design a mix that a farmer could plant between selected corn/soy rows and provide some habitat value while incurring minimal loss of yield. If we do a second phase of the project, we would advise trying to plant just the outside row of field with a mix of Golden Alexander, Milkweeds, and Woodland Brome. This mix would provide some early season pollinator habitat and a significant amount of summer Monarch reproduction habitat. And, since only the outside row of a field would be impacted, the total cost in lost yield should be under forty dollars. Additional evaluations of the planting will be conducted in May and June 2019.

Final Report Summary: August 2019

This project successfully demonstrated that perennial vegetation can be established and maintained between rows of corn/soy within a field—without taking land out of production. While establishment of many prairie species in the inter-row strips failed, several did not and are thriving after three years. We have demonstrated that species such as golden alexanders, bottlebrush grass and milkweeds can be established and maintained in a conventional corn/soy rotation.

Sixteen strips with various mixes of perennial prairie species or alfalfa were planted between 1 out of 24 rows on an 80-acre corn/soy field at Willow Lake farm, near Windom, MN. A custom planter (a.k.a. seed drill) was designed and built by RDHOutdoors of Wilmar Minnesota to plant the 30-inch inter-row strip. The drill performed well; both in ease of use and properly planting the seeds at the correct depth. Corn/soy fields were sprayed with a cocktail of broad spectrum contact and pre-emergent herbicides. To protect the strips from these herbicide applications, custom shields were constructed and fastened to the sprayer equipment. Shields were relatively simple in design; two arms extending back from the herbicide boom, each with a vertical 3ft x 2ft rubber barrier protecting the strip from the adjacent spray nozzle. Although the shields worked well, there was still significant injury, mortality or lack of germination to many species due to herbicide carry over from previous years and some herbicide drift that hung in the air after the sprayer and shields had passed. Herbicide carryover and drift, rather than competition and shading from the corn/soy, were the main cause for prairie species that failed to establish.

Eight rows were planted in the fall (November 2016) and eight rows were planted in the spring (May 2017). Final planting design and mixes used in each strip are shown in figure 1 and table 2 respectively. Due to the herbicide carry-over and drift problems, only one-third of the strips were deemed to have successful establishment. While this may seem like a disappointing outcome, the fact that some species/strips did establish, flower and thrive after three years, demonstrates that it is possible to establish perennial habitat within a corn/soy field. We said from the outset, that for this demonstration project to be a success, we don't need all perennial species or mixes to grow, we just need some mixes to work. The technique worked—just not for all species.

In general, the species that had the best establishment were *Elymus hystrix* (Bottle Brush Grass), *Bromus pubescens (*Woodland Brome), *Zizia aurea* (Golden Alexander), *Asclepias speciosa* (Common Milkweed), and *Asclepias incarnata* (Red Milkweed). These species had densities of more than 2 plants/ft^2, flowered and set seed over three growing seasons. Going forward, we think it is possible to design a mix using these species that a farmer could plant between selected corn/soy rows, or even just the outside row of a field, and provide some habitat value, while incurring minimal loss of yield or management expense.

ACTIVITY 2: Evaluate benefits of inter-row perennial cover strips to pollinators, monarchs, songbirds and gamebirds.

Description:

Strips will be searched multiple times during the growing season to inventory songbird/gamebird nesting, monarch production, and density of native bees (pollinators) as metrics of the strip's habitat value. Because it takes three years or more for native plantings to become established and fully flowering, the habitat evaluations conducted within the time frame of this project will offer only initial results −but will demonstrate the habitat potential for this conservation technique and provide the foundation for on-going evaluations.

Songbird and Gamebird Recruitment

May and early June are the peak nesting season for many songbirds and gamebirds. The entire length of all strips will slowly and systematically walked at two-week intervals in May and early June of 2018 and 2019 to detect nesting birds. With this technique, adult birds flush from their nests at close proximity to the searchers, allowing the nesting sites and eggs to be visually located. Each nest will be marked by placing a pink-pin flag two meters north of the nest. (Flags are placed away from the nest to avoid habituating predators to nest locations). Nesting species, number of eggs, surrounding vegetation and coordinates will be recorded for each nest found. Return visits will be conducted for all nests do determine the fate of the nest and estimate the number of individuals recruited. Number of bird species and nesting densities will be determined for each strip. A comparison between nesting preference and success will be done for strips within the neonicotinoid treated versus non-treated fields.

Monarch Butterfly Reproduction

All strips containing milkweeds will be searched once a month for Monarch larva in June, July and August of 2018 and early June of 2019. (We intend on completing additional Monarch larva surveys pending additional funding). In mixed plantings where the density of Milkweeds will be lower (e.g. Inter-row 1 of Table 2), we will search the entire length of the strip for larva. In strips that are planted with only Milkweeds (e.g. Inter-row 7 of Table 2), we will search four representative 10-meter long sections. Individual milkweed plants will be visually inspected for Monarch larva. Given the frass (fecal pellets) and leaf chewing associated with larva, locating them on milkweeds is fairly easy. Plants with feeding larva will be marked with flagging tape and coordinates will be logged with a handheld GPS. Instar stage, length and health of each larva will be recorded. It would be useful to survey and record chrysalides as well; however, even though Monarch larva feed exclusively on milkweeds, they often leave these plants and form their chrysalis on nearby, non-milkweed plants thus, making it difficult to locate them. We will return to the milkweeds that had been marked with larval presence and examine the surrounding area for chrysalides, but since we cannot guarantee finding the chrysalis associated with the larva, we will rely on larval densities as the metric to evaluate the strip. Total number (abundance) of monarch larva will be summarizing for each strip. Using the plant data collected in Activity 1, we will also estimate a density of larva per milkweed plant for each strip. A comparison in the number of larva found and their average length within the neonicotinoid treated versus non-treated fields will also be assessed.

Pollinators: Bumblebee Density

Because bumblebees are large and relatively easy to distinguish from other bees, they will be used as the indicator insect to evaluate the habitat value of the strips to pollinators. A timed, transect method will be used to assess bumble density in each of the strips. Two, 20-meter sections of each strip will be marked off with pin flags. These sections will be visually surveyed over a 15-minute time period and the total number of bumblebees (all species) will be counted. To create comparability between strips, all surveys must be conducted between 9:00am and 3:00pm, with winds less than 10mph, under dry conditions. All strips will be surveyed within a weeklong period of June and September of 2018. Abundance and density of bumblebees will be estimated for all strips. Additionally, while conducting surveys, a qualitative description of bumblebee vigor will be recorded, and the bare ground near the perennial strip will be visually inspected to check for dead or debilitated bees. This information will be contrasted between the neonicotinoid treated and non-treated fields.

Summary Budget Information for Activity 2: **ENRTF Budget: $ 74,000**
Amount Spent: $ 74,000
Balance: $ 0

Outcome	Completion Date
1. *Quantify gamebirds and songbird nesting recruitment from inter-row cover strips*	June 2019
2. *Estimate number of bumble bees per area utilizing cover strips*	June 2019
3. *Estimate number of Monarchs butterflies produces per cover strip*	June 2019

Activity Status as of: August 2017

Inter-row strips are just beginning to establish and no species are yet flowering, thus we would not expect high faunal use at this time. All strips were surveyed for bees, monarchs and nesting songbirds in mid-June and again in the second week of July. No nesting songbirds or monarch larva were observed. A small number of bumblebees were observed nectaring on annual weeds that we growing in the strips. Several adult butterflies were observed flying near the strips but their presence could not be directly attributed to the vegetation growing the inter-row area. We will conduct additional faunal surveys in August in and September.

Activity Status as of: February 2018

Faunal surveys for bee and butterfly use were conducted in August and September. Due to the fact that the plants were only in the establishment phase, and did not flower, there was minimal insect use during the first year. No songbird nesting surveys were conducted because no plantings were established during the nesting season. Very limited bee or butterfly use was recorded during either of the surveys—there simply were not enough plants that had reached flowering stage to offer a useful food source. Several butterfly species were observed in the vicinity of the strips but their presence could not be directly attributed to the plants present in the strips. Milkweed strips (Figure 2) were searched for evidence of Monarch caterpillar (*Danaus plexippus*) feeding which would indicate reproductive use of these planting. A few plants showed some evidence of feeding but no larva were found. The robust establishment of these strips and the observation of Monarchs in the vicinity are encouraging signs and we anticipate active use during the 2018 growing season.

As an interesting observation, we did note significant insect use in select sections of one strip while conducting the soybean yield estimates (Activity 3) in the late fall. The soybeans in about a 100 foot section of strip one had been greatly stunted by repeated grazing from Canada Geese. In this section, some prairie species in the strip grew faster and had reached flowing stage by October. These late maturing plants offered some of the best food/nectar sources at the time and had active use by both native bees and honeybees. We hope this represents the type of faunal use we will observe during the 2018 growing season.

Weekly surveys of pollinators, monarchs and songbird nesting for all strips will begin in May and continue through early August. Depending on the results and the feasibility of searching the strips once the corn has matured, monthly pollinator and monarch surveys will continue until harvest. A student from South Dakota State University is structuring her capstone thesis project based on faunal results of this study. She will be assisting with weekly faunal surveys and assist with summarizing the results and presenting the findings.

Activity Status as of: August 2018

Weekly faunal surveys were started on May 15th and are ongoing. Surveys will likely end by July 20th when the corn is too tall to walk through and the nesting season is done. Strips were inventoried weekly for bees, songbird nests and monarchs (larva and adults). For comparison purposes, four, 500 foot transects were also surveyed in the restored prairie adjacent to the crop field. Inventories were conducted by slowing walking along each strip and tallying the number of bees (native and honeybee) and noting the location of flushing birds and then searching for nests. Strips with milkweeds were walked slowly while looking for evidence of feeding Monarch larvae. Once larvae were found, their location was marked with a pin flag so that it would not be recounted in following surveys and to aid in finding expected chrysalis. A summer inter, hired by Willow Lake Farm helped conduct the surveys.

The most abundant flowering plants during the searches were Golden Alexander and alfalfa. Strips with these two species had pollinator densities of 1 to 4 bees per 100 lineal foot of vegetation. This density was much higher than in the prairie transects, although this is not unexpected since the density of the flowering plants (forbs) was also much greater in the inter-row strips. The strip that was planted with savanna grasses (Bottle brush grass and Woodland brome) did not have significant pollinators associated with it, but the dense grass seemed like it would be good songbird nesting habitat. Unfortunately, as of July 9th, no songbird nests have been found in this strip or any of the strips and only a single red-winged blackbird nest was found in a prairie transect. We think that the amount nesting habitat available (40 acres of adjacent prairie) is so large compared to the amount of habitat searched (strips plus prairie transects) that we are simply not encountering nesting grassland birds.

Strips with two-year old milkweeds were searched for Monarch butterfly larva. Forty-nine monarch larvae were found in the strips (a density of 1.9 larva per 100 feet) compared to five in the prairie transects (a density of 0.25 per 100 feet). While the density of milkweeds in the inter-row strips was much greater than in the prairie transects it was still impressive to see such high reproductive use in the strip vegetation. The tall, thick corn adjacent to the strips hampered our ability to locate monarch chrysalis, but we did confirm that at least four monarchs successfully pupated to adults—thus confirming that monarchs utilizing milkweed within this neonicotinoid treated cornfield can successfully reproduce. During faunal surveys, we did not note any differences in the strips bordered by corn planted with neonicotinoid treated seeds versus those planted with untreated seed.

Activity Status as of: February 2019

There are no new faunal results to report. However, we are pleased by the minimal corn yield loss (see Activity 3) that was observed in the rows adjacent to the Milkweed plantings (Strip 7, Table 3). The milkweed strip succeeded in both establishment and as a nursery for Monarchs. This single strip of Milkweeds produced nearly 50 larvae and cost only about $10 in lost grain yield. This is probably the highlight of the project and warrants further testing and promotion as a technique to create cost-effective Monarch habitat.

Final Report Summary: August 2019

This project successfully documented that the perennial vegetation established between corn/soy rows in field provided habitat value to pollinators (native and non-native bees) and butterflies, especially Monarch butterflies (*Danaus plexippus)*. No songbird or gamebird nests were documented in the strips.

Weekly faunal surveys were conducted during the growing season in each of the 16 inter-row perennial vegetation strips. Strips were inventoried for bees, songbird nests and monarchs (larva and adults). For comparison purposes, four, 500 foot transects were also surveyed in the restored prairie adjacent to the crop field. Inventories were conducted by slowing walking along each strip and tallying the number of bees (native and honeybee) and noting the location of flushing birds and then searching for nests. Strips with milkweeds were walked slowly while looking for evidence of feeding Monarch larvae. Once larvae were found, their location was marked with a pin flag so that it would not be recounted in following surveys and to aid in finding chrysalis. A summer inter, hired by Willow Lake Farm helped conduct the surveys.

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We think the technique of planting a few strips of perennial vegetation within corn/soy fields demonstrated in this project has the potential to offer a cost-effective method to provide pollinator and monarch habitat over a large area. Planting a mix of golden alexander, milkweeds and bottle brush grass in just the outside row of a field would provide some early season pollinator habitat and a significant amount of summer Monarch reproduction habitat. If implemented on a widespread scale, this could offer a very cost-effective way to provide significant benefit to Monarch populations.

ACTIVITY 3: Technology transfer: cost analysis, implementation recipes and field tours.

Description:

This project seeks to demonstrate a new conservation practice that will provide both habitat and water quality benefits within the agricultural landscape. Future adoption and implementation of this practice will be facilitated by providing a simple synthesis of the implementation method, expected outcomes and cost estimates. We will summarize and disseminate this information through a short fact sheet, an agro-ecology conference and on-farm tours.

<u>Cost Analysis.</u>

There are two principle costs associated with the conservation practice demonstrated in this project. One is the cost associated with getting the perennial strips established. The second is the cost to the farmer due to the yield reduction in the corn/soy rows adjacent to the perennial strips. Both implementation and yield-reduction costs will be summarized in the fact sheet, and together provide the foundation for estimating the cost-share necessary to get this practice implemented on a large number of acres.

We will document the cost of seed, fuel and labor associated with establishing the strips. Since some strips will perform better than others, we will provide an implementation cost estimate for each of the strips. In addition to the basic costs of seed, labor, and fuel there is the cost of the custom planter and herbicide shields.

We will document and describe these equipment costs, but will keep them separate from the general implementation costs as they are one-time capital costs and may be skewed higher due to the development phase of the technique.

The larger, and on-going cost of this conservation practice is the yield reduction in the corn/soy rows adjacent to the perennial strips. Vegetation in the perennial strips will compete with the corn/soy for water and nutrients and will almost certainly induce a yield reduction in the adjacent rows. We expect that yields in the two rows adjacent to the strips could be reduced by 10-25%. We will quantify grain yields in rows adjacent to the strips and compare those to whole field averages. Yields will be estimated using the *Corn Yield Calculator* (also known as the "slide rule" method) developed by the University of Illinois. The basic procedure for this method is:

Slide rule method for estimating corn yield

1. For 30" row spacing, mark off a 17.5-foot section of a row (this is equivalent to 1/1000th of an acre)
2. Count the number of harvestable ears in this section
3. On every 5th ear count the number of kernel rows per ear and determine the average
4. For these ears, determine the average number of kernels per row
5. Yield (bushel/acre) = Number Ears x Avg. Rows per Ear x Avg. Kernels Row

A similar method, using number of pods and beans per pod in 21 inches of a soybean row will used to estimate yields in the soybean fields. Using these methods, we will estimate yields in the rows adjacent to the strips and the row furthest from the strip—the difference between these is the yield reduction due to the perennial strip. The suite of perennial species tested in the strips will likely impact the corn/soy differently. Thus, we will estimate the yield reduction associated with each of the strips and calculate strip-specific "yield-loss cost" based on a range of market values ($/bushel) of the corn/soy. We will combine this yield-loss cost with the implementation costs to offer an estimate of the total cost to the farmer to adopt the conservation practice.

The Optimal Implementation Recipe

We will compile and summarize the establishment success, habitat results and costs (implementation plus yield reduction) associated with each of the strips. Some strips/species may establish well, but induce high yield loss. Conversely, other strips/species may not induce a significant yield loss but may also not provide meaningful habitat value or have poor establishment. We will review all factors together and select the strips that optimize the balance between establishment, habitat value and cost. For these optimum perennial strips, we will generate a short implementation recipe that will include planting method, species list, and a summary of expected costs and habitat value.

We will create a two-page, graphic rich, easy to follow fact sheet highlighting the conservation practice demonstrated in this project. The fact sheet will summarize the rationale, findings, costs and optimum method determined at the Willow Lake Farm. Information will be targeted at farmers and natural resource managers likely to adopt or promote the use of perennial strips. For users looking for more detailed information, we will direct them to the final report that will be submitted to LCCMR.

Field Tours

In person, farmer-to-farmer connection if often the best way to promote new conservation practices. Tony Thompson, owner/operator of Willow Lake Farm hosts an "agro-ecology" summit every two years at his farm. The theme of this conference always centers on new technologies, research and practices that promote healthy natural resources within an economically viable agricultural landscape. The Willow Lake Agro-Ecology Summit has an attendance of ~200 people, with good representation from the University of

Minnesota, MN Department of Ag and MN-DNR, along with farmers from the Minnesota River watershed. The next conference will be in August of 2017. The theme of this conference will be perennial vegetative crops, inter-seeding methods in row-crop agriculture and the economics and markets to make these practices viable. The concept and early results of this LCCMR project will be presented at the two-day conference and will be highlighted with an afternoon tour of the demonstration fields. At this conference and tour, attendees will see the strips in the flowering stage, observe insect/pollinator use of the strips and get a feel for the project objectives and be introduced to the concept of creating perennial strips within row crops. We hope to coordinate this field tour with other on-farm natural resource agency tours looking at cover crops in southern Minnesota. Both of the field tours will be attended by farmers and will offer an excellent opportunity to engage them in conversations about the need for perennial vegetation in the agricultural landscape −and techniques to accomplish this. The conference will also have a session on other recent innovations in perennial cropping systems and cover cropping methods including dual-use systems such as solar combined with conservation grazing. A full session will be devoted to creating an awareness and understanding of the economic challenges necessary to getting perennial vegetation on the landscape, and how markets and polices could be modified to stimulate perennial cropping systems. The Summit will be coordinated and "marketed" through the Science Museum of Minnesota to reach a broad audience of conservation professionals and policy makers.

Summary Budget Information for Activity 3:	**ENRTF Budget:**	**$ 54,332**
	Amount Spent:	**$ 54,332**
	Balance:	**$ 0**

Outcome	**Completion Date**
1. Cost Analysis: Determine cost of establishment, management, and yield loss associated with each perennial strip type	*March 2019*
2. Implementation Recipes: Summarize species and management techniques that optimize habitat value and minimize yield loss.	*May 2019*
3. Dissemination: Host two field tours, and on-farm agro-ecology summit sharing results with farmers and resource managers.	*May 2019*

Activity Status as of: August 2017

Cost analysis will be begin in the fall of 2017 when the first yield loss measurements are conducted. Planning for the first agro-ecology summit and farm tour will start in August of 2017.

Activity Status as of: February 2018

A demonstration field day was hosted at the study site in August 2107. This event was part of the 10th biannual Agro-ecology summit at Willow Lake Farm. There were about 50 participants, many who were local farmers testing cover cropping techniques to improve soil health. There was a mix of enthusiasm and skepticism regarding the perennial strips demonstrated in this project. Participants are intrigued to see the evolution of this project and are looking forward to the next Agro-ecology summit that will be hosted in August 2019. Based on the interest of these participants, we are beginning to plan the next field demonstration day and in addition to the our perennial strips study, we hope to bring in speakers that can offer presentations on a range of cropping systems that incorporate perennial crops, cover crops and relays crops—all of which benefit water and wildlife.

An important component of evaluating, and demonstrating the success of inter-row perennial strips is determining how the strips affect grain yield and farm profitability. Just before soybean harvest began, we used a method developed by Purdue University (https://www.agry.purdue.edu/ext/soybean/News/2012/2012_0814SOYSimplifiedYieldEstimates.pdf) to estimate soybean yields in the rows adjacent to the perennial strips versus soy rows distant from the strips. Yield estimates were done for all strips that had successful establishment of perennial plantings. In all strips except one, the soybean yields in the rows adjacent to the perennial strips was not statistically different from the yield in rows distant from the strips. In other words, competition from the perennial strips did not adversely affect soybean yield. This is not a surprise since the strips were only in the establishment phase and the plants were small and did not have extensive (i.e. competitive) root networks until fall. We anticipate much different results next year when the strips will have had a full growing season with established plants to compete with the adjacent corn/soy rows.

Strip number 1 offered an exception to the yield observation. In this strip there was a significant infestation of the weed lambsquaters. The poor establishment of the desired prairie species (and of course no herbicide control in the strips) allowed the lambsquater to flourish and grow to over 5 feet in height. The dense and robust growth of lambsquaters probably represents the maximum competition we would expect once the perennial strips are well established. The soybean rows adjacent to this strip had a soy yield that was 25% lower than the rows that were distant from the strip. We hope this represents the maximum yield drag we will observe from any of the strips in the future.

We can use the 25% yield drag observed in strip one as a worst case scenario to estimate how much it would cost a farmer each year to allow perennial vegetation in 1 out of 24 inter-row strips. The perennial strips are adjacent to 8% of the of soy rows. If these soy rows have a 25% reduction compared to a whole field average of 60 bushels to the acre, and soybeans sell for $8/bushel, then the perennial strips are costing the farmer about $10/acre in lost revenue. At this time, we think this is a worst case scenario, but we will have a better estimate after the third growing season. It is interesting to note that we compared our estimate of soybean yields to the yield measured by the combine. The whole field average yield estimated from the combine monitor was 60 bushel/acre. Our estimate, based on the sub-sampling method, was 60.6 bushel/acre. This indicates that the yield estimating technique seems to work well.

Activity Status as of: August 2018

While we feel confident in concluding that we can establish and maintain permanent vegetation within crop fields—and that this vegetation does provide at least some habitat value, we cannot say the project is a success until we know the agricultural costs associated with these habitat strips. Implementation of the strips is a minimal cost. We can now reasonably conclude that planting strips of Milkweeds or Golden Alexander on an 80-acre field could be done for a one-time cost of less than $200. The real cost to the producer is the potential yield loss created by the perennial vegetation. Now that some of the strips are fully established we can assess what this yield loss is. The new plan is to use the yield monitor in the combine during corn harvest to measure yield in the 12 rows encompassing the vegetation strip and compare this to the adjacent 12 rows that do not a permanent vegetation strip. We feel that using the combine monitor and measuring yield over the entire length of the strip and the associated 12 corn rows is a better than trying to choose short representative portions of single rows that are adjacent or distant from the strip and doing manual counts. Quantitative yield loss estimations during harvest will done in October, however visual observations while conducting habitat surveys has given some indication of what we will find. In some strips, such as the strip with Milkweeds, the corn adjacent to the strips looks about the same as the corn distant from the strip. However, in other strips, in particular the strip with the dense savanna grasses, the corn adjacent to the strip is noticeably stunted compared to the corn in distant rows.

Based on the habitat surveys, establishment results and qualitative assessment of yield loss, we think the optimum recipe for introducing perennial habitat into crop fields is the combination that includes Milkweeds. And, we think that adding even a small number of Milkweeds to the ag landscape could provide a significant benefit to Monarch recruitment. Thus, this fall we are hoping to test a modified technique for creating habitat strips. We will use the dropseeder to the plant the outside row of the field with Milkweeds. If this works, we would have a technique that would require a farmer to only plant one strip and because it is on the edge of the field should be comparatively easy to shield from herbicide applications. This strip would be low cost and yet based on Monarch surveys from 2108, would provide significant habitat value for Monarchs---especially if scaled to the landscape level.

Willow Lake Farm and the SCWRS have agreed to co-host the 2019 agro-ecology summit. We will use this this farm-based conference as a means to disseminate the ongoing efforts of many organizations and research studies on the benefits and economics of crop diversity and new cropping techniques---obviously including the results of this project. Planning efforts are currently underway. We are proposing a two-day conference that will feature both professionals and practitioners working with new cropping systems and perennial crops. This will include U of MN faculty, SMM scientists, Department of Ag staff, researchers from experimental stations, and local and statewide farmers with experience testing new methods. The second day of the conference will include a walking demonstration of the inter-row strips and tours to nearby farms experimenting with permanent cover. The strips project, with its embedded objectives of habitat and water quality while maintain ag-profitability, provides a good backdrop to start the conversation about how we are going to modify cropping systems to better meet our natural resources goals.

Activity Status as of: February 2019

The last task for data collection and cost-benefit analysis was to determine yield loss of corn in rows that were adjacent to the inter-row perennial strips. Rather than do individual sampling of sections of the rows, we decided to take advantage of the precision monitoring capabilities of the harvesting equipment (i.e. the combine and grain wagons). The combine harvests 12 rows of corn with each pass. At the end of each pass (i.e. the length of the field) the yield data was recorded, and for confirmation, the total weight of grain harvested was measured with a scale in the grain wagon. Together, these measurements give a very accurate and representative assessment of the corn yield and how it varies within the field. Each pass of the combine was either centered over 12 rows that included the perennial strip or the12 rows distant from the strip. Yield in the 12 rows with perennial inter-plantings were compared to those without inter-plantings (Figure 4). By collecting data from an entire pass, we were able to much more accurately account for field/soil variations, variability induced by the perennial plantings and natural fluctuations in yield. We assigned a market value to the corn of $4/bushel and translated the yield losses into economic costs. In general, we found that the perennial strips induced minimal yield loss or economic costs. In seven of the strips, the adjacent corn rows showed no significant yield reduction. In four strips the perennial vegetation induced a 2 to 6 bushel/acre yield reduction in the two corns nearest the strip. In the strips with well-established perennial vegetation the yield reduction was over 20 bushel/acre (Table 3, Strips 4, 6 and 12). However, since only the two corn rows near the perennial vegetation are impacted, the total loss on a field scale is small, and when converted to dollars lost, the cost to the farmer is around 10 to 30 dollars per strip. We estimate that the total cost in lost yield for the whole field (80 acres) due the perennial strips to be less than $200. Surprisingly, a much bigger yield reduction was found in the portions of the field planted with non-neonicotinoid treated seeds. As part of the experiment, non-treated corn was planted in the 12 rows either side of strips 1 and 9. This was done as a comparison to see if there were faunal differences in strips adjacent to treated versus non-neonicotinoid treated corn. Corn yields from the areas planted with non-treated seed were 50 bushels lower than the adjacent areas planted with conventional seed. Yield losses in these rows alone cost the farmer $200 per strip (Table 3). In short, the losses induced by using non-treated seed are much greater than the yield reduction created by not controlling for "weeds" in the inter-row strips. While this is a positive observation for the potential of incorporating the perennial inter-row technique, it is a stark reminder of the risks of using non-treated seed and the genetic enhancements that accompany treated seed.

Organization and planning for the summer Agro-ecology summit are well underway. The conference will have two major focus areas: existing and emerging cropping systems that incorporate perennial vegetation (including results from the perennial inter-row system of this project); and secondly policies and technology that could be used to stimulate perennial cropping systems. We will provide an overview of why perennial systems are needed, how they are critical to improve water quality and wildlife habitat, what future perennial systems could look like and how manipulating food and energy markets could be the cost-effective. We should have an agenda and list of speakers finalized by April. Once we have this, we will create a website as a node to direct people to for information as we recruit and advertise for the conference.

Final Report Summary: August 2019

This project successfully demonstrated that perennial vegetation established between rows of corn/soy within a field—without taking land out of production— can be done in a manner that induces only minimal yield loss to the adjacent corn/soy rows.

An important component of evaluating the success of inter-row perennial strips was determining their effect on grain yield and farm profitability. Yield differences between corn/soy rows adjacent to the perennial plantings, versus those distant from the strips, were measured in 2017 (soybeans) and 2018 (corn). Just before soybean harvest began, we used a method of random sub-sampling developed by Purdue University to measuring soybean yield loss due to the newly established strips. In 2018, a corn year, we measured the total weight of grain harvested from rows encompassing the strips and compared this to the weight of grain harvested in non-strip rows to determine yield reduction attributable to the perennial strips. This method gave a very accurate, whole-field assessment of differences in yield.

Soybean yields in the rows adjacent to the perennial strips were not statistically different from the yield in rows distant from the strips. In other words, competition from the perennial strips did not adversely affect soybean yield. This is not a surprise since the strips were only in the establishment phase and the plants were small and did not have extensive (i.e. competitive) root networks. The following year as the strips matured, we found more pronounced yield reductions in the corn. In seven of the strips, the adjacent corn rows showed no significant yield reduction—mostly due minimal competition from poorly established perennial vegetation in the strips. In four strips, including the milkweed strips, the perennial vegetation induced a 2 to 6 bushel/acre yield reduction in the two corn rows nearest the strip. In the strips with well-established perennial vegetation, the yield reduction was over 20 bushel/acre—these strips included the bottle brush grass and golden alexander plantings. However, since only the two corn rows near the perennial vegetation are impacted, the total loss on a field scale is small, and when converted to dollars lost, the cost to the farmer is around 10 to 30 dollars per strip. We estimate that the total cost in lost yield for the whole field (80 acres) due the perennial strips to be less than $200. If only the outside row of a field were planted with a mix of milkweeds, golden alexander and bottlebrush grass, the total annual cost in lost yield and maintenance of the strip should be under 40 dollars per 80 acres. And, if implemented on a widespread scale, this would offer a very cost-effective way to provide significant benefit to Monarch populations.

Surprisingly, a much bigger yield reduction was found in the portions of the field planted with non-neonicotinoid treated seeds. As part of the experiment, non-treated corn seed was planted in the 12 rows either side of strips 1 and 9. This was done as a comparison to see if there were faunal differences in strips adjacent to treated versus non-neonicotinoid treated corn. Corn yields from the areas planted with non-treated seed were 50 bushels lower than the adjacent areas planted with conventional seed. Yield losses in these rows alone cost the farmer $200 per strip (Table 3). In short, the losses induced by using non-treated seed are much greater than the yield reduction created by not controlling for "weeds" in the inter-row strips.

Results of this project were presented at two farm-day tours as part of the semi-annual Agroecology summit hosted at Willow Lake farm. At the 2017 Agroecology summit there were about 50 participants, many who were local farmers testing cover cropping techniques to improve soil health. There was a mix of enthusiasm, curiosity and skepticism regarding the perennial strips demonstrated in this project. Participants were intrigued to see the evolution of this project and are looking forward to ongoing observations and tests. The 2019 Agroecology summit will be held on August 16, 2019. The announcement for this event is attached (Figure 5). At the time of this report there are ~100 participants registered for the event. It is a two-day conference that will feature both professionals and practitioners working with new cropping systems and perennial crops. This will include U of MN faculty, SMM scientists, Department of Ag staff, researchers from experimental stations, and local and statewide farmers with experience testing new methods. The strips project, with its embedded objectives of habitat and water quality while maintaining ag-profitability, provides a good backdrop to start the conversation about how we are going to modify cropping systems to better meet our natural resources goals. The first day of the conference will have two major focus areas: existing and emerging cropping systems that incorporate perennial vegetation (including results from the perennial inter-row system of this project); and secondly policies and technology that could be used to stimulate perennial cropping systems. We will provide an overview of why perennial systems are needed, how they are critical to improving water quality and wildlife habitat, what future perennial systems could look like and how manipulating food and energy markets could be a cost-effective method to getting perennial crop/vegetation adopted. The second day of the conference will include an interpretive walk of the inter-row strips and tours to nearby farms experimenting with permanent cover.

V. DISSEMINATION:

Description:
This project will demonstrate a new conservation practice that will provide both habitat and water quality benefits within the agricultural landscape. Future adoption and implementation of this practice will be facilitated by providing a simple synthesis of the implementation method, expected outcomes and cost estimates. We will summarize and disseminate this information through a short fact sheet, an agro-ecology conference and two on-farm tours. The fact sheet, tours and conference will be targeted at farmers and natural resource managers likely to adopt or promote the use of perennial strips. See Activity 3 above for details.

Status as of: August 2017
Planning for the first agro-ecology summit and field tour will start in August of 2017.

Status as of: February 2018
See Activity 3 above.

Status as of: August 2018
See Activity 3 above.

Status as of: February 2019
See Activity 3 above.

Final Report Summary: August 2019
(Repeated from Activity 3 above)
Results of this project were presented at two farm-day tours as part of the semi-annual Agroecology summit hosted at Willow Lake farm. At the 2017 Agroecology summit there were about 50 participants, many who were local farmers testing over cropping techniques to improve soil health. There was a mix of enthusiasm, curiosity and skepticism regarding the perennial strips demonstrated in this project. Participants were intrigued to see the evolution of this project and are looking forward to ongoing observations and tests. The 2019 Agroecology summit was held on August 16, 2019. The announcement for this event is attached. At the

time of this report there are ~100 participants registered for the event. It is a two-day conference that will feature both professionals and practitioners working with new cropping systems and perennial crops. This will include U of MN faculty, SMM scientists, Department of Ag staff, researchers from experimental stations, and local and statewide farmers with experience testing new methods. The strips project, with its embedded objectives of habitat and water quality while maintaining ag-profitability, provides a good backdrop to start the conversation about how we are going to modify cropping systems to better meet our natural resources goals. The first day of the conference had two major focus areas: existing and emerging cropping systems that incorporate perennial vegetation (including results from the perennial inter-row system of this project); and secondly policies and technology that could be used to stimulate perennial cropping systems. The conference provided an overview of why perennial systems are needed, how they are critical to improving water quality and wildlife habitat, what future perennial systems could look like and how manipulating food and energy markets could be a cost-effective method to getting perennial crop/vegetation adopted. The second day of the conference included an interpretive walk of the inter-row strips and tours to nearby farms experimenting with permanent cover.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 134,332	Shawn Schottler, Project Manager $ 124,332 (70% Salary, 30% Benefits) 40% FTE for 3 years Alaina Fedie, Outreach Coordinator, $10,000 (70% Salary, 30% Benefits, 15% time for 1 year.
Professional/Technical/Service Contracts:	$ 20,000	Contract with Willow Lake Farm Staff, Equipment, Custom Spray/Plant, Facilities
Equipment/Tools/Supplies:	$ 5,000	Prairie Seed, field supplies, equipment repair
Capital Expenditures over $5,000:	$10,668	Design and fabrication of custom seed drill and herbicide shields.
Fee Title Acquisition:	$	
Easement Acquisition:	$	
Professional Services for Acquisition:	$	
Printing:	$	
Travel Expenses in MN:	$ 9,000	Mileage/ Lodging over 3 years
Other:	$	
TOTAL ENRTF BUDGET:	**$ 179,000**	

Explanation of Use of Classified Staff: Not Applicable

Explanation of Capital Expenditures Greater Than $5,000:

The seed drill designed and built to the plant the strips in this project will serve to demonstrate the technology specific to this new conservation practice. Going forward, as other landowners wish to adopt the inter-row conservation practice, the drill will be made available to them at no cost. The seed drill and herbicide shields will also serve as the prototype for the manufacture of additional inter-row seed drills in the future.

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:
1.35 FTE Equivalent (One FTE at 45% over 3 years)

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

0.24 FTE (Contract with Willow Lake Farm, 167 hours/year over 3 years)

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
Tony Thompson, owner and operator Willow Lake Farm was awarded the *Siehl Prize for Excellence in Agriculture* in 2011. Mr. Thompson is dedicating $22,500 from this prize as a cash match to the project.	$ 22,500	$ 22,500	Field Season Intern. $15/hr x 500 hr/yr x 3 years = $22,500
State			
TOTAL OTHER FUNDS:	**$22,500**	**$22,500**	

VII. PROJECT STRATEGY:

A. Project Partners:
Tony Thompson, owner and operator of Willow Lake Farm near Windom Minnesota, is the co-investigator on this project and has offered his farm as the location for the demonstration fields. Mr. Thompson and Willow Lake Farm staff will assist with field design, planting of the cover strips, habitat evaluation and yield monitoring**.** Willow Lake Farm will assist with hiring and supervising summer interns who will work on this project.

B. Project Impact and Long-term Strategy:
This project will demonstrate a new conservation technique that is applicable on farms using precision tillage methods (e.g. strip till and ridge till), and is thus applicable to tens-of-thousands of acres of Minnesota's cropland. Our intention is to show that perennial vegetation can be cost-effectively introduced into row-crops on these types of farms, providing both habitat and water quality benefits without removing land from production. Successfully demonstrating that perennial vegetation can be incorporated into crops with minimal impact to grain yields will accelerate this concept and allow natural resource managers to add this type of management technique to their suite of agricultural best management practices. Ultimately, we hope that this project provides a significant step forward in developing new methods to add cover crops and perennial vegetation to the agricultural landscape. Because of the time required for perennial plantings to establish and mature, this project can only provide initial assessments of the habitat value of the inter-row strips. We will actively seek funding from other sources to extend the floristic and faunal evaluations of the strips for several years beyond the timeframe of this project.

C. Funding History:

Funding Source and Use of Funds	Funding Timeframe	$ Amount
Not Applicable		$
		$
		$

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS:
Not Applicable

IX. VISUAL COMPONENT or MAP(S):
See attached figures and tables.

X. RESEARCH ADDENDUM:
Not Applicable

XI. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than August 1 of 2017, 2018, and February 1, 2019. A final report and associated products will be submitted between June 30 and August 15, 2019

Figure 1. Upper : custom no-till seed drill designed to plant four rows in the 30 inch area between corn rows. Lower: Savanna grasses planted in November of 2016 and growing well between soy row planted in June of 2017.

Table 1. Field sizes, crop rotation and variety of grain-seed used in demonstration fields. Non-treated means the corn seed is not treated with neonicotinoid and is a non-GMO variety. Soy fields are all non-treated

Field	Acres	Crop Rotation 2017	2018	2019	Variety
I	5	Soy	Corn	Soy	Non-treated
II	25	Soy	Corn	Soy	Conventional
III	25	Corn	Soy	Corn	Conventional
IV	5	Corn	Soy	Corn	Non-treated

Table 2. Species mixes planted in the 16 inter-rows (strips) shown in Figure 2. Inter-row strips are divided into a north and south half to allow testing of more species. Rows 1 to 8 were planted in the fall of 2016; rows 9 to 16 in spring of 2017. Species list and amounts for each mix are in Tables 3 and 4. Strips 1- 8 were planted in the fall, strips 9-16 were planted in the spring. Mixes are color-coded to help visualize where different mixes are replicated for comparison.

Inter-row	Field	Species Planted A: South-half of Strip	Species Planted B: North-half of Strip
1	I -Fall	Short Forbs-small seed size	Tall Forbs-small seed size
2	I- Fall	Short Forbs- large seed size	Tall Forbs – large seed size
3	II- Fall	Savanna Grasses	Short savanna grass
4	II- Fall	Tall Forbs-small seed size	Short Forbs-small seed size
5	II- Fall	Tall Forbs – large seed size	Short Forbs- large seed size
6	II-Fall	Early flowering forbs	Savanna Grasses
7	II-Fall	Milkweeds	Milkweeds
8	II-Fall	Short Forbs-small seed size	Tall Forbs-small seed size
9	III-Spring	Alfalfa - dense	Alfalfa - dense
10	III-Spring	Alfalfa -sparse	Alfalfa -sparse
11	III-Spring	Warm season grasses -tall	Warm season grasses -short
12	III-Spring	Legume Mix	Savanna Grasses
13	III-Spring	Warm season grasses -short	Warm season grasses -tall
14	III-Spring	Savanna Grasses	Diverse Forb Mix
15	IV-Spring	Cool Season Grasses	Cool Season Grasses
16	IV-Spring	Diverse Forb Mix	Legume Mix

Table 3. Fall Plantings: species mixes and amounts planted at Willow Lake Farm. November 2016 Rows 1- 8.

Mix: Tall Forbs--small seeded speices

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Agastache foeniculum	**Anise Hyssop**	70000	1	15.1	1B, 4A, 8B
Agastache nepatoides	**Yellow Hyssop**	65000	1	14.0	1B, 4A, 8B
Monarda fistulosa	**Bergamot**	30000	0.5	3.2	1B, 4A, 8B
Rudbeckia hirta	**Black-eye Susan**	75000	1	16.1	1B, 4A, 8B
Scrophularia lanceolata	**Figwort**	125000	1	26.9	1B, 4A, 8B
Verbena hastata	**Blue Vervain**	79834	1	17.2	1B, 4A, 8B
Rudbeckia laciniata	**Lance-leaf Coneflower**	10000	1	2.2	1B, 4A, 8B
Agastache scrophulaiaefolia	**Purple Giant Hyssop**	90000	1	19.4	1B, 4A, 8B
Campanula americana	**Tall Bellflower**	150000	1	32.3	1B, 4A, 8B
Penstemon digitalis	**White Beardtongue**	10000	3	6.5	1B, 4A, 8B

Mix: Savanna Grasses

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Elymus hystrix	**Bottle Brush Grass**	6000	12	23.2	3A, 6B
Bromus pubescens	**Woodland Brome**	6000	12	23.2	3A, 6B

Mix: Early Flowering Forbs-medium height

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Zizia aurea	**Golden Alexander**	11000	10	35.5	6A
Penstemon digitalis	**White Beardtongue**	10000	4	12.9	6A
Rudbeckia hirta	**Black-eye Susan**	75000	1	24.2	6A

Mix: Short, aggressive savanna grass

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Muhlenbergi mexicana	**Leafy Satin Grass**	100000	3	181.8	3B

Mix: Milkweeds

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Asclepias incarnata	**Red Milkweed**	4800	8	12.4	7A, 7B
Asclepias syriaca	**Common Milkweed**	4000	16	20.6	7A, 7B
Baptisia leucantha	**White Wild Indigo**	1300	4	1.7	7A, 7B

Mix: Short/Medium height Forbs--small seeded speices

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Gentiana alba	**Cream Gentian**	100000	3	64.5	1A, 4B, 8A
Hypericum pyramidatum	**Grt St. Johns Wort**	110000	2	47.3	1A, 4B, 8A
Lobelia siphilitica	**Great Blue Lobelia**	400000	4	344.1	1A, 4B, 8A
Penstemon digitalis	**White Beardtongue**	10000	3	6.5	1A, 4B, 8A
Potentilla arguta	**Cinqfoil**	170000	0.5	18.3	1A, 4B, 8A
Pycnanthemum virginianum	**Mountain Mint**	190000	0.3	12.3	1A, 4B, 8A
Veronicastrum virginicum	**Culvers Root**	375000	0.2	16.1	1A, 4B, 8A
Gentiana andrewsii	**Bottle Gentian**	175000	0.01	0.4	1A, 4B, 8A
Heuchera richardsonii	**Alumroot**	342610	0.1	7.4	1A, 4B, 8A
Muhlenberia mexicana	**Leafy Satin Grass**	100000	2	43.0	1A, 4B, 8A
Rudbeckia hirta	**Black-eye Susan**	75000	1	16.1	1A, 4B, 8A
Penstemon digitalis	**White Beardtongue**	30000	1	6.5	1A, 4B, 8A

Mix: Short/Medium height forbs-- large seeded speices

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Coreopsis palmata	**Prairie Coreopsis**	4500		0.0	2A,5B
Desmodium illinoese	**Tick Trefoil**	3000	1	1.0	2A,5B
Echinacea pallida	**Pale Purple Coneflower**	5200	8	13.4	2A,5B
Echinacea purpurea	**Purple Coneflower**	6600	8	17.0	2A,5B
Zizia aurea	**Golden Alexander**	9000	16	46.5	2A,5B
Carex blanda	**Common Wood Sedge**	12000	2	7.7	2A,5B
Baptisia leucantha	**White Indigo**	1300	3	1.3	2A,5B
Rudbeckia hirta	**Black-eye Susan**	75000	1	24.2	2A,5B

Mix: Tall Forbs--larger seeded speices

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Baptisia leucantha	**White Indigo**	1300	2	0.8	2B,5A
Liatris pycnostycha	**Prairie Blazing Star**	9000	16	46.5	2B,5A
Solidago rigida	**Stiff Goldenrod**	5000	1	1.6	2B,5A
Monarda fistulosa	**Bergamot**	30000	1	9.7	2B,5A
Gentiana flavida	**Cream Gentian**	100000	1	32.3	2B,5A
Rudbeckia laciniata	**Lanceleaf coneflower**	10000	0.5	1.6	2B,5A
Agastache scroph.	**Purple Giant Hyssop**	12000	0.5	1.9	2B,5A
Rudbeckia laciniata	**Black-eye Susan**	75000	1	24.2	2B,5A
Thalicrum dasycarpum	**Meadow Rue**	9000	2	5.5	2B,5A

Table 4. Spring Plantings: species mixes and amounts planted at Willow Lake Farm. November 2016 Rows 9- 16.

Mix: Warm season grasses -Tall.

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Andropogon gerardii	**Big Bluestem**	5000	6	9.7	11A, 13B
Panicum virgatum	**Switch grass**	12000	6	23.2	11A, 13B
Sorghastrum nutans	**Indian Grass**	7400	6	14.3	11A, 13B
Spartina pectinata	**Cord Grass**	5000	3	4.8	11A, 13B

Mix: Warm season grasses - Short

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Muhlenbergi mexicana	**Leafy Satin Grass**	100000	1	32.3	11B, 13A
Andropogon scoparius	**Little Bluestem**	2300	16	11.9	11B, 13A
Carex scoparia	**Oval Sedge**	1000	1	0.3	11B, 13A
Sporobolus heterolepis	**Dropseed**	12300	6	23.8	11B, 13A

Mix: Legume mix

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Desmodium illinoese	**Tick Trefoil**	3000	2	1.9	12A, 16B
Astragalus canadensis	**Milkvetch**	10000	3	9.7	12A, 16B
Desmodium canadense	**Illinois Trefoil**	4200	1	1.4	12A, 16B
Lespedeza capitata	**Bush Clover**	6000	4	7.7	12A, 16B
Baptisia leucantha	**White Indigo**	1300	3	1.3	12A, 16B
Petalostemum purpureum	**Purple P. Clover**	6000	3	5.8	12A, 16B
Lobelia siphilitica	**Great Blue Lobelia**	400000	0.2	25.8	12A, 16B
Scrophularia lanceolata	**Figwort**	120000	0.2	7.7	12A, 16B
Asclepias syriaca	**Milkweed**	4000	1	1.3	12A, 16B
Aquilegia canadensis	**Columbine**	31000	0.2	2.0	12A, 16B
Penstemon digitalis	**White Beardtongue**	10000	4	12.9	12A, 16B
Rudbeckia hirta	**Black-eye Susan**	75000	1	24.2	12A, 16B

Mix: Savanna grasses

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Elymus hystrix	**Bottle Brush Grass**	6000	8	15.5	12B, 14A
Bromus pubescens	**Woodland Brome**	6000	6	11.6	12B, 14A

Mix: Cool season grasses

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Elymus villosus	**Silky Wild Rye**	5000	4	6.5	15A, 15B
Elymus virginicus	**Virginia Wild Rye**	4000	6	7.7	15A, 15B

Mix: Diverse forb mix

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Rudbeckia hirta	**Black-eye Susan**	75000	0.5	12.1	14B, 16A
Scrophularia lanceolata	**Figwort**	125000	1	37.9	14B, 16A
Verbena hastata	**Blue Vervain**	79834	0.5	12.1	14B, 16A
Lobelia siphilitica	**Great Blue Lobelia**	400000	0.25	30.3	14B, 16A
Echinacea pallida	**Pale Purple Coneflower**	5200	0.5	0.8	14B, 16A
Zizia aurea	**Golden Alexander**	11000	1	3.3	14B, 16A
Heliopsis helianthodies	**Ox-eye sunflower**	3000	3	2.7	14B, 16A
Penstemon digitalis	**White Beardtongue**	10000	1	3.0	14B, 16A
Potentilla arguta	**Cinqfoil**	170000	1	51.5	14B, 16A
Penstemon digitalis	**White Beardtongue**	10000	1	3.0	14B, 16A
Lysmichia ciliata	**Fringed Loosestrife**	5000	0.2	0.3	14B, 16A
Hypericum pyramidatum	**Grt St. Johns Wort**	110000	1	33.3	14B, 16A
Asclepias syriaca	**Common Milkweed**	4000	1	1.2	14B, 16A
Gentiana alba	**Cream Gentian**	100000	1	30.3	14B, 16A
Pycnanthemum virginianum	**Mountain Mint**	190000	0.25	14.4	14B, 16A
Veronicastrum virginicum	**Culvers Root**	375000	0.2	22.7	14B, 16A
Monarda fistulosa	**Bergamot**	30000	0.5	4.5	14B, 16A
Aquilegia canadensis	**Columbine**	31000	0.2	1.9	14B, 16A
Eupatorium maculatum	**Joe-pye weed**	10000	0.5	1.5	14B, 16A
Lespedeza capitata	**Bush Clover**	6000	0.5	0.9	14B, 16A
Astragalus canadensis	**Canada Milkvetch**	10000	0.5	1.5	14B, 16A
Muhlenbergi mexicana	**Leafy Satin Grass**	100000	0.5	15.2	14B, 16A

Mix: Alfalfa -- Dense vs Sparse

Species	Common Name	Seeds/oz	Ounces	Seed/ft^2	Rows Planted
Medicago sativa	**Alfalfa - Dense Rate**	7000	16	36.1	9A, 9B
Medicago sativa	**Alfalfa- Sparse Rate**	7000	8	18.1	10A, 10B

Table 5. Assessment of perennial plant establishment in inter-row strips after first growing season.

Inter-row	Fall or Spring Planted	Mix Type	Establishment after first growing season	Species well established	Species missing or poorly established
1-A	Fall	Short Forbs-small seed size	Poor	Coneflowers, Black-eye Susan, Lambsquater	Gentian, Lobelia, Culvers Root, St. John's wort
2-A	Fall	Short Forbs-large seed size	Poor	Golden Alexander, Coneflowers	Indigo, Black-eye Susan, Desmodium
3-A	Fall	Savanna Grasses	Excellent-but may have delayed herbicide effects	Bottlebrush Grass, Woodland Brome	None
4-A	Fall	Tall Forbs-small seed size	Very poor	very low denisty of all species	Hyssops, Figwort, Beardtongue, Vervain, Bergamot
5-A	Fall	Tall Forbs –large seed size	Moderate	Golden Alexander, Coneflowers, Blazing Star	Goldenrods, Hyssop, Meadow Rue, Gentian
6-A	Fall	Early flowering forbs	Good	Golden Alexander, Coneflowers	Black-eye Susan
7-A	Fall	Milkweeds	Excellent	Common and Red Milkweed	None
8-A	Fall	Short Forbs-small seed size	Very poor	Leafy Satin Grass	Gentian, Lobelia, Culvers Root, St. John's wort, Alumroot, Mints
9-A	Spring	Alfalfa - dense	Excellent	Alfalfa	None
10-A	Spring	Alfalfa -sparse	Excellent	Alfalfa	None
11-A	Spring	Warm season grasses -tall	Moderate	Big Bluestem, Indian Grass Switch Grass	Cordgrass
12-A	Spring	Legume Mix	Poor	Desmodium	Indigo, Prairie Clovers, Bush Clover, Figwort
13-A	Spring	Warm season grasses -short	Poor	Leafy Satin Grass	Little Bluestem, Dropseed, Sedges
14-A	Spring	Savanna Grasses	Poor	Sparse Grasses	Bottlebrush Grass, Woodland Brome
15-A	Spring	Cool Season Grasses	Excellent	Silky Rye, Virginia Rye	none
16-A	Spring	Diverse Forb Mix	Very poor	Golden Alexander, Leafy Satin Grass	Figwort, Gentian, Bergamot, Prairie Clovers, Lobelia
1-B	Fall	Tall Forbs-small seed size	Poor	Coneflowers, Lambsquater	Hyssops, Figwort, Beardtongue, Vervain, Figwort
2-B	Fall	Tall Forbs –large seed size	Poor	Golden Alexander, Coneflowers	Black-eye Susan, Indigo, Sedges, Desmodium
3-B	Fall	Short savanna grass	Moderate	Leafy Satin Grass	None
4-B	Fall	Short Forbs-small seed size	Very Poor	None	Gentian, Lobelia, Culvers Root, St. John's wort, Alumroot, Mints
5-B	Fall	Short Forbs-large seed size	Moderate	Golden Alexander, Coneflowers	Desmodium, Black-eye Susan, Indigo, Sedges
6-B	Fall	Savanna Grasses	Excellent-but may have delayed herbicide effects	Bottlebrush Grass, Woodland Brome	None
7-B	Fall	Milkweeds	Excellent	Common and Red Milkweed	None
8-B	Fall	Tall Forbs-small seed size	Very Poor	Nine	Hyssops, Figwort, Beardtongue, Vervain, Bergamot
9-B	Spring	Alfalfa - dense	Excellent	Alfalfa	None
10-B	Spring	Alfalfa -sparse	Excellent	Alfalfa	None
11-B	Spring	Warm season grasses -short	Poor	Sparse Warm Season Grasses	Sparse Warm Season Grasses
12-B	Spring	Savanna Grasses	Poor	Good germination of Bottlebrush Grass, Woodland Brome but lost small seedlings to herbicide	
13-B	Spring	Warm season grasses -tall	Poor	Leafy Satin Grass	Sparse Warm Season Grasses
14-B	Spring	Diverse Forb Mix	Very Poor	Golden Alexander, Coneflowers, Blazing Star	Gentian, Lobelia, Culvers Root, St. John's wort, Alumroot, Mints
15-B	Spring	Cool Season Grasses	Excellent	Silky Rye, Virginia Rye	None
16-B	Spring	Legume Mix	Poor	Sparse establishment of legumes, especially Bush Clover	

Figure 2. Milkweeds established between soybean rows after one growing season

Figure 3. Clockwise from upper left. i) Savanna grasses (Bottlebrush grass + Woodland Brome) in May, prior to corn planting. ii) Alfalfa strip growing well just after corn planting. iii) same strip of alfalfa in early July, flowering under corn canopy. iv) Milkweed strip under corn canopy in late June—nearly in flower. v) Monarch larva feeding on Milkweed strip. vii) Mixed prairie strip with Golden Alexander in full flower- early June.

Table 6. Yield gain or loss of corn in rows adjacent to perennial vegetation strips compare to corn rows distant from strips with inter-row vegetation.

Strip	Gain or loss (bushels) in 12 corn rows near perennial strip compared to 12 corn rows distant from perennial strip (bushels)	Estimated yield loss in two corn rows adjacent to inter-row strip (bu/acre)	Dollars lost if corn is $4/bu (note each harvested pass is about 1.4-1.6 acres)
1	**-51.54**	A	-$206
2	3.29	B	
3	**5.89**	B	
4	**-5.15**	-22.49	-$21
5	-0.21	-2.17	-$1
6	-4.8	-20.1	-$19
7	-2.25	-6.77	-$9
8	**-46.19**	A.	-$185
9	-1.69	-5.79	-$7
10	**9.47**	B	$38
11	1.26	B	
12	**-9.84**	-34.47	-$39
13	6.61	B	
14	4.83	B	
15	0.6	B	
16	no data	NA	NA

A= Yield reduction was due to all 12 rows being planted with non-treated seed with different traits.

B= No yield reduction. Perennial strips did not induce a measurable yield loss.

Yield differences noted with **bold** type are greater than the variability in yields from harvested passes that did not encompass perennial strips. Thus numbers in **bold** represent a "statistically significant" yield loss or gain.

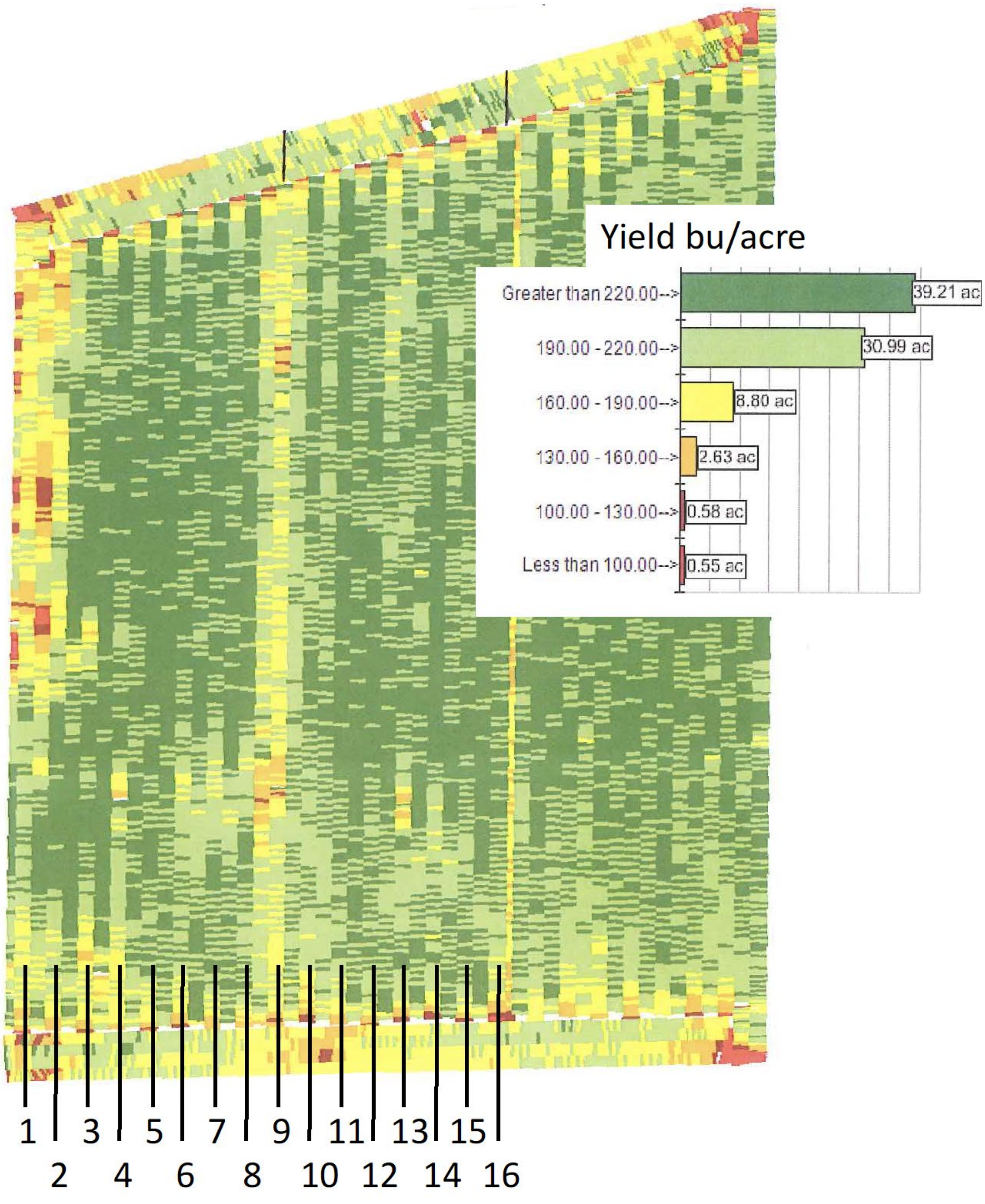

Figure 4. Corn yield for each pass of the combine-12 rows wide. Each pass with the combine was either centered over one of the strips, or was on the 12 rows furthest from a strip. If the two rows of corn adjacent to the strip were severely impacted, we would expect to see a 10-15% yield loss or a 20-40 bushel/acre difference in the pass encompassing the strip as compared to the 12 row pass that did not encompass a perennial vegetation strip. Yields in most passes with strips we not statistically different from adjacent passes with no strips. Greatest yield loss are in the pass that were planted with non-neonicotinoid treated seed corn—strips 1 and 9.

Figure 5. Announcement for the 2019 AgroEcology Summit.

Environment and Natural Resources Trust Fund
M.L. 2016 Project Budget Final Report

Project Title: Establishment of Permanent Habitat Strips Within Row-crops
Legal Citation: **M.L. 2016, Chp. 186, Sec. 2, Subd. 08c**
Project Manager: Shawn Schottler
Organization: Science Museum of Minnesota: St. Croix Watershed Research Station
M.L. 2016 ENRTF Appropriation: $ 179,000
Project Length and Completion Date: Three Years June 30, 2019
Date of Report: 7-30-2019

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Establish and Manage Perennial Inter-row Strips***										
Personnel (Wages and Benefits)	$32,000	$32,000	$0	$60,000	$60,000	$0	$42,332	$42,332	$0	$134,332	$0
Shawn Schottler, Project Manager $ 124,332 (70% Salary, 30% Benefits) 40% FTE for 3 years											
Alaina Fedie, Outreach Cordinator, $10,000 (70% Salary, 30% Benefits, 15% time for 1 year.											
Professional/Technical/Service Contracts	$2,500	$2,500	$0	$7,000	$7,000	$0	$10,500	$10,500	$0	$20,000	$0
Task Based Contract with Willow Lake Farm Staff for Assistance with Planting, Habitat Surveys, Equipment Design, Field Tours, Yield Loss											
Equipment/Tools/Supplies	$4,000	$4,000	$0	$500	$500	$0	$500	$500	$0	$5,000	$0
Prairie Seed, fuel, field supplies											
Capital Expenditures Over $5,000	$10,668	$10,668	$0							$10,668	$0
Design and fabrication of custom seed drill and herbicide sheilds											
Travel expenses in Minnesota	$1,500	$1,500	$0	$6,500	$6,500	$0	$1,000	$1,000	$0	$9,000	$0
Travel to and from Willom Lake Farm-Mileage; Three summers of Lodging for Intern in Windom Area											
Other	-		-	-		-			-	-	-
COLUMN TOTAL	**$50,668**	**$50,668**	**$0**	**$74,000**	**$74,000**	**$0**	**$54,332**	**$54,332**	**$0**	**$179,000**	**$0**