ONTO GREENER PASTURES WITH ROTATIONAL GRAZING OF COVER CROPS

by

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Abstract

Cover crops are recognized to improve soil health, reduce nutrient losses to ground and surface waters, and can provide protection to the soil between growing seasons in cash crop rotations. However, cover crops are also associated with seed, planting, termination, and labor costs, and in Wisconsin the short growing season poses barriers to establishment, resulting in persisting questions to their conservation efficacy and economic feasibility. This leads some farmers to consider rotational grazing to offset the cover crop costs but comes with its own conservation concerns. To assess the economic and ecological tradeoffs of rotationally grazing cover crops and to demonstrate the 'real world' risks associated in grain systems, we worked with four farmers in south-central Wisconsin to collect plant and soil samples, and agronomic data. Across the four farms rotational grazing of cover corps in row crop operations reduced plant cover, but maintained and sometimes improved sensitive soil health indicators, while sometimes offsetting cover crop seed costs.

Introduction

Cover crops sown into annual grain cropping systems of the upper Midwest are touted for improving soil health and reducing nutrient losses to ground and surface waters (Brooker et al., 2020; Jacobs et al. 2022; Malone et al. 2022; Wagg et al. 2021). Additionally cover crops can provide benefits to cash crop systems by protecting soil between growing seasons (Acuña and Villamil 2014; Blanco-Canqui et al. 2015; Blanco-Canqui 2018).

In Wisconsin, cover crop acreage grew from 553,005 in 2012 to 611,231 in 2017, making up ~6% of total cropland (USDA - National Agricultural Statistics Service - 2017 Census of Agriculture - Volume 1, Chapter 2: State Level Data 2023) (USDA NASS 2019a), but questions persist about cover crop cost, conservation efficacy, and economic feasibility (Cates et al. 2018; Snapp et al. 2005). Cover crops are associated with costs such as seed, planting, termination, equipment, and labor (USDA ERS - Land Use, Land Value & Tenure 2022).

In addition to concerns surrounding costs of cover crops, the growing season in Wisconsin is short, resulting in a small window for planting, establishment, and growth of cover crops following harvest (Malone et al. 2022). Planting cover crops between rows and following emergence of corn, known as interseeding, is a suggested remedy to increase cover crop growth in short growing seasons but poses its own difficulties (Curran et al. 2018). Spring weather can be a determinant of cover crop growth since rainfall following interseeding is fundamental to cover crop establishment (Brooker et al., 2020, Tribouillois et al., 2018). Without good establishment, cover crops are unlikely to provide conservation benefits (Cates et al. 2018). The combined challenges of cover crop costs and establishment in the short Wisconsin growing season, results in farmers questioning the overall economic feasibility of cover crops as a conservation practice (Roesch-McNally et al. 2018).

These concerns lead some to consider grazing of cover crops in fall and/or spring to increase revenue that may cover the costs of their implementation. Plastina et al. (2020) found that one farmer out of 16 had extra revenue from grazing cover crops, making it clear that if revenue was not generated via livestock production on the cover crops, they did not provide a return on investment. Another study found that the additional costs of grazing were higher than the additional income of grazing treatments in wheat-pea-cover crop systems at USDA-ARS Northern Great Plains Research Laboratory in Mandan, N.D. (Archer et al., 2020).

Farmers have expressed the need for further economic analysis to support future adoption. The 2017 *Iowa Farm and Rural Life Poll* found 77% of farmers *agree* or *strongly agree* that the decline of integrated grain and livestock farming has made the production of small grains and forages less viable. The report also indicated that 76% of farmers deem strong documentation of the economics/long-term profitability as important or very important as a potential facilitator of integration of small grains into rotations (*2017 Summary Report - Iowa Farm and Rural Life Poll* 2023).

Alongside a lack of robust understanding of the economic impacts of adding livestock grazing to cover crops in row crop systems, there are concerns about potential environmental trade-offs or unintended consequences (Byrnes et al. 2018). Repeated hoof action of grazing livestock can compact soil, stimulation of nutrient cycling can increase gaseous and aqueous N loss, and reducing plant density may affect the protective armor from erosion provided by the vegetation canopy (Byrnes et al., 2018).

We aim to address the concerns of potential economic and ecological tradeoffs when adding livestock grazing to cover crops in row crop systems. Working with four farmers in Sauk and Columbia Counties of southern Wisconsin, we observed and documented the short-term agronomic and ecological responses to fall rotational grazing of cover crops in the framework of a demonstration and outreach project. For each farm, we assessed the economic costs and benefits of grazing established cover crops, using livestock already on hand, to demonstrate how rotational grazing of cover crops affected the costs of including cover crops. We then estimated plant and soil responses to assess and demonstrate the short-term effects of grazing on the cover crops' capacity to provide conservation benefits.

It is important to note that this demonstration project was a collaboration among the farmers, NGO staff from the Sand County Foundation, and academics from UW-Madison. The project was not designed to generate data appropriate for inferential statistical analysis, but rather to stimulate conversations among the collaborators and other community partners. Outreach consisted of presentations at farmer-hosted pasture walks and contributions to videos and webinars hosted by Sand County Foundation. Here, we use a case study approach to explore a range of approaches and short-term outcomes in the hope that we continue stimulating conversations about the efficacy of cover crops in the upper Midwest.

Methods

Outreach

We participated in a local science talk, a pasture walk held at site 2, and a poster session at the Tri Societies conference in Baltimore, Maryland. A local eatery and cidery held a summer science series open to the public, where I talked about the project and my role within the project in a storytelling format. The pasture walk was held at site 2 and included a handout with a summary of the project and some of the preliminary data and a chance to talk about the project and answer any questions from fellow attendees. The audience included other local farmers from the area. The poster session was aimed at an academic audience and included a project summary and preliminary data. I thought it was important to connect with different audiences over this work to better understand its reaches and impact. Through talking with a public space with a diverse audience, farmers, and scientists/academics, I was able to gain knowledge in the pieces of the project that are exciting to each group, but also practice my fluency with each group.

Development of cover crop approaches at demonstration farms

The demonstration work occurred in 2021 and 2022 on four farms in Sauk County, Wisconsin, which are all described in detailed case study narratives below. Farms were selected because they were known to use cover crops in their annual cropping systems, maintained a cattle herd that could be grazed on cover crops, and were keen to participate in the demonstration and outreach effort. At each farm, an area was indicated as a field likely to have cover crops seeded in fall 2021. The farmer and graduate student then selected part of that field to be excluded from fall grazing based on ease of management for the farmer and using easily identifiable landmarks to mark boundaries, while the remainder would be managed with rotational grazing in fall. Hence, each farm had a grazed-ungrazed comparison at the time the project was established. We were particularly keen for each farmer to follow their own management ideas to allow for 'real world' vagaries of farming to be part of the demonstration. As a result, three of four farmers continued with cover crops seeded following annuals in 2021 while one decided to sequentially plant cover crops and graze those cover crops throughout the summer and fall 2021 and summer 2022. The 'real world' variation continued in 2022 growing season with each of the three sites having unique styles of interseeding into corn in 2022. Of the three farmers who interseeded in 2022, one had three variations of corn row spacing and seed density, and another chose to leave the volunteer cover crops, from the year previous, to grow in rather than interseed. By including differing farm operations, this allows us to better accommodate to the different operations potential adopters may have themselves rather than to compare replicable data across sites participating in this study.

Estimating success of cover crop establishment and effect of grazing on cover crops

To assess the grazing effect on the cover crops, green plant cover, average height, and aboveground plant biomass were collected. Plant biomass samples were collected immediately before and after grazing events. The treatment field was divided into 3 sections with a transect of 5 sampling locations with consistent spacing (site 1: 12

paces, site 2: 5 paces, site 3: 10 paces, site 4: 8 paces) in the middle of each treatment field section and in the middle of the control field. Plant cover, vegetation height, and a 0.0729-m^2 quadrat of aboveground biomass were collected for each sampling location. Plant cover was collected using the Canopeo™ mobile phone application by taking a picture and processing the pixels of the green cover. The picture was taken roughly 1 meter above the ground surface. Average vegetation height was measured within the quadrat using an Organic Valley™ grazing stick and recorded. Vegetation was clipped at 10.16 cm residual stubble height within the quadrat, bagged, and placed in a drying oven for 2 d at 59 ℃, and the dry matter was weighed and recorded.

In year two, plant biomass samples were collected similarly with the addition of corn residue collected and bagged separately at Site 2, and only the pre-grazing samples were collected at Site 4. The height of the corn was also recorded and rooted corn was cut to 10.16 cm and collected. Any corn residue lying within the quadrat was also collected in a separate bag. Post-grazing samples for Sites 2 and 4 were unavailable because of snowfall and pictures were taken of the fields to document the ground cover. In year two, Site 1 plant biomass was not collected: however, pictures were taken. Dry matter biomass samples were ground through a 1-mm screen using a downdraft table and the powder form of the biomass was stored in a sealable plastic bag. If the samples did not contain enough dry matter to be effectively ground or weighed < 5 g, replicates within a transect were combined and recorded. To maintain consistent particle size throughout the sample, a Udymill cyclone sampler was used on the biomass samples to run them through near-infrared spectrometry to assess the relative feed quality of the cover crop mix. Biomass was averaged for each field at each site. To assess utilization, the average post-grazing biomass was subtracted from the average pre-grazing biomass.

Assessing potential short-term effects of grazing cover crops on soils

Deep cores

Samples were taken in the fall before the ground froze. At Sites 1 and 3, grazing had begun at the time of sampling, while at Sites 2 and 4 sampling occurred before grazing had begun. In both the control and treatment fields, 5 samples were taken in the pattern of the 5 side of a die. Labeled NW, NE, Center, SW, and SE, based on the sample's location in the field. The samples were taken using a hydraulic probe on the back of a tractor. The coordinate location of the samples was obtained by dropping a pin on Google Maps to assure different sample locations in year 2. Soil cores were collected with a Giddings probe with a 6.5 cm diameter. The metal cylinder was laid on an incline, with the top of the soil profile at a higher elevation, to push the plastic sleeve towards the top. The plastic sleeve was capped using color-coded caps to indicate the top (red) and bottom (black) of the soil core. The cores were transported vertically with the top upward and immediately stored in a freezer at -11 °C. In year 2, samples were collected with the same methods with the exception of not using a plastic sleeve. The same Giddings metal open cylinder with a funnel shape at the bottom was used and the hydraulic probe on the tractor to collect the soil. Once brought back to the surface, the metal cylinder was guided into a metal trough on an incline with the top of the soil profile at the bottom. The soil core was divided into segments (0-15,15-30, 30-55, 55-60, 60-100), and each segment was put into a prelabeled sealable plastic bag. (Note that for cores shorter than 100 cm, the 60-100 cm section went from 60 cm to the end of the core.) The trough was cleaned between each core with a soft-bristled paintbrush, metal wire brush, and a rag. The samples were then placed into a cooler for transport back to the station where they were stored in the freezer until processing started.

At UW-Madison's Arlington Agricultural Research station, the depth of the soil core was recorded, then the 55 to 60-cm increment was removed using a bandsaw and sent to the Rock River Lab for nitrate and ammonium determination. Nitrate and ammonium were determined at a depth assumed to be below the rooting zone in order to assess potentially leachable nitrogen. This left two sections for each core: 0 to 55 cm and 60 to 100 cm. The deep core in the sleeve was laid on a table and a sleeve cutter was used to cut down the side of the sleeve length-wise then the core was rotated to slide the cutter down the other side of the sleeve to access the soil core intact. A meter stick was used to measure out 0 to 15 cm, 15 to 30, and 30 to 55 cm depth segments. Each depth segment was placed into a prelabeled sealable plastic bag. The bottom section of the core (60 to 100 cm) was also laid out on the table in the sleeve and measured with a meter stick to record to total height of the core and then the sleeve cutter was used to remove the soil and place into a prelabeled sealable plastic bag and were processed the same as the other depth segments. These steps were done in the field in year two and the processing at the station started with mixing the soil inside the sealable plastic bag.

After mixing the soil in the sealable plastic bag, roughly 20 g was weighed out onto a paper plate for soil moisture analysis and put into the 60 °C drying oven for 48 h. After 48 h the subsample's weight was recorded before placing it into the 105 °C drying oven for 24 h. The subsample was then removed from the drying oven, weighed, and sieved to 2 mm. Sieves were cleaned with 70% ethanol between samples. Gravel larger than 2mm was removed. If the subsample contained gravel, its mass was recorded and used to calculate gravimetric water content. After the soil moisture subsample was removed from the sealable plastic bag, the rest of the soil was sieved to 2 mm, removing all gravel and roots from the sample. The wet weight of the gravel and roots was recorded. Of the sieved soil a subsample of roughly 20 g was removed and placed on a paper plate to be air dried for POxC analysis. The rest of the sieved soil was transferred to a paper bag and placed into the 60-°C drying oven to dry out completely. Once dried, a subsample (~1 g) was collected into a small vial and run through the Thermo FlashEA1112 for total carbon and nitrogen analysis.

To estimate a sensitive indicator of soil health, POxC was determined using the 'Active Carbon' method described by Weil et al., 2003 and adapted by the Culman Lab at Kellogg Biological Station at Michigan State University. Values were determined using an average of replicates with a relative standard error of less than 5% (Calderón et al., 2017, Hurisso et al., 2016). POxC measures the active carbon pool, and was found to better illustrate conservation practices expected to promote accumulation and stabilization of organic matter and (Hurisso et al. 2016).

Bulk density

Bulk density was measured to assess the potential impact of hoof action on the grazed fields. Samples were taken before grazing occurred at sites 1, 2, and 4 and during grazing at site 3. In both the control and treatment fields at all sites, there were 3 samples taken, for a total of 6 per site. In year 2 at site 3, samples were only collected in the treatment field. Samples were taken in a diagonal transect across the field. The coordinate locations were recorded using Google Maps™ for all samples. An area just large enough for the sample was removed of visible vegetation before using a 15.24-cm-in long, 7.62-cm diameter plastic sleeve inside a metal cylinder with a medium relief probe tip fastened to a hammer corer, to cut through the ground. Once the core was hammered into the ground deep enough to fill the plastic sleeve with soil so that the top of the metal cylinder was flush with the surrounding soil, a trench shovel was used to loosen the surrounding soil and remove the metal cylinder. The lid to the metal cylinder was unscrewed and the plastic sleeve was removed. Using a metal food scraper tool, the ends of the plastic sleeve were cleaned so the soil was flush with the plastic sleeve. The plastic sleeve was capped and transported back to the lab. If the soil did not fill the plastic sleeve, the height of the soil was measured to calculate the volume of soil later. The caps were removed, and the weight of the sleeve was recorded. Using a soil knife (butter knife), the soil was scraped into a labeled paper bag taking care that no soil was lost. The weight of the empty plastic sleeve was recorded. The soil in the paper bag was dried at 59 C. After drying the mass of the bag containing soil was recorded. The soil was sieved to 2 mm, removing and keeping rocks from the soil. The mass of the empty paper bag and the rocks removed was recorded. The soil without rocks was then returned to the paper bag and weighed. Bulk density was calculated using the volume of the core ($V = pi * r^2 * h, V = volume, r = radius, h = height$), a gravel mass to density conversion factor of 2.5 g cm^{-3}, the rock mass, the paper bag mass, and the dried soil in paper bag mass.

Documenting farmer costs and revenues from planting and grazing cover crops

We developed a skeleton for the agronomic table to include a cost-benefit analysis of implementing rotational grazing to cover crops grown with row crops. Working with the Sand County Foundation, we met with the farmers individually at their farms to fill out the agronomic table and assess the table's usefulness.

Results

Case studies of four Sauk County Farms exploring cover crop grazing

Site 1: Echo-Y Farms

Echo-Y Farms Background and Approach

Echo-Y Farms is a family-owned and operated farm located in Loganville, Wisconsin. Their motto is “Farming with nature” and conservation agriculture is a foundation of their management practices. Echo-Y Farms is dedicated to soil health and animal welfare through the practice of rotational grazing of cover crops in row crop systems.

Echo-Y Farms has experience with cover crops, rotational grazing, and rotational grazing of cover crops and for this project expanded these practices to a new field. The farmer from Echo-Y farms reported that he was drawn to rotational grazing of cover crops because “getting the cattle back on the landscape is the biggest thing. I mean, just integrating … getting the manure cycling back out there. It is all about creating healthy soil and getting the animal in that field is just, is better than, manure, in my opinion.” Further, he commented that he wants to incorporate the 5th soil health principle: *livestock integration*.

Echo-Y Farms Role in Agriculture

The farmer lists two roles Echo-Y Farms has in the larger picture of agriculture **“**Educating others that there is more sustainable ways to produce food.” and “Trying and learning new ideas to better agriculture's future.” The farmer states that to be a farmer is “To be good stewards of the land and produce healthy foods.”

Echo-Y Farms Field Specifics

Echo-Y Farms has dedicated 50 acres towards the cover crop grazing project 5 miles up the road from the heart of their farm operation. According to the USGS soil survey, this field consists of Reedsburg silt loam and Valton silt loam soils. This field is being managed in a no-till corn-soybean-winter wheat cash grain rotation. Both the treatment and control fields have had cover crops and grazing in the past. In the fall of 2020 winter wheat was drilled at 160 lbs/ac leading into the project timeline in the following year.

Echo-Y Farms Project Operation

Grazed and control treatment areas are divided by a culvert within the 50-acre area, leaving roughly 5 acres for the control field west of the culvert and 45 acres for the grazed cover crops treatment, east of the culvert. The project started in the winter wheat harvest year, summer 2021. Following the winter wheat harvest, the field was sprayed with herbicide and then chicken litter was applied before planting the cover crop seed. A custom cover crop mix curated by the farmer was drilled on 25 July 2021 at 30 lbs/ac following the harvest of winter wheat. The custom mix consisted of Jerry oats (Avena sativa), spring peas (Pisum sativum), sunflower (Helianthus annuus), crown annual ryegrass (Lolium multiflorum), millet (Pennisetum glaucum), sudangrass (Sorghum x drummondii), nitro radish (Raphanus sativus), dwarf essex rape (Brassica napus), hybrid brassicas (Brassica rapa rapa x Brassica napus), hairy vetch (Vicia villosa), med. red clover (Trifolium pratense), and viner balansa clover (Trifolium michelianum). Once established, the cover crops had one grazing event in early September through mid-October and were left to rest over winter before termination in May 2022.

Corn was planted east-west on 13 May 2022 with three variations of north-south planting densities and row spacing. There were twenty-four 60-inch rows of corn planted at 40,000 seeds per acre, followed by twelve 30-inch rows planted at 21,500 seeds per acre, and another twelve 30-inch rows planted at 33,000 seeds per acre. Additionally, there was a chemical herbicide treatment 27 days before broadcasting the cover crop, at 20 lbs/ac. Due to a lack of cover crop growth, the corn residue alone was deemed not worthy of hauling the cattle 5 miles up the road, so grazing did not occur in year two. In an attempt to protect the soil through winter in the absence of the interseeded cover crop, a rye cover crop was planted in November 2022 and will be grazed in spring 2023.

Overall, the farmer felt that the season was good, despite struggles related to cooler weather events. Regarding cover crop growth and potential for grazing, this farmer did not have any cover crop growth or grazing, and he noted that what did grow was not resilient to the field's environmental conditions. He also shared that this project has provided him with alternative grazing fields for his cattle, thus allowing more regeneration time for his permanent pastures.

Agronomics

A cost-savings analysis was conducted through an interview with the Farmer and Sand County Foundation's Field Projects Director, to assess the incurred costs and savings from adding livestock to the cover crop field. In Table 1, the cost of cover crops is listed with all other costs of adding grazing that the farmer considers. The costs and savings that are considered by the farmer but not considered in the calculation of the net cost of adding grazing to cover crops are listed followed by '(not included)' (Table 1). The savings are the opportunity cost of having the cows on the cover crop field rather than on another pasture with baled hay. The net is the sum of the total cost (bolded) and the savings.

In year one, the cattle had to be hauled up to the field using trucks, trailers, and extra workers. Water and minerals also needed to be hauled daily to the field while cows were grazing. With a moving paddock system and roughly 10 paddocks, the 70 head of beef cattle were moved daily. Table 2 includes the aboveground biomass consumption and utilization. The fencing cost of $40.69/acre includes perimeter and cross fencing, as well as the perimeter fence posts, and an energizer as the field is remote from the rest of the farm. This is an initial, one-time cost as the fence will last many seasons before replacement. The setup/tear down, daily check/watering, and hauling in/out are the labor costs associated and are adjusted to the number of head. Land rent and fertilizer costs are considered zero to the farmer as they would have these costs for this field regardless. By grazing the farmer saved $133.70/ac in baled hay to offset his total cost of $84.51/ac, and a net positive of $49.19/ac.

Table 1. Agronomic cost ($/acre) and savings in Year 1 for Echo-Y Farms. Farmer deemed grazing not worth it in year 2 due to lack of cover crop growth. Fencing costs would not be incurred in year 2 if grazing had occurred. The not included items are considered by the farmer just not monetarily.

Item	Year 1	Year 2
Cover crop seed	-31.22	-53.00
Fencing equipment	-40.69	0.00
Fencing labor	-2.80	0.00
Daily checking/watering	-0.20	0.00
Livestock hauling	-9.60	0.00
Land rent (not included)	--	--
Fertilizer (not included in calculations)	--	--
Total cost ($/ac)	-84.51	-53.00
Savings ($/ac)		
Baled Hay ($1.91/head/day)	133.70	0.00
Soil health benefits (not included)	--	--
Net cost/benefit ($/ac)	49.19	-53.00

In year two, the cover crops planted were a variety selected to grow well with corn and this mix is more expensive than in year one. Due to the lack of cover crop growth, the farmer decided not to graze the field, so the labor costs are zero. Without grazing, there were no savings from baled hay. Without savings, the cost of cover crops becomes the net cost at $53.00/ac. Aboveground biomass was also not collected in year two.

Table 2. Aboveground biomass dry matter (lb DM/ac) and Utilization (%) at all sites. In 2021 at site 2, the values reflect unaccounted for growth that occurred because the sampling occurred in the southern two fields and the cattle started on the northern field. There was also some growth following grazing before sampling could occur after. There was not enough cover crop growth in 2022 at site 1 to graze. Early snowfall in 2022 prevented postgrazing sampling at site 2, and grazing and sampling at site 4.

		Pregrazing (lb DM/ac)		**Postgrazing (lb DM/ac)**		**Consumption (lb DM/ac)**	**Utilization (%)**
Site	**Year**	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Grazed
1	**2021**	2938	2544	1623	2381	1315	45
	2022	0	0	0	0	0	0

2	**2021**	356	4074	3062	3688	94	3
	2022	129	1684	na	na	na	na
3	**2021**	1993	1981	175	1591	1818	91
	2022	3602	na	1983	na	1619	45
4	**2021**	7359	2801	472	3059	6888	94
	2022	na	na	na	na	na	na

Future goals at Echo-Y Farms

In terms of possible plans or adaptations for the future, the farmer shared that he doesn't plan to change much because the weather was the main obstacle to cover crop growth. He has had past success with the process and recognizes the benefits that he has experienced. He also shared that he would still plant cover crops even without grazing due to their added benefits.

Echo-Y Farms Project Feedback

This farmer's feedback on the ongoing project was positive overall, and he looks forward to reviewing data at the end of the project to consider more specific information about his farm. He felt that the cost and time of transporting the cattle to and from the field was a drawback to the project. One of his favorite things about cover crop grazing was the public interest that it generated with his neighbors and this community, "it gets the neighborhood to talk. Like, oh, they're doing something different. You know?... the different neighbors are seeing it or we get a lot of traffic on (sic) some of them roads they're like, 'Oh yeah, look what they're doing here.' so then we get our name equated with it and then, you know, in the future just as business as beef sales too. So, I mean with the sunflowers out there especially, you need to see the cattle and sunflowers out there at the same time and yeah so, that's the funnest thing." He feels that it is "great PR from the farm."

Site 2: Roger Bindl's farm

Bindl Farm Background and Approach

Roger Bindl owns and operates the family farm, located near Plain, Wisconsin, with his trusty canine Digger. Roger has had help from his siblings and father. Roger manages both beef and a few dairy heifers as well as cash crop fields. Roger has experience with bale grazing his cattle but is a self-proclaimed “rookie grazer of the group” for this project, as he has not rotationally grazed before. Roger has been using cover crops for over 10 years and is a believer in their benefits. Roger shares that he saw a noticeable improvement in the quantity and quality of his corn yield between an area in the field that had cover crops and an area in the field that did not have cover crops,in another field on his farm. Roger relayed that extending the grazing season and having another way to utilize the feed left in the field, are aspects that drew him to grazing cover crops.

Bindl Farms Role in Agriculture

The farmer “will continue to use of no-till, diverse crop rotations, cover crops and rotational grazing to improve my farm. While doing so, I will share what I have learned with others through field days and as a member of the Sauk Soil & Water Improvement Group.” as this is how they see their role in the larger picture of agriculture. “To be a farmer means being a steward of the land. The farm is where your food comes from not the grocery store. Take care of your soil(land) and it will take care of you.”

Bindl Farms Field Specifics

For the project, the farmer has dedicated an area totaling 13.5 acres split between 3 fields. The soil type for the fields is a variety of silt loams, dominated by Jackson silt loam and Toddville silt loams. The fields had not been previously rotationally grazed, however, they had cover crops planted 3 times prior. The winter wheat was drilled at 120 lbs/ac in the fall of 2020. The fields are in a no-till corn-soybean-winter wheat-alfalfa rotation.

Bindl Farms Project Operation

Sampling was conducted on the southern two fields. Roughly one acre of the southernmost field was left ungrazed for the control. The project started in the winter wheat harvest year (summer 2021). Following harvest, the winter wheat was terminated with Round-up herbicide. The cover crop mix, which was created by another farmer in the project and consists of 12 different species, was drilled at 30 lbs/ac on August 12, 2021. There was one grazing event in the fall of 2021 starting on October 20 and finishing on November 13. The 28 head of beef cattle spent roughly one day in each moving paddock. After grazing, the fields were left to rest over winter and were terminated in May using an herbicide.

On May 17, 2022, the corn was planted with 30-inch rows at 27,500 seeds/acre and an herbicide treatment was applied. On June 15, 2022, cover crop was broadcasted at 14 lbs/ac to interseed. The cover crop mix was a combination of med. red clover (Trifolium pratense) and soil builder mix (annual ryegrass (Lolium multiflorum), hairy vetch (Vicia villosa), crimson clover (Trifolium incarnatum), and nitro radish (Raphanus sativus)). With a late and slow start, the farmer felt this field season was below expectations, compared to the previous year. In addition, “Mother Nature just seems to be tougher on us this year." The cover crop was planted later than the farmer had intended, resulting in less growth and a smaller amount of feed than hoped for. "And as far as the interseeding that I tried this year, that was a disaster." The farmer further shared that after broadcasting the cover crop seed, it rained two inches that night. In spite of low cover crop establishment, the fields were grazed following corn harvest. To supplement the lack of cover crop growth, the cattle were given a hay bale each day, half at night. Grazing 28 head started on November 5 and finished on December 19, 2022. Due to blizzarding weather conditions, grazing was finished sooner than hoped for and post-grazing biomass samples were unable to be taken. Adding grazing of cover crops under this project has not impacted the rest of the farm operations, however, it extended his grazing season, a desired outcome.

Agronomics

A cost-savings analysis was conducted through an interview with the Farmer and Sand County Foundation's Field Projects Director, to assess the incurred costs and savings from adding livestock to the cover crop field. In Table 3, the cost of cover crops is listed in addition to all other costs of adding grazing that the farmer considers. The costs and savings that are considered by the farmer but not considered in the calculation of the net cost of adding grazing to cover crops are listed followed by '(not included)' (Table 3). The savings are the opportunity cost of having the cows on the cover crop field rather than in the barnyard. The net is the sum of the total cost (bolded) and the savings.

In year one, fencing for the fields and corner fence posts designed by the farmer were purchased. These specially designed fence posts consisted of a concrete base that was designed to hold a wooden fence post and could be easily transported by his skid steer. These innovative corner posts cost $50 a piece and can be reused and transported around the farm. Water is also a non-value-added consideration by the farmer. The total cost is $114.23/ac. The fields are located directly outside the barnyard where the cattle would otherwise be if not grazing the cover crops. By grazing the farmer saves $2.57/head/day and adjusted to account for the 28 head grazing at $82.24/ac. Table 2 contains the consumption and utilization values of the aboveground biomass. Other benefits that are not calculated in the total savings include the manure value, bedding costs, and a 75% reduction in labor time. Combined the total net is negative $31.99/ac.

Table 3. Year 1 and 2 agronomics ($/ac) at the Bindl Farm. The fencing is only incurred in year 1 as an initial infrastructure cost and will not be in subsequent years. A different cover crop seed mix changes the price from year 1 to year 2. The not included items are considered by the farmer just not monetarily.

Item	Year 1	Year 2
Cover Crop Seed	-34.40	-15.07
Fencing	-79.83	0.00
Water (not included)		
Total Cost ($/ac)	-114.23	-15.07
Savings ($/ac)		
$2.57/head/day	82.24	82.24
Manure value (not included)		
Bedding (not included)		
¼ of the time (not included)		
Soil health benefits (not included)		
Net cost/benefit ($/ac)	-31.99	67.17

However, in year two, the reduction of cover crop seed costs, and with fencing infrastructure already purchased in year one, the farmer maintained a savings of $82.24/ac for a net positive of $67.17/ac. The year two consumption and utilization were not calculated due to early snowfall limiting post-grazing aboveground biomass samples.

Future goals at Bindl Farms

The farmer is continuously looking to improve upon current practices, and one of the main ways is finding ways to keep the cattle on the fields and pastures for as long as possible, to “extend the grazing season”. Thinking about plans for next year, the farmer reported that the chemical program for the weeds was unsuccessful and plans to make adjustments. Despite difficulties with weeds and mother nature, the farmer still plans to continue cover cropping.

Roger Bindl’s Project Feedback

Overall, the farmer is impressed with the project. “Like I said, I was planning on grazing cover crops anyhow, so to get some data now from it is going to make it all that much more worth it.” The time it takes to set up fencing in the beginning is reported as the biggest drawback to this system, however the ease and extension of grazing season outweigh the initial time commitment. “Like I said, just the ease of it. Yep. And then just the, you know, like I said, extending that grazing season out there farther for me. It's just, like I said, that's the whole name of the game.”

Site 3: Ron Bula, Bula’s Pleasant Valley Farm

Bula’s Pleasant Valley Farm Background and Approach

Ron Bula and his family own and operate Bula’s Pleasant Valley Farm in Baraboo, Wisconsin. At their regenerative farm, they raise grass-finished beef and lamb, pasture-raised laying hens, broiler chickens, pigs, and an array of organic produce. The Bula's have experience with rotational grazing and cover crops. Their success after the first year of planting cover crops following winter wheat and "the amount of forage that was produced" got them wondering if it would "Make sense for people that had a row crop rotation to include one year of cover crops for grazing," and "would it make economical sense not only from the grazing benefits, but also from the soil improvement benefits?"

Bula's Pleasant Valley Farm Role in Agriculture

The farmers believe their role in the larger picture of agriculture is to make an impact as a small farm. The farmer stated:

> Look at the impact the Rodale Farm made. They only have a couple hundred acres and everybody knows about them and the research they've done and the changes they've made to agriculture. And maybe we could do that in our area. Where people are seeing this and providing an example and just demonstrating the viability of these systems and how to do them successfully so that other people don't have to overcome those same hurdles that we've run into.

To these farmers being a farmer means, "Maybe just a steward of the land as a placeholder for the next generation. Try to leave it a little better than you found it." In addition, it also means, "providing quality food."

Bula's Pleasant Valley Farm Field Specifics

There were two fields of roughly 14 acres each dedicated to this project. According to the USGS, the soil type of the project area is Toddville silt loam. Both fields had cover crops previously, and both have been grazed previous to the project. The farmer originally assigned one field to be the treatment field that would get grazed, and the second to be the control field that would be left ungrazed. In the fall of 2020, rye was no-till drilled in the treatment field at a rate of 110-120 lbs/ac. The control was planted with a different mix.

Bula's Pleasant Valley Farm Project Operation

At the start of the project, in early May of 2021, the treatment field was grazed for 8 days. All of the cover crops were no-till drilled. The field had between 7 and 10 paddocks, with the southernmost larger than the others due to the location of the water spigot. In mid-May 2021, oats (avena sativa) and clover (Trifolium) were planted into the rye (secalee cereale) in the treatment field, and then it was grazed in late May 2021. On June 20, 2021, the warm season 10-way mix of cover crops, including sorghum-sudangrass (sorghum x drummondii), sunflowers (Helianthus annuus), and millet (Pennisetum glaucum), was planted at a rate of 30-40 lbs/ac, in the treatment field. The farmer shared that "some of the stuff didn't come up" in the 10-way mix. The following day, the same field was grazed by 22 cows (1400 lbs), 10 yearly heifers (900 lbs), and 20 calves (600 lbs). The control field was baled for hay in June and July 2021, producing six 1300 lb bales and thirty and a half 1600 lb bales. The control also was grazed in late summer and in the fall of 2021 due to a drought and a need for the feed. The field was grazed twice in August before planting the cereal rye in September. The sixth and final grazing event of 2021 was in early November.

In year two of the project, the control field was removed from the project as it no longer could be used as a control in comparison, due to grazing in the 2021 season and thus was not sampled in 2022. The treatment field was grazed in mid-May. Solid manure was spread in mid-June, preceding the planting of the warm season cover crop mix on June 15, 2022. On July 12, 2022, the cattle started grazing and the sheep started grazing a day behind the cattle. They finished grazing on July 21 and 22, 2022, respectively. The cattle and sheep started grazing again on August 21 and 22, 2022 and finished grazing on August 28 and 29, 2022 respectively. In the beginning of September, the cover crops were terminated using an herbicide, and winter wheat was planted on September 15, 2022. The farmers reported that compared to years previous, this growing year was busy with all of the plantings and grazing events. The cover crop growth in both years was good but they expected to see more growth in year two. The project allowed the farmers to gain summer forage and save labor and forage costs for their beef cattle.

Agronomics

A cost-savings analysis was conducted through an interview with the Farmer and Sand County Foundation's Field Projects Director, to assess the incurred costs and savings from adding livestock to the cover crop field. In Table 4, the cost of cover crops is listed with all other costs of adding grazing that the farmer considers. The costs and savings that are considered by the farmer but not considered in the calculation of the net cost of adding grazing to cover crops are listed followed by '(not included)' (Table 4). The savings are the opportunity cost of having the livestock on the cover crop field rather than in another pasture. The net is the sum of the total cost (bolded) and the savings.

The fields were located near the center of the farm and minimal transport of the cattle was required. In year one the cover crop seed costs include the two cover crop mixes, totaling $97.83/acre. Planting three times brought a cost of $75.00/ac, for a total cost in year one of $172.83/ac. The average aboveground biomass consumption and utilization are tabulated in Table 2. Other costs that are considered but not calculated in the total cost, are land rent, water, and labor cost of moving the livestock. Other typical costs that were not present in year one are fencing and plant termination. The farmers already had fencing for the project area fields. Termination of the cover crops before planting did not occur during this project timeline, however, the farmers mentioned that in the future they plan to terminate. Since the farmers would have had the livestock on another pasture, the savings are difficult to quantify. The net total is $172.83/ac.

Table 4. Agronomics for year 1 and 2 at the Bula's Pleasant Valley Farm. The difference in seed and planting costs is a result of one less planting in year 2. The not included items are considered by the farmer just not monetarily.

Item	Year 1	Year 2
Cover crop seed	-97.83	-55.00
Planting ($25each)	-75.00	-50.00
Land rent (not included)		
Water (not included)		
Plant termination (not included)		
Fencing (not included)		
Labor livestock (not included)		
Total cost ($/ac)	-172.83	-105.00
Savings ($/ac)		
Different type of pasture*		
Net cost/benefit ($/ac)	-172.83	-105.00

*Difficult to quantify feed value from cover crop field vs other hay pastures. Saved feed from other pastures, more fields that generate feed.

In year two, the treatment field was grazed by both cattle and sheep in a leader-follower system in year two of the project. The cover crop seed cost is $55.00/ac and the cost of planting is $50.00/ac. The total cost is the same as the net cost of $105.00/ac.

Future goals at Bula's Pleasant Valley Farm

The farmers' main takeaway from this year was, "So it worked out. What we've learned is we don't like to use any more chemicals than (sic) we have to. But honestly, when you are planting these relay crops, unless you terminate either through tillage, which we don't do unless we have to, or through chemical means, the more robust weeds are going to overrun your field (sic)."

The farmers also shared that they learned not to do two consecutive years of warm-season cover crop mixes. The farmers' overall goals are to convert more of the farm to grass and increase cattle production and direct marketing their cattle.

Bula's Pleasant Valley Farm's Project Feedback

The farmers reported that this project has been a big learning experience in regard to the cost of not having row crops, the cover crop yield, and the long game for the cattle industry. Extension of the grazing season, forage value, and forage diversity are listed as some of the farmer's top benefits to grazing cover crops. The main drawback that was shared was the excessive time spent planting in the summer for the project.

Site 4: Ron Schoepp, Schoepp Farms

Schoepp Farms Background and Approach

Ron Schoepp co-owns and operates Schoepp farms located near Lake Wisconsin, with help from his family. Schoepp farms grow corn, soybean, wheat, and alfalfa and graze heifers and dry cows. Ron Schoepp is an experienced grazier, switching to rotational grazing in 2006, and grazing cover crops in the past. Further, he has experience with planting cover crops following row crops and interseeding, although his past interseeding efforts have had little success. Something that was new to him was this particular cover crop mix. The ability to extend the grazing season is what appealed to Ron Schoepp about rotational grazing of cover crops.

Schoepp Farms Role in Agriculture

What the farmer sees as his role in agriculture is: “to teach? I’ve been doing this a long time. I got a tape I’m going to take to the university here soon, that’s of when (sic) I was on the news in 1998 and I’m pretty sure I’m saying the same stuff, I’m still saying.” To be a farmer it means that he’s taking care of the earth.

Schoepp Farms Field Specifics

An 18-acre field, made of Dresden loam and Plano silt loam soils, was allocated for the project area. In the northwestern part of the field is a sandy knoll. The field is in a corn-soy-wheat rotation and has had peas (Pisum sativum) and rye (secale cereale) cover crops following corn. The field has been grazed within the last 3 years. The field was no-till drilled at 110 lbs/ac winter wheat in the fall of 2020 prior to project start.

Schoepp Farms Project Operation

On the southern end of the field, 1 acre was left ungrazed for the control. The project started in the winter wheat harvest year and the cover crop was planted on July 31, 2021. The farmer used Round-up to terminate the winter wheat before no-till drilling a 12-species cover crop mix that was curated by another farmer in the project and added barley (Hordeum vulgare), buckwheat (Fagopyrum esculentum), and extra sunflower (Helianthus annuus) at a rate of ~30 lbs/ac. The farmer applied manure from the spring to the project area. The field was grazed once through in non-consecutive days for a total of 15 days between November 4, 2021, and December 25, 2021. The field had a total of 21 paddocks of differing sizes to accommodate the two groups of dairy replacement heifers grazing the field: 106 head of dry cows and springing heifers (1100 lbs average body weight) and 60 head breeding heifers (800 lbs average body weight). The project has allowed the farmer to require less stored feed and less manure handling.

In year 2 of the project, corn was planted roughly around May 15, 2022, at 32,000 seeds/ac. Rather than interseeding, the farmer let the volunteer cover crops from the previous field season establish. Round-up was applied following corn planting "for burning down the cover crops", and was not applied later to allow volunteer buckwheat to grow. Fertilizer was applied a couple of times throughout the season using 4-10-10 liquid, 28% UAN liquid at 8 gallons/ac each at planting, and ammonium sulfate (AMS), and potash were applied as corn was established. While the farmer had hoped to give the field one more application of 28% UAN at 20 gallons/ac, this did not occur due to the corn height being above the machine's clearance. The farmer shared that this season went better than expected. The volunteer cover crops and especially the buckwheat were a concern to reduce the corn yield, however, the corn yield was not impacted with the exception of the sandy knolls. Due to weather conditions and early snowfall, grazing did not occur in year two fall, but the farmer hopes to graze in the following spring. Overall, the farmer thinks that this season is similar to other seasons due to the amount of variability in farming. The farmer reported that the cover crop growth would have been good to graze, however, it was too wet to graze.

Agronomics

A cost-savings analysis was conducted through an interview with the Farmer and Sand County Foundation's Field Projects Director, to assess the incurred costs and savings from adding livestock to the cover crop field. In Table 5, the cost of cover crops is listed with all other costs of adding grazing that the farmer considers.

Table 5. Agronomics for year 1 ($/ac) at Schoepp Farms. The seed and planting costs in year 2 is zero because the farmer let volunteer cover crops grow in. In year 2 there was also no grazing and so the savings of having the cattle elsewhere is also zero. The not included items are considered by the farmer just not monetarily.

Item	Year 1	Year 2
Cover crop seed	-45.00	0.00
No-till planting	-15.00	0.00
Labor and management (not included)		
Mineral supplement (not included)	-20.00	-20.00
Ear corn (5 lbs/head/day) (not included)	-47.00	-47.00
Fencing (not included)		
Wind breaks (not included)		
Forage nutrient removal (not included)		
Total costs ($/ac)	-60.00	0.00
Savings ($/ac)		
$2.30/head/day	251.00	0.00
Manure nutrient credits/soil health (not included)		
Yield increase to following crops (not included)		
Net cost/benefit ($/ac)	191.00	0.00

The costs and savings that are considered by the farmer but not considered in the calculation of the net cost of adding grazing to cover crops are listed followed by '(not included)' (Table 5). The savings are the opportunity cost of having the cows on the cover crop field rather than in the lot. The net is the sum of the total cost (bolded) and the savings to show the ability of grazing to offset the costs of cover crops.

In year one, the cover crop seed cost $45.00/ac and the no-till planting cost of $15.00/ac were the total costs considered by the farmer to total $60.00. Although there are other costs associated, the farmer considered these to be a part of the daily chores to be done regardless. The daily chores included walking the cattle back once a day for mineral supplements, ear corn grains, and water. Fencing is also grouped with these costs but since the farmer purchased fencing previous to the project, it is not an initial cost for this farmer. For this project, the cattle grazed non-consecutive days and the number of head in a paddock varied, a breakdown is shown in Table 6. The aboveground biomass consumption and utilization by the cattle are included in Table 2. In the field, the cattle were protected with windbreaks positioned with one field in between. Year one's net total is a savings of $191.00/ac.

Table 6. Grazing days and number of head per paddock acreage.

Date	Number of Head	Paddock Acres
11/4/2021	106	0.95
11/17/2021	106	0.71
11/18/2021	106	0.71
11/19/2021	60	0.48
	106	0.83
11/23/2021	60	0.48
	106	0.95
12/1/2021	60	0.48
	106	0.95
12/2/2021	60	0.48
	106	0.95
12/3/2021	60	0.48
12/8/2021	106	0.95
12/17/2021	106	0.95
12/18/2021	106	1.18
12/19/021	60	0.71
	106	1.18
12/21/2021	106	0.71
12/23/2021	60	0.71
	106	1.42
12/25/2021	106	1.18

In year two, the farmer let the volunteer cover crops from the previous year grow and did not replant any cover crop seed, resulting in a cover crop seed cost of zero. The farmer planned to harvest ear corn which requires a lower moisture content to harvest and thus delaying the harvest. Combined with the early snowfall, the field was not grazed following the corn harvest, resulting in the previous year's savings return to a business-as-usual cost of $251.00/ac. The net total for year two is zero.

Future goals at Schoepp Farms

In the future, the farmer plans to change the nitrogen application to a variable rate to make sure the sand knolls can get enough fertilizer. The farmer would still graze the corn residue without cover crops but not graze the winter wheat residue. The farmer relayed that his goals are “to teach other people or give them ideas.”

Schoepp Farms’ Project Feedback

The farmer is pleased with how the project is going, “met a lot of people.” The farmer shared that he likes that he can see the benefit of grazing cover crops, and that it is cheap feed and improves the biological soil health. When asked what his least favorite part of grazing cover crops the farmer responded “Do I have to have one? I don’t have a drawback to it.”

Cross-site results

Agronomics

‘Only one farm had a net negative return to cover cropping in both years (Site 3), while the other 3 farms had mixed results (Table 7). Schoepp Farms was positive or breakeven in both years, while the other two farms had one net positive year and one net negative year.

Table 7. Net profitability for grazed cover crops on four farms ($/ac).

Site	Year 1	Year 2
1 (Echo-Y Farms)	49.19	-53.00
2 (Bindl Farm)	-31.99	67.17
3 (Bula Pleasant Valley Farm)	-172.83	-105.00
4 (Schoepp Farms)	191.00	0.00

Plants

Year-1 post-grazing aboveground plant cover was reduced by roughly 50% compared to the ungrazed control field at the same time at 3 of the 4 sites (Figure 1A). Site 2 had the largest reduction of the three sites (54.4%), while at Site 1 grazing reduced plant cover by an ~49.6%. At Site 4, there was a 10% reduction in plant cover, which was quite low overall without grazing. This comparison could not be made for Site 3 because the farmer decided to graze what was to be the ungrazed plot, but in Year 2 plant cover at Site 3 in the cover crop grazed field was ~85% (Figure 1B).

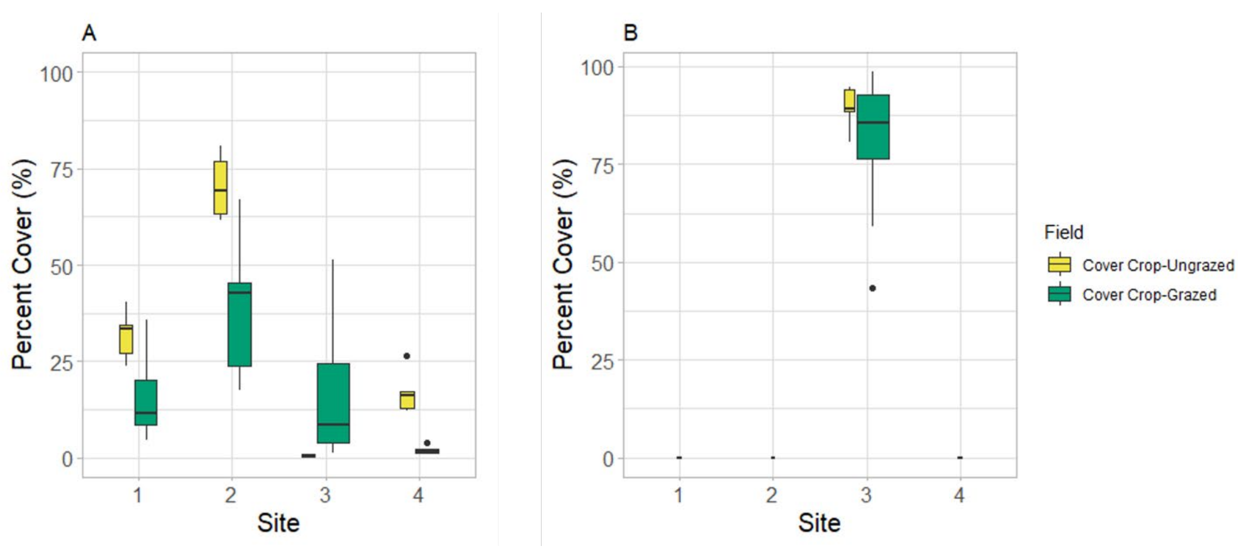

Figure 1. Post grazing plant cover A) Year 1 B) Year 2 (no grazing occurred at sites 1,2, and 4 in year 2). This shows the four sites along the x-axis and percent plant cover on the y-axis. The paired fields cover crop grazed and cover crop ungrazed for each site are also shown. In B) site 3 was the only site to obtain data due to no grazing (sites 1 and 4) or weather events (site 2).

Soils

Bulk density before grazing occurred ranged from 1.23 to 1.44 g/cm^3 across all sites (Figure 2A). Following grazing, bulk density ranges from 1.17to 1.47 g/cm^3 (Figure 2B). Grazing did not have any obvious effects on soil bulk density as post grazing values ranged from 1.17to 1.47 g/cm^3 (Figure 2). The grazed fields at all sites and the ungrazed field at site 2 show a decrease in the average bulk density while the ungrazed fields at sites 1 and 4 show an increase in the average bulk density within each farm (Table 8).

Table 8. Differences in bulk density after grazing treatment.

Site	Grazed	Ungrazed
1 (Echo-Y Farms)	-0.02	0.04
2 (Bindl Farm)	-0.12	-0.12
3 (Bula Pleasant Valley Farm)	-0.05	
4 (Schoepp Farms)	-0.03	0.04

While ammonium-N at 55 to 60 cm depth before and after grazing had similar magnitudes, the values were lower in year two after grazing. Ammonium-N before grazing was similar across all four sites with a range between 10.67 and 20.13 ppm (Figure 3A). After grazing the ammonium-N was more variable from site to site ranging from 4.3 to 15.92 ppm (Figure 3B). Nitrate-N in year one before grazing at all four sites hovers around the 2 ppm with a range of 0.79 to 3.25 ppm (Figure 3C, Figure 4). After grazing in year two, there was more variability across the four sites with a range of 0.16 to 86.21 ppm (Figure 3D). Total N as a percent by mass in year one for 0 to 15-cm depth, before grazing ranged from 0.14 to 0.27% (Figure 5A). In year two, after grazing in the 0 to 15-cm depth, total N as percent by mass ranged from 0.13 to 0.24% (Figure 5B).

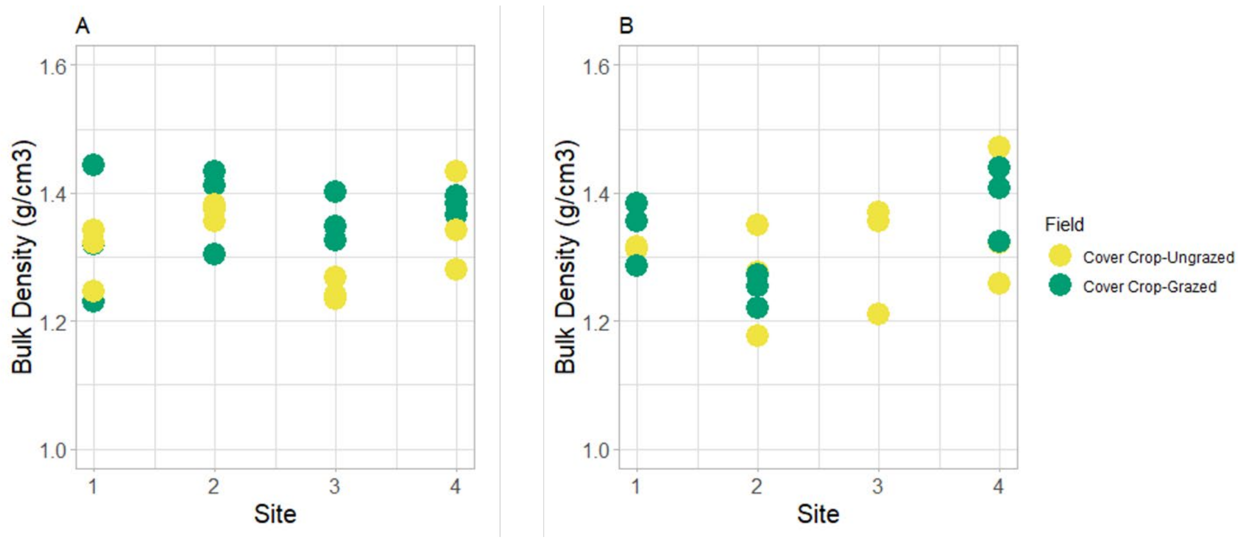

Figure 2. Bulk density 0-6 inches A) before grazing B) after grazing. The four sites are plotted along the x-axis and the bulk density on the y-axis, with the paired cover crop grazed and cover crop ungrazed fields shown.

Total C as a percent by mass in year one before grazing in the 0 to 15-cm surface soil ranged from 1.48 to 3.02% (Figure 6A). In year 2 following grazing in the surface 0 to15-cm, total C ranged from 1.38 to 2.91% (Figure 6B). Permanganate oxidizable carbon (POxC) in the surface depth (0 to15 cm) in year 1 before grazing ranged from 441.9 mg oxidizable carbon/kg soil to 937.2 mg oxidizable carbon/kg soil (Figure 7A). In year 2 following grazing, POxC ranged from 450.7 mg oxidizable carbon/kg soil to 906.7 mg oxidizable carbon/kg soil (Figure 7B).

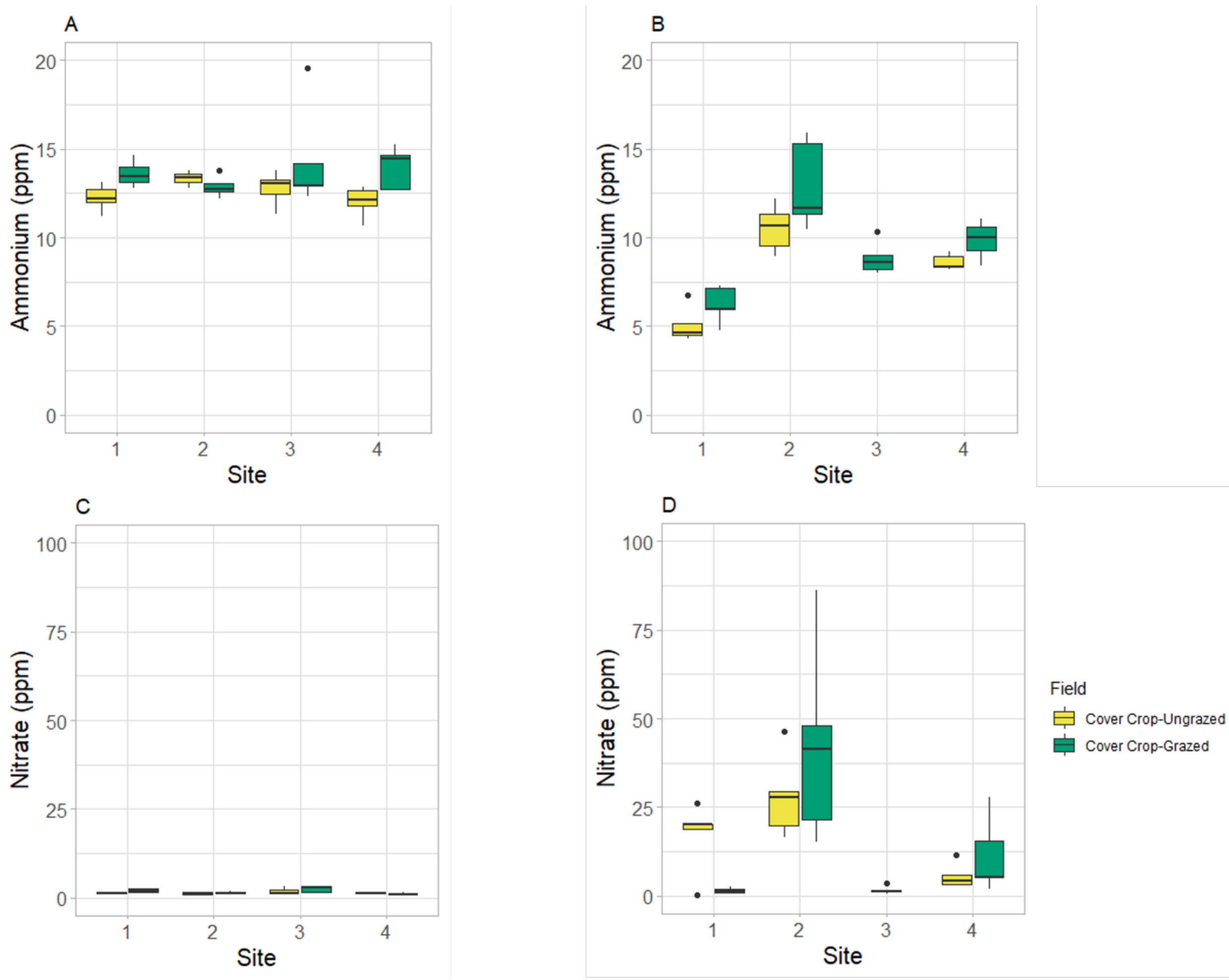

Figure 3. Nitrogen at 55-60 cm A) ammonium-N in year 1 before grazing, B) ammonium-N in year 2 after grazing, C) nitrate-N in year 1 before grazing, and D) nitrate-N in year 2 after grazing. The four sites are plotted along the x-axis and the Ammonium-N (A and B) or the Nitrate-N (C and D) on the y-axis, with the paired cover crop grazed and cover crop ungrazed fields shown.

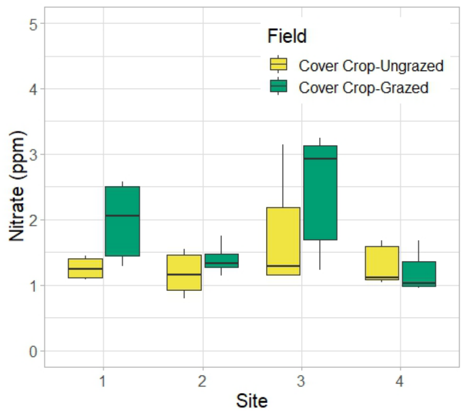

Figure 4. Nitrate-N in year one before grazing.(Y-axis scale 0-5 ppm). The four sites are plotted along the x-axis and the Nitrate-N on the y-axis, with the paired cover crop grazed and cover crop ungrazed fields shown.

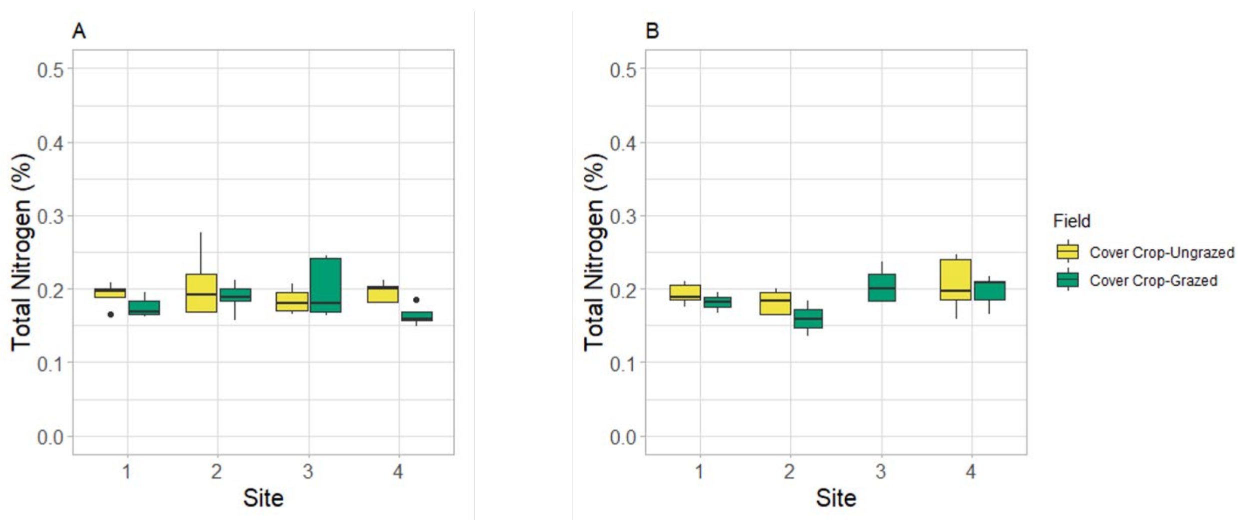

Figure 5. Total N as percent in 0-15 cm A) Year 1 before grazing and B) Year 2 after grazing. The four sites are plotted along the x-axis and the total N on the y-axis, with the paired cover crop grazed and cover crop ungrazed fields shown.

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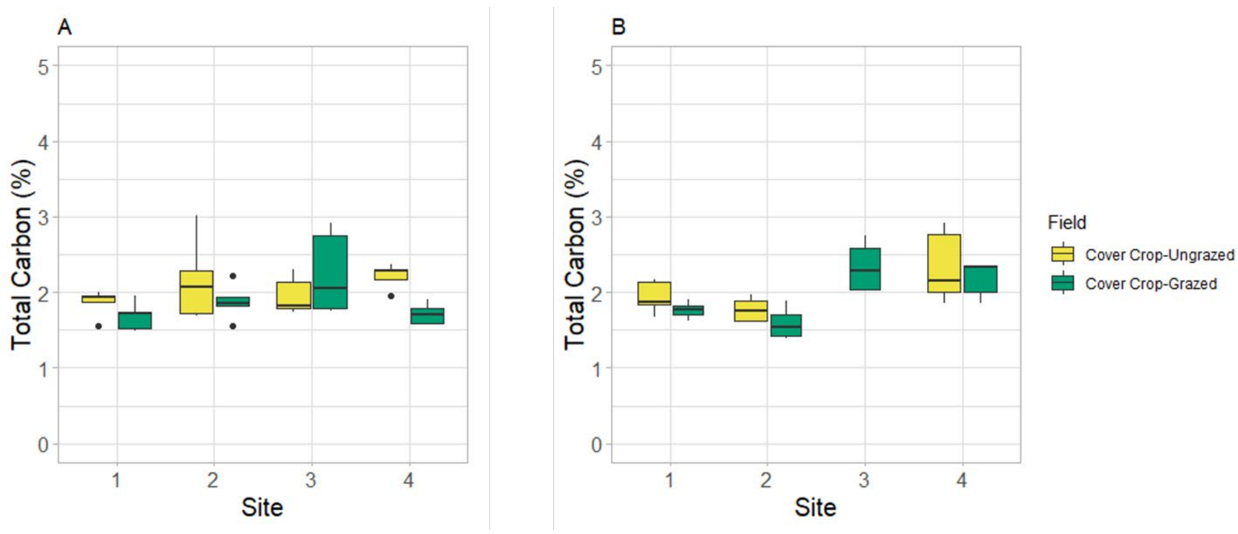

Figure 6. Total C as percent in 0-15 cm A) Year 1 before grazing and B) Year 2 after grazing. The four sites are plotted along the x-axis and the total C on the y-axis, with the paired cover crop grazed and cover crop ungrazed fields shown.

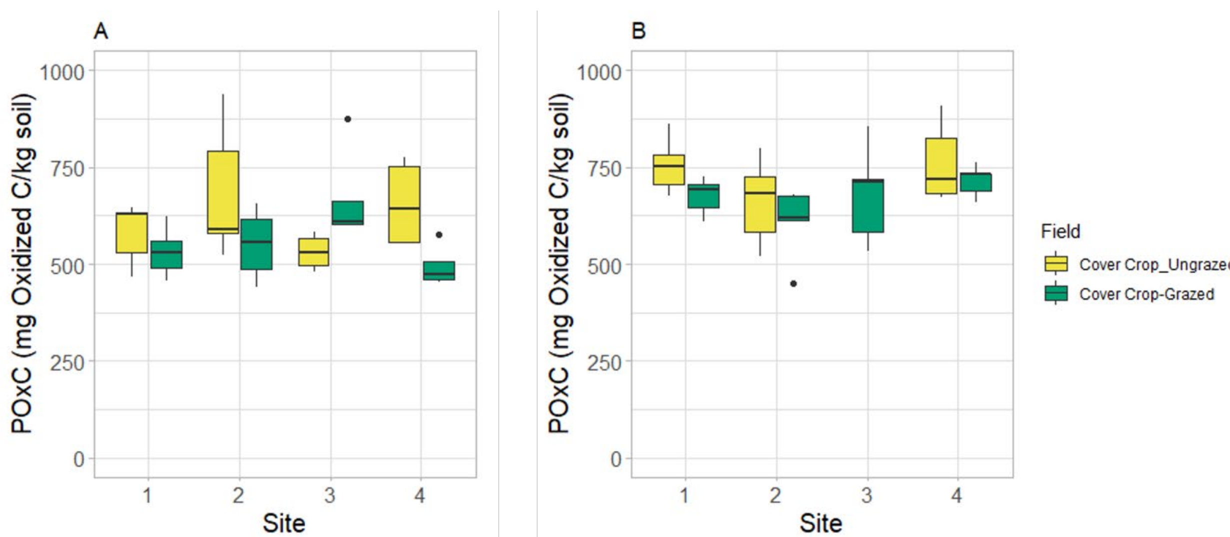

Figure 7. POxC in 0-15 cm A) Year 1 before grazing and B) Year 2 after grazing. The four sites are plotted along the x-axis and the active C as POxC on the y-axis, with the paired cover crop grazed and cover crop ungrazed fields shown.

Discussion

Rotationally grazing cover crops can counterbalance and even exceed the costs of the cover crops, but the cover crops must establish well for grazing to be an option. In the upper Midwest, the success of cover crop establishment is risky (Cates et al. 2018). The ability of rotational grazing of cover crops to offset a farmer's cover crop seed costs is dependent on many variables including extant livestock, fencing, watering, and logistics associated with livestock movement. The opportunity costs and rotational grazing infrastructure start-up costs such as fencing can be an indicator of whether a farmer realizes a net positive return on the cover crop allotment of their enterprise. If a farmer is moving livestock from a barn or bunker, where there are feed and labor costs, to rotationally graze a cover crop field near the barn that is already equipped with fencing and water, the farmer will save those costs of labor and feed and likely be able to offset the cover crop seed costs, such as at site 2 did in year two, or site 4 in year one. However, in year one, site 2 had a net negative return on cover crops because the initial fencing infrastructure costs were relatively high. Without an opportunity cost to offset, there is not much opportunity for revenue to cover the cover crop seed cost, as observed at Site 3.

These factors are also dependent on cover crop establishment and growth. While the cover crop growth in year one following winter wheat was plentiful, the lack of cover crop growth in year two interseeded into corn aligns with the finding that establishment in the upper midwest can be risky provided by Cates et al. 2018. Site 1 lacked these infrastructure costs in year one resulting in a net positive at the end of the season, but in year two with barely any cover crop establishment and they lacked proximity to the barn, deemed it unworthy of grazing and incurred the cost of the cover crop seed and the cost of feeding the livestock elsewhere. If a farmer can minimize the cover crop seed costs or even eliminate it by allowing volunteer cover crops, as done at site 4 in year two, especially in unpredictable cover crop years, can bring your net value to zero even if grazing does not occur. While Plastina et al., 2020 found that most of their farmer participants had net negative returns, we found that roughly half were net negative, just under half were net positive, and one breakeven. This was a learning opportunity for all involved, and with more practice and research on cover crop establishment and with initial infrastructure costs out of the way, there is potential for future net positives. Despite findings of Brooker et al. (2020), our farmers reported that early spring precipitation hindered cover crop establishment and growth. This difference could be explained by the timing and quantity of rainfall.

A 50% reduction in cover-crop plant cover as a result of grazing, from plant cover levels that were relatively low already, was concerning. If grazing cover crops significantly reduces green plant cover heading into the winter months when soils desperately need protection, the conservation value of the cover crops may be undermined. However, the soil health parameters we measured, which were chosen because they are believed to be sensitive early indicators of soil health change, indicated that grazing had little impact on soils. Instead, the potentially leachable nitrate-N data implied that the main crop type, in particular land put into corn, was the primary driver for increases in potentially leachable nitrate-N, which aligns with observations of others (Brye et al. 2001; Hussain et al. 2019; Jackson 2020).

Wisconsin can have a risky climate to grow cover crops and while grazing reduced cover by roughly 50% across all four sites, crop type posed a more negative response to the soil health parameters measured than grazing. Aligning with the literature (Elhakeem et al., 2023), cover crops can help mitigate the negative impacts of planting cash crops. Our farmers echoed this sentiment when collating and developing cost/savings tables; all identified *soil health* as a factor that is not captured monetarily. The minimal negative response in soil health parameters as a result of grazing may also be attributed to this project was not the first time the farmers have planted cover crops or implemented conservation practices, such as “take half/leave half”.

Even with half as much cover, soil response variables generally experienced little change in the short-term, but more long-term monitoring and data is needed to understand how cover crop grazing affects the efficacy of cover crops under a range of interactions between the main crop, cover crop, grazing management, and environment. With little measured change in compaction, other sensitive indicators of soil health such as the readily available carbon (Malone et al. 2023), plant available nitrogen, and potentially leachable nitrogen, between the ungrazed cover crop fields and the grazed cover crop fields also indicated that grazing had no short-term negative impacts. That said, a meta-analysis found that compared to no grazing, rotational grazing can increase the soil bulk density, and when compared to continuous grazing, rotational grazing can decrease soil bulk density and SOC (Byrnes et al. 2018), but this work was not specific to grazing of cover crops. These comparisons are limited by the wide range of grazing strategies. Similarly, our study was limited to the variance in grazing strategies employed by the four farmers, which were not only different from farm to farm, but also varied within a farm from one season to the next.

Indeed, rather than negative soil responses, we observed some increases in labile carbon pools (POxC), which may point to SOC increase under grazed cover crops in the long-term, but this remains an untested hypothesis. Recent work by Augarten et al. (2023) indicated that the only way to improve soil health indicators in Wisconsin agroecosystems was via perennialization (i.e., cover crops and no-tillage) and livestock integration (i.e., manure return and grazing), results that aligned with Becker et al. (2022), Sanford et al. (2022), and Sanford et al. (2012). But, of all these soil health interventions, only grazed pastures resulted in significantly greater soil organic matter. Whether these effects might be translated to grazing of cover crops in grain systems is an open question, especially if the grain systems receive periodic soil disturbance.

Decreases in ammonium-N and increases in nitrate-N at the three sites that planted corn in year two following winter wheat in year one, while at Site 3 had little to no change between years who only planted cover crop mixes, suggests that planting corn and interseeding cover crops can hinder the soil's ability to hold onto nutrients. But this interpretation is limited by the lack of cover crop establishment and growth in year two by the three sites that interseeded corn.

Conclusions

Our work demonstrated how real-world vagaries of cover crop establishment make it a risky proposition for grain farmers of the upper Midwest. Rotational grazing of cover crops in row crop operations of southern Wisconsin reduced plant cover, but maintained and sometimes improved sensitive soil health indicators, while sometimes offsetting cover crop seed costs. Growing cover crops in Wisconsin has many challenges including establishment, growth, and economic viability. But, if cover crops establish well and a farmer has existing infrastructure to facilitate rotational grazing management, risks seem lower that cover crops will not pay for themselves in short-term financial return. The long-term effects of cover crop returns on investment and how grazing influences these returns by influencing soil health, main crop yields, environmental performance, and livestock revenue streams remains to be studied.

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Appendix

Timeline

Date	Site 1	Site 2	Site 3	Site 4
Fall 2020			Planted rye	
4/27/21			Mercedes sampled biomass treatment field	
5/1/21			Grazing started	
5/04/21			Mercedes sampled biomass treatment field	
5/8/21			Grazing finished	
			Planted oats and clover into rye	
5/20/21			Grazing started	
5/24/21			Grazing finished	
6/3/2021			Baled six 1300lb bales	
6/20/21			Planted warm season mix: sorghum, millet, 10 way mix	
6/21/21			Grazing started	
6/26/21			Grazing finished	
July	Harvest	Harvest		Harvest

	Herbicide application			
	Chicken litter application			
7/08/2021			Mercedes and Carly sampled biomass in control field	
7/15/2021			Baled 30.5 bales each 1600 lb	
7/25/2021	Cover crop planted			
8/2/21			Grazing started	
8/9/21			Grazing finished	
8/12/2021		Cover crop planted		
End of august				Cover crop planted
8/29/21			Grazing started	
9/7/21			Grazing finished	
			Cereal rye planted	
9/14/2021	Bulk Density taken			
9/15/2021	Bulk density & Pregrazing biomass taken			
9/21/2021	Grazing started			
9/22/2021		Bulk density taken		

9/29/221		Bulk density taken		
10/12/2021			Bulk density taken in treatment field	
10/14/2021				Bulk density taken
10/15/2021			Deep cores taken	Deep cores taken
10/18/2021		Pregrazing biomass taken		
10/20/2021		Grazing started		
10/22/2021	Deep cores taken	Deep cores taken		
10/29/2021			Bulk density taken in control field	
11/04/2021			Grazing started in treatment field	Grazing started & pregrazing biomass taken
11/05/2021	Grazing finished		Pregrazing biomass taken	
11/13/21		Grazing finished		
11/15/21			Grazing finished	
11/17/2021		Post grazing biomass taken		
11/19/2021	Postgrazing biomass taken			
12/21/2021				Post grazing biomass taken
12/22/2021			Post grazing biomass taken	

4/20/2022			Ow biomass taken	Ow biomass taken
4/27/2022	Ow biomass taken	Ow biomass taken		
May	Spray off cc	Spray off cc		
5/13/2022	Planted corn			
5/14/2022			Started grazing	
5/17/2022		Planted corn	Pre graze biomass taken (C1G north true pre graze)	
				Planted corn green into volunteer cover crops
5/18/2022	Chemical application			
5/20/2022			Finished grazing	
5/23/2022			Post graze biomass taken	
6/1/2022			Cut ryelage (and 'control' field hay)	
6/6/2022	Started processing			

	deep cores (yr1)			
6/14/2022	interseeded CC.	Started processing deep cores (yr1)		
			Spread manure	
6/15/2022		Interseeded CC	Planted warm season mix	
6/21/2022	Finished processing deep cores (yr1)			
6/22/2022				Started processing deep cores (yr1)
6/27/2022			Started processing deep cores (yr1)	
6/28/2022		Finished processing deep cores (yr1)		
6/29/2022				Finished processing deep cores (yr1)
7/6/2022	Brix Cider Science talk	Brix Cider Science talk	Brix Cider Science talk	Brix Cider Science talk

7/12/2022			Started grazing cattle (cut 'control' field for hay)	
7/13/2022			Started grazing sheep	
7/18/2022	Samples prepared for TC/TN	Samples prepared for TC/TN	Samples prepared for TC/TN	Samples prepared for TC/TN
7/20/2022	Ground biomass (yr1)		Finished processing deep cores (yr1) Ground biomass (yr1)	
7/21/2022	Ground biomass (yr1)	Ground biomass (yr1)		
7/21/2022			Finished grazing cattle	
7/22/2022			Finished grazing sheep	
7/28/2022			Ground biomass (yr1)	Ground biomass (yr1)
7/29/2022			Ground biomass (yr1)	
8/9/2022	Ground biomass (yr1)			

8/18/2022		Ground biomass (yr1)		
8/19/2022				Ground biomass (yr1)
8/21/2022			Started grazing cattle (and cut ‘control’ field for hay)	
8/22/2022			Started grazing sheep	
8/23/2022			Pre graze biomass taken	
8/28/2022			Finished grazing cattle	
8/29/2022			Finished grazing sheep Post graze taken and bulk density	
8/30/2022			Deep soil cores taken	
September			Spray off cover crop	
9/15/2022			Plant winter wheat	
10/6/2022	Agronomic data collected	Agronomic data collected		

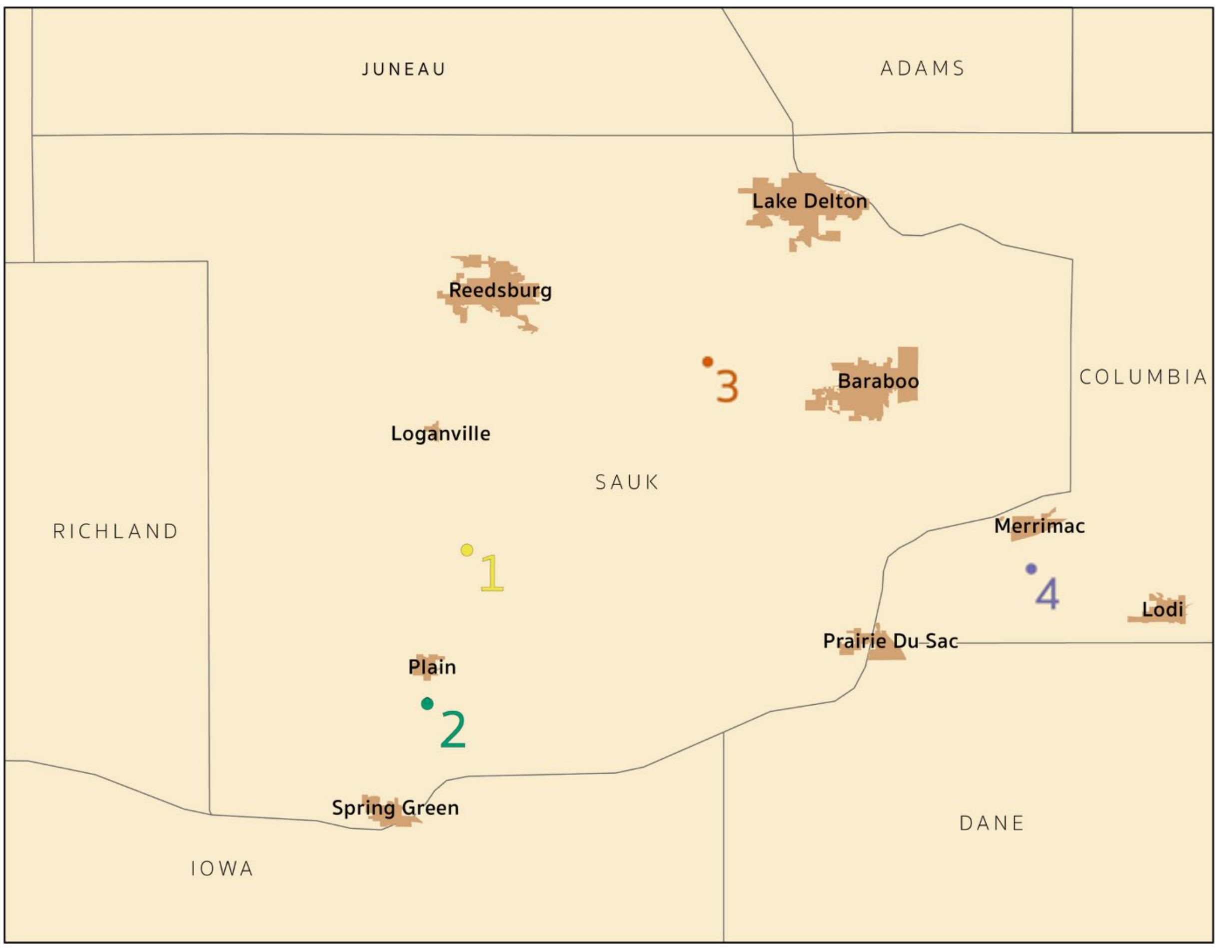
10/16/2022	Harvested corn			
10/20/2022		Pasture walk		
10/24/2022	Planted rye CC			
10/25/2022	Bulk density samples collected (yr2)			
11/1/2022		Harvest corn		
11/3/2022		Bulk density and pre graze biomass samples collected (yr2)		
11/5/2022		Started grazing		
11/9/2022	Tri societies Poster session	Tri societies Poster session	Tri societies Poster session	Tri societies Poster session
11/14/2022				Harvested part of the corn
11/17/2022				Bulk density and pre graze biomass samples collected (yr2)
11/21/2022	Deep cores collected (yr2)	Deep cores collected (yr2)		
11/22/2022				Harvested part of the corn

11/23/2022				Deep cores collected (yr2)
12/19/2022		Finished grazing		
12/21/2022		Fields were pictured to characterize field cover with snow		Fields were pictured to characterize field cover with snow
1/26/2023	Started processing deep cores (yr2)			
3/14/2023		Started processing surface depths (y2)		
3/16/2023		Finished surface depths (y2)		Started processing surface depths (y2)
3/21/2023			Started processing surface depths (y2) Finished surface depths (y2)	Finished surface depths (y2)
3/21/2023	Continued processing the soil cores (y2)			

3/30/2023	Started POxC prep	Started POxC prep	Started POxC prep	Started POxC prep
4/11/2023	POxC started and finished (y1)	POxC started (y1)		
4/14/2023		Continued processing the soil cores (y2)		
4/19/2023	Finished processing deep cores (y2)	POxC finished (y1)		POxC started (y1)
4/25/2023			POxC started (y1)	POxC finished (y1)
4/20/2023				Continued processing soil cores (y2)
4/26/2023		Finished processing deep cores (y2)	Continued processing soil cores (y2)	
4/27/2023	POxC started (y2)		POxC finished (y1)	
4/28/2023	POxC finished (y2)	POxC started (y2)		
5/1/2023		POxC finished (y2)		Finished processing deep cores (y2) POxC started (y2)

5/2/2023			Finished processing deep cores (y2) POxC started and finished (y2)	POxC finished (y2)

Figure_. Map of Sauk County, with the site locations and the major nearby cities. Map created by Randi Selvey.



Questionnaire:

SARE On to Greener Pastures Project

Fall 2022 Farmer Interviews

Farmer:

Interviewers: Greg Olson- Sand County Foundation, Field Projects Director

Carly Huggins- UW-Madison, Agroecology MS Grad Student

Date/Time:

What is your take on hoe this season has went overall? Compared to last season?

What is your take on how the cover crop growth and possible grazing value is this year? Versus last yer?

What might you do differently in the future based on this year? Last year?

Overall, how do you think the project is going?

Carly-Data sheet fill in questions? Refer to data sheet.

How has adding the grazing of cover crops under this project effect the rest of your farming system/operation?

What do you want to know about your forage? RFO, TC, TN, etc.?

Would you prefer that data be displayed in papers/presentation in a private manner? (Example site id with no name and just general location.)

What aspects of rotational grazing of cover crops and just cover cropping in general got you trying this system?

If you were not grazing the cover crops, would you still put them in? If so, why do you think is their benefit beyond the feed?

So far, what if your favorite thing about grazing of cover crops?

What is your least favorite thing about grazing cover crops?

Anything that you would like to add?

What are your overall goals for your farm operation and management?

What do you see is your role in the larger picture of agriculture?

What does it meant to you to be a farmer?

Data Sheet:

	Site 1:Yanke	Site 2: Bindl	Site 3: Bula	Site 4: Schoepp
Treatment Field (ac)	50 (total)	13.5 (3 fields samples in southern 2)	14	17 (18 total)
Control Field (ac)	West of culvert	~1	14	~1
Paddock system style	moving	moving	moving	moving
# of Paddocks	10		7-10	21
Paddock Area (ac)	5			
Soil Type				
2021				
Previously Grazed?	yes	no	yes	Yes within 3 years
Previously CC?	yes	Yes, 3x	yes	Yes rye for corn and peas
Control Previously grazed?	yes	no	yes	yes
Cash Crop	Winter wheat	Winter wheat	Cover crop	Winter wheat
Drilled, broadcast	drilled	drilled	No-till drill	no -till drill
Planting rate	160 lbs/ac	120lbs/ac		110lbs/ac
Cover Crop	Custom mix, outer edge different mix	Darrens mix	3 different mixes, warm season, relay crops	Darren’s mix with barley, buckwheat, and extra sunflower
drilled , broadcast	drilled	drilled	Drilled, all	No-till drilled

Planting rate	30lbs/ac	30 lbs/ac	Variable to mix: rye:110-120lbs/ac, sorghum/10 way mix:30-40lbs/ac	Little over 30lbs/ac
Cover Crop Planting date	7/25/2021	8/12/2021	6/20/2021,	7/31/21
Grazing Start date	9/21/2021	10/20/2021	11/04//2021	11/04/2021
Grazing end date	Before 11/19/2021	Before 11/17/2021	Before 12/22/2021	Before 12/21/2022
Days/paddock	~1-2	~1	~1 except ~2 days on the first paddock due to size because of water spigot	~1
# head	70 @ 1000 lbs	28	22 cows (1400lbs), 10 yearly heifers (900lbs), 20 calves (600lbs)	106 dry cow @1100, 60 breeding @80
# grazing events	1	1	6	1 non consecutive days
Rest period	na	na		na
Fertilizer Treatments	Chicken litter after winter wheat before CC		Spread manure	Yes had manure to hall from spring
Herbicide Treatments	Harvest, take grain for straw first	Spray wheat (husky)	no	Roundup before CC
CC seed cost	1560.80	481.64 (44$/ac?)		1045.40
Feed cost				Grain
Fertilizer cost	Time costs, lack of permanent			

	fencing, getting cattle			
Operating cost	3ppl, 2 trailers, 2 trucks			
Fencing cost	Cross fencing=510.60, about the same for perimeter fencing, also 12 volt energizer, polypro fence post every 33’	Corners $50/piece		
Water supply cost	No hauling water	na	Get spreadsheet from Patrick	
Cattle Income				
Feed savings		$2.57/day/head		
Other Income		Manure value, bedding savings, ¼ of the time		
Other notes			Baled 6 1300lb bales on 6/3//2021; 30.5 1600lb bales on 7/15/2021	Wind breaks for winter, walk back for water 2x/day also get grain
2022				
Cash Crop	corn	corn	Cover crop	corn
Plant date	5/13/2022	5/17/22	na	5/15/22 (probably)
Drilled, broadcast	Corn planter	Corn planter	na	No-till planter
Planting rate	24 rows of 60” corn, planter set to 45,000 but only got 42,000, divide in half since only half the rows and 21,500 is actual seeds/acre. 12	30”, 27,500 seeds/ac		32000 seeds/ac

	rows at 30” at 21,500 seeds/acre. 12 rows at 30” at normal 33,000 seeds/acre. Update from plant counts the 60” is 40,000 seeds/acre, planted thick and had a miscalculation and trouble with the monitor.			
Cover Crop	Custom mix	Red clover+Soil builder: Annual ryegrass, hairy vetch, crimson clover, nitro radish	Get from Patrick/Greg	Nothing all volunteer from last year, a lot of buckwheat in June
drilled , broadcast	Broadcast with mounted spinner spreader at 30’.but breezy so could be heavier.	broadcast	drill	
Planting rate	20lbs/ac	14lbs/ac	patrick?	na
Cover Crop Planting date	6/14/2022	6/15/2022	Check timeline	
Grazing Start date	Cover crop didn’t come through. No Grazing	Check notebook/texts/Check timeline	Check timeline	Hopefully next month (as of 3/30/23)
Grazing end date	na	Check timeline	Check timeline	
Days/paddock				
# head		28		

# grazing events				
Rest period				
Fertilizer Treatments	Chicken litter possibly			8gallon/ac 4-10-10 liquid, 8gal/ac 28% UAN liquid, went in with the planter; ammonium sulfate (AMS), potash, shouldve gotten 1 more application of 20 gal/ac 28% UAN but didn't
Herbicide Treatments	Chemical treatment 27 days before interseeding			Round up
CC seed cost		Check picture in shared google drive		
Feed cost				
Fertilizer cost				
Operating cost				
Fencing cost				
Water supply cost				
Cattle Income				
Other Income				

Feed savings	Had previous success with interseeding	Maybe?check with Greg		Have interseeded before w/ poor success, too much canopy