IMPORTANCE OF SITE PREPARATION AND PRESCRIBED FIRE ON TALLGRASS PRAIRIE RECONSTRUCTIONS

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Land Resources and Environmental Sciences

MONTANA STATE UNIVERSITY
Bozeman, Montana

December 2025 ETD is accepted by Grad School

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to the Shakopee Mdewakanton Sioux Community, the Natural Resources Department, and Ferin Davis Anderson for their support, collaboration, and commitment to this project and my continuing education. I am especially thankful to the Dream Team for their plant identification skills, insight, and excellent teamwork every day at work, I'm appreciative of having such wonderful people to work with. I would also like to extend a special thanks to Sam Swanson for his invaluable assistance with R coding and data analysis, and to Erin Teichroew for her thoughtful edits and guidance with statistical analyses and testing. Their expertise and support greatly improved the quality of this work.

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ABSTRACT

Prairie ecosystems have experienced dramatic declines in species diversity due to habitat loss, the introduction of invasive species, and the suppression of fire. Historically, fire was a key ecological process in shaping the tallgrass prairie, promoting the dominance of native grasses and forbs while preventing the spread of woody vegetation. Without fire, many prairies shift toward lower biodiversity, with invasive plants such as smooth brome *(Bromus inermis*) and Kentucky bluegrass *(Poa pratensis*) outcompeting native species like big bluestem *(Andropogon gerardii)* and Indian grass *(Sorghastrum nutans)*. My study addresses the importance of site preparation in prairie reconstructions, and how fire can be used to maintain these ecosystems and reduce non-native species abundance. I analyzed field data from prairie reconstructions on the Shakopee Mdewakanton Sioux Community land. Vegetation surveys were conducted on prairies where prescribed fire was used as a management tool. Total number of species and their abundance were recorded before and after the burn to compare native species regeneration and changes in diversity. These data were compared against prairies where no management took place between vegetation surveys. Species richness and alpha diversity were stable or slightly declined in the unburned prairies and increased in the burned prairies. Contrary to expectations, the percentage of native species decreased moderately in both the burned and unburned prairies. This pattern suggests that something beyond the fire treatment is shaping community composition, possibly drought stress, pressure from disturbance-tolerant species, or larger landscape-level shifts that neither treatment could fully counteract. A similar trend appears in the changes in overall plant height, reinforcing the idea that broader environmental factors were likely driving vegetation responses during this period.

INTRODUCTION

Historically, the Midwest consisted of tall- and short grass prairie with extensive areas of wet meadows. There were 97.1 million hectares of tallgrass prairie pre-European settlement, with less than 3% of that original habitat remaining today (Smith et al. 2010). This loss of habitat, and consequently biodiversity, is being observed, not only in prairie ecosystems, but across all differing habitats. Biodiversity is essential for maintaining ecosystem services (Enkhtur et al. 2021). Therefore, restoration of these prairie ecosystems is critical for increased carbon storage, improved water quality, and increased biodiversity (Woosaree and Otfinowski 2018). Prairie vegetation reduces soil loss and increases wildlife habitat (Khanal et al. 2022). Efforts are underway across North America to reconnect these ecosystems through prairie restoration/reconstruction work and maintenance (Gerla et al. 2012). Before European settlement in the United States, the primary processes that maintained the health of prairie ecosystems was fire (natural and anthropogenic) and grazing by bison herds (Smith et al. 2010).

Today the continued health of remnant prairies (prairies which have never been tilled), restored and reconstructed prairies depend on active management techniques such as prescribed fire, haying, selective mowing, grazing, brush cutting and selective herbicide applications. A reconstructed prairie starts with a bare, plowed agricultural field, versus a prairie restoration where the area is heavily degraded but some remnant, native species are still present (Kurtz 2013). Prescribed fire is a common management treatment of remnant, restored and reconstructed prairies. In grasslands throughout the world, frequent fire has played a critical role in maintaining plant diversity and creating healthy habitat for many different taxa (Beck et al. 2025). Prescribed fire removes biomass such as thatch/plant detritus, leaving openings for sunlight to reach the ground and aid in seed germination (Lesica and Martin 2003). The nutrients released from the burning vegetation are used readily by the soil microbial community (Tuininga and Dighton 2004), along with providing nitrogen, sulfur, and potassium for plant regeneration (Espinosa et al. 2020). Prescribed fire has been shown to be effective in controlling certain invasive species and promoting native plant diversity (Hendrickson et al. 2019). Prescribed burning in the spring exposes dark soils which will warm faster than unburned areas, promoting early plant emergence which increases native plant biomass in those areas (Li et al. 2013). At the Kerr Wildlife Management area in central Texas, Meek et al. (2008) reported that prescribed fire significantly increased herbaceous production and species diversity.

Proper site preparation is essential for successful reconstruction projects because it directly determines the establishment, competitiveness, and long-term resilience of the planted community, be that prairie, wetland or forest (Kurtz 2013). Effective preparation reduces the existing weed seedbank, removes dense, built-up vegetation and detritus, improves seed to soil contact, and creates the open space required for native species to germinate and persist. Without adequate preparation, including repeated herbicide treatments, strategic tillage, and sufficient time for weed suppression, non-native grasses and broadleaf weeds rapidly outcompete slow-establishing prairie species (Smith et al. 2010). Thorough site preparation also promotes even seed distribution and reduces early-stage management demands and shortfalls. The quality of site preparation sets the ecological course of a project, and incomplete or rushed preparation is one of the primary causes of establishment failure in prairie reconstructions (Kurtz 2013).

Prairie reconstruction projects frequently have two main goals, to control invasive species and to restore and promote native plant biodiversity and abundance (Trowbridge et al. 2017). Monitoring these projects is key to understanding what is working and what can be improved. These tasks can be very time consuming and costly, and finding qualified botanists poses more issues (Leahy and Buchanan 2022). There are a variety of diversity metrics used to monitor these reconstructions including species richness, Shannon's alpha diversity index, Shannon's Evenness, Floristic Quality Index, and average conservatism. Floristic Quality Index and average conservatism are used to determine site habitat quality, but are not the best metrics to detect trends over time (Reemts and Eidson 2019). For this reason, those matrices were not used in this research paper.

In the prairies of the Midwest, frequent fires were essential for maintaining plant health and promoting graminoid fuels which are the main component that carry fire through prairie ecosystems. When fire is removed from fire-adapted ecosystems, grass abundance declines, and woody vegetation starts to take over. Without intervention, the landscape will continue to change into a system that will not support a continuous burn and will, over time, be classified as a different ecosystem type (Bowles and Jones 2013). The historical fire frequency in upland prairie systems in Minnesota was 10 years or fewer. Climatic conditions such as excess precipitation or drought not only influenced the burn intervals but the fire intensities as well (MN DNR 2005). In years 2021 and 2022, the study area experienced a severe drought (Figure 1), which can shift prairie vegetation dynamics by favoring drought-tolerant species and suppressing those more sensitive to moisture stress (Grace et al. 2000).

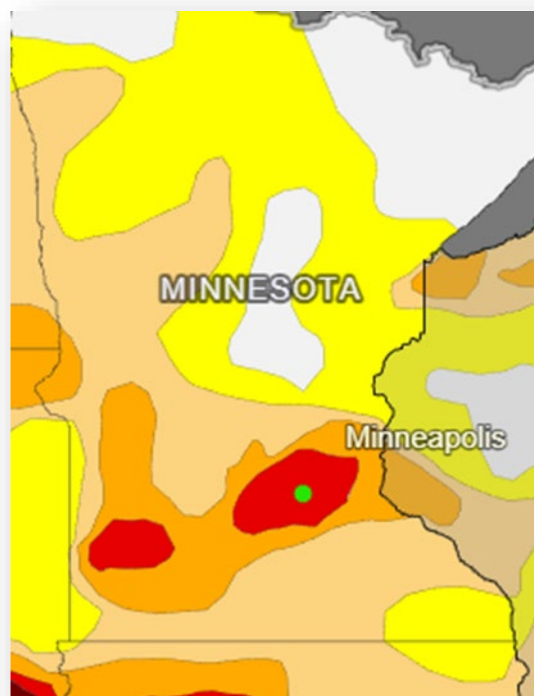

Figure 1. Drought map of Minnesota from August 2022. The green dot is the location of Scott County, MN. This drought lasted into the spring of 2023. (Image from drought.gov)

The long-standing assumption that lightening was the primary cause of these prairie fires and other wildfires has been highly questioned with recent research on anthropogenic burning in North America by Native Americans (Stambaugh et al. 2018). Margolis et al. (2022) in Voyageurs National Park, MN, examined more than 400 burn scars on red pine (*Pinus resinosa)* representing 126 unique fire years (Figure 2). The average fire interval from years 1736 to 1936 varied from 7 to 18 years, with a drastic decrease following European settlement in the area (Kipfmueller et al. 2017). The removal of Indigenous burning practices following European settlement led to a decline in fire frequency, resulting in woody encroachment and woody debris build up, reduced prairie and savanna extent, and the loss of fire-adapted plant and animal communities (Margolis et al. 2022).

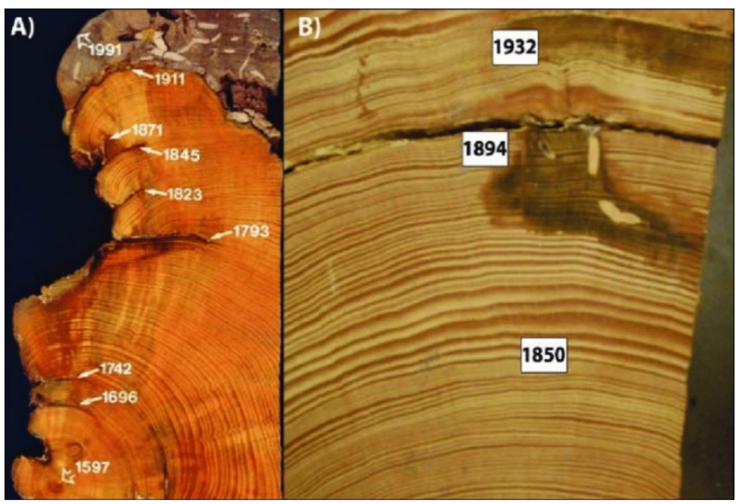

Figure 2. Tree-ring evidence of fires includes cross-dated fire scars and abrupt increases or decreases in ring width. A) Cross-dated fire-scarred sample (Photo: P. Brown, Rocky Mountain Tree-Ring Research). B) Pine exhibiting growth anomalies following an 1850 wildfire, a buried fire scar dated to an 1894 wildfire, and both a fire scar and growth change from the 1932 Matilija Fire (Photo: K. Lombardo, Laboratory of Tree-Ring Research, University of Arizona).

<u>Purpose</u>

The purpose of my study is to compare the effectiveness of prescribed fire on native plant biodiversity which includes species richness, alpha diversity, evenness, and percent composition of native species, along with vegetation height and thatch thickness. There are four main objectives to this study. 1) To determine if species richness differed in burned and unburned prairies. I hypothesized that there will be a significant increase in the number of species in the burned treatment, as fire reduces thatch and increases available space, allowing a greater number of plant species to germinate and establish. 2) To compare Shannon's diversity (alpha diversity) and Shannon's evenness before and after each treatment. I hypothesized that Shannon's diversity would be higher in burned treatments compared to the control, and that evenness would increase in burned plots while remaining stable or decreasing in the control. I expected fire to reduce dominance by a few grass species and promote a more even distribution of native forbs and grasses. By opening the canopy, fire also allows less abundant forbs and shorter grasses to become more evenly represented within the community. 3) To calculate the percentage of native species before and after each treatment. Native species are expected to increase in burned areas because fire removes non-native plants that are not well adapted to fire disturbance. The control is expected to remain the same or decrease in percentage native species. 4) To compare thatch thickness and average plant height for the burned treatment versus the control. I hypothesized that thatch thickness would decrease for the burned treatment and increase in the control, as fire removes the duff layer from the ground. I predicted that vegetation height will vary across sites regardless of the treatment, as local site characteristics such as drought or soil type will likely have more influence on vegetation height and the burn treatment.

Process of Prairie Reconstruction

The Shakopee Mdewakanton Sioux Community (SMSC) is located in the southern suburbs of Minneapolis, MN (Figure 3), on land that has been used for agricultural purposes for the past 80 years (44.738523, -93.474197). Suburban development has increased significantly in the past decade around the land belonging to the SMSC ("About Scott County | Scott County, MN," n.d.). One of the seven values of the SMSC is *Wòohoda* or respect for *Wakan Tanka* (Mother Earth). To follow that specific Dakota Value, the SMSC is dedicated to restoring tribal land to a natural state. This does not always mean pre-colonial conditions, as there are many aspects to consider when planning habitat restoration. The first prairie reconstruction on SMSC land was completed in 2001. This reconstruction was part of a larger project to slow eutrophication and improve water quality in Arctic Lake, which at the time was surrounded by agricultural fields. As of November 10th, 2025 the Natural Resources Department of the SMSC has reconstructed over 1050 acres of tallgrass prairie, pothole wetlands and forests.

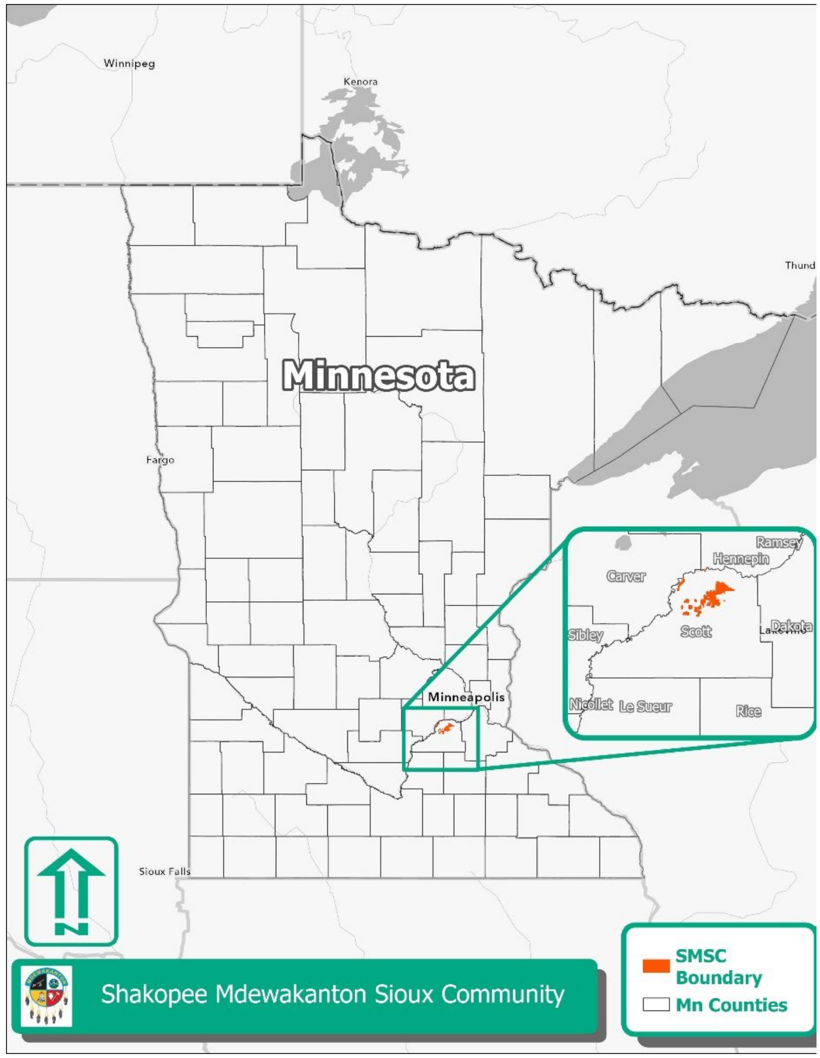

Figure 3. Map showing the general area of the Shakopee Mdewakanton Sioux Community where the study took place (44.738523, -93.474197).

The reconstruction process starts once the SMSC Business Council requests that a former agricultural field be converted back to native habitat. The habitat plans that the SMSC Natural Resources Department create consider many aspects, including but not limited to, current land-use, soil types, reviewing historical aerial imagery, current plant species present, percentage cover of native versus invasive species, hydrology, disturbance history, and cultural resources. The majority of our reconstructions have been tallgrass prairies at 378 hectares, followed by forest reconstruction at 30 hectares, and pothole wetlands at 16 hectares.

Broad-spectrum, non-selective herbicides are almost always used in preparation of habitat reconstruction. Even if an agricultural field was plowed, planted and harvested in a year, there will still be areas of infestation of invasive species that need to be controlled before planting native plants and seed. Controlling these aggressive invasive species from the start will save time and money as the reconstruction matures. One of the fields that was reconstructed by SMSC's Natural Resources Department was only prepared with tillage. It was decided that no herbicide was needed because it had only been fallow (unfarmed) one year. This reconstruction is an example of the consequences of improper site preparation. This prairie now has an influx of non-native burdock *(Arctium minus)* and invasive Canada thistle *(Cirsium arvense).* This encroachment was so severe that we eventually needed to control the invasives with an herbicide treatment, thus defeating the original purpose of avoiding the use of chemicals. The negative aspect of applying herbicide after the reconstruction has been planted is the harmful effects on the native plants that were resilient enough to germinate. Less damage is done by applying this herbicide at the beginning of a prairie reconstruction project and will save significant time and frustration later in the process. Without this upfront control, invasive plants often rebound quickly, requiring repeated management efforts that can delay reconstruction progress and increase long-term costs (Smith et al. 2010).

The site preparation for abandoned farm fields or pasturelands, also known as fallow fields, is slightly different than active agricultural land which has bare, exposed soil. These fallow fields are usually comprised of non-native grasses and annual weeds. The first step in preparing these sites is mowing the vegetation to approximately 20 centimeters in mid-summer (July or August) and allowing the vegetation to regrow for several weeks. Next, me or my team use a sprayer rig on a tractor and apply a broad-spectrum herbicide to the entire site. The vegetation is allowed to senesce for three to four weeks and is followed up with tillage using a 12-foot disk and tractor. We check the site after a month and if patches of vegetation are starting to grow back, a spot treatment application of broad-spectrum herbicide is applied only to the needed areas.

The equipment used to till the fallow fields are large and heavy (Figure 4). To avoid unnecessary soil compaction, it is preferable that we only till the site once. Following site preparation is the planting of the native seed mix. There are native restoration companies that sell pre-mixed seed, however, the SMSC's Natural Resources Department works with local seed companies that allow custom seed mixes to be created. The advantage of using custom seed mixes is that it ensures that the appropriate native species

Figure 4. A-- Tractor pulling the tillage equipment used to prepare reconstruction sites for planting. Soil compaction is mitigated by only tilling the area once. B-- Heavy disk used to break up thick, established non-native grasses. The cultipacker in the back of the disk flattens the disturbed soil in preparation of the native seed being planted. This promotes seed to soil contact.

are being used for the soil and hydrological conditions. A custom seed mix is typically composed of species with similar moisture requirements, whereas a generic mix often contains both facultative wet and dry upland species. The generic seed mix approach is often inefficient, as only a portion of the species in the mix are suited to the site's conditions, meaning many of the seeds will fail to germinate or establish and the cost-effectiveness and biodiversity declines (Meissen et al. 2020).

We utilize two main planting techniques: fall planting and winter over-the-snow seeding. If the site is a bare, prepared farm field, a specialized prairie seed planter is used to seed the site in late fall. These machines are designed to work with fluffy native grass seed which would plug a traditional grain planter. The heavy front cultipacker flattens the ground, seed falls behind, and a second cultipacker ensures solid seed-to-soil contact, improving seed germination (Figure 5).

Figure 5. Tractor pulling the native seed planter (Truax Drop Seeder). This equipment is designed specifically to plant "fluffy" native seed. A conventional seeder would not work with prairie seeds. (photo from Truax.com)

Prairie plants native to the Midwest have evolved seed dormancy mechanisms that prevent their seeds from germinating immediately after they are released. Instead, the seeds require exposure to cold, moist conditions over winter, a process known as cold stratification. This freeze-thaw cycle breaks down the seed's dormancy and signals that conditions are favorable for growth in spring (Baskin et al. 1992). By requiring this period of winter weather, prairie plants ensure their seeds do not sprout too early in the fall when seedlings would be unlikely to survive. However, when purchasing native seed mixes from companies, the seeds have already been through the process of stratification. The reason for this is some organizations prefer to plant their prairies in the spring like conventional farming. Pre-stratified seed helps to promote germination of native plants in the first growing season. If a fall planting is decided upon, seeds need to be planted in cold temperatures to ensure that the seeds do not germinate that year. Not only does planting seeds in late fall mimic the natural cycle of prairie plant establishment, but our Natural Resources Department has made observations from the past decade that fall seedings establish better over time than spring seedings.

We also use over-the-snow winter seeding, this is generally used to increase diversity in already established prairies. This process is referred to as "interseeding". This method improves species richness by introducing new species to a prairie reconstruction. Seeds are collected from the different prairies at SMSC and redistributed during the winter to prairies lacking high species richness. Once there is between 10 to 25 centimeters of snow, the seed is broadcasted using equipment on the back of a tractor (Figure 6). The freezing and thawing of the ground in the spring helps improve seed-to-soil contact, which will improve germination rates. This seeding technique is also used in areas that cannot be tilled or planted with the native seed planter because of excess roots and woody debris. This pertains mostly to oak savannas or woody encroached pasturelands.

During the first growing season of a prairie reconstruction, the site often looks “messy”, and that’s completely normal. Most of what appears early on are annual weedy species and short-lived pioneer species that take advantage of the bare soil. These plants help protect the soil from erosion and begin building the conditions native prairie plants need to thrive. The native perennial species seeded during reconstruction generally invest most of their energy in belowground development during this period, establishing extensive root systems rather than producing substantial aboveground biomass (Nyamai et al. 2011). It can take several years before the site begins to resemble a mature prairie community, but this early stage is a natural and important part of the reconstruction process.

Figure 6. Broadcast seeder used in over-the-snow seeding. The seed is evenly distributed by the spinning disk on the bottom of the equipment. This seeding technique is used to inter-seed, and on sites that have extensive woody vegetation and debris. (photo from johndeere.com)

A specific example of this community progression can be observed by examining annual vegetation monitoring that I conducted on an SMSC wetland mitigation reconstruction to document change over time from 2018 to 2022. These data show the slow progression of prairie species establishment after reconstruction, as prairie species take several years before they are stable. Each year saw an increase in species richness and increased percentage cover of native species (Table 1).

Table 1. Vegetation data from a 40-acre prairie and wetland reconstruction on SMSC land. An extensive vegetation survey was done each year and documented. This table shows the slow progression of native cover improvement over time. Note the large change in percentage native cover after the prescribed burn.

Mesic Prairie Vegetation Standard	2018	2019	2020	Prescribed Burn	2021	2022
# Native Species	13	49	52		42	41
% Native Cover	37%	63%	77%		90%	96%
% Non-native/ Invasive Cover	63%	38%	23%		10%	4%

During the first growing season, if annual species such as giant ragweed *(Ambrosia trifida*) are too aggressive and tall, they will shade out the soil layer decreasing the likelihood of seed germination. We manage these aggressive species by mowing the site vegetation 10 to 25 centimeters from the ground. This allows light to penetrate the soil surface, aiding in seed germination. Management for the first three years includes vegetation monitoring for any invasive species infestation. A common invasive plant is Canada thistle, which is usually managed by mowing the plants right as they start to flower around the beginning of July in Minnesota. At this stage of growth, they are putting all their resources into the flower. By mowing them at this stage, it reduces thistle vigor and reproductive output. We map those areas with a GPS to monitor the effectiveness of the mowing management. If the patches become too aggressive, even with mowing, spot herbicide spray can be used to control this invasive species. The next management step is conducting a prescribed burn, which usually happens during the fourth growing season. After the first prescribed burn, prairies are monitored using the vegetation protocol from the Prairie Reconstruction Initiative on a three-year rotating basis, along with being burned on a three- to four-year interval.

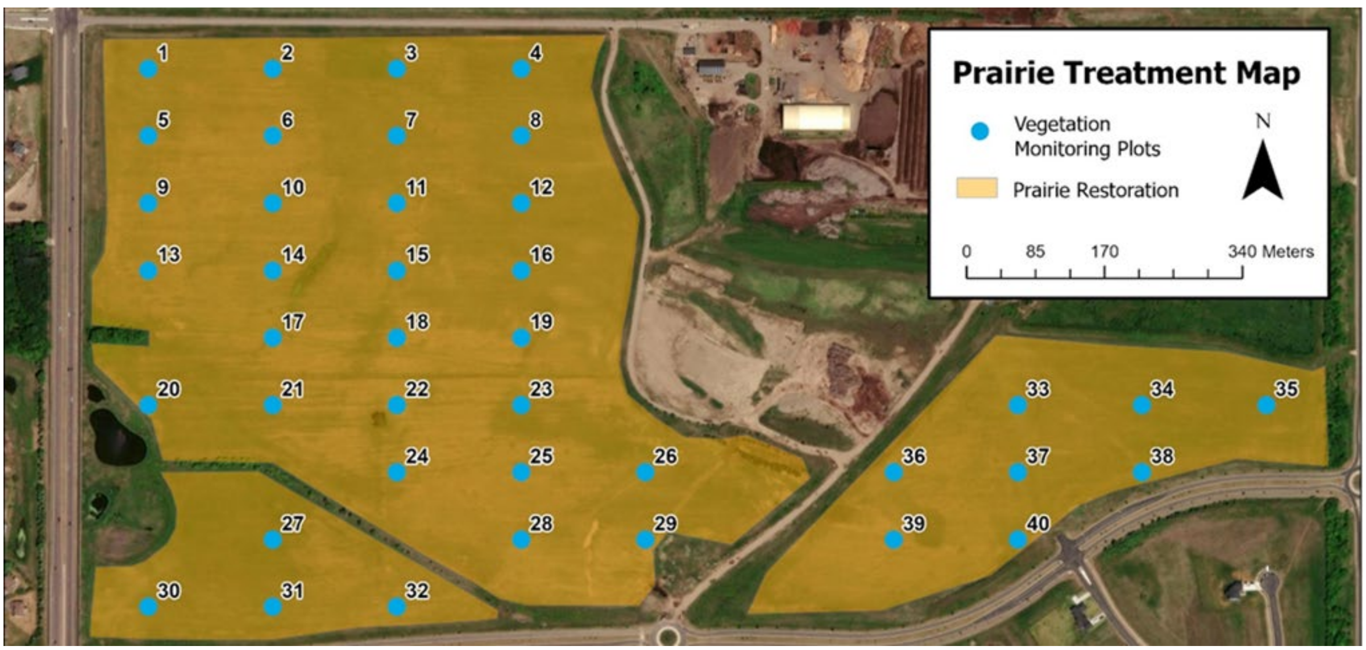

Figure 7. Aerial imagery of one prairie reconstruction on SMSC land and the systemic grid vegetation sample plots. The number of systematic sampling points is dependent on the size of the prairies.

Table 2. List of prairies that were used for this study, along with year of first vegetation survey, year of the prescribed burn, year of the second survey, total acres of prairie, and the number of vegetation plots surveyed. Note the control prairies are listed at the bottom of table.

Prairie Unit	Year of 1st Survey	Year of Burn	Year of 2nd Survey	Total Acres	Number of Plots
Bauer	2022	Spring 2025	2025	34.2	40
Buffalo Pasture	2020	Fall 2020	2023	173.6	40
Cook 01	2022	Fall 2022	2024	18	15
Cook 02	2022	Spring 2023	2024	29.6	18
Cook 03	2022	Spring 2024	2024	22.1	14
Cultural Center 02	2022	Fall 2022	2025	8.75	13
Mitigation	2019	Spring 2021	2022	37.1	40
Peterson 01	2021	Fall 2022	2024	7.9	10
Peterson 03	2020	Spring 2023	2023	30.1	26
Tewapa 1 & 2	2021	Spring 2022	2024	8.2	12
Tewapa 3	2021	Spring 2022	2024	1.9	6
Tewapa 4	2021	Spring 2022	2024	2.4	6
Tollefson	2019	Spring 2021	2024	67.7	40
Wetland C-18 Wacipi	2020	Fall 2020, Spring 2023	2023	5.8	15
Cultural Center 01	2022	No Burn - Control	2025	33	22
Shakopee Memorial	2018	No Burn - Control	2021	4.1	10
Shutrop 01	2022	No Burn - Control	2024	64.7	40
S-5 Oak Savannah	2019	No Burn - Control	2022	2.5	10
Wetland C-7	2019	No Burn - Control	2022	2.3	10

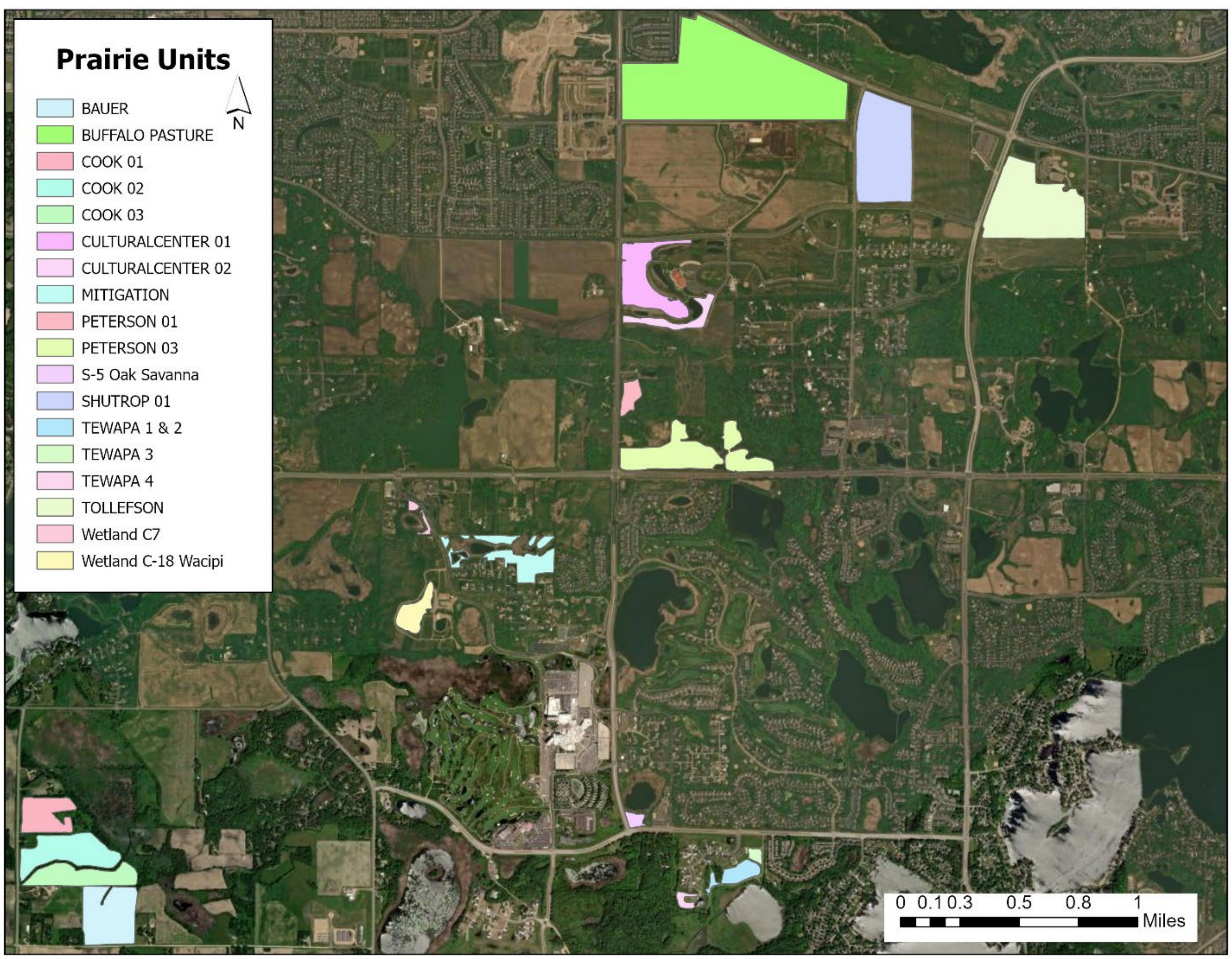

Figure 8. Location of the different prairie units on SMSC land.

METHODS

My study at SMSC consisted of two treatments - prairies that were managed with prescribed fire (Burned) and prairies that received no management (Control). The prairies in this study were all established, fully functioning ecosystems, with a minimum of four growing seasons since reconstruction. All prairie vegetation surveys were completed twice: before and after treatment. The prairies at SMSC are monitored for vegetation on a three-year rotating basis.

Systematic grid sampling was used in each of the prairies to complete the vegetation surveys with the burned treatment having 156 total vegetation plots and the control having 133 total vegetation plots (Table 2). The number of plots per prairie is dependent on the acreage of the prairie. The greatest number of vegetation plots a single prairie can have, regardless of size, is 40.

I personally trained all vegetation survey members and was present with at least one team throughout the summer field season, alternating to work with all survey teams. Nested plot sampling frames with a total of five different subplots, were used to sample vegetation (Figure 9). This protocol was developed by The Prairie Reconstruction Initiative, and is used by many organizations including the Minnesota Department of Natural Resources and The Nature Conservancy (Prairie Reconstruction Initiative 2020).

Starting with subplot A, I recorded all plant species rooted within the plot. If a new plant species was found in the remaining B-E plots, I recorded the species in the appropriate subplot. Subplot E was created by flipping the nested plot frame the long way (Figure 10). The total area

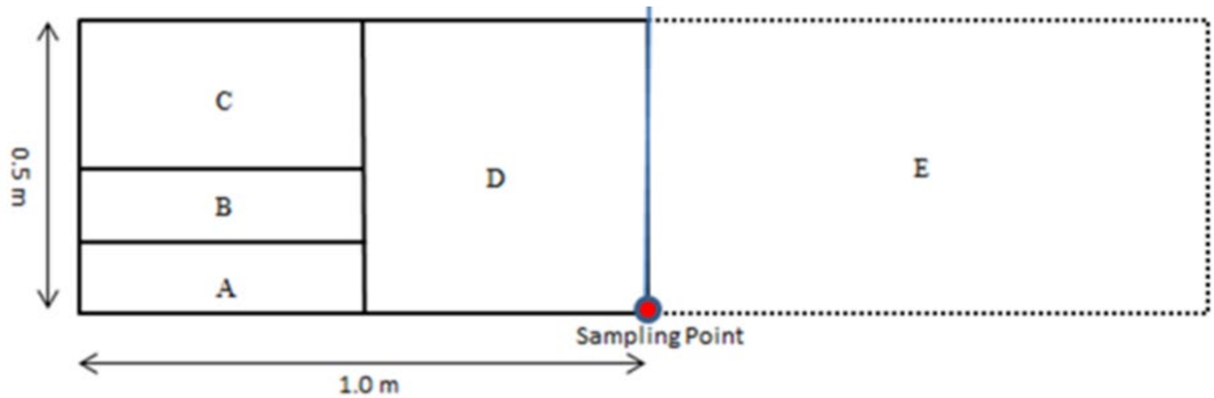

Figure 9. Size and dimensions of nested plots. Each 1m2 sampling plot is divided into five subplots (A-E), which are combined sequentially to create the five nested plots (1-5). Area examined doubles as nested plot increases.

of all subplots combined was 1.0 m^2. Species data were collected as presence or absence in the 5 subplots to calculate species frequency at each survey plot. For example, if the plant was rooted in subplot A, then it was counted five times for that plot, however if a species was not recorded until subplot E, it was only counted once (Table 3). This nested plot protocol was used because percent cover is subjective and difficult to calibrate amongst the vegetation survey team. Any plant specimens that could not be identified in the field were collected and brought back to the lab for proper identification, and I oversaw all quality-control determinations.

Table 3. Example of how species frequency was calculated for each plot using the nested-subplot design. Species detected in the smallest subplot (A) were recorded as present in all five nested plot sizes, yielding a frequency value of 5. Species first detected in the largest subplot (E) contributed a frequency of 1, with intermediate subplots contributing proportionally. This approach reflects the standard PRI nested-frequency method, where earlier appearance in smaller subplots corresponds to higher frequency values.

Smallest Subplot Species Was Observed In	Status for Nested Plot 1	Status for Nested Plot 2	Status for Nested Plot 3	Status for Nested Plot 4	Status for Nested Plot 5
A	Present	Present	Present	Present	Present
B	*Absent*	Present	Present	Present	Present
C	*Absent*	*Absent*	Present	Present	Present
D	*Absent*	*Absent*	*Absent*	Present	Present
E	*Absent*	*Absent*	*Absent*	*Absent*	Present

In addition to the species data collected, vegetation height and density were estimated using the Robel pole method (Robel et al. 1970). A Robel pole marked in decimeter intervals was placed vertically at the plot center, and visual obstruction readings were taken from four meters away at a height of 1 meter above ground level in each cardinal direction. A 1-meter-tall plastic pole was connected to the Robel pole with a four-meter-long rope. I would kneel down so I was eye level with the top of the plastic pole. I determined the reading of the Robel pole by observing the first decimeter section that was completely covered by the vegetation (Figure 11). The average of these four readings was recorded as the mean visual obstruction value for that plot. This approach provides a standardized measure of vegetation structure, reflecting both plant

Figure 10. A-- The PVC frame used for vegetation surveys. There are five subplots on the measuring frame. The fifth plot is created by flipping the frame on the short end. B-- Vegetation survey team: Rachel Crownhart and Chase Emmers. Photos taken on the Shakopee Mdewakanton Sioux Community mitigation prairie 2025.

height and horizontal density, and has been shown to correlate strongly with aboveground biomass in prairie and grassland ecosystems (Fisher and Davis 2010).

In tallgrass prairie communities, thatch is the layer of dead grass and litter that builds up at the soil surface as previous years' vegetation decomposes. Thatch influences microclimate and plant community dynamics by modifying soil temperature, moisture, and light availability near the ground, and can either facilitate or inhibit seedling establishment depending on its thickness (Gerhard et al. 2022). I measured thatch thickness at three locations within each vegetation plot using a metal ruler. Measurement points were chosen to reflect the representative conditions across the plot.

Species diversity within each vegetation plot was quantified using multiple indices. Species richness was calculated as the total number of species observed per plot. Shannon's diversity index was used to account for both species richness and the relative abundance of each

Figure 11. A-- Robel Pole and sampling frame set up. B— This picture shows me taking a vegetation height reading four meters from the Robel Pole. This is an up-close photo of the 1-meter-high pole used to take vegetation height reading. The decimeter section that is completely covered by vegetation is recorded for each cardinal direction.

species. Shannon's evenness was calculated to assess how evenly individuals were distributed among species, with higher values indicating a more equitable distribution and lower values indicating dominance by a few species. I calculated Shannon's diversity and evenness using the vegan package in R (Oksanen et al. 2024). The proportion of native species in each plot was calculated as the number of native species divided by the total number of species, expressed as a percentage. In addition, I calculated average vegetation height and thatch thickness between the two treatments. I performed all analysis in R-studio (version 4.4.0 "R Core Team" 2024).

Species richness was analyzed using a generalized linear model with a Poisson distribution which is appropriate for count data (whole-number observations). Shannon's diversity, evenness, percent native species, vegetation height, and thatch thickness were analyzed using linear regression models assuming Gaussian distribution for continuous measurements. I implemented linear mixed-effects models using the lme4 R package (Bates et al. 2015), with fixed effects representing the main predictors (treatment, timepoint, and their interaction) and random effects accounting for repeated measurements from the same vegetation plots over time, with those plots grouped within larger study areas (units). When the interaction between treatment and timepoint was not statistically significant, I removed the interaction term and simplified the model to evaluate main effects only. To ensure that the linear regressions were modeled with an appropriate random-effects structure, I tested several plausible grouping combinations based on how data were collected across treatments, plots, units, and survey years (Table 4). Model selection was based on Akaike's Information Criterion (AIC), where lower AIC values indicated better fit. The final model structure was chosen based on the lowest AIC among candidate models: unit/plot:

Table 4. Combinations of random intercepts to use in the linear mixed-effects models, along with the reasoning behind each combination.

Combination	Reasoning for Combination
Unit	to account for differences between large sampling areas
Plots within Units	to reflect repeated sampling of individual plots inside the same prairie unit
Plots within Year	to account for individual plot differences over time
Year	to test for overall differences between survey seasons
Units within year	to examine whether plot responses were more strongly influenced by annual conditions
Years within Plot	to examine whether plot responses were more strongly influenced unit-level site characteristics

Since I hypothesized that vegetation height would be more dependent on climatic and site characteristics than my treatments, I also assessed changes to vegetation height across the entire study period by year. I analyzed mean vegetation height using a one-way ANOVA with year included as a fixed categorical factor. When the overall effect of year was significant, I used Tukey's HSD post-hoc test to identify which years differed. Records with missing height values were excluded to ensure a complete dataset.

RESULTS

When analyzed at the plot level, species richness and Shannon's diversity both exhibited a significant interaction between treatment and timepoint, indicating that the change over time differed between burned and control treatments. Species richness increased in burned plots,

Table 5. The mean value ± standard deviation, for each diversity index measured in the field. Data are listed before and after the vegetation surveys for the Burned and the Control treatments.

Index (mean values)	Burned - Before	Burned - After	Control - Before	Control - After
Richness	10.9 ± 4.1	11.4 ± 3.9	11.2 ± 4.1	9.9 ± 4.3
Shannon	2.18 ± 0.4	2.24 ± 0.4	2.21 ± 0.4	2.02 ± 0.7
% Native Species	82.3 ± 17.3	79.2 ± 19.0	83.7 ± 15.7	79.9 ± 17.7
Height (cm)	58.0 ± 3.5	78.0 ± 4.2	47.0 ± 3.9	68.0 ± 3.3
Thatch (cm)	2.8 ± 3.5	4.1 ± 19.0	1.4 ± 2.4	4.7 ± 4.7

while the control plots demonstrated a decrease in species richness. Shannon's evenness, percent native species, and vegetation height did not show a significant interaction between treatments and timepoint but had significant main effects, with percent native species decreasing in both burned and control treatments, and both vegetation height and Shannon's evenness increasing in both treatments. Thatch thickness showed no significant differences between treatment or timepoint (Table 5).

Median species richness showed no evidence of a difference between treatments following the first vegetation survey ($p = 0.47$), providing a consistent baseline for assessing change over time. Over the three-year period between vegetation surveys, richness decreased slightly in the control plots and showed a moderate increase in the burned plots ($p = 0.03$). For

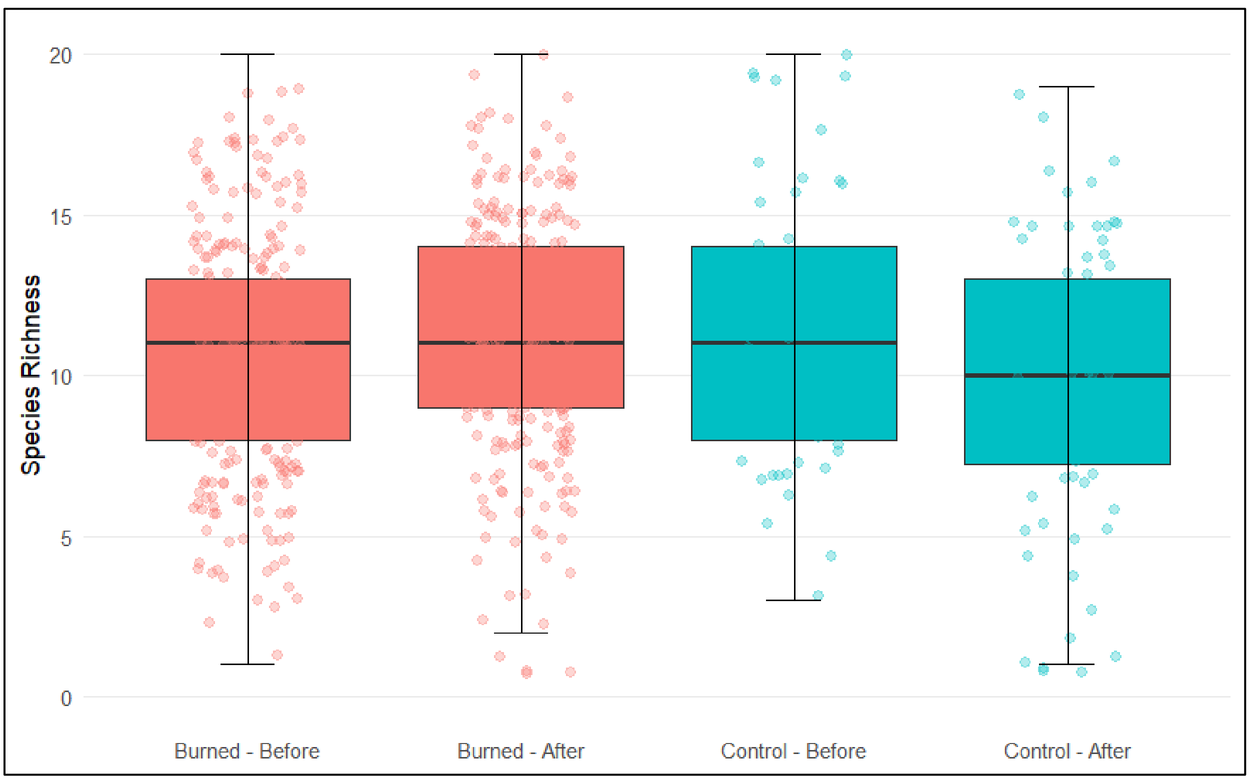

Figure 12. Comparison of mean species richness in burned and control treatments before and after vegetation surveys. Each box represents the median and interquartile range of species richness across sampling plots, with individual points showing prairie-level data. Fourteen prairies were included in the burned treatment and five in the control. Nested plot data collected from reconstructed prairies on SMSC land in Scott County, MN.

the interaction between treatment and timepoint there was moderate evidence of a decrease in species richness in the control relative to the burned treatment ($p = 0.03$). This indicates that the magnitude and direction of change in species richness over time differed between burned and control plots (Figure 12).

Shannon diversity index did not differ significantly between burned and control treatments following the first vegetation survey, creating a baseline for measurement. Over time, the control treatment exhibited a slight decrease in Shannon diversity, whereas the burned treatment showed a moderate increase ($p = 0.03$; Figure 13). The interaction between treatment and timepoint also showed moderate evidence of a difference in alpha diversity ($p = 0.02$),

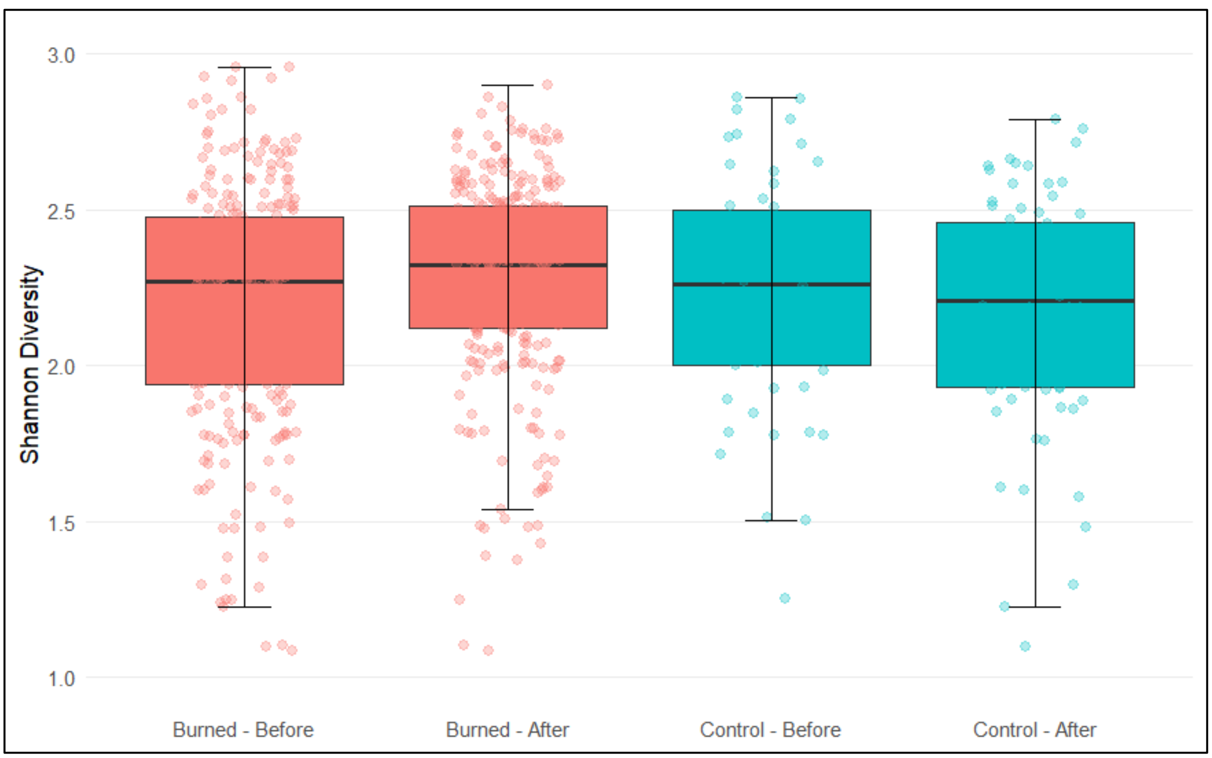

Figure 13. Comparison of Shannon's diversity in burned and control treatments before and after vegetation surveys. Each box represents the median and interquartile range of Shannon's diversity across sampling plots, with individual points showing prairie-level data. Fourteen prairies were included in the burned treatment and five in the control. Nested plot data collected from reconstructed prairies on SMSC land in Scott County, MN

indicating that changes over time differed between treatments, with alpha diversity declining in the control plots.

Shannon's evenness followed the trend with no statistical difference between treatments after the first vegetation survey. However, following the second vegetation survey, there was strong evidence of an increase in both burned and control plots ($p = 0.01$). The interaction between treatment and timepoint were not statistically significant, indicating that burned and control plots responded similarly over time.

I analyzed temporal changes for the 10 most frequent species within each treatment (Table 6). A notable change in the control treatment was the increase of *Poa pratensis*, an invasive grass that can change prairie ecology. The burned treatment shows an invasive thistle species *Cirsium arvense* (Canada thistle) after the first vegetation survey, however that species is exempt from the top 10 species following a burn. While *Taraxacum officinale* is a non-native species, it is considered "naturalized" and does not aggressively alter ecosystems.

At the start of the study, the percentage of vegetation that were native species were almost the same for both treatments, creating a baseline for data analysis. Intially, burned treatments were 82% native and the control treatments were 83% native. Although not signficant,

Table 6. List of top 10 most common species found in each treatment and timepoint. The highlighted species indicate an invasive or non-native plant species.

	Control - Before	Control - After	Burned - Before	Burned - After
1	*Andropogon gerardii*	*Andropogon gerardii*	*Andropogon gerardii*	*Sorghastrum nutans*
2	*Monarda fistulosa*	*Monarda fistulosa*	*Monarda fistulosa*	*Andropogon gerardii*
3	*Heliopsis helianthoides*	*Sorghastrum nutans*	*Sorghastrum nutans*	*Monarda fistulosa*
4	*Solidago canadensis*	*Poa pratensis*	*Heliopsis helianthoides*	*Ratibida pinnata*
5	*Poa pratensis*	*Rudbeckia hirta*	*Zizia aurea*	*Solidago Canadensis*
6	*Bouteloua curtipendula*	*Ratibida pinnata*	*Ratibida pinnata*	*Taraxacum officinale*
7	*Sorghastrum nutans*	*Elymus canadensis*	*Elymus trachycaulus*	*Zizia aurea*
8	*Elymus canadensis*	*Symphyotrichum ericoides*	*Solidago canadensis*	*Penstemon digitalis*
9	*Ratibida pinnata*	*Penstemon digitalis*	*Solidago rigida*	*Schizachyrium scoparium*
10	*Symphyotrichum ericoides*	*Heliopsis helianthoides*	*Cirsium arvense*	*Eriochloa villosa*

both treatments saw a decrease in percentage following the timepoint (*p* = 0.21). In the control, the mean native species decreased from 83% to 79% following the vegetation survey while the burned treatment decreased from 82% to 79%. There was no significant interaction of treatment and timepoint indicating that both treatments responded similarily over time.

Median vegetation height increased significantly after the vegetation surveys in both treatments (Figure 14). The burned treatment's mean height increased from 58 cm to 78 cm, while the control increased from 47 cm to 68 cm. The interaction between treatment and timepoint was not significant. Vegetation height in burned treatments was moderately greater than the control (*p* = 0.03), and following the second vegetation survey, there was moderate evidence of an increase in both the burned and control treatments (*p* = 0.01).

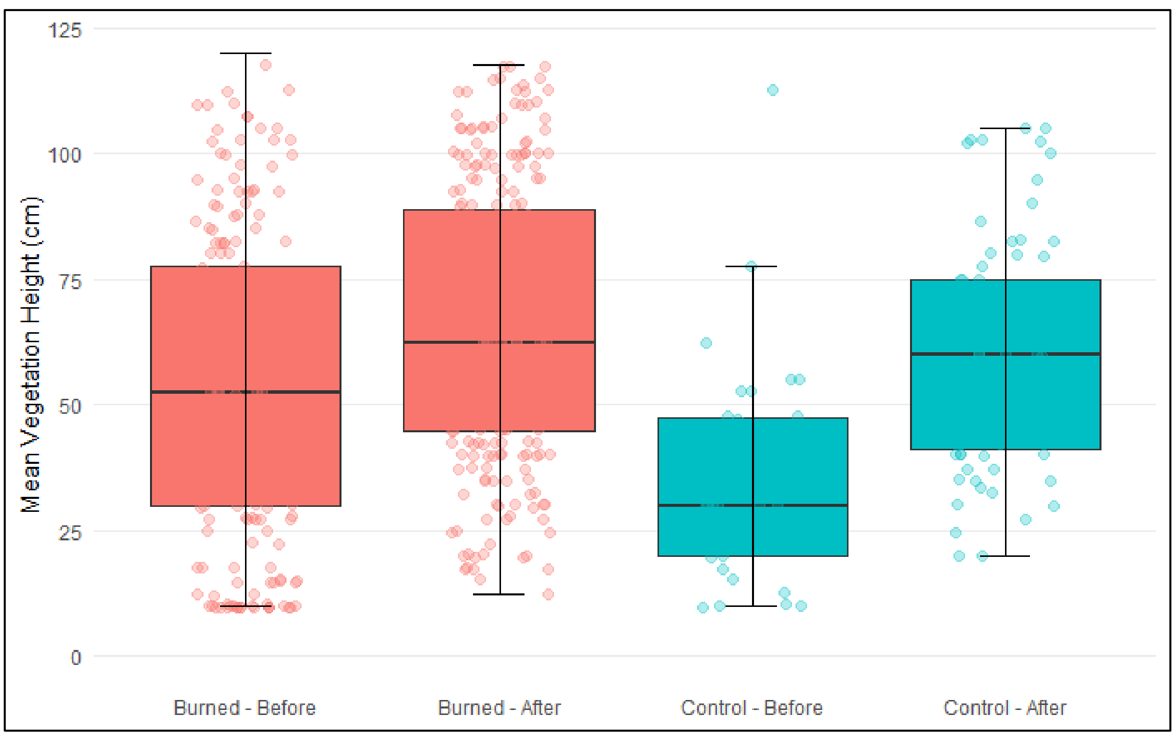

Figure 14. Comparison of mean vegetation height in burned and control treatments before and after vegetation surveys. Each box represents the median and interquartile range of vegetation height across sampling plots, with individual points showing prairie-level data. Fourteen prairies were included in the burned treatment and five in the control. Nested plot data collected from reconstructed prairies on SMSC land in Scott County, MN.

For the supplemental data analysis, vegetation height was compared in years 2020-2021 (the start of the drought), there was strong evidence of a decrease in vegetation height over all the study units ($p < 0.001$). Comparing years 2021-2022 ($p = 0.93$) and 2022-2023 ($p = 0.19$) shows no evidence of a change in vegetation height. However, there was very strong evidence of an increase in vegetation height from 2023 to 2024 ($p < 0.0001$) and also in years 2024 to 2025 ($p = 0.003$).

When examining thatch thickness, the burned and control treatments both show a slight increase after the vegetation survey. Burned treatment mean thatch thickness increased from 2.6 cm to 4.2 cm, and the control increased from 1.4 cm to 4.7 cm. The linear model showed no significance between the interaction, or differences in treatment ($p = 0.96$) and timepoint ($p = 0.16$).

DISCUSSION

I found that the results of this study partially supported my initial hypotheses regarding the effects of prescribed burning on prairie vegetation. I expected that burned plots would show an increase in native species richness and diversity over time, while control plots would remain stable or decline. Consistent with these predictions, I observed significant increases in species richness and Shannon's diversity in the burned treatment, whereas values in the control plots remained stable or slightly decreased. These results suggest that prescribed fire may help maintain plant diversity and species richness over time.

In contrast, the proportion of native species declined in both treatments, suggesting that short-term community responses to burning may not immediately favor native species recovery. Vegetation height increased similarly across both treatments, likely reflecting broader environmental factors such as improved growing conditions during the second vegetation survey rather than treatment-specific effects. Overall, these findings suggest that prescribed fire may play a role in stabilizing plant diversity, even if short-term changes are modest.

One explanation for the lack of strong evidence of an increase in species richness and Shannon's diversity in burned plots may be the overall baseline health of the study prairies. Most of the sites reconstructed by the Natural Resources Department were established using high-quality, locally sourced seed mixes designed to maximize native species diversity and habitat complexity. These reconstructions were implemented with meticulous attention to site preparation, seeding, and long-term management, and the plant communities were already functioning at a relatively high ecological quality prior to my study. As a result, there may have been limited potential for measurable increases in diversity or native composition over the three-year period. In other words, these prairies may have reached a level of maturity and stability where additional benefits from a single management action, such as a prescribed burn, are low.

A specific example of this baseline prairie health can be observed from data that I collected from a prairie and wetland reconstruction on SMSC land. I personally planted this reconstruction in the fall of 2017. I was responsible for monitoring this reconstruction annually and reporting my results to the United States Army Corps of Engineers to ensure vegetation standards were on schedule to be completed. This included having at least 90% native species cover by the fifth year of the reconstruction (Table 1). There was a 13% increase in native cover following a spring burn in 2021. I hypothesize that the burn removed the non-native species that were not adapted to fire, leaving the native, fire-tolerant prairie species to thrive. These data demonstrate the importance of using prescribed fire as a management tool. It is doubtful that mowing or spot herbicide spraying alone would have allowed this reconstruction to reach 90% or greater native cover. All of the prairies in this study were established, fully functioning ecosystems and because of this, significant improvement might not be possible without other management techniques such as interseeding.

Another consideration is the timeframe in which vegetation responses to fire become apparent. Fire plays a critical role in maintaining prairie ecosystems by reducing litter accumulation, releasing nutrients, and stimulating growth of native warm-season grasses (Smith et al. 2010). However, the effects of a single prescribed burn are often gradual and may take multiple years or repeated burns to produce measurable shifts in species composition. Studies have shown that significant increases in native dominance or diversity typically occur after several consecutive burn cycles, particularly when combined with other management actions such as invasive species control or interseeding (Anderson & McPherson 2024). This study captured only one prescribed burn which suggests the vegetation community may not have had sufficient time to fully respond to the management. Another consideration is that the period of time between the vegetation surveys and the prescribed burn varied across prairie units, along with the time of year the prescribed burn took place: some burns were in the spring while others were in the fall.

It is also possible that natural variability among sites and environmental conditions influenced the outcomes of this study. Differences in soil texture and drainage, moisture availability, and microtopography can strongly affect species establishment and growth, even within relatively small areas. Annual weather fluctuations, particularly in precipitation and temperature, can also influence germination and plant vigor, potentially masking treatment effects (Grace et al. 2000). For example, a dry or unusually hot growing season may limit the recruitment of certain native forbs or favor fast-growing annuals, regardless of management treatment. A specific plant species called rosin weed *(Silphium integrifolium)* is only found in three of the prairies on SMSC land. I have closely monitored this species every summer. During two severe years of drought in 2021 and 2022 this plant did not emerge from the prairie and was thought to not have survived the drought. However, the plant underwent dormancy, or aestivation, where it survives by using underground structures such as rhizomes, roots, or bulbs. When conditions are favorable again, these dormant plants can resprout. When the Scott County drought was over in 2023, I observed rosin weed again return to the SMSC prairies. Given that prairie dynamics are driven by complex interactions between management, weather, and site history, some of the variation observed in this study may reflect natural ecological change rather than direct effects of the burn treatment.

<u>Species Richness</u>

My initial hypothesis predicted that species richness would differ significantly among treatments following a prescribed burn. There was a moderate increase in the burned treatment, while the control decreased insignificantly. There was enough change overtime however to show a moderate difference in the interaction between treatment and timepoint, indicating that the burned treatment responded differently than the control. This could be a direct effect of the prescribed burn promoting species richness. A study of coastal prairies in Texas by Twidwell et al. (2012), shared the same hypothesis as this study, that species richness would improve with a prescribed burn. However, their data showed inverse results, with total species richness not differing between burned and unburned prairies. Twidwell et al. (2012), also separated grasses from forbs and compared those across treatments. Grass richness did not change between burned treatments, however, forb richness was significantly greater in the burned prairies versus unburned. I chose not to split vegetation type in this study, but this could be something to consider for future research. Another study completed in eastern tallgrass prairies showed that an increase in fire frequency had a direct positive effect on species richness (Bowles and Jones 2013). The burn interval (frequency) for my study was three years, perhaps a change to this timeframe would show different outcomes for species richness.

Although the slight decrease in species richness observed in the control plots of my study was not statistically significant, a continued downward trend, if unmanaged, could indicate early stages of community simplification or degradation. This stresses the importance of maintaining ecologically appropriate fire regimes, as prescribed burning can help sustain or enhance plant species diversity and counteract declines that may occur in the absence of disturbance.

Alpha Diversity

Alpha diversity was hypothesized to increase significantly in the burned treatment, while the control would remain the same or decrease. My hypothesis was partially supported: the control treatment decreased slightly, but the burned treatment only showed a moderate increase in alpha diversity. A study on the Black River–Mima Prairie Glacial Heritage Preserve (Rook et al. 2011) reported a similar pattern, where Shannon's diversity increased modestly after prescribed fire, though the relationship was weak. Rook et al. (2011) also found a moderate increase in species richness in burned prairies compared to unburned areas, consistent with the results from the SMSC prairies. Like species richness, the control in my study saw only a slight decline, however, without a return to active management, these reconstructed prairies will likely continue to shift toward lower diversity and reduced ecological resilience.

Examining evenness from the SMSC's prairies, both treatments increased significantly after the second vegetation survey. There was not a significant interaction which suggests an external factor influenced evenness and not the burned treatment. One explanation could be the drought that Scott County, MN experienced in 2021 and 2022. Prairie species with lower drought tolerance may have responded by entering a prolonged phase of aestivation, relying on stored belowground reserves and producing little to no aboveground vegetation. When precipitation is scarce, drought-tolerant species such as side-oats grama *(Bouteloua curtipendula)* gain a competitive edge and can become temporarily more dominant. I observed vast areas of side-oats gram during the 2022 field season. When precipitation returns, less drought-tolerant species rebound, reducing drought-tolerant plant dominance and spreading relative abundances across more species. The increase in Shannon's evenness across both treatments is to be expected as drought-tolerant dominant species decline and other species return to the landscape.

Native Composition

Percentage of native species did not increase as predicted in the burn treatment; instead, both burned and control treatments showed a slight decrease between vegetation surveys. My hypothesis that prescribed fire would increase the proportion of native species was based on prior observations from other SMSC prairies. For example, the prairie and wetland mitigation reconstruction I referenced previously in this paper showed a significant increase in percentage native cover following a burn. However, when native species already comprise a high baseline percentage as they do at SMSC, at approximately 82%, large increases from fire alone are unlikely. Additional management actions such as selective herbicide treatment of invasive species or targeted interseeding would likely be required to produce further gains. A similar pattern was reported by Coulter et al. (2010), who found no significant increase in native species cover at the landscape level following prescribed burns. Their comparisons of spring and fall burns demonstrated the same outcome.

Prescribed fire can reduce non-native, fire-intolerant species by removing accumulated thatch, altering resource availability, and selectively disadvantaging shallow-rooted or disturbance-sensitive invaders. It is possible that such reductions contributed to the small decline observed in overall native percentage in the burned treatment. However, because the control treatment also exhibited a decline, despite the absence of fire, this suggests that outside influences such as seasonal conditions, or moisture patterns, may have played a larger role in the observed patterns than the fire treatment alone.

Examining the top ten species before and after the vegetation surveys shows an increase in the frequency of Kentucky bluegrass (*Poa pratensis*) within the control treatment. *Poa pratensis* is a widespread and persistent invader of tallgrass prairie reconstructions, and once established, it is notoriously difficult to suppress, even under repeated fire cycles. The observed increase in Kentucky bluegrass over just three years highlights the ongoing need for prescribed fire to maintain reconstructed prairies. Based on field observations that me and my team have made, late-spring burns are the most effective timing for suppressing Kentucky bluegrass, as the species is actively growing and highly susceptible to heat at that stage. However, these conditions also generate substantial smoke due to the moisture content of green vegetation, meaning that firefighter health and safety must be considered in fire planning.

Canada thistle (*Cirsium arvense*) also provided an important indicator of fire effects. Although it appeared in the top ten species prior to the burn, it no longer ranked among the dominant species after the fire treatment. This aligns with ecological expectations: Canada thistle can be temporarily suppressed by fire, especially when burns reduce litter layers and expose meristems to heat (Davis et al. 2018). While fire alone rarely eliminates Canada thistle, reductions in its relative frequency suggest that burns helped limit its competitive advantage during the sampling window.

These patterns collectively highlight the importance of continuing prescribed fire management. Without routine burning, Kentucky bluegrass would likely expand rapidly, outcompeting native warm-season grasses and accelerating a shift toward a lower-diversity, cool-season–dominated system. Continued burning, not as a one-time intervention but as a long-term, management practice, is essential to keeping invasive cool-season species in check, promoting native species health, and maintaining the ecological integrity of reconstructed prairies.

Vegetation Height

Mean vegetation height increased significantly in both burned and control plots over the study period. The likely explanation for this, as previously mentioned, is that Scott County experienced a severe drought in 2021 and 2022, which likely reduced plant growth for a number of consecutive years. As conditions improved in 2023, vegetation across all plots would have recovered and produced greater overall plant height. My hypothesis is further supported by the lack of significant interaction between treatments, suggesting the observed increase reflects a general post-drought recovery rather than a direct effect of fire. Additional support of this hypothesis is observed in the vegetation height decreasing significantly from 2020 to 2021, the start of the drought. Vegetation height then remains consistent in 2021, 2022, and 2023 with no significant changes. The drought ended in June of 2023, however there is still not a significant increase in height from 2022-2023, which is an indication that prairie vegetation requires more than a single year of normal precipitation to recover from a preceding drought. This lagged response suggests that many species continued reallocating resources to root systems or stored energy before resuming full above-ground growth, delaying canopy height recovery in 2023. Finally, in years 2023-2024 and 2024-2025, vegetation heights increased significantly as prairie vegetation made a full recovery.

Thatch Thickness

Thatch thickness remained consistent across all treatments and years, indicating limited responsiveness of litter accumulation during the study period. This suggests that site-level factors such as similar species composition, amount of precipitation, and soil types exerted stronger control over litter dynamics than the management treatments themselves. Any short-term reductions in litter from burning were likely offset by rapid post-fire regrowth, resulting in similar thatch levels between burned and control treatments. Consequently, thatch did not appear to mediate vegetation responses or influence diversity metrics in this study. However, longer-term monitoring may be required to capture the ecological effects of multi-year thatch accumulation, which would not be detectable within the time frame of this project. Lesica and Martin (2003) found that prescribed fire was critical for removing old plant detritus and litter in the Dancing Prairie Preserve of northwest Montana, creating patches of exposed soil that enhanced seed germination. To fully assess how excess thatch affects plant communities at SMSC, a management experiment that excludes fire from a subset of prairie for several years, allowing litter to accumulate, would provide valuable insight into the longer-term consequences of unmanaged thatch buildup.

CONCLUSION

Overall, the results of my study highlight the importance of using fire as a management tool in prairie reconstructions, and the value of site preparation and species-rich seed mixes to create resilient and stable prairie reconstructions. Although significant short-term changes in diversity and number of species were not detected in the burned treatment, the continued use of fire remains an essential management tool for maintaining prairie structure, controlling invasive species, and preventing encroachment by woody plants. The trajectory of the control treatments, if left unchecked, would most likely continue to degrade over time. The subtle trends observed here suggest that long-term monitoring across multiple burn cycles may be necessary to detect shifts in community composition and fully capture the ecological benefits of fire. Continued implementation of prescribed burning, invasive species control and interseeding, will help sustain the ecological integrity and biodiversity of the Shakopee Mdewakanton Sioux Community's prairie reconstructions for years to come.

LIMITATIONS

My study focused on alpha diversity metrics (species richness and Shannon-Weiner indices) to evaluate within-plot diversity responses to treatment. Beta diversity, which measures differences in species composition between plots, was not analyzed here but could provide valuable insight into how community composition varies across treatments. Future analyses using dissimilarity indices such as Jaccard or Bray–Curtis could help determine whether burning influences community turnover or homogenization across the prairie.

Another limitation of my study is that vegetation was analyzed as a single community instead of being divided into functional groups, as in several referenced studies. Incorporating functional groups may have revealed more complex responses to prescribed fire. Different types of plants like grasses, forbs, and shrubs often respond very differently to things like fire, drought, and competition. By not examining these groups separately, it's possible that some treatment-specific patterns were hidden. For example, grasses tend to increase after fire while forbs or shrubs show little change or even move in the opposite direction. Breaking the vegetation into functional groups and testing how each one changes in richness, evenness, or composition could give me a clearer picture of how the treatments influence the prairie habitat.

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APPENDICES

R-Code for Diversity Index Calculations

```
################### Updated Plot Data #############
getwd()
list.files()
combined_data <- read.csv("combined_data.csv")

#combined_data
#combined_data <- combined_data %>%
#mutate(unit == recode(unit, "Wetland S-5 (Menden)" ~ "Wetland S5"))

combined_data <- combined_data %>%
mutate(unit = case_when(
unit == "Wetland S-5 (Menden)" ~ "Wetland S5",
TRUE ~ unit
))

Plot_level_diversity <- function(x, z = combined_data, delim = "-") {
y = strsplit(x, split = delim)
unit_val = y[[1]][1]
year_val = y[[1]][2]

df <- z %>%
filter(unit == unit_val, year == year_val)

plot_summary <- df %>%
group_by(unit, plot) %>%
summarise(
richness = n_distinct(Scientific),
shannon = diversity(table(Scientific), index = "shannon"),
simpson = diversity(table(Scientific), index = "invsimpson"),
evenness = ifelse(richness > 1, shannon / log(richness), NA),
mean_height = mean(c(east, north, west, south), na.rm = TRUE),
mean_thatch = mean(Thatch, na.rm = TRUE),
native_pct = mean(status == "N", na.rm = TRUE) * 100,
invasive_pct = mean(status == "I", na.rm = TRUE) * 100,
year = first(year),
.groups = "drop"
)
```

<u>APPENDIX B</u>

Plot-Level Mean Diversity and Vegetation Characteristics Before and After Surveys

Prairie Unit Name	Treatment	Timepoint	Richness	Shannon	Percentage Native Species	Vegetation Height	Thatch Thickness
Bauer	Burned	Before	11.4 ± 2.6	2.29 ± 0.2	63 ± 13.2	3 ± 2.6	0.7 ± 1
Bauer	Burned	After	11.7 ± 3.6	2.28 ± 0.4	65.3 ± 10.9	9.9 ± 3.2	9.4 ± 50.7
Buffalo pasture	Burned	Before	6.4 ± 2.1	1.66 ± 0.3	94.6 ± 7.9	8.7 ± 2.5	8.5 ± 4.7
Buffalo pasture	Burned	After	9 ± 2.2	2.04 ± 0.2	89.7 ± 11.6	4.1 ± 1.7	7 ± 6.4
C7	Control	Before	10.2 ± 3.9	2.15 ± 0.3	80.3 ± 13.4	NaN ± NA	NaN ± NA
C7	Control	After	10.1 ± 2.7	2.16 ± 0.2	80.2 ± 9.6	5.5 ± 2	3 ± 1.5
Cook 1	Burned	Before	10.4 ± 3.8	2.14 ± 0.3	74.7 ± 17.2	3.3 ± 3.1	0.9 ± 0.9
Cook 1	Burned	After	10.7 ± 2.9	2.22 ± 0.3	56.8 ± 16.1	7.5 ± 3.1	4.4 ± 5.7
Cook 2	Burned	Before	12.7 ± 2.9	2.4 ± 0.25	82 ± 12.1	5.8 ± 2.1	0.7 ± 0.6
Cook 2	Burned	After	11.9 ± 3.8	2.28 ± 0.6	67.9 ± 20.1	9.3 ± 2.3	1.5 ± 4.8
Cook 3	Burned	Before	11.5 ± 2.6	2.31 ± 0.2	74.9 ± 13	4.5 ± 2.6	1.6 ± 1.4
Cook 3	Burned	After	15.2 ± 4.8	2.56 ± 0.2	70.5 ± 14.7	9.9 ± 1.3	0.3 ± 1
Cultural Center 01	Control	Before	12.9 ± 4.3	2.34 ± 0.3	81.2 ± 18.7	2.9 ± 1.7	0.1 ± 0.3
Cultural Center 01	Control	After	11.2 ± 3.9	2.23 ± 0.3	84.5 ± 19.9	7.5 ± 4.1	3.4 ± 3.5
Cultural Center 02	Burned	Before	11.2 ± 1.7	2.24 ± 0.1	74.5 ± 16.2	3.7 ± 1.8	1.2 ± 0.9
Cultural Center 02	Burned	After	9.5 ± 4	1.97 ± 0.6	83 ± 13	8.6 ± 5.5	0.4 ± 0.9
Mitigation	Burned	Before	9.2 ± 4.5	1.93 ± 0.5	85.2 ± 25.2	NaN ± NA	NaN ± NA
Mitigation	Burned	After	9.7 ± 4.4	2.01 ± 0.5	77.5 ± 26.2	10.2 ± 5.4	2.1 ± 3.1
Peterson 01	Burned	Before	11.1 ± 3.1	2.23 ± 0.2	90.5 ± 13.7	3.4 ± 1.2	2.8 ± 1.1
Peterson 01	Burned	After	13.3 ± 4.1	2.44 ± 0.3	84.4 ± 16.6	4.8 ± 2.6	2.1 ± 1.5
Peterson 03 & 04	Burned	Before	13.5 ± 4.1	2.42 ± 0.3	83.4 ± 10.2	8.3 ± 2.8	1.9 ± 1.3
Peterson 03 & 04	Burned	After	12.8 ± 3.5	2.35 ± 0.4	75.2 ± 14.8	6.5 ± 3	2 ± 2.9
Shakopee Memorial Park	Burned	Before	6.2 ± 2.7	1.61 ± 0.4	69.2 ± 18.8	8.6 ± 4.5	2 ± 1.8
Shakopee Memorial Park	Burned	After	13.4 ± 5.3	2.29 ± 0.4	80.2 ± 14.6	7.6 ± 2.6	0 ± 0
Shakopee Memorial Park	Control	Before	9.2 ± 2.5	2.08 ± 0.3	93.2 ± 6	4 ± 1.5	1.1 ± 0.3
Shakopee Memorial Park	Control	After	6.2 ± 2.7	1.61 ± 0.4	69.2 ± 18.8	8.6 ± 4.5	2 ± 1.8
Shutrop 01	Control	Before	8.1 ± 3.1	1.86 ± 0.5	87.7 ± 13.9	11 ± 4.4	5.7 ± 2.5
Shutrop 01	Control	After	9.4 ± 4.5	1.9 ± 0.86	81.7 ± 18.6	7 ± 2.7	7.4 ± 5.5
Tewapa 01 & 02	Burned	Before	12.8 ± 4.4	2.33 ± 0.3	97.6 ± 4.6	5.4 ± 2.2	3.7 ± 1.4
Tewapa 01 & 02	Burned	After	11.5 ± 4.2	2.26 ± 0.3	90.2 ± 11.2	8.3 ± 5.9	3.6 ± 1.9
Tewapa 03	Burned	Before	12.7 ± 3.3	2.34 ± 0.2	75.1 ± 22.8	5.2 ± 2.6	2.7 ± 0.8
Tewapa 03	Burned	After	10 ± 4	2.12 ± 0.4	70.2 ± 33.1	8.6 ± 3.3	4.4 ± 1.8
Tewapa 04	Burned	Before	14.3 ± 4.2	2.53 ± 0.2	86.1 ± 4.7	6.3 ± 2.8	3.3 ± 2.2
Tewapa 04	Burned	After	12.8 ± 1.9	2.43 ± 0.1	88.8 ± 7.5	9.2 ± 5.3	5.5 ± 1.4
Tollefson	Burned	Before	12.4 ± 4	2.36 ± 0.3	93.8 ± 6.1	NaN ± NA	NaN ± NA
Tollefson	Burned	After	12.1 ± 2.6	2.36 ± 0.2	96.9 ± 5.4	6.9 ± 4.4	5 ± 3.3
Wetland S5	Control	Before	13.5 ± 4.1	2.42 ± 0.3	78.5 ± 17.5	NaN ± NA	NaN ± NA
Wetland S5	Control	After	13.3 ± 3.8	2.39 ± 0.3	76.5 ± 11.6	3.9 ± 1.2	1.8 ± 0.8