2021

The Relationship Between Time and Plant Diversity in Prairie Restorations Within the Prairie Corridor on Haines Branch

Elizabeth Park

THE RELATIONSHIP BETWEEN TIME AND PLANT DIVERSITY IN PRAIRIE RESTORATIONS WITHIN THE PRAIRIE CORRIDOR ON HAINES BRANCH

by

Elizabeth Park

An Undergraduate Thesis

Presented to the Faculty of

The Environmental Studies Program at the University of Nebraska-Lincoln

In Partial fulfillment of Requirements

For the Degree of Bachelor of Science

Major: Environmental Studies

With the Emphasis of: Natural Resources

Under the Supervision of

David Wedin, Ph.D., School of Natural Resources

Katharine Hogan, M.S., School of Natural Resources

Abstract

This study focuses on better understanding the relationship between the age of prairie restorations and their plant diversity. The study looks specifically at the prairie restorations within the Prairie Corridor on Haines Branch, located west of Lincoln, Nebraska. The data gathered from these restorations show a positive correlation between age and native plant diversity. This diversity indicates that the restorations are fulfilling their purpose by bringing native prairie plants back to the area. From the data I came to these four conclusions, 1) Because the study only included two restorations greater than 10 years old, it is unclear if the number of native plant species has stabilized or will continue to increase. 2) For the first two years, the restorations are dominated by agricultural weeds, but these weeds decrease in abundance dramatically in years two through four. 3) The plant species composition of the restorations differs considerably from the remnants and the two grassland types are not converging over time. 4) Some native plant species are common in remnant prairies of the Prairie Corridor but are rare or absent in the restorations, these species are good candidates for transplanting. More data from future years are needed to strengthen the data sets, but this study's results are promising.

Keywords: restoration, conservation, environmental studies, grasslands, prairies, plants

Acknowledgements

First, thank you to Dave Wedin and Katharine Hogan for their knowledge, patience, and support throughout this process. I would not have been able to produce this thesis without them! Thank you to Lincoln Parks and Recreation, Prairie Plains Research Institute, and all the other stakeholders of the Prairie Corridor. Thank you to the Nebraska Environmental Trust, this research was partially funded through a grant and would not have been possible without it. Finally, thank you to my family, specifically Phillip and my mom for always believing in me and encouraging me to follow my passions and dreams.

Contents

Introduction

Prairie restorations are crucial in the state of Nebraska. Ecological restoration helps recover ecosystems that are damaged, degraded, or destroyed (Society for Ecological Restoration n.d.). The United Nations recently declared 2021-2030 as the "Decade of Restoration," stating that "there has never been a more urgent need to restore damaged ecosystems than now" (United Nations n.d.).

The Prairie Corridor on Haines Branch is a developing network of restored and remnant prairie outside Lincoln, Nebraska. The Corridor aims to "support economic development, build on Lincoln's nationally recognized trail system, support environmental education and promote the enhancement and preservation of one of Nebraska's most valuable resources – tallgrass prairie" (Prairie Corridor 2019). Research projects within the Corridor may prove valuable in understanding restorations within the state and the tallgrass prairie region. The Corridor partners with the Prairie Plains Resource Institute (PPRI) in its restorations. PPRI was founded in 1980 with a mission to preserve "native Nebraska habitats for use as educational sites for biodiversity, preservation, science, history and land management" (Prairie Plains Resource Institute 2020).

The Prairie Corridor missions and PPRI are similar; both organizations seek to preserve Nebraska's prairies for environmental education. The Prairie Corridor takes it one step further, intending to generate economic development by building on Lincoln's trail system.

The Prairie Corridor study on Haines Branch is an asset to the stakeholders within and outside the organization. The Prairie Corridor partners, including Lincoln Parks and Recreation, Lower Platte South Natural Resources District, and Spring Creek Prairie Audubon Center, have an ambitious vision that includes future prairie restorations. This analysis will help them understand how the restorations have progressed and identified what should be implemented in future restorations. Outside of the organization, stakeholders such as landowners can look at the analysis when deciding what to do with their land. Understanding the importance of plant diversity and how diversity changes over time are pivotal to these stakeholders.

This thesis aims to understand the relationship between time and plant diversity in the Prairie Corridor by asking, "What impact does time have on plant diversity within restorations in the Prairie Corridor on Haines Branch?" I investigate total plant diversity, native plant diversity, and the coefficient of conservatism within the restorations. Ecologists define species diversity as having two components: species richness (defined as the number of species present in an area or sample) and evenness (a measure of the relative abundance or frequency of different species). In this study, I surveyed 30 one-square meter quadrats per field for eight prairie restorations of different ages (Table 1). Because some of the fields were surveyed in multiple years, the data set has 17 total field-by-year combinations. In addition to the presence or absence of a species in a single quadrat, the frequency of that species across 30 quadrats provides a measure of relative abundance for that field in that year. The frequency of a species across all quadrats (17 x 30 = 510) provides a measure of its relative abundance across all the fields studied (appendix). In addition to species richness and frequency, for each species, I considered its Coefficient of Conservatism, an index ranging from 0 to 10 indicating the rarity and conservation value of a particular native species (Swink & Gerould 1994).

The study of restorations within the Prairie Corridor can add to the understanding of the processes that maintain diversity. Understanding plant diversity within these restorations benefits the Prairie Corridor on Haines Branch, land managers across the state, and the tallgrass prairie region as it documents the long-term behavior of prairie restorations. This study aims to add to the general understanding of plant diversity within aging restorations.

Literature Review

Tallgrass prairie is one of the most endangered ecosystems in North America, as only 1% of it remains (Rowe 2013). Restoration aims at assisting the recovery of this landscape. Prairies provide multiple benefits to both flora and fauna and human users of prairies. Plants and animals within prairies benefit from habitat, food, and water, while the landscape, region, and planet benefit from carbon sequestration and hydrologic functioning (Steiner et al., 2019).

In addition to services provided above ground, there are many benefits to below-ground ecosystems, such as the ones found within grassland soils. Prairie ecosystems create high microbial diversity. This microbial diversity is especially apparent in comparison to agricultural systems (Upton et al., 2018). The belowground microbiome is damaged due to the switch to agricultural land. However, prairie restoration can reconstruct the microbiome (Fierer et al., 2013). Through the analysis of various microbial activities, one study found that using genetic approaches "can be used to reconstruct belowground biogeochemical and diversity gradients in endangered ecosystems" (Fierer et al., 2013). Tallgrass prairie once dominated the midwestern United States and once had a very productive microbiome. The Midwest could reap a productive microbiome's benefits underneath a restored prairie through reconstruction of the microbiome.

Microbial diversity is essential within soil systems. One benefit of high microbial diversity is an increased resilience to drought (Upton et al., 2018). As climate change creates more uncertain weather patterns, resilience is key to a productive ecosystem. Ecological resilience is the amount of stress an ecosystem can take before it changes from one structure to another (Angeler & Allen 2016). Restoring the land to prairie will help protect our region from the negative impacts of climate change, such as drought.

Restoration has never been more crucial given our changing climate. Tallgrass prairies and grasslands, in general, provide an enormous amount of benefits, including carbon storage (Wilsey 2020). The carbon sequestration benefits are especially apparent when comparing cropland and prairies. A study conducted in 2010 found that the "establishment of prairies on previously cultivated cropland provides an opportunity for greater soil organic carbon sequestration rates" than cropland alone (Guzman & Al-Kaisi, 2010). Carbon sequestration is a critical way to mitigate the future effects of climate change. Carbon sequestration is the capture of carbon dioxide to prevent it from reaching the atmosphere, thus avoiding warming via the greenhouse gas effect (University of California-Davis 2020).

Prairie restorations also positively impact remnant, unplowed prairie remnants. When looking at remnant prairies, one study found that "nonnative [plant] dominance increased from interior to edges by 78% when adjacent to roads/abandoned lands and by 29% when adjacent to crops but remained even (and low) when adjacent to prairie restorations" (Rowe 2013). Understanding that the merits of a productive prairie restoration extend beyond the prairie's borders can help individuals prioritize restoring these vital grasslands. Combining restorations with remnants is an effective tool for buffering prairie remnants and slowing the advancement of nonnative and invasive plants. By providing connectivity among remnant prairies and isolated populations of plants and animals, restoration enhances the viability of native prairie populations.

Furthermore, a 2020 study from the United States Department of Agriculture found that prairies further from habitat edges had higher native forb diversity (Grant et al., 2020). This is due to several reasons. Non-native species are easily dispersed from adjacent roads and agricultural fields. Also, less fertile and steeply sloped areas are less likely to be converted into agricultural land. This leads these areas to be less disturbed and, therefore, higher in native diversity and lower in non-native diversity. This is important to note when looking at what areas can be the most productive and effective for restoration and how they can connect to existing restored or remnant prairies.

To effectively restore prairies, practitioners must also enact best land management practices for the land as well as replanting native species. A study conducted in southwest Michigan found that across 27 restoration sites, "management, especially the composition, diversity, and density of seed mixes applied, and history, especially site age, were the most important drivers of prairie restoration species richness" (Grman et al., 2013). This might seem intuitive, but it is still crucial to keep in mind when developing prairie management plans and procedures.

Due to the nature of prairie ecosystems and how degraded and damaged they have become, wide scale replicated studies across the grassland region are difficult to do. There are commonalities among various prairie restoration sites both in restoration methods and management. In 2010, Helen Rowe conducted a survey to find those commonalities and help understand the impact and effectiveness of various prairie management tools. She concluded hydrologic restoration was often necessary. Most restoration projects emphasized the need to increase forb (i.e., flowering herbaceous plants) diversity (Rowe 2010). Over two-thirds of experts surveyed also stated that invasive plants were a significant threat to the land and spent 25% of their time trying to curb the spread of invasives (Rowe 2010). It is important to acknowledge these practitioners' perspectives in light of the lack of extensive, replicated studies. One study analyzed data from two prairies over ten years and called for a public database to understand geographic variability within restorations (Larson 2018). This would help land managers understand the correlation between seeding and management within different areas and different land types.

Another study followed the same prairie for fifty years. It tracked changes in diversity and “the overall integrity of the native plant community” (Dornbrush 2004). Mathew Dornbrush found that the site managers were successful in reducing the abundance of nonnative plant species. Still, they observed large losses in the prevalence of native species over half a century. He urged that we need to “merge our current understanding of the processes that help sustain diversity into implemented management practices that will prolong the diversity of our remaining small isolated prairie preserves” (Dornbrush 2004).

When identifying effective management techniques, especially appropriate seed mixes, there is some uncertainty. Some efforts to increase diversity include adding different seed types and manipulating the ecosystem to impact establishment (Sluis 2020). There is more to study when it comes to understanding restoration outcomes. With the influx of new technology and accumulating knowledge, we can better understand how time impacts diversity within prairie restorations as a whole.

Methods

The methods for this study are in two sections. The first section covers the seeding methods used in Prairie Corridor restorations. The second section covers the research methods of this particular study.

Prairie Plains Research Institute Seeding Methods

PPRI provided the seed and planting for all of the prairie restorations used in this study. Their methods for seed collection, processing, and planting have changed little over the last 15 years. PPRI, along with the Nebraska Game and Parks Commission, created a manual titled "A Guide to Prairie and Wetland Restoration in Eastern Nebraska." The methods from the manual are summarized here. This included gathering prairie seed, developing seed mixes, and planting the restorations. Planning consists of identifying sites for restoration and dedicating the time to obtain quality seed and create a restoration timeline. PPRI uses High Diversity Local Ecotype (HDLE) seed for their restorations. HDLE seed is defined as a seed mix with over 75 species that were collected from wild populations less than 100 miles from the restoration site. An example of the PPRI seeding plan and seed mix for the Twin Creeks Prairie restoration (Plot 33 in this study) is in the appendix. In that planting, the “mesic” mix used in most of the restoration had 149 native species.

Prairie seed collection occurs in many remnant prairies and wetlands throughout eastern Nebraska. PPRI starts collecting seed in mid-May and continues through October and in some years to early November. Prairie seed sites are checked regularly for ripened seeds. PPRI collects the seed when the majority of it has matured to prevent seed fallout. In addition, PPRI only collects what is needed for restorations to avoid overharvesting. They do this by limiting the amount of seed that they take from each site. The organization gathers seed by hand collection and through the use of combines and mechanical seed strippers. After the seed is collected, it is dried and then processed if needed. PPRI recommends processing seed collected by hand. Processing includes threshing the seed to remove it from the seed head or various capsules. The seed is then stored until it is ready to be put into seed mixes.

Over the last 15 years, PPRI has used two seed mixes for the eight Prairie Corridor restorations I studied: a "mesic" mix on wetter sites and an "upland" mix on drier sites. Some plantings contain both mesic and upland areas based on surveys of soil type and site hydrology done by PPRI in each project proposal (see appendix). Because their two mixes have about 70% species overlap in most years and the mixes vary slightly from year to year based on seed availability, I did not separate sites originally planted with different mixes in my analyses. PPRI typically plants 10 gallons of seed per acre: 2 gallons of forbs and 8 gallons of grasses. The forb mixture is hand collected by single species, while the grass mixture is combined from native prairie and contains some tall forbs, such as *Helianthus maximiliana*. A gallon of PPRI seed has been standardized to contain approximately one pound of seed. In order to compare the seeding rate in terms of viable seed between PPRI and other conservation projects using certified seed (e.g., the Conservation Reserve Program), PPRI tests its seed mixtures for purity (percent seed versus chaff) and germination (% viable seed) at the Colorado Seed Laboratory (Colorado State University). Lab analyses and calculations with the 2019 mesic mix indicated that the planting rate was 4.6 lbs PLS (pure live seed) per acre and contained about 85% grass seed by weight and 15% forb seed. The PLS planting rate is an important metric in conservation plantings. Prairie plantings in Iowa and the eastern Midwest tend to have heavier seed rates and seeding rates for commercial projects (e.g., new road construction) tend to be much heavier. The experience of

PPRI and the Nature Conservancy in Nebraska have found that restorations planted with heavier seeding rates tend to have few forbs and more continuous grass cover (Helzer et al. 2010).

PPRI plants restorations typically from October to late May. For small restorations, the seed mixes are broadcast by hand. These plantings utilize volunteers and are typically done on restorations up to 50 acres. For larger restorations, PPRI uses a fertilizer spreader pulled by an ATV as a broadcast seeder. Under ideal conditions, 10 acres can be planted in an hour using this type of machinery. After the restoration site is planted, various management practices such as prescribed fire and haying can be used to curb non-native plants. However, patience is key to the development of a prairie. Perennial prairie plants allocate the majority of their biomass to roots, while annual weeds allocate the majority of their biomass to leaves. Until the prairie plants, particularly the grasses, establish their perennial root system over several years, they are not competitive with annual weeds. PPRI generally does not manage or mow newly planted sites for the first two growing seasons. This "hands-off" approach for the first two years distinguishes PPRI from managers in higher rainfall regions to the east (e.g., Iowa, Illinois), where mowing is recommended to reduce weed competition for the first few seasons. One value of this study is to determine the success of PPRI's hands-off approach and provide some data for the regional "to mow or not to mow" debate. Burning, haying, or another form of biomass removal is usually recommended in year 3 or 4 and approximately every three years subsequently. Once plants establish, data collection can help determine the prevalence of different types of plants and the diversity within a restoration as it matures.

Methods within the Prairie Corridor Research

Within the Prairie Corridor, eight restoration fields were selected for long-term study. The ages of the restorations ranged from 1-year-old to 14-years-old in 2020. See Table 1 for information on each restoration site. Each of the restoration fields was given an ID# and name as identifiers. The majority of the restorations were planted in soybean stubble, except site #12-Spring Creek planted in disked corn stubble. Regardless of whether a field was seeded in late fall or spring, it was assigned an age based on the restoration's first growing season. For example, the Honvlez field was seeded in December 2019 and the Kapke field in April 2020, but both were considered one year old in 2020.

Plant surveys were done in the first half of August of 2017, 2018, and 2020. In each of the restoration fields, a 60-yard radius circle (2.4 acres) was established near the center of the restoration field. The center of the plot was marked using GPS. 30 one-square-meter quadrats were randomly placed within the circle. Presence or absence for each plant species, as well as an estimate of its areal cover, was recorded for each of the quadrats. Scientific names are used in this paper, but common names for all species are provided in the appendix. The analyses presented here used presence/absence data for plant species in the quadrats, which provided an estimate of frequency of occurrence at the field level and for the overall study. The data were collected by the UNL Prairie Corridor research team or by botanists from Prairie Legacy Inc. I worked with both teams on data collection in 2019 and 2020. For an example datasheet, see Appendix C. Each field was sampled between one and three times. For example, site #13-Twin Creeks was analyzed as a one-year-old, two-year-old, and four-year-old restoration. Thus, the data set combines two ecological approaches to studying succession: a chronosequence, which surveys fields of different ages at one point in time, and surveys over time of individual fields as they age. Plant surveys were also done in June 2017, but analyses found almost the same species richness and frequency patterns in June and August, so only one sampling date was used in subsequent sampling.

We surveyed the species composition of 15 remnant prairies in the Prairie Corridor with the same plot size and number of quadrats. That data set is summarized here for comparison with the restored prairies.

Each years' data were entered into Excel from the hand-written datasheets. Summary data for each field in each year sampled were calculated in Excel and transferred to the statistical software JMP for graphing and analyses. The variables used for this analysis were total species richness per field, native species richness as a percent of total richness, and the mean score for Coefficient of Conservatism in one-square meter quadrats in that field (Figure 1). Figure 2 shows frequency versus age for the ten most abundant species across all restorations. The lines in Figure 2 are smoothed running averages created by JMP for visualization and are not statistical curve fits.

The table in the appendix lists all species found in the 17 surveys conducted in the restorations. Note that non-native species do not receive a Coefficient of Conservatism and are indicated by an asterisk. The frequencies for each species in this table are for all quadrats surveyed (17 fields x 30 quadrats) and thus indicate the likelihood of observing a species in a square meter across all restorations regardless of age.

Results

We observed 182 plant species within the restoration plots: 37 graminoids (grasses and sedges), 128 forbs (other herbaceous species), seven shrubs, and ten trees. The graphs below summarize 17 surveys of unique site-year combinations. The total species observed per field was generally constant (Figure 1a). The number of species observed per field was not significantly related to field age when analyzed with regression (r^2=0.10, F=1.266, P=0.216). In contrast, the proportion of total species in each field that were native increased with field age (Figure 1b). After transforming field age to the natural log of field age (lnAge) because of the non-linear response, the regression between the proportion of native species and lnAge was highly significant (r^2=0.685, F=32.5, P<0.0001). I also calculated the mean Coefficient of Conservatism value per square meter quadrat for each field. After transforming field age with natural logs, the mean Coefficient of Conservatism increased significantly with field age (Figure 1c; r^2=0.698, F=34.7, P<0.0001).

I analyzed the response to field age of the top ten plant species based on their frequency across all the restorations. The top ten species were *Andropogon gerardii, Elymus* sp., *Conyza canadensis, Helianthus maximiliana, Monarda fistulosa, Sorghastrum nutans, Solidago canadensis, Helianthus pauciflorus*, *Setaria* sp., and *Ambrosia trifida*. We combined *Elymus canadensis* and *Elymus virginicus* as some observations were only recorded to the genus. For the complete list of species with their rank, Coefficient of Conservatism value, and frequency across all fields, see Appendix C.

Andropogon gerardii increased in frequency quickly with field age and then leveled off. In contrast, the annuals *Conyza canadensis* and *Setaria sp.* were initially abundant but dropped off sharply by year 4. The native perennial grass *Elymus sp* and the native annual *Ambrosia* *trifida* appeared to reach maximum abundance between years 3 and 5 and then decreased somewhat. The remaining five top species, all native perennials, increased in abundance by year four but showed variables patterns with age.

Tables 2 and 3 provide the frequencies of the top 15 graminoid, forb, high quality (defined as C of C value >= 5), and alien species in the restorations and the remnant prairies within the Prairie Corridor. The complete remnant prairie dataset is not presented, but the top species are listed here to provide a comparison with the restored prairie dataset.

Discussion

Native plant diversity within the Prairie Corridor's High Diversity Local Ecotype (HDLE) restorations increases as they age. The mean Coefficient of Conservatism value for each field also appears to increase as the restorations age. Thus, the conservation value of these prairie restorations continues to increase for 14 years, the oldest restorations in this study. For the first two years, the restorations are dominated by agricultural weeds, but these weeds decrease in abundance dramatically in years two through four. By year 5, the restored prairie has about 85% native plant species and appears to be resistant to invasion by non-native perennials such as *Bromus inermis* and Eurasian forbs. However, the Prairie Corridor's oldest restorations are just 14 years old, so their long-term species composition is unclear.

Big bluestem (*Andropogon gerardii*) is the dominant grass in both restored and remnant prairies of the Prairie Corridor. However, the plant species composition of the restorations differs considerably from the remnants, and the two grassland types are not converging over time. Both grassland types undoubtedly differ from the historic tallgrass prairie community encountered by European settlers in the mid-1800s. Today, the two grassland types complement each other and together increase diversity in the Prairie Corridor. Compared to prairie remnants, the restorations have lower frequencies of alien or non-native species such as the perennial cool-season grasses *Bromus inermis* and *Poa pratensis* or non-native perennial forbs. If the goal of restoration in the Prairie Corridor was to replicate current remnant prairies, we should be planting *Bromus inermis* alongside the native grasses. On the other hand, the remnant prairies have some plant species not found in the restorations. In a recent Prairie Corridor study, bee and flower surveys by entomologist Katie Lamke indicated that the native prairie remnants provide more floral resources and support more native bee species in the spring, while the restorations provide more floral resources for native bees later in the growing season (Lamke 2019).

Of the 182 plant species found in our surveys, 135 were native to Nebraska. Seventy-seven of these native species are listed in the HDLE seed mixes planted by PPRI, which have from 145 to 175 species in a particular year (appendix). Thus, about half of the species from the HDLE seed mixes have not been established in the restorations or were rare and not observed because of our survey methods. Because our study only included two restorations greater than ten years old, it is unclear if the number of native plant species has stabilized or will continue to increase. Some native perennials, such as *Elymus canadensis* and *Helianthus maximiliani*, peak in years four to six and then decline in abundance. Management, such as burning and grazing, and natural disturbance, such as badgers and gophers, will also affect the species diversity of these restorations in the long term.

Some native plant species are common in remnant prairies of the Prairie Corridor but are rare or absent in the restorations. For example, *Panicum oligosanthes* is the second most abundant native grass in remnants (36% frequency in square-meter quadrats across all 15 remnant fields) but has a frequency of less than 1% in restorations. Similarly, *Viola pedatifida*, the obligate host for a rare prairie butterfly, has a frequency of 8% in remnants but was never observed in a restoration. The failure of certain prairie species in restorations may result from poor seed production, germination, or establishment. These species are candidates for greenhouse establishment and transplanting into restorations, which, although expensive, may be necessary for species such as *Viola pedatifida*.

The primary limitation of this study is the amount of data collected. By surveying only 30 quadrats per field, we get a good picture of the prairie plant community but undoubtedly miss rare species. Rare species may include high-value native species or, in contrast, non-native noxious weeds newly established in a field. Monitoring for rare plant species in the Prairie Corridor should be done but requires different survey methods. Increased sampling frequency in both time and space would lead to stronger data sets. Larger data sets are necessary to tease out the effects of spatial variability (e.g., mesic versus dry prairies), interannual variability associated with climate, and the short- and long-term effects of management such as grazing or fire on individual plant species. These issues should be addressed as the amount of restored prairie in the Prairie Corridor (295 acres in 2020) continues to grow, and land managers seek the best ways to manage both restored and remnant prairies.

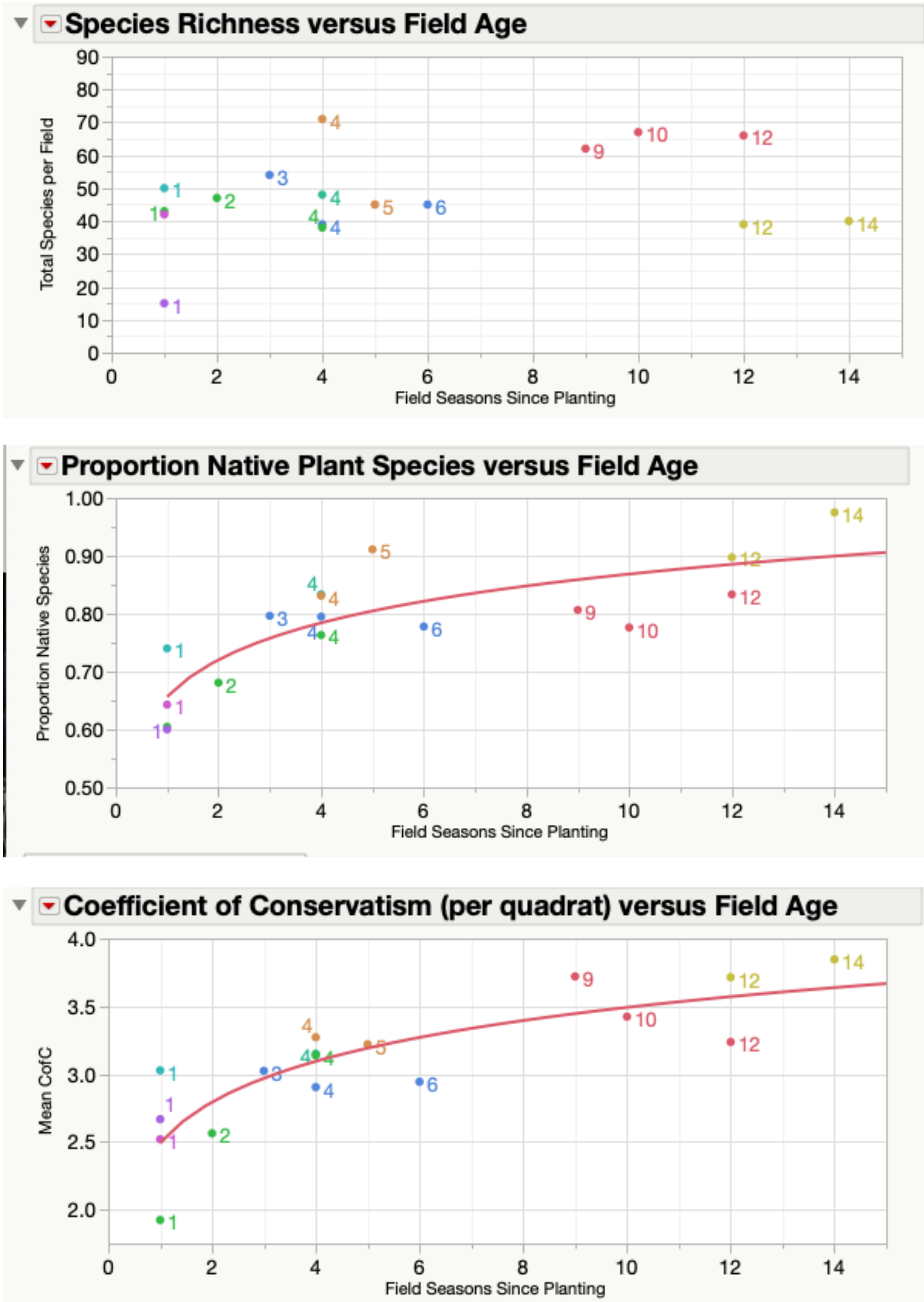
Future Directions

In addition to the HDLE seed mix, greenhouse-grown transplants (e.g., “plugs” in tube-shaped pots) may be useful in prairie restoration. These plug plantings could help target species that are not found in prairie restorations but are present in remnant prairies. PPRI has utilized plug plantings in a few areas within the prairie corridor, specifically within Denton Prairie and Pioneers Park. In the fall of 2019, 500 *Viola pedatifida* plants were planted in Denton Prairie, which was four years old at the time. Decisions on where to plant transplants were made by both the City of Lincoln and PPRI. The plantings were done in restoration fields ranging from two to four years old and in upland conditions where vegetation density is lower.

If these plantings are successful, the Prairie Corridor may benefit from approaching other rare species in the same way. Prairie flowers such as *Astragalus crassicarpus*, *Sisyrinchium campestre*, and *Pediomelum tenuiflorum* rarely succeed within prairie restorations. Getting species such as these into restorations may be as simple as planting them there in plugs. These plant species are beneficial because they bloom in the spring and provide additional resources to pollinators during a time of year when few plants are flowering. However, transplants are both labor-intensive and expensive when compared to broadcast seeding.

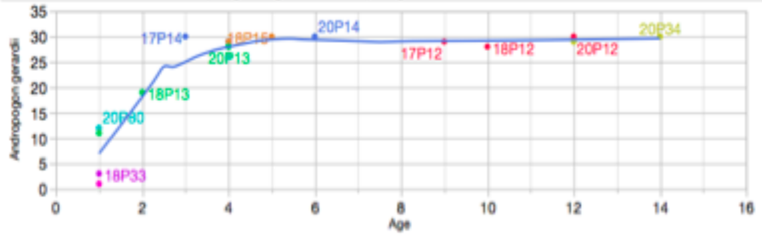
Conclusion

Prairie restorations, like the ones found in the Prairie Corridor, are crucial not only in Nebraska but throughout the prairie region. Prairies provide a multitude of benefits, including habitat for plants and animals in addition to carbon sequestration and water regulation (Steiner et al., 2019). This study focused on the Prairie Corridor and aimed to understand the relationship between time and plant diversity within restorations. The data show that while the total number of types of plants remained relatively constant, there was a positive correlation between the age of restorations and native plant diversity. Furthermore, there was a positive correlation between the age of restorations and the average Coefficient of Conservatism values for restored fields. Thus, the value of the restorations to conservation is increasing with time. Will that pattern continue as the restorations age beyond 14 years? On-going monitoring and research are needed in the Prairie Corridor to answer that question.

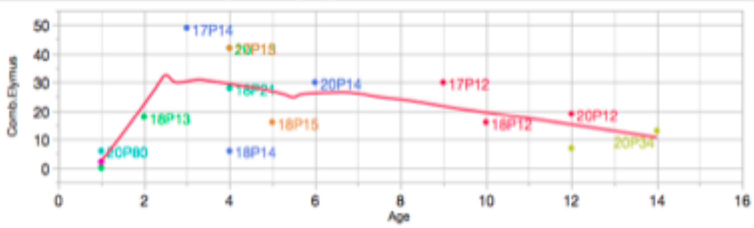


Figures 1a-1c. Graphs comparing the total plant species richness per field, the proportion of native plant species, and mean C of C values for one-square meter quadrats compared to restoration age. The linear regression for 1a was not significant. Field Age was transformed for 1b and 1c with Natural Log before linear regression analyses. Regressions in both 1b and 1c were both highly significant (see Results for details). Symbols of one color represent the same field surveyed over several years (e.g., Plot 12 in 2017, 2018, and 2020 values are in red).

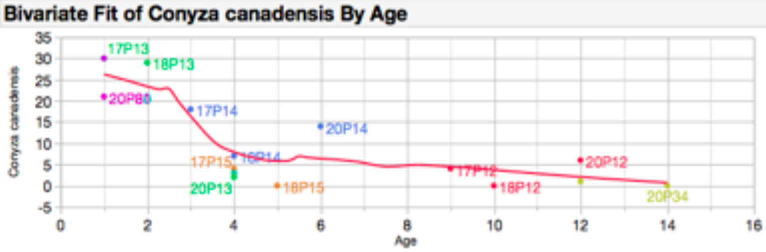
Bivariate Fit of Andropogon gerardii By Age



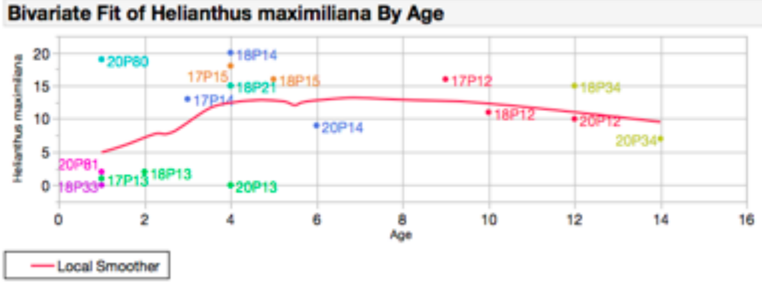
Bivariate Fit of Comb.Elymus By Age



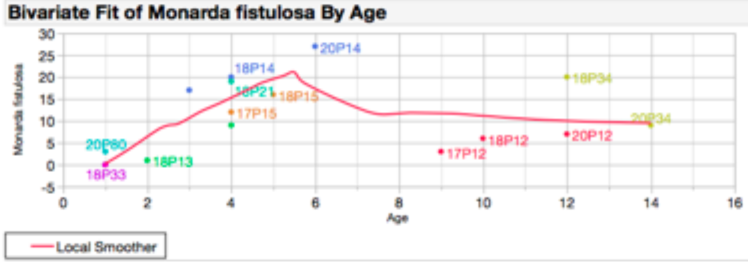
Bivariate Fit of Conyza canadensis By Age

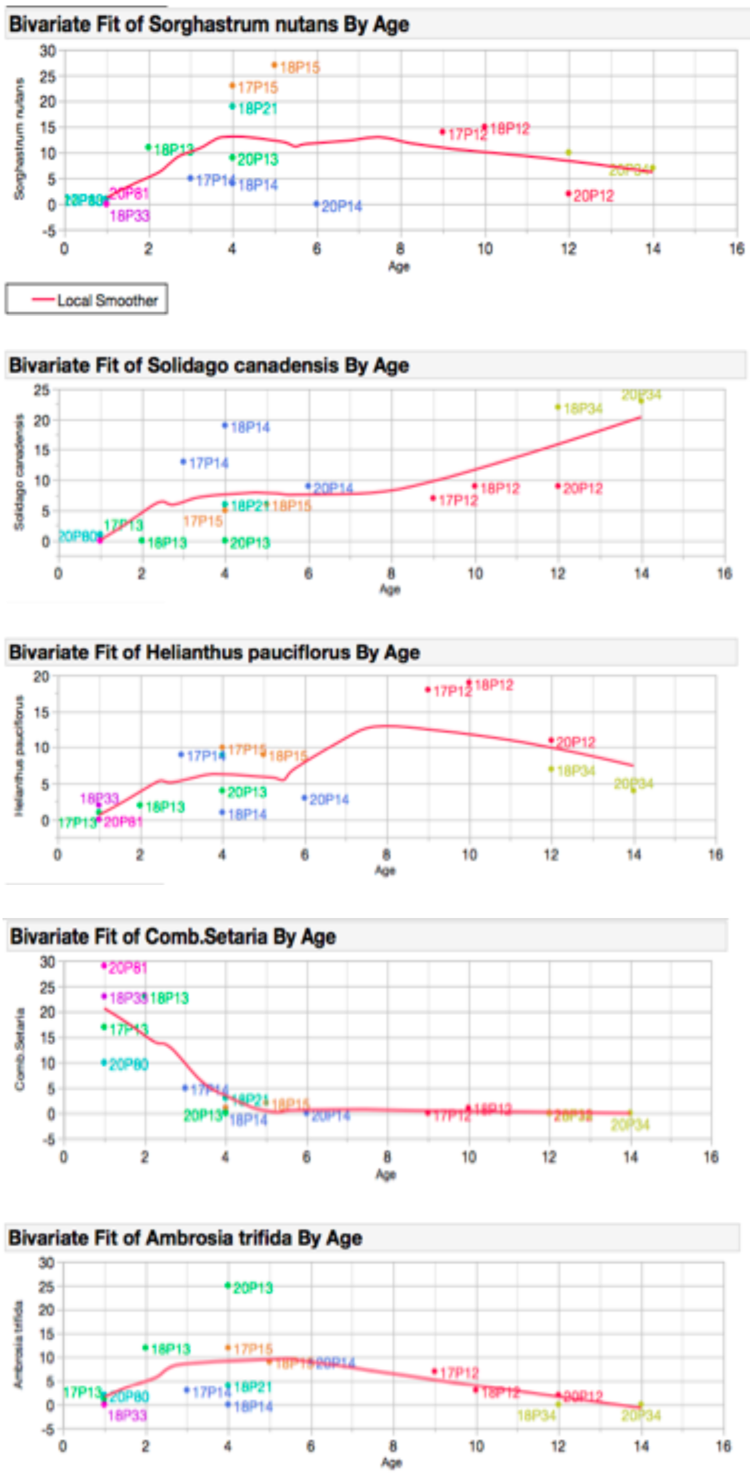


Bivariate Fit of Helianthus maximiliana By Age



Bivariate Fit of Monarda fistulosa By Age





Figures 2a-2j: Graphs comparing the frequency of occurrence to restoration age for the ten most abundant plant species found in HDLE restorations in the Prairie Corridor. The maximum frequency is 30 out of 30 quadrats, except for *Elymus* sp. Lines on the graphs are smoothed averages provided for visualization and are not statistical fits.

ID# 2020	NAME	AGE (2020)	PLANTING DATE	VEGETATION SURVEY YEARS	ACRES	SEED MIX	PREP
34	SpringCreek	14	4/16/2007	2018, 2020	13.96	upland	bean stubble
12	SpringCreek	12	3/20/2009	2017, 2018, 2020	13.85	upland	disked corn stubble
14	Denton Pr N	6	12/12/2014	2017, 2018, 2020	24.9	mesic	bean stubble
21*	Denton Pr N	6	12/12/2014	2018	24.9	mesic	bean stubble
15	Denton Pr S	5	5/15/2015	2017, 2018	9.2	mesic	bean stubble
13	Twin Creeks	4	2/21/2017	2017, 2018, 2020	17.12	upland	bean stubble
33	Twin Creeks	3	3/15/2018	2018	11.4	upland	bean stubble
81	Honvlez	1	12/12/2019	2020	19.19	upland	bean stubble
80	Kapke	1	4/4/2020	2020	48.09	mesic	bean stubble

Table 1. Table of restoration information provided by PPRI. * Plot 21 is the portion of Plot 14 that was burned in 2018 and surveyed separately that year.

HDLE Restorations	Frequency	Remant Prairie	Frequency
Native Graminoid top 15			
Andropogon gerardii	0.7725	**Andropogon gerardii**	0.8778
Elymus canadensis	0.3922	Panicum oligosanthes	0.3600
Sorghastrum nutans	0.2902	**Bouteloua curtipendula**	0.2800
Elymus virginicus	0.2471	**Sporobolus compositus**	0.2778
Panicum virgatum	0.1137	Schizachrium scoparium	0.2133
Muhlenbergia racemosa	0.0529	**Carex sp.**	0.2111
Carex brevior	0.0490	**Carex brevior**	0.1511
Panicum dichotomiflorum	0.0392	**Sorghastrum nutans**	0.1400
Carex sp.	0.0314	**Carex gravida**	0.1244
Sporobolus compositus	0.0216	Eragrostis spectabilis	0.1000
Bouteloua curtipendula	0.0196	Panicum ovale	0.0733
Leersia virginica	0.0157	Sporobolis heterolepis	0.0489
Phalaris arundinacea	0.0118	Hesperostipa spartea	0.0467
Carex gravida	0.0098	Tridens flavens	0.0333
Digitaria cognata	0.0098	**Panicum virgatum**	0.0311
Native Forb top 15			
Conyza canadensis	0.3725	Ambrosia psilostaycha	0.3778
Helianthus maximiliana	0.3412	**Conyza canadensis**	0.3400
Monarda fistulosa	0.3314	Vernonia baldwinii	0.2333
Solidago canadensis	0.2549	**Solidago canadensis**	0.2267
Helianthus pauciflorus	0.2137	Aster eriocoides	0.1711
Ambrosia trifida	0.1745	Ambrosia artemisiifolia	0.1667
Asclepias syriaca	0.1137	Brickellia eupatorioides	0.1400
Achillea millefolium	0.1118	**Asclepias syriaca**	0.0956
Solidago rigida	0.1078	Salvia azurea	0.0867
Silphium integrifolium	0.0980	Erechtities hieracifolia	0.0822
Solidago gigantea	0.0961	Viola pedatifida	0.0822
Amaranthus tuberculatus	0.0922	**Achillea millefolium**	0.0733
Solidago missouriensis	0.0863	Physalis virginiana	0.0600
Cirsium altissimum	0.0843	Oxalis stricta	0.0600
Rudbeckia hirta	0.0784	Verbena stricta	0.0600

Table 2. Lists of top native graminoid species (grass or sedge) and top forb species in 17 HDLE prairie restorations and 15 remnant prairies in the Prairie Corridor. The restorations range in age from 1 to 14 years old. The frequency of occurrence in square meter quadrats was calculated across all fields within each grassland type. Species in bold are shared by both grassland types.

	HDLE Restorations	Frequency	Remant Prairie	Frequency
Top 15 "quaiity" species(CofC >=5)				
	Andropogon gerardii	0.7725	**Andropogon gerardii**	0.8778
	Elymus canadensis	0.3922	**Bouteloua curtipendula**	0.2800
	Sorghastrum nutans	0.2902	**Sorghastrum nutans**	0.1400
	Helianthus pauciflorus	0.2137	Amorpha canescens	0.0911
	Solidago missouriensis	0.0863	Salvia azurea	0.0867
	Zizia aurea	0.0647	Viola pedatifida	0.0822
	Desmodium canadense	0.0608	Panicum ovale	0.0733
	Desmodium illinoense	0.0569	**Physalis virginiana**	0.0600
	Liatris pycnostachya	0.0451	Psoralidium tenuiflorum	0.0600
	Desmanthus illinoensis	0.0451	Sporobolis heterolepis	0.0489
	Astragalus canadensis	0.0431	**Desmodium illinoense**	0.0467
	Physalis virginiana	0.0255	Hesperostipa spartea	0.0467
	Silphium laciniatum	0.0216	Dalea candida	0.0400
	Bouteloua curtipendula	0.0196	Koeleria macrantha	0.0289
	Lespedeza capitata	0.0176	**Solidago missouriensis**	0.0267
Top 15 Alien Species				
	Setaria sp	0.1843	**Bromus inermis**	0.7089
	Taraxacum offinale	0.1235	**Poa pratensis**	0.3444
	Convolvulus arvensis	0.0824	Medicago lupulina	0.2267
	Abutilon theophrasti	0.0804	Dianthus armeria	0.2044
	Poa pratensis	0.0765	Melilotus officinalis	0.1711
	Lactuca serriola	0.0667	**Convolvulus arvensis**	0.1667
	Digitaria sanguinalis	0.0647	Poa compressa	0.1511
	Bromus japonicus	0.0549	**Bromus japonicus**	0.1378
	Bromus inermis	0.0471	Bromus tectorum	0.1311
	Setaria pumila	0.0373	Trifolium pratense	0.1067
	Sonchus asper	0.0353	**Lactuca serriola**	0.0889
	Glycine max	0.0333	Hypericum perforatum	0.0556
	Lotus purshianus	0.0333	**Taraxacum offinale**	0.0533
	Mollugo verticillata	0.0333	Euphorbia esula	0.0489
	Chenopodium album	0.0275	Lolium arundinaceum	0.0333

Table 3. Lists of top native species with high CofC values and top alien species in 17 HDLE prairie restorations and 15 remnant prairies in the Prairie Corridor. Restorations range in age from 1 to 14 years old. The frequency of occurrence in square meter quadrats was calculated across all fields within each grassland type. Species in bold are shared by both grassland types.

Reference List

Angeler DG, & Allen CR. (2016). Quantifying resilience. *Journal of Applied Ecology* 53:617–624

Bailey, S., Bullerman, M., & Whitney, B. (2020). *A Historical Perspective, Work in the Prairie Corridor & the Value of Education*. Lecture presented in Prairie Corridor Summer Seminar Series 2020 in Https://prairiecorridor.org/2020-summer-seminar-series/, Lincoln, NE. Last Accessed: February 2, 2021

Dornbush, M. E. (2004). Plant Community Change Following Fifty-years of Management at Kalsow Prairie Preserve, Iowa, U.S.A. *The American Midland Naturalist* 151(2): 241-250.

Fierer, N., Ladau, J., Clemente, J. C., Leff, J. W., Owens, S. M., Pollard, K. S., & Mcculley, R. L. (2013). Reconstructing the Microbial Diversity and Function of Pre-Agricultural Tallgrass Prairie Soils in the United States. *Science 342*(6158): 621-624.

Grant, T. A., Shaffer, T. L., & Flanders, B. (2020). Resiliency of Native Prairies to Invasion by Kentucky Bluegrass, Smooth Brome, and Woody Vegetation. *Rangeland Ecology & Management* 73(2), 321-328.

Grman, E., Bassett, T., & Brudvig, L. A. (2013). Confronting contingency in restoration: Management and site history determine outcomes of assembling prairies, but site characteristics and landscape context have little effect. *Journal of Applied Ecology 50*(5), 1234-1243.

Guzman, J. G., & Al-Kaisi, M. (2010). Landscape position and age of reconstructed prairies effect on soil organic carbon sequestration rate and aggregate associated carbon. *Journal of Soil and Water Conservation*, 65(1): 9-21.

Helzer, C., Kleiman, B., O'Leary, C., & Glass, B. (2010). LESSONS LEARNED FROM THE GRASSLAND RESTORATION NETWORK: 2003-2010 [web log]. https://theprairieecologist.files.wordpress.com/2010/12/grnlessons2010.pdf.

Lamke, K. (2019). A descriptive study of wild bees and angiosperms in a tallgrass prairie corridor of southeastern Nebraska. *MSc Thesis,* University of Nebraska – Lincoln.

Larson, D. L., Ahlering, M., Drobney, P., Esser, R., Larson, J. L., & Viste-Sparkman, K. (2018). Developing a Framework for Evaluating Tallgrass Prairie Reconstruction Methods and Management. *Ecological Restoration 36*(1), 6-18.

Lincoln-Lancaster County Planning Department. (2012). Salt Valley Greenway and Prairie Corridor Master Plan (pp. 1-143, Rep.). Lincoln, NE: The Flatwater Group.

Prairie Corridor. (2019, May 30). Home - Prairie Corridor: On Haines Branch: Lincoln Parks. Retrieved October 16, 2020, from https://prairiecorridor.org/

Prairie Plains Resource Institute. (2020). Mission. Retrieved February 22, 2021, from https://www.prairieplains.org/mission

Rowe, H. I. (2010). Tricks of the Trade: Techniques and Opinions from 38 Experts in Tallgrass Prairie Restoration. *Restoration Ecology 18*, 253-262.

Rowe, H. I., Fargione, J., & Holland, J. D. (2013). Prairie Restorations can Protect Remnant Tallgrass Prairie Plant Communities. *The American Midland Naturalist 170*(1):26-38.

Sluis, W. (2020). Dark Diversity in Restorations: What's missing? *Ecological Restoration, 38*(3), 180-192.

Society for Ecological Restoration. (n.d.). Home. Retrieved October 02, 2020, from https://www.ser-rrc.org/what-is-ecological-restoration/

Steiner, J. L., Starks, P. J., Neel, J., Northup, B., Turner, K., Gowda, P., Coleman, S., Brown, M. (2019). Managing Tallgrass Prairies for Productivity and Ecological Function: A Long-Term Grazing Experiment in the Southern Great Plains, USA. *Agronomy* 9(11): 699.

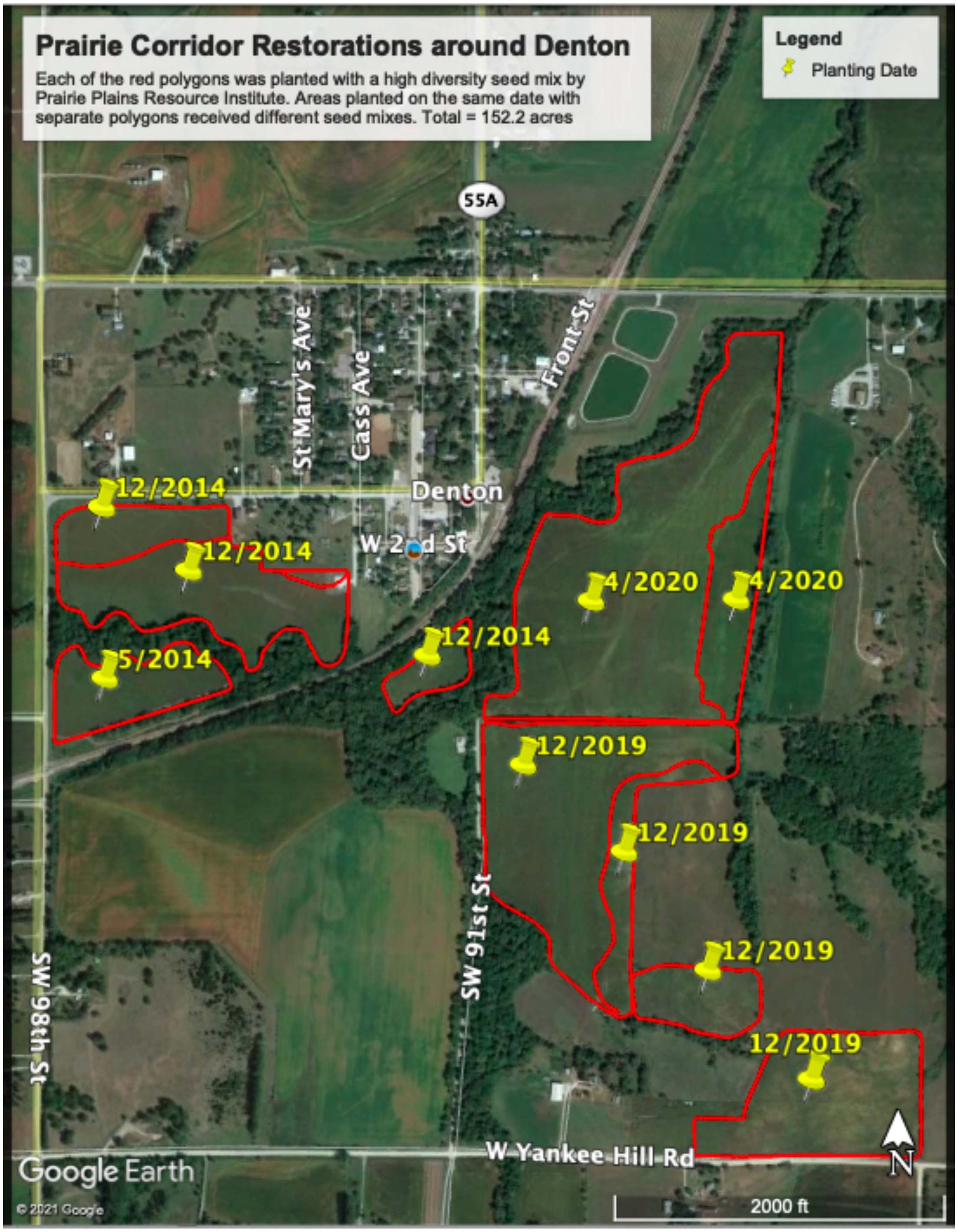
Swink, F., & Gerould, W. (1994). *Plants of the Chicago Region*. Indianapolis, Indiana: Indiana Academy of Science.

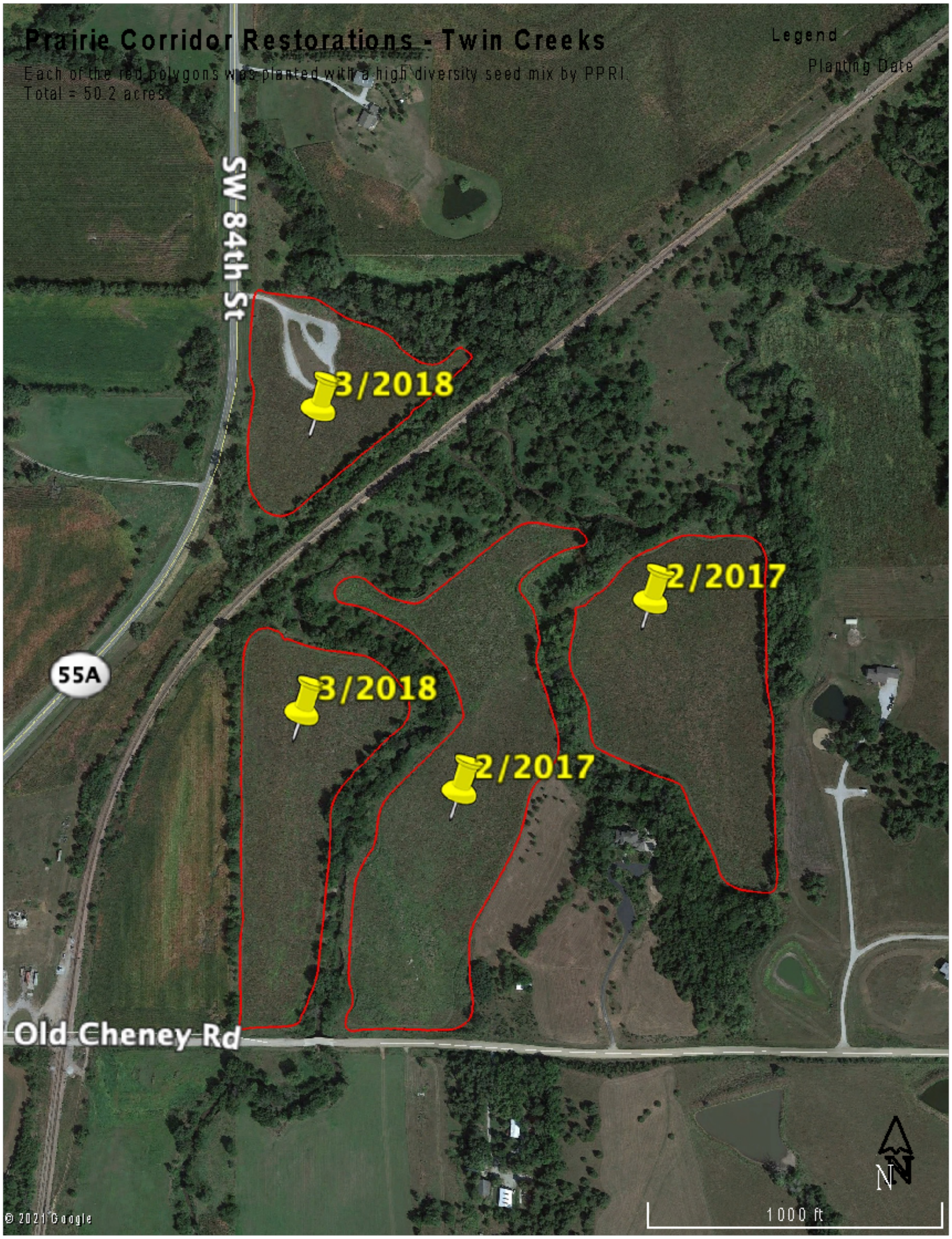
University of California - Davis. (2020). Carbon Sequestration. Retrieved November 18, 2020, from https://climatechange.ucdavis.edu/science/carbon-sequestration/

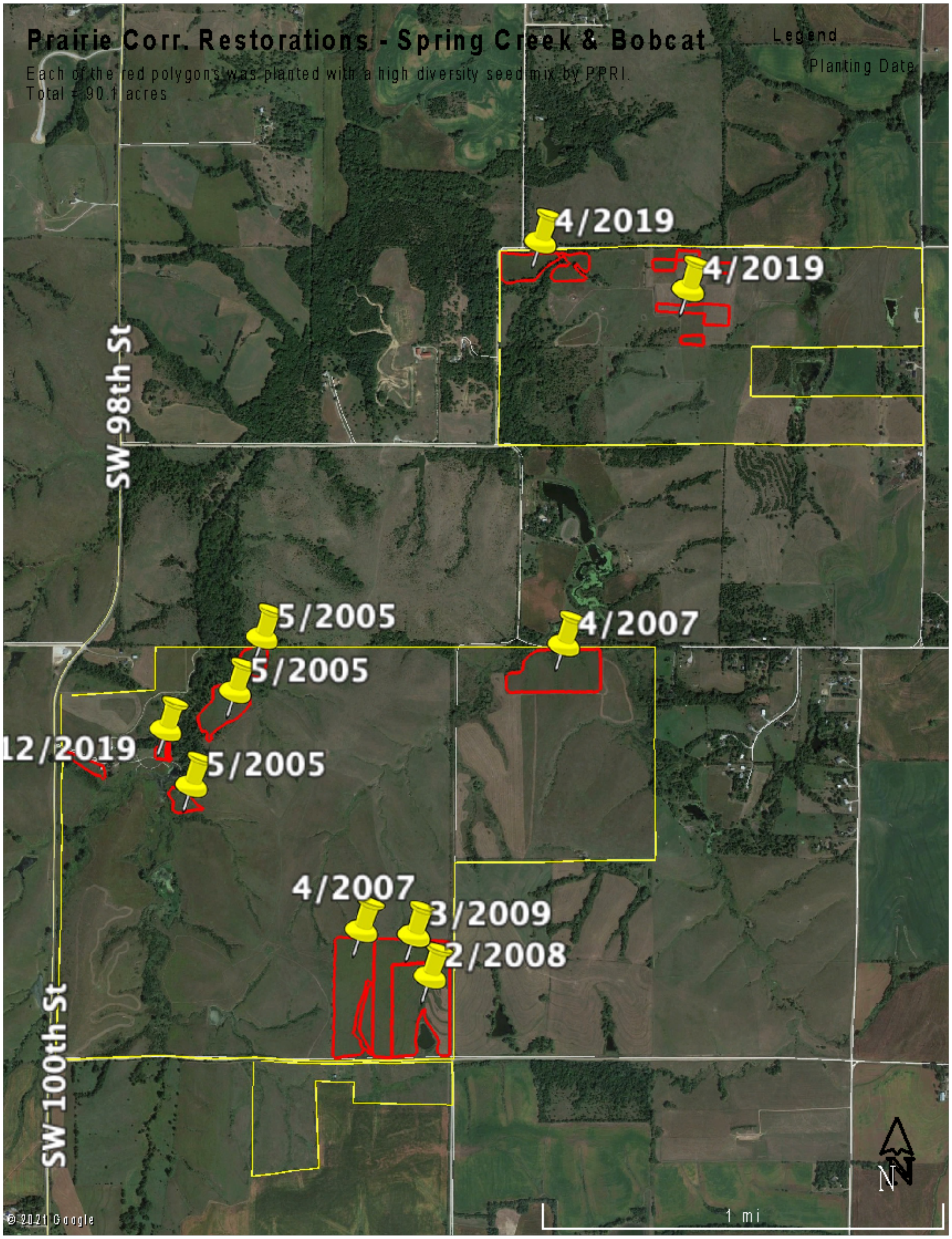
Upton, R.N., Bach, E.M., & Hofmockel, K.S. (2018). Belowground response of prairie restoration and resiliency to drought. *Agriculture, Ecosystems and Environment* 266: 122-132.

Wilsey, B. (2020). Restoration in the face of changing climate: Importance of persistence, priority effects, and species diversity. *Restoration Ecology.* doi:10.1111/rec.13132

Appendix A


Prairie Corridor Restorations around Denton
Each of the red polygons was planted with a high diversity seed mix by Prairie Plains Resource Institute. Areas planted on the same date with separate polygons received different seed mixes. Total = 152.2 acres
Legend
Planting Date
55A
St Mary's Ave
Cass Ave
Front St
Denton
W 2nd St
12/2014
12/2014
5/2014
12/2014
4/2020
4/2020
12/2019
12/2019
12/2019
12/2019
SW 98th St
SW 91st St
W Yankee Hill Rd
N
Google Earth
© 2021 Google
2000 ft


Prairie Corridor Restorations - Twin Creeks
Each of the red polygons was planted with a high diversity seed mix by PPRI.
Total = 50.2 acres
Legend
Planting Date
SW 84th St
3/2018
3/2018
2/2017
2/2017
55A
Old Cheney Rd
N
1000 ft
© 2021 Google


Prairie Corr. Restorations - Spring Creek & Bobcat
Each of the red polygons was planted with a high diversity seed mix by PPRI.
Total = 90.1 acres
Legend
Planting Date
4/2019
4/2019
SW 98th St
5/2005
4/2007
5/2005
12/2019
5/2005
4/2007
3/2009
2/2008
SW 100th St
N
© 2021 Google
1 mi

Appendix B

Prairie Corridor 2020 | Date: 8/5 | Cover classes: 1 (<1%), 2 (1-5%), 3 (5-20%), 4 (20-50%), 5 (>50%)

Site Name: Denton | Site # 15

Surveyor(s): A. Admiraal, Elizabeth Park

species		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Achillea millefolium									1	3					2		
Amaranthus tuberculatus																	
Ambrosia artemisiifolia													1				
Ambrosia psilostaycha																	
Ambrosia trifida		2		2		3	2			1					1	2	3
Amorpha canescens																	
Andropogon gerardii		5	5	4	5	5	3	4	5	5	5	5	5	5	5	3	4
Antennaria neglecta																	
Apocynum cannibinum																	
Arabis pycnocarpa																	
Artemisia ludoviciana																	
Asclepias stenophylla																	
Asclepias sullivantii																	
Asclepias syriaca																2	
Asclepias verticillata																	
Asclepias viridis																	
Aster ericoides																	
Aster lanceolatus														2			
Baptisia bracteata																	
Bouteloua curtipendula																	
Brickellia eupatorioides																	
Bromus inermis					1												
Bromus japonicus																	
Bromus tectorum																	
Callirhoe involucrata																	
Calystegia sepium																	
Carex bicknellii																	
Carex brevior			2					3	3					2	3		
Carex gravida																	
Carex sp.																	
Chamaecrista fasciculata																	
Chloris verticillata																	
Cirsium altissimum				2	2					2							
Cirsium flodmanii																	
Cirsium undulatum																	
Cirsium vulgare																	
Convolvulus arvensis										1							
Conyza canadensis			1		2	1			1						1	1	1 3
Cornus drummondi																	
Cyperus lupulinus																	
Dactylis glomeratus																	
Dalea candida																	
Desmodium illinoense											2						
Dianthus armeria																	
Digitaria cognata																	
Digitaria sanguinalis																	
Drymocallis arguta																	
Echinacea purpurea																	
Equisetum laevigatum																	
Eragrostis spectabilis																	
Erechtities hieracifolia																	
Erigeron strigosus																	
Eupatorium altissimum																	
Euphorbia cyathophora																	
Euphorbia davidii																	
Euphorbia esula																	
Euphorbia maculata																	
Euphorbia marginata																	
Euphorbia nutans																	

Appendix D

	CoC	Total Frequency	Rank Frequency	Species
1	5	394	0.773	Andropogon gerardii
2	5	200	0.392	Elymus canadensis
3	0	190	0.373	Conyza canadensis
4	4	174	0.341	Helianthus maximiliana
5	4	169	0.331	Monarda fistulosa
6	5	148	0.29	Sorgastrum nutans
7	2	130	0.225	Solidago canadensis
8	4	126	0.247	Elymus virginicus
9	5	109	0.214	Helianthus pauciflorus
10	*	94	0.184	Setaria sp
11	0	89	0.175	Ambrosia trifida
12	*	63	0.124	Taraxacum offinale
13	1	58	0.114	Asclepias syriaca
14	4	58	0.114	Panicum virgatum
15	2	57	0.112	Achillea millefolium
16	3	55	0.108	Solidago rigida
17	4	50	0.098	Silphium integrifolium
18		50	0.098	Ulmus sp
19	3	49	0.096	Solidago gigantea
20	0	47	0.092	Amaranthus tuberculatus

21	5	44	0.086	Solidago missouriensis
22	1	43	0.084	Cirsium altissimum
23	*	42	0.082	Convolvulus arvensis
24	*	41	0.08	Abutilon theophrasti
25	4	40	0.078	Rudbeckia hirta
26	*	39	0.076	Poa pratensis
27	*	34	0.067	Lactuca serriola
28	*	33	0.065	Digitaria sanguinalis
29	4	33	0.065	Helianthus grosserratus
30	6	33	0.065	Zizia aurea
31	5	31	0.061	Desmodium canadense
32	1	30	0.059	Oenothera biennis
33	6	29	0.057	Desmodium illinoense
34	4	29	0.057	Heliopsis helianthoides
35	*	28	0.055	Bromus japonicus
36	4	27	0.053	Muhlenbergia racemosa
37	4	25	0.049	Carex brevior
38	*	24	0.047	Bromus inermis
39	5	23	0.045	Desmanthus illioensis
40	3	23	0.045	Lactuca ludoviciana
41	7	23	0.045	Liatris pycnostachya
42	5	22	0.043	Astragalus canadensis
43	0	20	0.039	Panicum dichotomiflorum

44	3	19	0.037	Eupatorium altissimum
45	*	19	0.037	Setaria pumila
46	*	18	0.035	Sonchus asper
47	*	17	0.035	Glycine max
48	*	17	0.033	Lotus purshianus
49	*	17	0.033	Mollugo verticillata
50	3	16	0.031	Asclepias verticillata
51	2	16	0.031	Carex sp.
52	0	16	0.031	Euphorbia maculata
53	*	14	0.027	Chenopodium album
54	3	14	0.027	Cornus drummondi
55	1	14	0.027	Erechtities hieracifolia
56	3	13	0.025	Aster eriocoides
57	2	13	0.025	Erigeron strigosus
58	*	13	0.025	Melilotus officinalis
59	0	13	0.025	Oxalis stricta
60	6	13	0.025	Physalis virginiana
61	3	13	0.025	Vernonia baldwinii
62	1	12	0.024	Ambrosia psilostaycha
63	2	12	0.024	Aster lanceolatus
64	2	12	0.024	Fraxinus pennsylvanica
65	*	12	0.024	Morus alba
66	1	11	0.022	Bidens frondosa

67	5	11	0.022	Silphium lanciniatum
68	3	11	0.022	Sporobolus compositus
69	3	11	0.02	Vitis riparia
70	5	10	0.02	Bouteloua curtipendula
71	4	10	0.02	Brickellia eupatoriodes
72	*	10	0.02	Kochia scoparia
73	*	9	0.018	Cirsium vulgare
74	5	9	0.018	Lespedeza capitata
75	4	9	0.018	Rosa arkansana
76	2	9	0.016	Symphoricarpos occidentalis
77	3	8	0.016	Gaura longiflora
78	4	8	0.016	Leersia virginica
79	2	8	0.016	Verbena stricta
80	0	7	0.014	Ambrosia artemisiifolia
81	1	7	0.014	Chamaecrista fasciculata
82	1	7	0.014	Gleditsia triacanthos
83	0	7	0.012	Helianthus annus
84	3	6	0.012	Euphorbia corollata
85	5	6	0.012	Fragaria virginiana
86		6	0.012	Mulhenbergia sp.
87	0	6	0.012	Phalaris arundinacea
88	*	6	0.012	Rumex crispus
89	4	6	0.012	Solidago mollis

90	4	5	0.01	Carex gravida
91		5	0.01	Chenopodium sp.
92	1	5	0.01	Coreopsis tinctoria
93	4	5	0.01	Digitaria cognata
94	1	5	0.01	Gaura parviflora
95	3	5	0.01	Populus deltoides
96	4	5	0.01	Schizachrium scoparium
97	*	5	0.01	Thlaspi arvense
98	*	5	0.008	Ulmus pumila
99	*	4	0.008	Bromus tectorum
100	*	4	0.008	Conium maculatum
101	6	4	0.008	Dalea candida
102	*	4	0.008	Medicago lupulina
103	*	4	0.008	Melilotus alba
104	0	4	0.008	Physalis longifolia
105	3	4	0.008	Verbena urticifolia
106	4	3	0.006	Ageratina altissima
107	2	3	0.006	Apocynum cannibinum
108	4	3	0.006	Asclepias incarnata
109	1	3	0.006	Chenopodium pratericola
110	*	3	0.006	Cirsium arvense
111	6	3	0.006	Drymocallis arguta
112	3	3	0.006	Humulus lupulus

113	1	3	0.006	Iva annua
114	0	3	0.006	Panicum capillare
115	4	3	0.006	Panicum oligosanthes
116	3	3	0.006	Pascopyrum smithii
117		3	0.006	Polygonum sp.
118	0	3	0.006	Portulaca oleracea
119	4	3	0.006	Rudbeckia laciniata
120	6	3	0.006	Salvia azurea
121	2	3	0.006	Sanicula canadensis
122	0	3	0.006	Solanum ptycanthum
123	*	3	0.006	Sonchus arvensis
124	*	3	0.006	Trifolium pratense
125	4	3	0.006	Vernonia fasciculata
126	0	2	0.004	Acalypha rhomboidea
127	6	2	0.004	Amorpha canescens
128	3	2	0.004	Artemisia dracunculus
129	7	2	0.004	Asclepias sullivantii
130	6	2	0.004	Ceanothus americanus
131	*	2	0.004	Echinochloa crus-galli
132	8	2	0.004	Eryngium yuccifolium
133	*	2	0.004	Hibiscus trionum
134	1	2	0.004	Hordeum jubatum
135	*	2	0.004	Lonicera tatarica

136	*	2	0.004	Plantago major
137	0	2	0.004	Polygonum pensylvanicum
138	8	2	0.004	Polytaenia nuttallii
139	4	2	0.004	Ratibida columnifera
140	2	2	0.004	Solanum carolinense
141	0	2	0.004	Solanum rostratum
142	5	2	0.004	Spartina pectinata
143	4	2	0.004	Symphotrichum novae-angliae
144	*	1	0.002	Arctium minus
145	4	1	0.002	Artemisia ludoviciana
146	6	1	0.002	Asclepia tuberosa
147	5	1	0.002	Baptisia leucophaea
148	3	1	0.002	Bidens cernua
149	1	1	0.002	Calystegia sepium
150	*	1	0.002	Carduus nutans
151	4	1	0.002	Celtis occidentalis
152	*	1	0.002	Commelina communis
153	3	1	0.002	Cyperus acuminatus
154	3	1	0.002	Cyperus odoratus
155	*	1	0.002	Dactylis glomeratus
156	6	1	0.002	Dalea purpurea
157	5	1	0.002	Echinacea angustifolia
158	*	1	0.002	Eragrostis cillianensis

159		1	0.002	Euphorbia sp.
160	4	1	0.002	Glandularia bipinnatifida
161	1	1	0.002	Grindelia squarrosa
162	2	1	0.002	Hackelia virginiana
163	4	1	0.002	Helianthus tuberosus
164	1	1	0.002	Juniperus virginiana
165	6	1	0.002	Koeleria macrantha
166	2	1	0.002	Lactuca canadensis
167	*	1	0.002	Lamium amplexicaule
168	5	1	0.002	Linderia dubia
169	6	1	0.002	Penstemon digitalis
170	4	1	0.002	Physalis heterophylla
171	*	1	0.002	Poa compressa
172	*	1	0.002	Polygonum aviculare
173	3	1	0.002	Prunus americana
174	3	1	0.002	Prunus virginiana
175	4	1	0.002	Ratibida pinnata
176	*	1	0.002	Setaria faberi
177	*	1	0.002	Setaria italica
178	4	1	0.002	Strophostyles leiosperma
179	4	1	0.002	Tradescantia ohiensis
180	*	1	0.002	Tragopogon dubius
181	4	1	0.002	Verbena hastata

182	3	1	0.002	Viola sororia
183	1	0	0	Plantago patagonica

Appendix E

Twin Creeks HDLE Prairie Restoration Proposal

December 26, 2017

Prairie Plains Resource Institute (PPRI) has been providing high-diversity/local ecotype (HDLE) prairie restoration services in central and eastern Nebraska since 1980. Our work includes multiple examples in Lancaster County, including four projects along the Haines Branch Prairie Corridor and Spring Creek Prairie.

PPRI has partnered with Lincoln Parks & Recreation and Lower Platte South NRD in the past, and is again offering ecological restoration services in the effort to establish examples of high-quality prairie along the corridor. Specifically, this seeding project will be implemented on the Stiefel Tract located in the SW1/4 of S11, T9N, R5E, Lancaster County, Nebraska.

Geographic Information System (GIS) analysis of the site shows the project encompasses 18.6 acres in two parcels, with mesic (lowland tallgrass) seeding units comprising nearly 100% of the project site (figure 1). These two units are characterized by nearly level to gently sloping, moderately well drained to poorly drained soils formed in alluvium. These silt loam and silty clay loam surface soils with clayey subsoils (Appendix C) tend to support rich native plant communities.

Figure 1. Stiefel Tract seeding units derived from SSURGO soil unit boundaries and LIDAR data.

With many different wildflower species blooming throughout the growing season, these diverse native plant communities provide superior butterfly and pollinator habitat while preserving some of the native local prairie plant genetic material that has been lost to years of agricultural conversion and urban development. Furthermore, HDLE restorations are very resilient to drought and other extreme climatic and weather events because they are populated with the progeny of the very plants that evolved in Nebraska over centuries of such harsh conditions.

These newly restored acres will augment the Stiefel complex by 60% and will enhance stream buffering capabilities, slowing runoff and providing increased filtering services. It will also provide excellent upland game and non-game habitat, as well as expanding education and recreation opportunities.

Project Specifics:

- A mesic (lowland tallgrass) prairie seed mix will be broadcast onto two tracts totalling 18.6 acres of disced or harrowed cropland no later than May 15th, 2018, at a cost of $500.00 per acre, for a total of $9,300.00.
- The mesic seed mix will contain no less than 149 species (Appendix A).
- Additionally, a wetland mix will be sown in the lowest spots on appropriate soils as identified by LIDAR and SSURGO data on approximately 0.12 acres of Nodaway series soils (Appendix B).
- The mesic seed mix will be planted at no less than 8 gallons of combine harvested grass seed per acre, 2.0 gallons of hand-collected forb mix per acre.
- 100% of this seed mix was harvested from wild populations of native plants within 150 miles of the project site.
- PPRI will use EZ Flow drop spreaders pulled by ATVs to broadcast the seed.
- Any GPS/GIS data generated by PPRI during the restoration process will be made available to LPSNRD and/or the City of Lincoln.
- This seed mix will provide high quality monarch/pollinator habitat, enhancing the overall conservation value of the area.
- The established native plant community will provide high quality upland game and non-game habitat.
- The established native plant community will provide educational and recreational opportunities to the public.

Appendix A: HDLE Mesic (Lowland Tallgrass) Seeding Species List (149 spp.)

Grasses (20)

Andropogon gerardii	Big Bluestem
Calamagrostis stricta	Northern Reedgrass
Digitaria cognata	Fall Witchgrass
Elymus canadensis	Canada Wildrye
Elymus trachycaulus	Slender Wheatgrass
Elymus virginicus	Virginia Wildrye
Eragrostis spectabilis	Purple Lovegrass
Hordeum jubatum	Foxtail Barley
Hordeum pusillum	Little Barley
Koeleria macrantha	June Grass
Panicum acuminatum	Tapered Rosette Grass
Panicum oligosanthes	Scribner's Panicum
Panicum virgatum	Switchgrass
Pascopyrum smithii	Western Wheatgrass
Schizachyrium scoparium	Little Bluestem
Sorghastrum nutans	Indiangrass
Spartina pectinata	Prairie Cordgrass
Sphenopholis obtusata	Prairie Wedgegrass
Sporobolus asper	Tall Dropseed
Tridens flavus	Purpletop

Sedges/Rushes (21)

Carex brachyglossa	Yellowfruit Sedge
Carex brevior	Fescue Sedge
Carex crawei	Crawe's Sedge
Carex cristatella	Crested Sedge
Carex gravida	Wetland Gravida
Carex gravida	Heavy Sedge
Carex laeviconica	Smooth Cone Sedge
Carex mesochorea	Midland Sedge
Carex molesta	Troublesome Sedge
Carex molesta	Troublesome Sedge
Carex pellita	Wooly Sedge
Carex scoparia	Broom Sedge
Carex tribuloides	Blunt Broomsedge
Carex vulpinoidea	Fox Sedge
Fimbristylis puberula	Hairy Fimbry
Juncus dudleyi	Dudley Rush
Juncus interior	Interior Rush
Juncus tenuis	Tenuis Rush
Schoenoplectus pungens	Common Threesquare
Scirpus pallidus	Pale Bulrush
Scirpus pendulus	Rufous Bulrush

Legumes (17)

Amorpha canescens	Leadplant
Astragalus canadensis	Canada Milkvetch
Cassia chamaecrista	Partridge Pea
Dalea candidum	White Prairieclover
Dalea leporina	Foxtail Dalea
Dalea purpurea	Purple Prairieclover
Desmanthus illinoensis	Illinois Bundleflower
Desmodium canadense	Canada Tickclover
Desmodium canescens	Hoary Tickclover

Desmodium illinoense	Illinois Tickclover
Glycyrrhiza lepidota	Wild licorice
Lespedeza capitata	Roundhead Bushclover
Lotus purshianus	Deervetch
Psoralea argophylla	Silver-leaf Scurf Pea
Psoralea tenuiflora	Wild Alfalfa
Schrankia nuttallii	Sensitivebriar
Strophostyles leiosperma	Wild Bean

Composites (46)

Achillea millefolium	Yarrow
Arnoglossum plantagineum	Pale Indian Plantain
Artemisia ludoviciana	Sagewort
Aster ericoides	Heath Aster
Aster novae-angliae	New England Aster
Aster prealtus	Blue Willowleaf Aster
Aster simplex	Tall White Aster
Boltonia asteroides	False Aster
Brickellia eupatoroides	False Boneset
Cirsium altissimum	Tall Thistle
Cirsium flodmanii	Flodman Thistle
Coreopsis tinctoria	Plains Correopsis
Echinacea angustifolia	Purple Coneflower
Erigeron philadelphicus	Marsh Fleabane
Erigeron strigosus	Daisy Fleabane
Eupatorium altissimum	Tall Joe Pye Weed
Euthamia graminifolia	Grassleaf Goldenrod
Gnaphalium obtusifolium	Fragrant Cudweed
Grindelia squarrosa	Gumweed
Helenium autumnale	Sneezeweed
Helianthus grosseserratus	Sawtooth Sunflower
Helianthus maximilianii	Maximillian Sunflower
Helianthus rigidus	Stiff Sunflower
Helianthus tuberosus	Jerusalem Artichoke
Heliopsis helianthoides	False Sunflower
Hieracium longipilum	Longbeard Hawkweed
Iva annua	Small Marsh Elder
Lactuca canadensis	Canada Lettuce
Lactuca ludoviciana	Wild Lettuce
Liatris lancifolia	Thickspike Gayfeather
Liatris punctata	Dotted Gayfeather
Prenathes aspera	Rough Rattlesnake Root
Ratibida columnifera	Upright Prairie Coneflower
Rudbeckia hirta	Black-eyed Susan
Rudbeckia laciniata	Cutleaf Coneflower
Senecio plattensis	Prairie Ragwort
Silphium integrifolium	Entire-leaf Rosinweed
Silphium laciniatum	Compass Plant
Silphium perfoliatum	Cup Plant
Solidago canadensis	Canada Goldenrod
Solidago gigantea	Giant Goldenrod
Solidago missouriensis	Missouri Goldenrod
Solidago rigida	Stiff Goldenrod
Solidago speciosa	Showy Goldenrod
Vernonia baldwinii	Western Ironweed
Vernonia fasciculata	Ironweed

Misc. Forbs (45)

Allium canadense	Canada Garlic (Sets)
Allium canadense	Canada Garlic (Seed)
Anemone canadensis	Meadow Anemone
Anemone cylindrica	Candle Anemone
Apocynum cannabinum	Prairie Dogbane
Asclepias speciosa	Showy Milkweed
Asclepias sullivantii	Sullivant's Milkweed
Asclepias syriaca	Common Milkweed
Asclepias verticillata	Whorled Milkweed
Callirhoe alcaeoides	Pale Poppy Mallow
Callirhoe involucrata	Purple Poppy Mallow
Calylophus serrulatus	Serrate-leaf Primrose
Euphorbia marginata	Snow-On-The-Mountain
Gaura parviflora	Velvety Guara
Gentiana puberulenta	Downy Gentian
Linum sulcatum	Grooved Flax
Lobelia siphilitica	Blue Cardinal Flower
Lobelia spicata	Palespike Lobelia
Mirabilis nyctaginea	Wild Four O'clock
Monarda fistulosa	Wild Bergamot
Oenothera villosa	Common Evening Primrose
Onosmodium molle	Marbleseed
Penstemon digitalis	Smooth Penstemon
Penstemon gracilis	Slender Penstemon
Penstemon grandiflorus	Shell-leaf Penstemon
Physalis longifolia	Common Ground-cherry
Plantago patagonica	Wooly Plantain
Polygonum pensylvanicum	Pennsylvania smartweed
Polytaenia nuttallii	Prairie Parsley
Potentilla arguta	Prairie Cinquefoil
Potentilla norvegica	Norwegian Cinquefoil
Prunella vulgaris	Self-heal
Pycnanthemum virginianum	Mountain Mint
Rosa arkansana	Wild Rose
Rosa woodsii	Wood's Rose
Salvia azurea	Pitcher Sage
Sisyrinchium campestre	Prairie Blue-eyed Grass
Sisyrinchium montanum	Strict Blue-eyed Grass
Teucrium canadense	American Germander
Thalictrum dasycarpum	Purple Meadow Rue
Tradescantia bracteata	Bracted Spiderwort
Verbena hastata	Blue Vervain
Verbena stricta	Hoary Vervain
Verbena urticifolia	Elm-leaf Verbena
Symphoricarpos orbiculatus	Coralberry

Appendix B: HDLE Wetland Overseeding Species List (139 spp.)

Grasses (15)

Alopecurus	aequalis	Shortawn Foxtail
Calamagrostis	canadensis	Bluejoint
Calamagrostis	stricta	Northern Reedgrass
Elymus	trachycaulus	Slender Wheatgrass
Elymus	virginicus	Virginia Wildrye
Glyceria	grandis	Large Manna Grass
Glyceria	striata	Manna grass
Hordeum	jubatum	Foxtail Barley
Leersia	oryzoides	Rice Cut Grass
Muhlenbergia	racemosa	Marsh Muhly
Panicum	acuminatum	Tapered Rosette Grass
Panicum	oligosanthes	Scribner's Panicum
Pascopyrum	smithii	Western Wheatgrass
Spartina	pectinata	Prairie Cordgrass
Sphenopholis	obtusata	Prairie Wedgegrass

Sedges/Rushes (34)

Carex	bebbii	Bebb's Sedge
Carex	brachyglossa	Yellowfruit Sedge
Carex	brevior	Fescue Sedge
Carex	crawei	Crawe's Sedge
Carex	cristatella	Crested Sedge
Carex	emoryi	Emory's Sedge
Carex	gravida	Heavy Sedge
Carex	gravida	Wetland Gravida
Carex	hystericina	Bottlebrush Sedge
Carex	interior	Interior Sedge
Carex	laeviconica	Smooth Cone Sedge
Carex	molesta	Troublesome Sedge
Carex	pellita	Wooly Sedge
Carex	praegracilis	Clustered Field Sedge
Carex	sartwellii	Sartwell's Sedge
Carex	scoparia	Broom Sedge
Carex	stipata	Saw-beak Sedge
Carex	tribuloides	Blunt Broomsedge
Carex	vulpinoidea	Fox Sedge
Eleocharis	palustris	Common Spikerush
Eleocharis	erythropoda	Bald Spikerush
Fimbristylis	puberula	Hairy Fimbry
Juncus	balticus	Baltic Rush
Juncus	dudleyi	Dudley Rush
Juncus	interior	Interior Rush
Juncus	marginatus	Grassleaf Rush
Juncus	tenuis	Tenuis Rush
Juncus	torreyi	Torrey's Rush
Schoenoplectus	acutus	Chairmaker's Rush
Schoenoplectus	pungens	Common Threesquare
Scirpus	atrovirens	Dark Green Bulrush
Scirpus	maritimus	Prairie Bulrush
Scirpus	pallidus	Pale Bulrush

Scirpus	pendulus	Rufous Bulrush

Legumes (6)

Astragalus	canadensis	Canada Milkvetch
Cassia	chamaecrista	Partridge Pea
Dalea	leporina	Foxtail Dalea
Desmanthus	illinoensis	Illinois Bundleflower
Glycyrrhiza	lepidota	Wild licorice
Lotus	purshianus	Deervetch

Composites (32)

Achillea	millefolium	Yarrow
Aster	ericoides	Heath Aster
Aster	novae-angliae	New England Aster
Aster	prealtus	Blue Willowleaf Aster
Aster	simplex	Tall White Aster
Bidens	comosa	Threelobe Beggarticks
Boehmeria	cylindrica	False Nettle
Boltonia	asteroides	False Aster
Coreopsis	tinctoria	Plains Correopsis
Erigeron	philadelphicus	Marsh Fleabane
Erigeron	strigosus	Daisy Fleabane
Eupatorium	maculatum	Spotted Joe Pye Weed
Eupatorium	perfoliatum	Boneset
Euthamia	graminifolia	Grassleaf Goldenrod
Grindelia	squarrosa	Gumweed
Helenium	autumnale	Sneezeweed
Helenium	autumnale	Sneezeweed (Fertig)
Helianthus	grosseserratus	Sawtooth Sunflower
Helianthus	tuberosus	Jerusalem Artichoke
Iva	annua	Small Marsh Elder
Lactuca	canadensis	Canada Lettuce
Lactuca	ludoviciana	Wild Lettuce
Liatris	lancifolia	Thickspike Gayfeather
Ratibida	columnifera	Upright Prairie Coneflower
Rudbeckia	hirta	Black-eyed Susan
Rudbeckia	laciniata	Cutleaf Coneflower
Senecio	plattensis	Prairie Ragwort
Silphium	integrifolium	Entire-leaf Rosinweed
Silphium	perfoliatum	Cup Plant
Solidago	canadensis	Canada Goldenrod
Solidago	gigantea	Giant Goldenrod
Vernonia	fasciculata	Ironweed

Misc. Forbs (52)

Agalinis	tenuifolia	Slender False Foxglove
Alisma	trivale	American Water Plantain
Allium	canadense	Canada Garlic (Sets)
Allium	canadense	Canada Garlic (Seed)
Ammania	coccinea	Tooth Cup
Anemone	canadensis	Meadow Anemone
Anemone	cylindrica	Candle Anemone
Apocynum	cannabinum	Prairie Dogbane

Asclepias	incarnata	Swamp Milkweed
Asclepias	speciosa	Showy Milkweed
Asclepias	sullivantii	Sullivant's Milkweed
Asclepias	syriaca	Common Milkweed
Asclepias	verticillata	Whorled Milkweed
Epilobium	coloratum	Cinnamon Willow Herb
Gentiana	andrewsii	Bottle Gentian
Impatiens	capensis	Spotted Touch-me-not
Lippia	lanceolata	Fog Fruit
Lobelia	cardinalis	Cardinal Flower
Lobelia	siphilitica	Blue Cardinal Flower
Lobelia	spicata	Palespike Lobelia
Lycopus	americanus	American Bugleweed
Lycopus	asper	Rough Bugleweed
Lysimachia	ciliata	Fringed Loosestrife
Lythrum	alatum	Winged Lythrum
Mentha	arvensis	Field Mint
Oenothera	villosa	Common Evening Primrose
Penstemon	digitalis	Smooth Penstemon
Penstemon	gracilis	Slender Penstemon
Penthorum	sedoides	Ditch Stonecrop
Physalis	longifolia	Common Ground-cherry
Polygonum	coccineum	Swamp Smartweed
Polygonum	hydropiperoides	Mild Water Pepper
Polygonum	lapathifolium	Pale Smartweed
Polygonum	pensylvanicum	Pennsylvania smartweed
Polytaenia	nuttallii	Prairie Parsley
Potentilla	arguta	Prairie Cinquefoil
Potentilla	norvegica	Norwegian Cinquefoil
Prunella	vulgaris	Self-heal
Pycnanthemum	virginianum	Mountain Mint
Ranunculus	sceleratus	Cursed Crowfoot
Sagittaria	brevirostra	Shortbeak Arrowhead
Sagittaria	calycina	Hooded Arrowhead
Sagittaria	latifolia	Broadleaf Arrowhead
Scutellaria	galericulata	Marsh Skullcap
Sisyrinchium	montanum	Strict Blue-eyed Grass
Teucrium	canadense	American Germander
Thalictrum	dasycarpum	Purple Meadow Rue
Tradescantia	bracteata	Bracted Spiderwort
Tradescantia	occidentale	Western Spiderwort
Verbena	hastata	Blue Vervain
Verbena	stricta	Hoary Vervain
Verbena	urticifolia	Elm-leaf Verbena

Appendix C: Non-technical Soil Descriptions

Judson C series (1%) 0.2 acres: |"Nontechnical description"|"SOI"|"461"|"This gently sloping, moderately well drained soil formed in colluvium and alluvium on foot slopes and alluvial fans. It has a silt loam surface layer and moderately permeable silty clay loam subsoil."|"98120"|"98120:m:65417"

Kennebec series (59%) 11.0 acres: |"Nontechnical description"|"SOI"|"462"|"This nearly level, moderately well drained soil formed in alluvium on bottom land. It has a silt loam surface layer and moderately permeable silt clay loam underlying material. It is occasionally flooded."|"98121"|"98121:m:65418"

Lamo series (39%) 7.28 acres: |"Nontechnical description"|"SOI"|"289"|"This deep, nearly level, somewhat poorly drained soil formed in calcareous alluvium on bottom land. It has a calcareous silty clay loam surface layer and moderately slow permeable, silty clay loam underlying material. It is occasionally flooded."|"98122"|"98122:m:65419"

Nodaway series (< 1%) 0.12 acres: |"Nontechnical description"|"SOI"|"120"|"This deep, nearly level, moderately well drained soil formed in alluvium on bottom land. It has a silt loam surface layer and moderately permeable, silt loam underlying material. It has many entrenched, meandering stream channels and is frequently flooded."|"98132"|