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Influences of grazing on habitat characteristics, avian community composition and nesting bird abundance within Cheyenne Bottoms, KS

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INFLUENCES OF GRAZING ON HABITAT CHARACTERISTICS, AVIAN COMMUNITY COMPOSITION AND NESTING BIRD ABUNDANCE WITHIN CHEYENNE BOTTOMS, KS

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PREFACE

This thesis was written in the style of the Southwestern Naturalist. Keywords: Kansas, wet meadow, grazing, avian community, vegetative characteristics

ABSTRACT

Cheyenne Bottoms is a 41,000-acre prairie-marsh ecosystem in central Kansas. Approximately 8,000 acres of mixed grassland are dedicated for the conservation of bird populations, but little is known about the status of bird communities within these areas. This study took place within grassland areas of Cheyenne Bottoms from May – July 2021. I investigated bird community composition, relative abundance of frequently observed bird species, vegetative characteristics, and similarity of sites across different grazing intensities (continuous, rotational, and non-grazed). The four most common bird species observed were dickcissel (*Spiza americana*), grasshopper sparrow (*Ammodramus savannarum*), meadowlark species (*Sturnella spp.*), and red-winged blackbird (*Agelaius phoeniceus*). Dickcissel abundances were greatest within non-grazed and rotationally grazed sites. Grasshopper sparrows had the highest abundance in a continuous site with low flooding, moderately high abundance in rotational sites, low abundance in a continuous site with high flooding, and abundance approaching zero in non-grazed sites. Red-winged blackbirds had higher abundances in non-grazed sites than other treatments. Vegetative similarity was generally highest within grazing treatments. Grass height and litter depth were highest at sites of the non-grazed treatment, with similarities across other treatments. Forb comparisons across sites show different distributions for sites of each treatment type, with rotational sites exhibiting a strong right skew and a relatively constrained height range. Presence of sweet clover (*Melilotus spp.*) was highly apparent at rotational sites within multispectral imagery. Management should continue to maintain pastures with both continuous and rotational grazing regimes.

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INTRODUCTION

The southern mixed-grass prairie region comprised 565,000 km^2 before European settlement, extending from the southern portion of Nebraska to the southern tip of Texas and covering a significant portion of the Kansas prairie ecosystem (Pieper, 2005). However, 30-99% of native mixed-grass prairie regions throughout the United States have been lost since 1830 (Johnson, 2000; Sampson and Knopf, 1994). The mixed-grass region is defined as a mixture of both shortgrass and tallgrass prairie vegetation, possessing a complex array of forbs, suffrutescents, shrubs, and grasses (Sims and Risser, 2000). Though historically mixed-grass prairie was a haven for a variety of grassland wildlife species across the southern Great Plains, it is now dominated largely by agricultural regions. Considerable areas are dedicated to cropland, and patches unsuitable for crop production are dominated by grassland used by grazing livestock (Rohweder, 2015). Few large unfragmented or undisturbed mixed-grass regions remain, and those that do are highly subject to conversion to farmland or disturbance through grazing practices, which could influence the organization of native animal communities (Rohweder, 2015).

Grassland birds have experienced extensive population declines, attributed primarily to human-based disturbance regimes (see Brennan and Kuvlesky, 2005; Knopf 1994; Rosenberg et al., 2019; Sampson and Knopf, 1994; Stanton et al., 2018). A recent report on the status of bird populations documented that grassland birds have experienced a population reduction of 700 million birds since 1970 abundance records, the most significant decline of all North American avifauna groups (Rosenberg et al., 2019). The most severe declines among grassland bird declines have been documented within insectivorous guilds, driven by food loss through pesticide use, habitat fragmentation, and direct mortality from human equipment or chemical exposure (Stanton et al., 2018). Furthermore, plantings of woody vegetation and control of natural fires that historically prevented woody plant encroachment have altered grassland bird habitat, resulting in increases of forest-edge birds and displacement of native grassland bird species (Sampson and Knopf, 1994). The mixed-grass prairies of Kansas are currently home to multiple avian species of greatest conservation need including the greater prairie chicken *(Tympanuchus cupido)*, the eastern kingbird *(Tyrannus tyrannus)*, the western kingbird (*Tyrannus verticalis*), and the grasshopper sparrow *(Ammodramus savannarum),* which are all imperiled due to habitat fragmentation and agricultural pressures encroaching on native avian habitats (Rohweder, 2015). Large-scale human intervention may be necessary to restore bird populations to historical numbers.

Grazing is a widespread land management practice, with pasture and rangeland covering approximately 29% of land area in the United States (Bigelow and Borchers, 2017). Grazing can be an effective grassland management tool, with targeted cattle trampling and browsing working to achieve specific vegetation management objectives and improve biodiversity (Bailey et al., 2019). However, uncontrolled continuous grazing by cattle can have substantial negative impacts on biological systems, reducing vegetative diversity in certain plant communities (Cingolani et al., 2005; Milchunas et al., 1993). While intense grazing has the potential to reduce plant diversity in grassland systems, individual bird species respond positively to specific grazing intensities. Bird species such as horned lark (*Eremophila alpestris*) which are shortgrass specialists prefer heavy continuous grazing, while other species that depend on greater forb cover, such as sage grouse (*Centrocercus urophasianus*), respond more positively to rotational grazing as it improves forb diversity and reduces nesting disturbance by cattle (Dinkins et al., 2002; Neel, 1980). The benefits of various grazing regimes on different bird species may have practical implications for producing grazing systems that employ a variety of management techniques.

Wet meadows are poorly drained grassland habitats that frequently occur in basins or ecotonal areas between upland areas and wetlands or marshes (Galatowitsch et al., 2000; Toogood and Joyce, 2009). Frequent and intense flooding in these habitats can have strong effects on vegetation, as water spreads soil, transports nutrients, and promotes the propagation of flood tolerant species (Toogood and Joyce, 2009). Habitat characteristics often differ depending on the degree of water inundation, with wetter areas tending to have more patches of bare ground and a mix of grass and water-tolerant species including sedges (Cyperaceae *spp*.; Toogood and Joyce, 2009). The unique relationship these habitats possess with water can have profound implications on animal communities. Certain grassland-occurring bird species are correlated with wet conditions, with species such as red-winged blackbirds (*Agelaius phoeniceus*) associated with sedge-meadow habitats (Kim et al., 2008; Mossman and Sample, 1990). On the other hand, species such as brown-headed cowbirds (*Molothrus ater*) and dickcissels (*Spiza americana)* appear to prefer drier or more mesic habitats (Dechant et al., 2002a; Kim et al., 2008).

Cheyenne Bottoms, a 41,000-acre prairie marsh ecosystem, is located in a naturally occurring basin in the central Kansas mixed-grass region. While it is primarily classified as a prairie marsh wetland, it contains a variety of other habitat types including wet meadows, agricultural areas, and mixed-grass prairie. Grassland conservation areas, designated as Cheyenne Bottoms Preserve, make up around 8,000 acres of the total area of Cheyenne Bottoms and are managed by the Nature Conservancy through the use of multiple grazing regimes. Current conservation plans for grassland areas are centered around the improvement of nesting success among grassland bird populations (R. L. Penner, conservation manager, Ellinwood, pers. comm.). However, realistic conservation targets have been elusive because of a lack of information regarding the present status or organization of grassland bird communities in the Preserve.

Study of bird populations has historically been accomplished through bird point counts, a common, standardized survey method in which bird calls and sightings are counted at defined stations within a specified time frame. Point count methods are used to compare avian community compositions, relative populations, and species abundance across both space and time (Ralph et al., 1995). However, bird point counts have some potential limitations that may result in inaccurate community estimates. Point count methods are sensitive to high wind velocity and noise disturbance (Ralph et al., 1995), can miss non-calling birds out of sight, and can miss nesting birds within the station radius that are silent on nests. Methods including double observer and double sampling can be effective for population estimation, but they require known detection probabilities, are time consuming, and can be cost prohibitive (Taylor and Pollard, 2008). However, point counts can be effective in estimating species calling out of the line-of-sight or species that occur at low densities and may be calling from a substantial distance away (Lynch, 1995; Savard and Hooper, 1995), which make them a highly beneficial tool for community analysis. For studies with limited observer effort, bird point counts may be most useful when used in conjunction with other analysis methods.

Nest dragging and haphazard walking are methods that are used to locate grassland-nesting species. Typically, these methods are used to find nests and determine nest success of grassland birds and can provide estimates of the productivity of avian populations (Winter et al., 2003). Nest dragging consists of pulling a rope with cans or bells attached through grassland habitat to flush nesting birds, and haphazard walking involves random walking to achieve similar objectives (Winter et al., 2003). Though nest dragging and haphazard walking have generally been used for the determination of nest fate (Winter et al., 2003), these methods may be beneficial for population analysis due to the way they influence bird behavior and enable observer movement. Nest searching methods direct bird movement in a predictable manner (Winter et al., 2003), encourage birds to contact call and exhibit nest defense behavior (Winter et al., 2003), allow observers to count hidden birds that are located in nests or on the ground, and allow observers to directly see fledgling occurrence. Additionally, as nest dragging allows observers to approach birds, detection may be possible in conditions with noise disturbance, which is an important concern in point count studies (see Ralph et al., 1995). These aspects indicate that nest searching may be a suitable method to determine relative abundance for grassland bird species.

Relating bird occurrence to vegetation is a fundamental consideration in community studies. The presence of certain bird species can be directly related to habitat attributes, as birds use vegetation and ground cover for the purpose of nesting, feeding, and territorial disputes (Cody, 1968; Fisher and Davis, 2010). Studies relating grassland birds to vegetation typically analyze vegetative characteristics including vegetation height, litter depth, and presence of dead vegetation (Fisher and Davis 2010). Studies quantifying bird habitat generally consider plant structure or characteristics rather than plant species, as birds respond most heavily to structural features when selecting habitat (Fisher and Davis, 2010). However, from a management perspective, knowledge of vegetative species may also be important, as richness and the presence or absence of plants can be closely related to site treatments and geomorphology (Assani et al., 2006; Gao and Carmel, 2020). Additionally, the presence of certain plant species with competitive advantages such as cheatgrass (*Bromus tectorum*) can play a crucial role in vegetative structure as it influences the morphology of other plant species (Parkinson et al., 2013).

The use of unoccupied aerial systems or drones as a platform for remote sensing and the capture of multi-spectral reflectance imagery for vegetation mapping is a relatively new field, but it holds significant promise for habitat studies. Multispectral imagery separates images into multiple spectral reflectance bands that can be analyzed to ascertain the presence of soil, determine the amount of vegetative stress, and can delineate vegetation into separate classes, which can be useful for analyzing habitats (Barnes and Baker, 2000; Huang et al., 2020). This analysis is typically accomplished with the used of NDVI, or a Normalized Difference Vegetation Index, which is an equation that uses near infrared (NIR) and red bands to assess plant chlorophyll content (Huang, 2020). Analysis of ground cover with drones could be particularly beneficial for bird studies, as individual bird species respond to features such as forb, grass, or soil cover (see Dechant et al., 2002a; Whitmore, 1981 and others) that could be analyzed with multispectral imagery. In addition, drones can acquire this information efficiently, at large scales, with low costs, and with minimal atmospheric effects (Huang et al., 2020).

The primary objectives of this study were to acquire information about the relative abundance and organization of nesting bird communities, and the characteristics of vegetative communities within grassland areas of Cheyenne Bottoms in relation to different grazing treatments. These objectives were accomplished through nest searching methods, bird point counts, vegetation measurements, multi-spectral image classification, and comparisons of bird and plant species at sites of different grazing intensities. Results of this study will aid the Nature Conservancy in conducting future conservation management for the improvement of grassland bird populations within Cheyenne Bottoms Preserve.

METHODS

Sites

This study took place from May – July 2021 within grassland areas surrounding Cheyenne Bottoms Wildlife Area (38°27'46.19" N -98°39'9.97" W), a sizable wetland area located in central Kansas, USA. Though Cheyenne Bottoms holds incredible value to shorebirds and waterfowl, it also has a diverse range of mixed-grassland habitats that support a substantial number of prairie birds. In addition, the surrounding grassland area hosts unique landscape elements including water bodies, streams, floodplains, wet meadows, and grazing regimes that have the potential to influence grassland bird communities in unique ways. Land in this area is managed by the Nature Conservancy and the Kansas Department of Wildlife and Parks (KDWP).

Sites were selected based on grazing treatment (non-grazed, continuous, rotational) and distance from other habitat types. Individual site selection was determined through a combination of supplemental information from land managers (J. Wagner, area manager, pers. comm.; R. L. Penner, conservation manager, Ellinwood, pers. comm.), examination of aerial photography, and direct observation through ground-truthing. This information aided in defining sites with characteristics unique to rotationally managed rangeland, pasture with continuous cattle presence, and unmanaged and non-grazed grasslands. Aerial photography was used to determine the boundaries of the habitats to be used for surveys, with all bird point count, vegetation, and drone stations at least 150 m from the treatment border (Huff et al., 2000). The boundaries of nest dragging and haphazard-walking plots were a minimum of 50 m from other treatment types and from roadways to avoid bias. Effort was made to ensure habitats were as homogenous as possible and to have similarities in both slope and aspect to prevent potential differences in vegetation due to variation in geomorphology (Assani et al., 2006; Menghi et al., 1989)

For the rotational grazing treatment, I chose two pastures used for three-pasture rotational grazing. Rotational sites were designated R1 and R2. Both pastures are located on the western portion of Cheyenne Bottoms Preserve and were635 and 800 acres in area (Fig. 1). These particular rotational grazing sites were chosen due a history of rotational grazing treatment and the assurance that they would not contain Substantial wetland habitat was present within the pasture boundaries at site R2.

For the continuous grazing treatment, I used two pastures with traits associated with season-long continuous grazing. Continuous pastures were designated C1 and C2. The continuous pastures are located on the north to north-northeastern portions of Cheyenne Bottoms Preserve and were 480 and 510 acres in area (Fig. 1). These particular season-long grazing sites were chosen due to structural similarity to each other and ease of access. Both pastures have a history of continuous grazing that have led to vegetative characteristics synonymous with continuous grazing regimes, though site C1 was switched over to rotational grazing during the spring of 2020. Care was taken by management to ensure cattle would be a constant presence at both sites throughout the field season. Site C2 was also bordered by a private continuous pasture at the northern edge and was noted to have considerable flooding throughout the 2021 field season.

For the non-grazed treatment, I used two non-grazed grassland sites located on KDWP property. Non-grazed sites were designated N1 and N2. Sites were chosen on KDWP property as the available non-grazed grassland contains vegetation that closely resembles plant communities present on the season-long and three-pasture rotational grazing sites (R. L Penner, area manager, Great Bend, pers. comm.). Exact area of the grassland is not absolute as the non-grazed grassland available does not have definitive fenced-in boundaries, but overall the area for non-grazed grassland sites spans approximately 500 acres. The two non-grazed grassland sites are located on the northeast portion of the Cheyenne Bottom Wildlife Area (Fig. 1).

Nest Dragging and Haphazard Walking

Thirty-six nest dragging and haphazard walking surveys were performed to estimatebird relative abundance, dominant bird species, species composition, and bird community proportions. A total of 6 surveys were executed at each site within a plot of 79c acres from May 26 to July 15, 2021. Surveys were distributed temporally throughout the season such that each site had a survey conducted approximately every 7 to 9 days to ensure that time of season would not disproportionately influence bird counts. Surveys took place from 0600 h to 1000 h under conditions with no rain present. Observers took note of average wind speed and temperature (4 measurements taken at the beginning of each hour) as well as weather conditions at the beginning and midway through each survey (fair, partly cloudy, cloudy, hazy, and foggy). Exact distance walked was measured at the end of each survey using a FitBit (mean ± SE = 5.56 ± 0.046 km).

For nest dragging, we used a 30.48 m weighted rope with cans filled with rocks attached every 0.91 m at rotational and continuous sites. Two observers started at a corner of the nest dragging plot holding the rope taught between them and walked back and forth until approximately 5.56 km had been covered. We used a GPS unit to avoid previously walked paths. We changed the direction of travel or starting point of each survey to reduce bias. Haphazard walking occurred at non-grazed sites as the use of rope was not effective due to substantial litter depth and grass height, a finding that has been remarked on in other studies (Winter et al., 2003). We walked the full survey distance within the non-grazed area, taking care not to walk over the same path twice. In instances where we disbanded and counted birds separately, distance walked was divided in half.

Surveys had a heavy focus on recording bird species and nesting behavior. Observers took note of all species flushed or observed directly on the plot under 50 m, taking care to avoid recounting birds previously seen. If any birds were observed as originating from or approaching a neighboring habitat they were not included in counts. In addition to recording species observed, observers also documented time of observation, sex (male, female, unknown), bird age (adult, fledgling, unknown), and whether the bird was displaying suspicious behavior that would indicate nesting activity. Suspicious behavior was defined as birds circling, alarm chipping, observed with nesting material in the bill, observed with fecal sac or food in the bill, exhibiting distraction displays, or flushing and flying a short distance away (Winter et al., 2003). If a bird was flushed directly at or near the rope or was displaying otherwise suspicious behavior, observers spent 5 minutes searching for a nest. If a nest was located, nest contents and presence of brown-headed cowbird (*Molothrus ater*) eggs or nestlings were recorded to confirm nesting activity. Due to difficulty in exact species identification of meadowlarks unless birds were calling or observed at close range, observers combined meadowlark species (*Sturnella spp.*) unless eastern (*S. magna*) or western meadowlarks *(S. neglecta)* could be identified with certainty.

Bird Point Counts

Twenty-one bird point counts were conducted from June 8 until July 15, 2021, with the primary objective of determining the presence or absence of bird species within different site treatments. Results of these surveys served to supplement nest dragging data and to increase understanding of bird communities across treatment types. As point count data was largely supplementary, the protocol for surveys took a simplified approach. Bird point counts were based on established protocols for surveying terrestrial birds in different habitats (Huff et al., 2000), with station count increased to improve bird detectability and increase representation of the entire survey site.

A total of eight survey stations were examined during each count: five survey stations were central within the nest dragging area in a pentagonal shape and three additional stations extended toward the site boundary edge to incorporate the nest dragging area. Survey stations were located 200 m away from other surrounding stations, 150 m away from any nearby roads, and 150 m away from surrounding wetland or any abrupt discontinuity in vegetation structure (Huff et al., 2000). Following Huff et al., (2000), I recorded birds seen and heard within and beyond 50 m from the point count station,. I used pink flagging to mark the boundary of the 50 m plot.

Bird point counts began at sunrise and were concluded by 1000 h to maximize dawn bird calls heard (Huff et al., 2000). To avoid disparities in detectability, one person (KGA) was the sole observer during all surveys. Bird point count detection periods each lasted for 5 minutes at each survey station, with birds heard and seen recorded on a data sheet (Huff et al., 2000). Birds were only recorded if seen or heard during this 5-minute period. At the end of each survey, I listened to previously recorded bird songs and calls to confirm those observed in the field, noting differences in call due to bird dialects and age when listening to audio. Date, air temperature, cloud cover, and audible disturbance were recorded at each survey. All surveys were conducted on days where the temperature was at least 17°C with mild wind (under 20.92 km per hour) and no rain (Huff et al., 2000).

Bird point counts focused largely on singing males and nesting bird species as as an indicator that the habitat was use for breeding. Other bird species on or near stations that were opportunistic with feeding (e.g. swallow species, *Hirundo spp.*), were primarily utilizing habitat or man-made structures bordering the plot (red-tailed hawk, *Buteo jamaicensis*), were flyover or audible species associated with wetland habitat (e.g. great egret, *Ardea alba;* pied-billed grebe*, Podilymbus podiceps*), or were predominantly arboreal species that were heard nearby but were not seen directly on the plot (e.g. Eurasian collared-dove, *Streptopelia decaocto*) were excluded from final comparisons. Due to the sizable distance at which ring-necked pheasant (*Phasianus colchicu*s) calls can be heard, I only recorded presence for this species during point count surveys if a pheasant was visually confirmed at the site or if calls could not reasonably be coming from plots of differing treatment types. Species observed were combined across treatments with observation from nest dragging and haphazard walking data, with the exception of the greater prairie-chicken (*Tympanuchus cupido*) which had a known lek at a single rotational site.

Vegetation Surveys

Vegetation surveys included conducting a combination of measurements at the start of the season (May 26) and regular species composition surveys throughout the season. We measured grass height, forb height, and litter depth within a plot area of 50 m by 50 m around 5 point count stations per site. Grass and forb height were measured to the nearest mm, with measurements taken from the base to tip of the plant. All measurements above 1000 mm were rounded down to 1000 mm. Measurements were taken using a compass and using pink tape as markers, with observers taking measurements in a circular pattern and moving inwards to ensure as much habitat heterogeneity could be perceived as possible. Due to time constraints, we recorded as many measurements as feasible within 40 minutes at each station. Measurements were taken every 5 meters, with the proposed measurement distance calculated using the equation $D = L / (\sqrt{n} - 1)$, where L is the length of one side of the plot (50 m) and n is the maximum number of measurements (120).

We also performed vegetative species surveys to ensure plant species were similar within treatments and were not a determining factor in bird abundance or presence. Species surveys took place at the conclusion of each individual bird point count within the 50 m by 50 m area around each point count station in a 5-minute period and were completed by a single observer (KGA). Species identification was confirmed when possible; if a grass or forb could not be definitively identified, it was listed by genus. Once a species was listed by genus, all species under the genus were combined for further statistical analysis. Sedge and rush species were listed by genus (*Carex* or *Juncus*) in all cases.

Drone Surveys

An unoccupied aerial system (UAS) was used to examine vegetation cover from June 14 to June 16, 2021. A Matrice 210 V2 UAS with an infrared sensing system was used to capture multispectral imagery data (visible to NIR; 0.1 to 1.0 μm) due to its ability to collect large amounts of vegetative data quickly and over extensive spatial scales. Flights occurred at all six study sites, with individual sites completed in their entirety on a single day. Flights were focused around the 8 bird point count stations at each site. All flights occurred at wind speeds of less than 32.2 kilometers per hour and in conditions with minimal cloud cover. Flights occurred at an altitude of 70 m above ground level and captured a total area of approximately 100 m x 100 m around each station, with 50 m x 50 m of the total area used for data analysis. Each flight was automated using the mobile application Pix4D Capture.

The most abundant 4-6 vegetation species were indicated in plots by placing a combination of orange buckets and GPS markers near them so that they could be easily discerned in further imagery analysis. Markers were positioned immediately before flight and GPS points were marked using a Garmin 680 Montana GPS.

Imagery was stitched into orthomosaics using the application Pix4D (Version 4.7.3) and images were classified and analyzed using the spatial analysis package in ArcMap (Version 10.8.1).. Classification analysis of drone data at all sites was conducted using the Landsat Normalized Difference Vegetation Index (NDVI, (NIR - Red) / (NIR + Red)). As sites were not standardized with radiometric calibration targets during surveying, NDVI value ranges were not compared across sites.

Classification involved a combination of identifying groups that had distinguishable NDVI reflectance values, use of previously identified plant species, careful analysis of RGB images, and category assignment using maximum-likelihood estimation. Due to a lack of standardization and dryness of sites at time of surveys, water was not considered in classification analysis and values below determined thresholds were assumed to be soil or litter. Two areas with high soil content were cut out from site N2, because these locations were either manmade or not representative of overall habitat and soil signals frequently overlapped with dry plant signals in these areas. Two areas were removed from site C2, because data became corrupted and residual portions of these areas could not be reliably compared to remaining vegetation.

Classification was divided into vegetative groups when values were highly similar within groups. Fifteen training samples were chosen per group. Plants with an identical signal to soil (e.g., common yarrow, *Achillea millefolium*) were not included in groups because they comprised a negligible proportion of land area and could not be separated reliably. Classification included a total of 7 groups: soil (Soil; areas with no vegetation), low signal (LoSi; plants with lower signal values), high signal (HiSi; plants with higher signal values), saturated forb (SaFo; forb species with a signal at saturation or approaching saturation), saturated grass (SaGr; grass species with a signal at saturation or approaching saturation), saturated mix (SaMi; forb, grass, and sedge species with comparable signals at saturation or approaching saturation), and dry plant (DrPl; litter and dried plant signals at non-grazed sites with no soil patches present). Dominant plant species within individual classification groups were analyzed separately for each site.. Plant species were only included in classification groups if I noted they had a distinct presence across the entirety of the site or had presence recorded at a minimum of 2 stations.

Statistical Analysis

I used R software (R Core Team, Version 4.0.2) for all statistical analyses. An alpha level of 0.05 was used for statistical tests. I first compared bird species most frequently observed and overall bird community composition across treatments and sites.

I then compared adult counts of all species observed and averaged these values across sites and visually analyzed proportions of different species observed in each site. Bird species counts were graphically represented in bar graphs indicating the following percentage range classes: 0-1 %, 1-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, and 70-80%. There were no sites that had a proportion of any species above 80%. Bars on bar graphs were set at the midpoint of percentage range classes (e.g., 25 for the 20-30% class). Species with a percentage of 0-1 % were grouped together and unknown birds observed (age or species) were not included in proportions.

Community composition was evaluated using a Sorensen similarity index to compare species presence or absence across treatments and sites. The Sorensen index was used because it counts common species twice and gives less weight to outliers (Sorensen, 1957). This is an important consideration as rarer species could have been present at any of my sites but simply not observed, leading to similarity values lower than expected.

Kruskal-Wallis and exact Wilcoxon rank sum tests were performed to analyze relative abundance for adult birds seen for bird species most frequently observed across both sites and treatments. Boxplots were created to visually evaluate differences. For each species most frequently observed, I created a linear regression model with a Poisson distribution to compare counts within treatments and across overall counts.I used counts of species most frequently observed as the response variable, and wind, temperature, weather, and distance as predictor variables to ensure that the variables other than sites did not influence counts.

A Sorensen similarity index was used to measure species overlap among plant species across sites and treatments. Measurements of litter depth, grass height, and forb height were compared across treatments using a Kruskal-Wallis test, with post-hoc analysis performed using a Tukey's test. Trends were examined using boxplots to visually compare differences.

Drone classification and vegetation index histograms were produced using R software and the spatial analysis package in ArcMap (Version 10.8.1). Histograms were visually compared across sites and descriptive statistics were produced for classification histograms to compare class proportions.

RESULTS

Twenty-two bird species and genera were observed during nest dragging, haphazard walking, and bird point count surveys (Appendix A). A total of 1874 adult birds, 110 fledgling, and 69 birds of unknown age were detected across sites during surveys of nest dragging and haphazard walking. Two hundred ninety-eight total birds (adult, fledgling or unknown) were flushed or observed at site Continuous 1 (C1), 202 birds at site Continuous 2 (C2), 563 birds at site Non-grazed 1 (N1), 444 birds at site Non-grazed 2 (N2), 256 birds at site Rotational 1 (R1), and 290 birds at site Rotational 2 (R2). Nine bird species were confirmed nesting in all grassland treatments by observers (Table 1).Species of sufficient count for statistical analysis included dickcissel (*Spiza americana*), grasshopper sparrow (*Ammodramus savannarum*), meadowlark species (*Sturnella magna, S. neglecta*), and red-winged blackbird (*Agelaius phoeniceus*).

Bird Community Analysis

The average number of adult birds observed and species occurrences observed per dragging or haphazard walking survey were compared across sites. Site N1 had the highest average adult bird counts per survey (mean ± SE = 90.67 ± 6.39), followed by site N2 (mean ± SE = 65.17 ± 9.46), C1 (mean ± SE = 44.5 ± 6.39), R1 (mean ± SE = 41 ± 4.06), R2 (mean ± SE = 40.83 ± 5.7), and C2 (mean ± SE = 30.17 ± 5.1; Fig. 2). At site C1, grasshopper sparrows comprised the highest proportion of adult birds observed (40-50 %), followed by meadowlark species (20-30 %), and finally brown-headed cowbirds (*Molothrus ater*) and dickcissels in similar proportions (10-20 %; Fig. 3). At site C2, meadowlark species made up the largest proportion of birds observed (40-50 %) and dickcissels, grasshopper sparrows, and great-tailed grackles (*Quiscalus mexicanus*) the second largest in similar proportions (10-20 %; Fig. 3). At site N1, red-winged blackbirds made up the greatest proportion (70-80 %) followed by dickcissels (10-20 %; Fig. 4). At site N2, red-winged blackbirds made up the largest proportion (70-80 %) followed by dickcissels (10-20 %; Fig. 4). At site R1, the most common bird species observed was the dickcissel (40-50 %), followed by grasshopper sparrows (20-30 %) and meadowlark species (10-20 %; Fig. 5). At site R2, dickcissels made up the largest proportion (40-50 %), grasshopper sparrows the second largest (20-30 %), and meadowlark species the third largest (10-20 %, Fig. 5).

Bird Community Similarity

I used a Sorensen similarity index to compare bird species composition across treatments, and across sites. The Sorensen similarity index is a value between 0.00 and

1.00 that indicates similarity across different areas based on the species encountered in both areas. Values closer to 1 indicate that areas are more similar in terms of species shared, and values closer to 0 indicate dissimilarity in species shared. Across treatments, continuous and rotational sites had the greatest similarity index indicating that they shared a relatively high number of species (Table 4). Continuous and non-grazed sites were somewhat similar to one another, as were rotational and non-grazed sites, but their similarity index values were both lower than that of the comparison of continuous and rotational sites (Table 4).

Because I noted that some species were more common in some individual sites compared to others, I also compared similarity across all sites. Sites C1 and C2 were relatively similar to each other, as were sites R1 and R2. However, N1 and N2 were less similar to each other (Table 5). In addition, the greatest similarity index value was between C1 and R1 (Table 5).

High Frequency Species Analysis

I observed dickcissels a total of 395 times at study sites over the study period. I found that wind, temperature, weather, and distance did not significantly influence dickcissel counts (linear regression: p-value > 0.05). I found that significant differences were present across both treatment (Kruskal-Wallis one-way analysis of variance: chi-square = 22.958, df = 2, p-value < 0.001) and site (Kruskal-Wallis one-way analysis of variance: chi-square = 21.361, df = 4, p-value < 0.001). I found significant differences between continuous and non-grazed treatments and continuous and rotational treatments, but no significant differences were observed between non-grazed and rotational treatments (Wilcoxon exact rank sum analysis: Table 2). Visual examination of trends revealed noticeably higher average dickcissel counts at non-grazed and rotational sites than continuous sites (Fig. 6). An exact Wilcoxon rank sum test conducted on individual sites revealed similar trends, with significant differences between individual continuous and non-grazed or rotational sites but no differences between individual sites of the same treatment (C1, C2; N1, N2; R1, R2) or non-grazed and rotational sites (N1, N2 = R1, R2; Table 3). Visual analysis revealed similar trends to treatment comparison, with continuous sites lower in average counts than remaining sites (Fig. 7).

I observed 263 adult grasshopper sparrows over the study period. Wind, temperature, weather, and distance did not significantly influence grasshopper sparrow counts (Linear regression: p-value > 0.05). I found that significant differences were present across both treatment (Kruskal Wallis one-way analysis of variance: chi-square = 24.792, df = 2, p-value < 0.001) and site (Kruskal Wallis one-way analysis of variance: chi-square = 24.334, df = 4, p-value <0.001). Because significant differences were observed between individual continuous sites with site C2 counts noticeably lower than site C1 counts (Wilcoxon exact rank sum analysis: Table 3, Fig. 7), site C2 was excluded from treatment analysis. Wilcoxon exact rank sum treatment analysis between C1 and remaining treatments found significant differences between all treatments (Wilcoxon exact rank sum analysis: Table 2), with site C1 having the highest average counts, followed by rotational treatment, and finally non-grazed treatment with close to no counts recorded (Fig. 6). Visual analysis and Wilcoxon exact rank sum comparisons between all sites revealed that for continuous sites, C1 had higher counts compared to C2. There were no significant differences in average counts between R1 and R2, and between N1 and N2.

There were also significant differences in average counts between continuous and non-grazed sites (C1 > N1, N2; C2 > N1, N2), continuous and rotational sites (C1 > R1, R2 > C2), and non-grazed and rotational sites (R1, R2 > N1, N2; Table 3).

I observed 110 adult meadowlarks over the study period. Wind, weather, and distance did not significantly influence counts (linear regression: p-value > 0.05). Sites R1 and R2 were significantly influenced by temperature (linear regression: p-value = 0.0067), but this relationship was not observed over any other within treatment comparison or overall treatment comparisons, so it was deemed biologically irrelevant. No significant differences were present across treatment (Kruskal Wallis one-way analysis of variance: chi-square = 1.8917, df = 2, p-value = 0.388) or site (Kruskal Wallis one-way analysis of variance: chi-square=8.6541, df = 4, p-value = 0.07). No significant differences in counts were found based on treatment (Wilcoxon exact rank sum analysis: Table 2; Fig. 6). Similar trends to treatment comparisons were observed with site comparisons, but sites N1 and N2 and sites N2 and R2 were significantly different (Wilcoxon exact rank sum analysis: Table 3). Visual analysis of site trends revealed a high degree of overlap over site count ranges (Fig. 7).

I observed 694 adult red-winged blackbirds over the study period. Wind, temperature, weather, and distance did not significantly influence red-winged blackbird counts across treatment or sites (linear regression: p-value > 0.05). Red-winged blackbird counts were significantly different across treatment (Kruskal Wallis one-way analysis of variance: chi-square=24.163, df=2, p-value < 0.001) and site (Kruskal Wallis one-way analysis of variance: chi-square=15.155, df=4, p-value < 0.01). Counts were significantly different between non-grazed and continuous treatments and non-grazed and rotational treatments, but no significant difference was observed between continuous and rotational treatments (Wilcoxon exact rank sum analysis: Table 2). Visual analysis revealed noticeably higher counts at non-grazed sites than either continuous or rotational sites (Fig. 6). Comparisons across sites show similar trends to treatment analysis, but I also found that counts were not significantly different within treatments (Wilcoxon exact rank sum analysis: Table 3). Visual analysis of sites showed higher red-winged blackbird counts at both non-grazed sites compared to continuous or rotational sites (N1, N2 > C1, C2, R1, R2; Fig. 7).

Plant Community Similarity

I used a Sorensen similarity index to compare 82 plant species and genera across treatments and sites. Across treatments, continuous and rotational sites shared a moderately high level of species, with an index value comparable to non-grazed and rotational sites (Table 6). Continuous and non-grazed sites were somewhat similar but showed the lowest similarity index value (Table 6).

I compared similarity across sites to ensure within treatment plant species and genera had moderately high to high similarity. Site N1 and N2 had the highest similarity value, followed by R1 and R2, C2 and R2, and finally C1 and C2 (Table 7). Other site comparisons had low to moderately high similarity values, but values appeared noticeably lower than the four site comparisons (Table 7).

Plant Measurements

I observed significant differences in height and depth measurements across treatments for grass (chi-square=661.62, df=2, p-value <0.001), forb (chi-square=661.62, df=2, p-value <0.001), and litter (chi-square = 1347, df=2, p-value <0.001). Tukey's multiple comparison test revealed significant differences in forb height across all treatments (Table 8). Grass height and litter depth were significantly different in comparisons of non-grazed treatment to continuous and rotational treatments, but litter depth and grass height were not significantly different between continuous and rotational treatments (Table 8). Visual comparisons of differences in forb height across treatments reveal that all treatments have unique distributions, with the non-grazed treatment trending towards having the highest values with a wide range in height, continuous treatment trending towards moderate values and a wide range in height, and rotational trending towards the lowest values with a relatively constrained height range and an abundance of outliers (Fig. 8). Visual comparisons of grass height and litter depth reveal higher measurements at the non-grazed treatment than either rotational or continuous treatments, with few differences apparent across rotational or continuous treatments (Fig. 8). A right skew is apparent in litter depth distributions (Fig. 8).

Drone Classification

I classified sites based on distinct NDVI color ranges, RGB images, and ground truthing of plant species. NDVI classification values were not standardized and mean values differed at each site. I classified a total of 8 stations at site C1 (Fig. 9C). Site C1 NDVI values ranged from -0.05 to 0.91 (Fig. 9A). Classification groups for site C1 include Soil (mean + SD = 0.24 + 0.02), LoSi (low signal; mean + SD = 0.43 + 0.03), HiSi (high signal; mean + SD = 0.63 + 0.04), and SaGr (saturated grass; mean + SD = 0.80 + 0.03; Fig. 9B). A total of 71357 pixels were classified. Soil made up 3.8% of pixels, LoSi made up 43.7% of pixels, HiSi 49.3% of pixels, and SaGr 3.1% of pixels. Plant species most frequently observed in the LoSi class include *Bouteloua dactyloides* and *Bromus tectorum*. Plant species most frequently observed in the HiSi class include *Bouteloua dactyloides, Pascopyrum smithii*, and *Poa arida*. Finally, plant species most frequently observed in the SaGr class include *Carex/Juncus spp., Panicum virgatum,* and *Pascopyrum smithii.*

I classified a total of 6 stations at site C2 (Fig. 10C). Site C1 NDVI values ranged from -0.03 to 0.87 (Fig. 10A). Classification groups for site C2 include Soil (mean + SD = 0.13 + 0.07), LoSi (low signal; mean + SD = 0.37 + 0.03), HiSi (high signal; mean + SD = 0.55 + 0.03), and SaMi (saturated mix; mean + SD = 0.76 + 0.04; Fig. 10B). A total of 134083 pixels were classified. Soil made up 1.8% of pixels, LoSi made up 29.8% of pixels, HiSi 66.5% of pixels, and SaMi 1.9% of pixels. Plant species most frequently observed in the LoSi class include *Bouteloua dactyloides*, *Bromus tectorum, Hordeum pusilum,* and *Pascopyrum smithii*. Plant species most frequently observed in the HiSi class include *Ambrosia psilostachya, Bouteloua dactyloides, Bromus tectorum, Panicum virgatum,* and *Pascopyrum smithii*. Finally, plant species most frequently observed in the SaMi class include *Carex spp., Iva annua,* and *Panicum virgatum*.

I classified a total of 8 stations at site N1 (Fig. 11C). Site N1 NDVI values ranged from -0.35 to 0.9 (Fig. 11A). Classification groups for site N1 include DrPl (dry plant; mean + SD = 0.24 + 0.07), LoSi (low signal; mean + SD = 0.32 + 0.05), HiSi (high signal; mean ± SD = 0.62 ± 0.05), and SaMi (saturated mix; mean ± SD = 0.84 ± 0.03; Fig. 11B). A total of 68728 pixels were classified. DrPl made up 1.2% of pixels, LoSi made up 40.8% of pixels, HiSi 57.0% of pixels, and SaMi 1.0% of pixels. Plant species most frequently observed in the DrPl class include *Panicum virgatum,* dead plants including *Helianthus annuus,* and various other unknown grass species. Plant species most frequently observed in the LoSi class include *Distichlis spicata, Pascopyrum smithii,* and *Poa arida*. Plant species most frequently observed in the HiSi class include *Apocynum cannabinum, Bromus tectorum, Distichlis spicata, Pascopyrum smithii, Rumex crispus,* and *Solidago canadensis*. Finally, plant species most frequently observed in the SaMi class include *Apocynum cannabinum, Carex spp., Distichlis spicata,* and *Solidago canadensis*.

I classified a total of 6 stations at site N2 (Fig. 12C). Site N2 NDVI values ranged from -0.16 to 0.92 (Fig. 12A). Classification groups for site N2 include DrPl (dry plant; mean ± SD = 0.17 ± 0.06), LoSi (low signal; mean ± SD = 0.4 ± 0.04), HiSi (high signal; mean ± SD = 0.62 ± 0.04), and SaMi (saturated mix; mean ± SD = 0.84 ± 0.03; Fig. 12B). A total of 41065 pixels were classified. DrPl made up 1.6% of pixels, LoSi made up 32.2% of pixels, HiSi 63.3% of pixels, and SaMi 2.9% of pixels. Plant species most frequently observed in the DrPl class include dead plants such as *Helianthus annuus* and various other unknown grass species. Plant species most frequently observed in the LoSi class include *Distichlis spicata, Pascopyrum smithii,* and *Poa arida*. Plant species most frequently observed in the HiSi class include *Bromus inermis, Bromus tectorum, Distichlis spicata,* and *Pascopyrum smithii*. Finally, plant species most frequently observed in the SaMi class include *Asclepias spp., Carex spp.,* and *Helianthus annuus.*

I classified a total of 8 stations at site R1 (Fig. 13C). Site R1 NDVI values ranged from -0.02 to 0.92 (Fig. 13A). Classification groups for site R1 include Soil (mean ± SD = 0.16 ± 0.02), LoSi (low signal; mean ± SD = 0.32 ± 0.04), HiSi (high signal; mean ± SD = 0.58 ± 0.04), and SaFo (saturated forb; mean ± SD = 0.82 ± 0.04; Fig. 13B). A total of 75613 pixels were classified. Soil made up 1.2% of pixels, LoSi made up 42.5% of pixels, HiSi 47.0% of pixels, and SaFo 9.3% of pixels. Plant species most frequently observed in the LoSi class include *Aegilops cylindrica, Bouteloua dactyloides, Bromus tectorum, Hordeum pusilum,* and *Pascopyrum smithii*. Plant species most frequently observed in the HiSi class include *Ambrosia psilostachya, Bromus tectorum, Melilotus officinalis, Pascopyrum smithii,* and *Tragopogon dubius*. Finally, plant species most frequently observed in the SaFo class include *Medicago sativa* and *Melilotus officinalis*.

I classified a total of 8 stations at site R2 (Fig. 14C). Site R2 NDVI values ranged from -0.07 to 0.93 (Fig. 14A). Classification groups for site R2 include Soil (mean ± SD = 0.15 ± 0.02), LoSi (low signal; mean ± SD = 0.40 ± 0.04), HiSi (high signal; mean ± SD = 0.63 ± 0.03), and SaFo (saturated forb; mean ± SD = 0.88 ± 0.03; Fig. 14B). A total of 40546 pixels were classified. Soil made up 2.3% of pixels, LoSi made up 39.4% of pixels, HiSi 52.3% of pixels, and SaFo 6.0% of pixels. Plant species most frequently observed in the LoSi class include *Aegilops cylindrica, Bouteloua dactyloides, Bromus tectorum, Hordeum pusilum,* and *Pascopyrum smithii,* and *Poa arida*. Plant species most frequently observed in the HiSi class include *Ambrosia psilostachya, Bromus tectorum, Meliotus albus, Melilotus officinalis, Pascopyrum smithii,* and *Symphyotrichum ericoides*. Finally, plant species most frequently observed in the SaFo class include *Medicago sativa, Melilotus albus,* and *Melilotus officinalis*.

DISCUSSION

In this study, I sought to acquire information about the status of bird and plant communities across grazing treatments to improve management of Cheyenne Bottoms Preserve. Bird abundances and community compositions were compared across continuous, rotational, and non-grazed treatments. Vegetative characteristics and plant community composition were analyzed to determine if differences in bird populations were the result of vegetative differences. Two sites with similar grazing histories were chosen for each treatment, but I did detect instances where bird abundances and proportions differed across sites of the same treatment.

Bird Community Analysis

Continuous sites differed greatly in community proportions which may have been the result of flooding. This likely reduced nesting bird numbers at site C2. Grasshopper sparrows (*Ammodramus savannarum*) comprised most birds seen at site C1 (40 – 50 %) but were noticeably lower in proportion at site C2 (10 – 20 %). Meadowlark (*Sturnella spp.*) proportions were distinctly higher at site C2, indicating meadowlarks may not be influenced by the same environmental conditions that affect grasshopper sparrow presence such as flooding (Perkins and Vickery, 2005). Brown-headed cowbirds (*Molothus ater*) also comprised a greater proportion of counts at site C1 than site C2. Brown-headed cowbirds are typically associated with cattle for feeding, but were still lower at site C2 despite the presence of cattle being higher at this site due to a second continuous pasture bordering the northern edge. Brown-headed cowbirds are brood parasites (Goguen and Mathews, 2008), so differences in proportion might be due to a relatively lower number of nesting birds at site C2. Great-tailed grackles (*Quiscalus mexicanus*) are another cattle-associated species (Davis and Arnold, 1972)and were observed in appreciable numbers only at site C2. Additionally, great-tailed grackles are colonial nesters that often place nests in shrubs and trees (Johnson et al., 2000), and an appreciable tree line (approximately 1800 m^2) was located within 400 m of the C2 plot, which might also account for their presence.

The non-grazed grazing treatment had high overall bird abundance compared to the other grazing treatments. Both sites had substantial red-winged blackbird (*Agelaius phoeniceus*) numbers present. Across the two non-grazed sites, species that occurred frequently were consistent. Notable exceptions include blue-winged teal (*Spatula discors*) and mallard (*Anas platyrhynchos*) observed at site N1, which are prairie-nesting duck species that tend to nest near pond water bodies (Mulhern et al., 1985). A pond was present near site N1 and absent from the area surrounding site N2.

Rotational sites were consistent in both bird abundance and proportions of high frequency birds seen, but less common species did differ widely in proportions or presence across sites. Notable grassland nesting birds include the greater prairie chicken (*Tympanuchus cupido*) which only has a single known population within Cheyenne Bottoms in the pasture containing site R2. Upland sandpipers (*Bartramia longicauda*) were not observed within pasture R1 during point count or dragging surveys, and limited recent studies are available regarding habitat preferences of upland sandpipers in mixed-grass in Kansas (though see Dechant et al., 2002b).

Bird Community Similarity

Understanding similarities in bird species presence across treatments can indicate whether birds are responding to treatment or vegetation at the community level. Sorensen index comparisons for bird populations across treatment indicated that continuous and rotational sites were relatively similar, continuous and non-grazed somewhat similar, and non-grazed and rotational the least similar. However, though greater similarities were present at sites within rotational and continuous treatments, non-grazed sites showed noticeably lower similarity, and values between other sites (e.g., C1 vs R1) were unexpectedly high. Upon further examination of bird species present at sites (Appendix A), differences in sites appear to largely be the result of the presence or absence of rarer or less concentrated species at sites such as blue-winged teal, common nighthawk (*Chordeiles minor*), or killdeer (*Charadrius vociferus*) that could have appreciable populations but were simply not observed in most surveying efforts. Differences at sites also appeared to be due to the presence of bird species that were not grassland nesters (e.g., orchard oriole, *Icterus spurius*; prairie falcon, *Falco mexicanus*) that were likely using sites for feeding or behavioral purposes. These results suggest that a similarity index for bird populations may necessitate greater bird point count or search efforts to reveal vegetation-based community differences. Additionally, habitat within or surrounding pastures and site locations including nearby wetland, live trees, or dead tree stands should be considered in site differences.

High Frequency Species Analysis

Some species were more commonly observed at the different sites than others, possibly due to site-level habitat selection. Accordingly, I analyzed most frequently observed species present across treatments and sites, and revealed interesting relationships between treatment and presence of higher frequency bird species. Dickcissel (*Spiza americana*) numbers were significantly lower at continuous sites than non-grazed and rotational sites, which could be due to multiple factors. Continuous sites had lower grass heights than non-grazed sites and fewer forb outliers than rotational sites, which could indicate that there was less ideal nesting or calling habitat present at continuous sites. Dickcissel numbers were lowest at site C2, a site with substantial flooding, however counts at C2 were not significantly different from site C1. Dickcissels have been reported showing a preference for dry-mesic habitats (Dechant et al., 2002a; Kim et al., 2008), so water content could potentially be a factor in lower counts, but the weak difference between these two sites suggests that treatment may be a greater indicator for dickcissel presence within Cheyenne Bottoms. At rotational and non-grazed sites, I observed nests, fledglings, and calling dickcissels repeatedly in or under trees including honey locust (*Gleditsia triacanthos*) or with sturdy forbs such as annual sunflower (*Helianthus annuus*), prairie dogbane (*Apocynum cannabinum*) and sweet clover species (*Melilotus alba, M. officinalis*), supporting relationships found in multiple studies that suggest dickcissels are associated with forb, shrub, and tree species within grasslands (see Dechant et al., 2002a).

Counts of grasshopper sparrows were lowest at non-grazed sites, with numbers at or close to zero over all counts, which may suggest litter depth at these sites was too high for effective foraging as has been indicated in other studies (Whitmore, 1981). Rotational sites, on the other hand, had relatively high counts indicating that this treatment was used by grasshopper sparrows to an appreciable extent. At the site level, counts were significantly higher at site C1 than all other sites, which may represent a preference for continuous sites under ideal conditions. However, counts were significantly lower at site C2 than site C1, R1, or R2. Site C2 had highly comparable forb height, grass height, litter depth, and plant species composition to site C1.It seems likely that the differences in grasshopper sparrow numbers were due to the notably higher flooding that occurred at site C2 throughout the study season compared to other continuous or rotational sites. The negative relationship between grasshopper sparrow nesting success and flooding has been indicated in other studies (Perkins and Vickery, 2005), so this may suggest highly flooded sites should be managed for a different focal species.

Meadowlark species did not appear to select any particular treatment type over another. Numbers were significantly higher at certain sites compared to others (R2, N1 > N2) but this pattern was driven by differences of just a few individuals across these sites (Fig. 7), which could represent a difference of a few breeding pairs and may not be biologically relevant. These patterns may suggest that meadowlarks are flexible in habitat occurrence, as has been indicated previously (Davis and Duncan, 1999). One study suggested that eastern meadowlarks (*Sturnella magna*) have similar occurrence in a range of prairie habitats but low occurrence in strip crop or haying plots (Ribic et al., 2009), the latter two of which are treatment types not heavily used within Cheyenne Bottoms Preserve. The similar meadowlark numbers that I observed across continuous, rotational, and non-grazed treatment types likely indicates that meadowlarks should have low consideration for management decisions.

Red-winged blackbirds were more commonly seen at non-grazed sites than sites of all other treatments. Vegetation and drone surveys of non-grazed sites revealed an abundance of intermixed sedge and grass species at non-grazed sites, and the association between red-winged blackbirds and sedge-meadow habitats has been previously documented (Kim et al., 2008; Mossman and Sample, 1990). While it is possible this pattern may simply be related to high proximity to wetland at non-grazed sites, it is important to note that numbers at site R2 were similar to those at sites R1, C1, or C2, even though substantial wetland habitat was present directly within the pasture surrounding site R2. However, even though red-winged blackbirds were a bird species observed at all sites and had a clear preference for the non-grazed treatment over other treatments, they are a wetland nesting bird species, were not observed nesting on plots, and were likely using grassland areas for feeding or other non-nesting purposes. The preferences of this species should not be heavily considered in future management decisions.

Plant Community Similarity

Understanding vegetative similarity is important to determine whether plant communities differ across treatments and ensure that communities within treatments have similar plant species. When comparing vegetation community similarity across treatments, I found that rotational sites shared a moderately high level of species with continuous and non-grazed sites, while continuous and non-grazed sites shared a distinctly lower level of species. This potentially suggests that rotational sites share certain unique plants with non-grazed and continuous sites. Site-level differences show that plant communities were mostly organized as expected, with higher similarities between sites of the same treatment. Surprisingly, however, sites C2 and R2 were slightly more similar to each other than were sites C1 and C2. The reason behind this relationship is not entirely clear, though both C2 and R2 either have high water inundation (C2) or high proximity to wetland (R2). To examine why C2 would be more similar to R2 than C1, another continuous site, I examined plants that were shared between C2 and R2 but not C2 and C1. Of the 6 plant species that were uniquely shared between C2 and R2, only one species, annual marsh elder (*Iva annua*), is common to wetland areas. Somewhat higher similarities between these two sites may therefore be due partly to chance or an unknown driver may be influencing both sites. Further survey efforts may reveal true similarities.

Plant Measurements

Vegetative characteristics were analyzed to determine which plant structural attributes affected differences in bird abundances, proportion, and presence. I found that non-grazed sites had taller grass and greater litter depth than continuous or rotational sites. Continuous and rotational sites did not differ with regards to litter depth and grass height. The greatest differences were observed in forb height, with each treatment appearing to have a distinct organization of forb characteristics. Rotational sites had a highly unique organization of measurements, with distributions having a strong right skew and over 50% of measurements ranging below 250 mm. This pattern was likely due to a greater number of new-growth forbs or shorter forb species scattered across sites, as cattle were not present to consume smaller plants. Outliers from this pattern included taller forb species such as *Melilotus alba* or *Melilotus officinalis* that were absent or did not grow to substantial heights at continuous or non-grazed sites.

Drone Classification

Drone imagery results showed distinct classes with a large degree of signal variably and class overlap in certain species depending on flooding conditions or plant maturity (e.g., *Bouteloua dactyloides, Bromus tectorum*), which mirrors similar relationships in variability that have been observed in other NDVI land cover studies (Bradley and Mustard, 2004). Certain classification patterns were present that indicated differences in land cover and differing degrees of water content at sites. Most notably, high signal values made up a considerably greater proportion of classified values at site C2 (66.5%) than site C1 (49.3%), while repeated flooding was observed at site C2 by observers, indicating that historical flooding can be appropriately observed using NDVI surveys. Site N2 had distinctly lower low signal values than site N1 (32.2% < 40.8%), which may suggest that site N2 had higher water inundation. Rotational sites had very distinct forb values that constituted a substantial percent of pixels (6.0% - 9.3%), with *Melilotus alba* and *Melilotus officinalis* making up the majority of forb values seen on NDVI imagery. Site R2 had a slightly greater percent of high signal values than site R1 (52.3% > 47.0%) and a lower percent of low signal values than site R1 (39.4% < 42.5%), but sweet clover signals overlapped in the high signal and saturated forb classes for both sites, so differences in sites could not be conclusively attributed to flooding.

RECOMMENDATIONS AND FUTURE STUDIES

Continued management of grassland plots by the Nature Conservancy should strive to maintain a diversity of grazing types including both rotational and continuous treatments. As grasshopper sparrows appear to prefer continuous sites under low-flood conditions, I recommend that drier pastures have a continuous treatment regime to encourage grasshopper sparrow nesting. If continuous treatments cannot be used within drier pastures, cattle should be placed in these pastures during the nesting season to discourage new forb growth and encourage growth of clump grasses (e.g., *Panicum virgatum*) that are attractive to grasshopper sparrows (Whitmore, 1981). Highly flooded sites may benefit from switching over to a rotational grazing regime, as rotational grazing encourages higher floristic richness (McDonald et al., 2019) and advantages of this regime may help to outweigh downsides of high-water inundation. Sweet clover species (*Melilotus alba, M. officinalis*) or similar forbs should be encouraged at rotational sites to attract dickcissels. Furthermore, sites with observed higher forb or sweet clover concentrations may benefit from decreased cattle presence at the beginning of the dickcissel nesting season to increase nesting and calling habitat for dickcissels.

As management recommendations do not consider rarer or less concentrated bird species such as upland sandpipers that may be influenced by grazing and floodplain regimes present at Cheyenne Bottoms, future studies should have a high focus on the relative abundance, specific habitat preference, and nesting success of these species.

Future drone reflectance imagery studies should be standardized and may benefit from a focus on flooded vs. non-flooded habitat.

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TABLES

Table 1: Grassland bird species with confirmed nesting behavior across Continuous (C), Non-grazed (N), and Rotational (R) sites from May 26 – July 15, 2021. Lack of nesting behavior observed does not confirm an absence of nesting birds. See Appendix A for a full list of species codes.

Species	C1	C2	N1	N2	R1	R2
BHCO	1	1	1	0	1	1
BWTE	0	0	1	0	0	0
DICK	1	0	1	1	1	1
GPCH	0	0	0	0	0	1
GRSP	1	1	0	0	1	1
MALL	0	0	1	0	0	0
MEAD	1	1	1	1	1	1
MODO	0	0	0	0	1	0
UPSA	1	1	0	0	0	1

Table 2: Exact Wilcoxon rank sum values for high frequency bird species across Continuous (C), Non-grazed (N), and Rotational (R) treatments. Bird species include DICK (Dickcissel, *Spiza americana*), GRSP (Grasshopper sparrow, *Ammodramus savannarum*), MEAD (Meadowlark species, *Sturnella spp.*), and RWBL (Red-winged blackbird, *Agelaius phoenicus*). Site C2 was not included in treatment analysis for GRSP. ** indicates $P < 0.01$, *** indicates $P < 0.001$.

Species	Treatment 1	Treatment 2	P-value	
DICK	C	N	<0.001	***
	C	R	<0.001	***
	N	R	0.27	
GRSP	C	N	<0.001	***
	C	R	0.005	**
	N	R	<0.001	***
MEAD	C	N	0.83	
	C	R	0.34	
	N	R	0.19	
RWBL	C	N	<0.001	***
	C	R	0.89	
	N	R	<0.001	***

Table 3: Exact Wilcoxon rank sum values for high frequency bird species across sites within/among Continuous (C), Non-grazed (N), and Rotational (R) treatments. Bird species include DICK (Dickcissel, *Spiza americana*), GRSP (Grasshopper sparrow, *Ammodramus savannarum*), MEAD (Meadowlark species, *Sturnella spp.*), and RWBL (Red-winged blackbird, *Agelaius phoenicus*). * indicates P < 0.05, ** indicates P < 0.01.

Species	Site 1	Site 2	P-value		Species	Site 1	Site 2	P-value	
DICK	C1	C2	0.23		MEAD	C1	C2	0.60	
	C1	N1	0.004	**		C1	N1	0.71	
	C1	N2	0.002	**		C1	N2	0.17	
	C1	R1	0.002	**		C1	R1	0.62	
	C1	R2	0.002	**		C1	R2	0.21	
	C2	N1	0.011	*		C2	N1	0.23	
	C2	N2	0.002	**		C2	N2	0.40	
	C2	R1	0.002	**		C2	R1	0.87	
	C2	R2	0.002	**		C2	R2	0.084	
	N1	N2	0.32			N1	N2	0.045	*
	N1	R1	0.29			N1	R1	0.29	
	N1	R2	0.33			N1	R2	0.37	
	N2	R1	0.55			N2	R1	0.29	
	N2	R2	0.80			N2	R2	0.006	**
	R1	R2	0.77			R1	R2	0.076	
GRSP	C1	C2	0.002	**	RWBL	C1	C2	0.66	
	C1	N1	0.002	**		C1	N1	0.002	**
	C1	N2	0.002	**		C1	N2	0.002	**
	C1	R1	0.026	*		C1	R1	0.59	
	C1	R2	0.015	*		C1	R2	0.85	
	C2	N1	0.002	**		C2	N1	0.002	**
	C2	N2	0.002	**		C2	N2	0.002	**
	C2	R1	0.015	*		C2	R1	1.00	
	C2	R2	0.006	**		C2	R2	0.74	
	N1	N2	1.00			N1	N2	0.17	
	N1	R1	0.002	**		N1	R1	0.002	**
	N1	R2	0.002	**		N1	R2	0.002	**
	N2	R1	0.002	**		N2	R1	0.002	**
	N2	R2	0.002	**		N2	R2	0.002	**
	R1	R2	0.45			R1	R2	0.75	

Table 4: A comparison of Sorensen similarity index values compiled from presence/absence of birds across Continuous (C), Non-grazed (N), and Rotational (R) treatments. See Appendix A for exact species observed.

Treatment 1	Treatment 2	Index Value
C	N	0.36
C	R	0.47
N	R	0.27

Table 5: A comparison of Sorensen similarity index values compiled from presence/absence of birds across Continuous (C), Non-grazed (N), and Rotational (R) sites. See Appendix A for exact species observed.

Site 1	Site 2	Index Value
C1	C2	0.51
C1	N1	0.33
C1	N2	0.33
C1	R1	0.60
C1	R2	0.51
C2	N1	0.25
C2	N2	0.31
C2	R1	0.55
C2	R2	0.40
N1	N2	0.37
N1	R1	0.28
N1	R2	0.25
N2	R1	0.27
N2	R2	0.24
R1	R2	0.55

Table 6: A comparison of Sorensen similarity index values compiled from presence/absence of plant species and genera across Continuous (C), Non-grazed (N), and Rotational (R) treatments. See Appendix B for exact species or genera observed.

Treatment 1	Treatment 2	Index Value
C	N	0.31
C	R	0.41
N	R	0.37

Table 7: A comparison of Sorensen similarity index values compiled from presence/absence of plant species and genera Continuous (C), Non-grazed (N), and Rotational (R) sites. See Appendix B for exact species or genera observed.

Site 1	Site 2	Index Value
C1	C2	0.41
C1	N1	0.29
C1	N2	0.22
C1	R1	0.32
C1	R2	0.36
C2	N1	0.33
C2	N2	0.26
C2	R1	0.38
C2	R2	0.42
N1	N2	0.44
N1	R1	0.28
N1	R2	0.32
N2	R1	0.32
N2	R2	0.29
R1	R2	0.43

Table 8: Multiple comparison Tukey's test showing differences in grass height, forb height, and litter depth across Continuous (C), Non-grazed (N), and Rotational (R) treatments.

Measurement	Treatment 1	Treatment 2	Obs.dif	Critical.dif	Difference
Grass Height	C	N	596.60	67.29	TRUE
	C	R	56.37	74.33	FALSE
	N	R	652.97	70.73	TRUE
Forb Height	C	N	51.90	41.65	TRUE
	C	R	70.38	35.15	TRUE
	N	R	122.28	39.43	TRUE
Litter Depth	C	N	1066.89	80.85	TRUE
	C	R	4.71	81.85	FALSE
	N	R	1062.18	80.43	TRUE

FIGURES

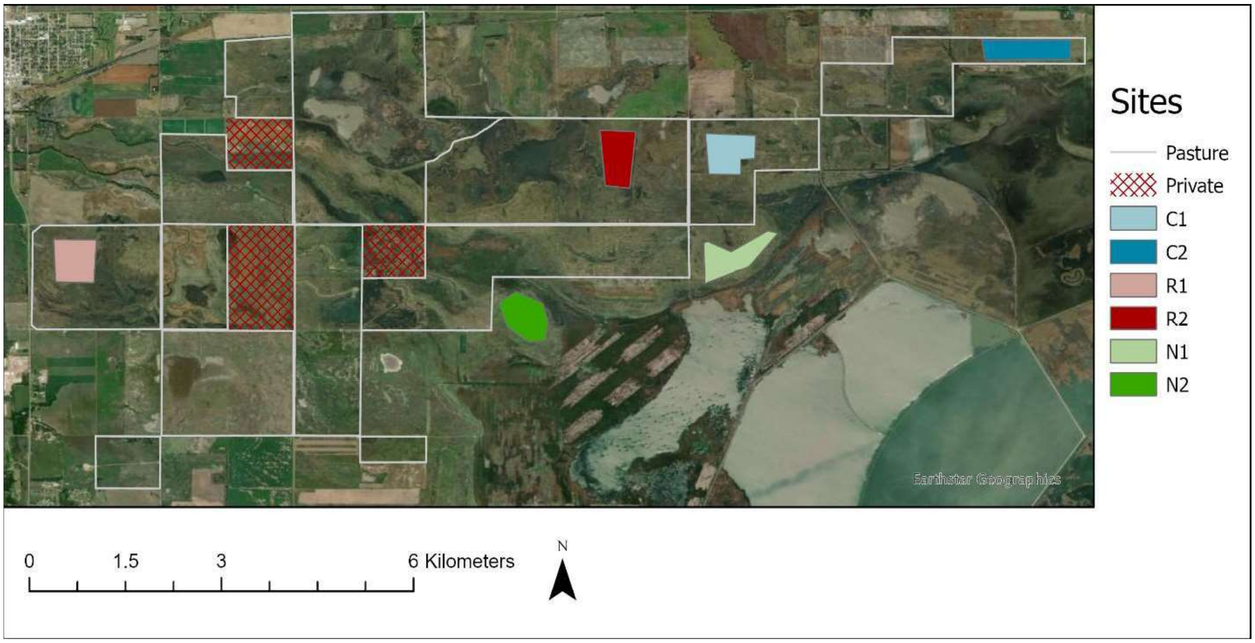

Figure 1: A map of nest-dragging and haphazard walking plots for sites of three treatment types: Continuous (C), Non-grazed (N), and Rotational (R). Site plots are 32 hectares in area. Marked

pastures are owned by the Nature Conservancy. Base map was developed by Earthstar Geographics LLC.

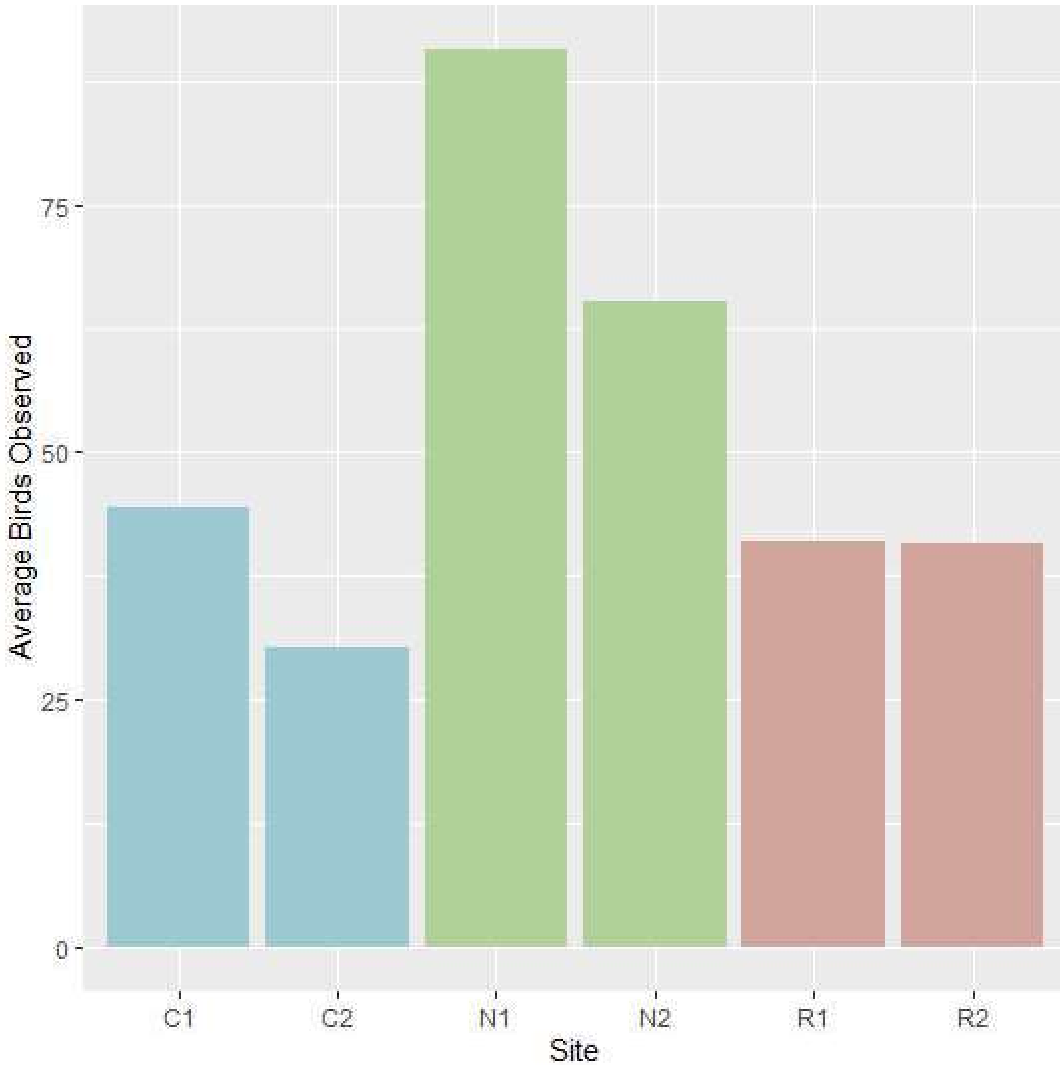

Figure 2: A comparison of the average number of adult birds of all species observed during nest-dragging/haphazard walking across Continuous (C), Non-grazed (N), and Rotational (R) sites.

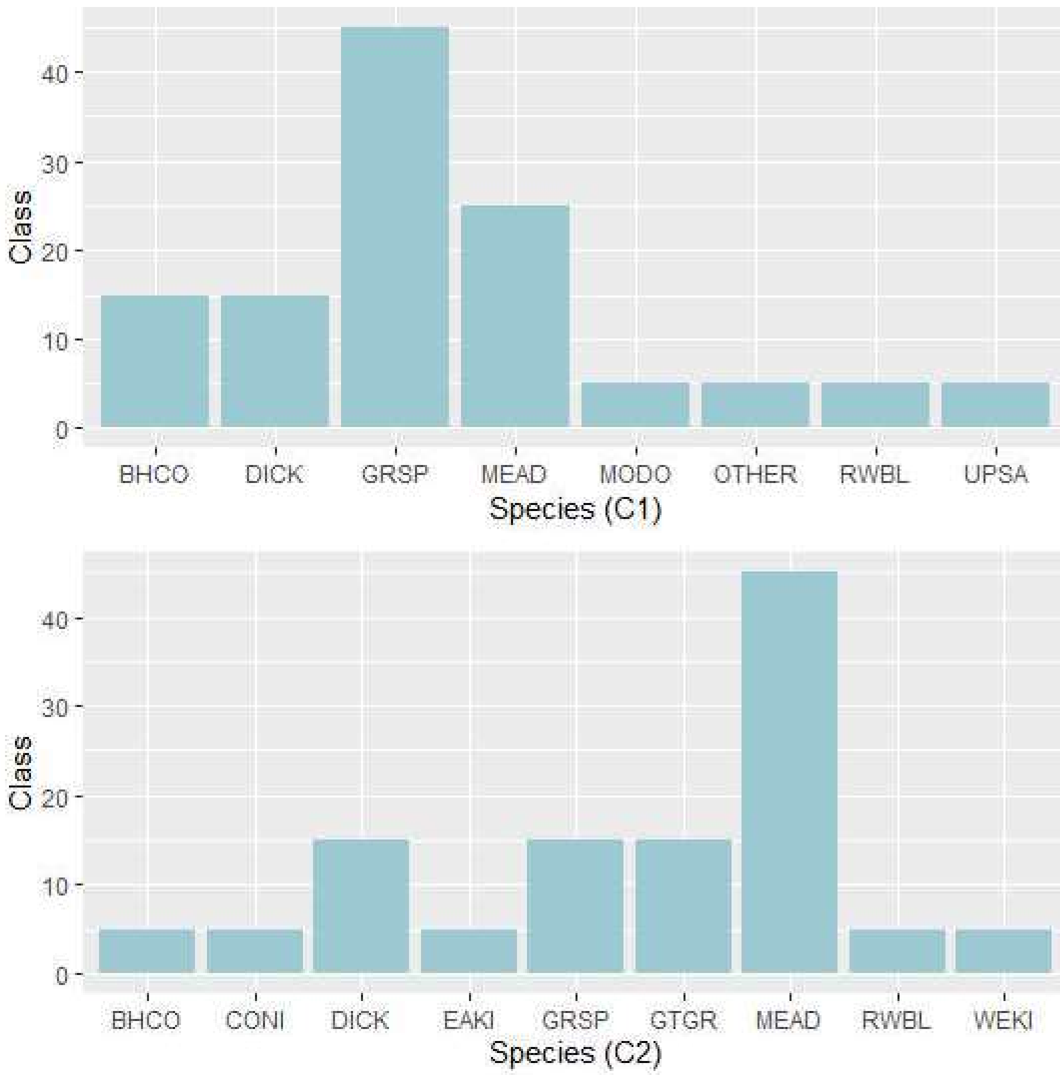

Figure 3: A comparison of average bird species observed during nest-dragging across continuous sites C1 and C2. Values represent the midpoint of percentage classes (e.g., 0-10%, 10-20%, etc.). Refer to Appendix A for a list of all species codes and scientific names. OTHER species for site C1 include killdeer and western kingbird.

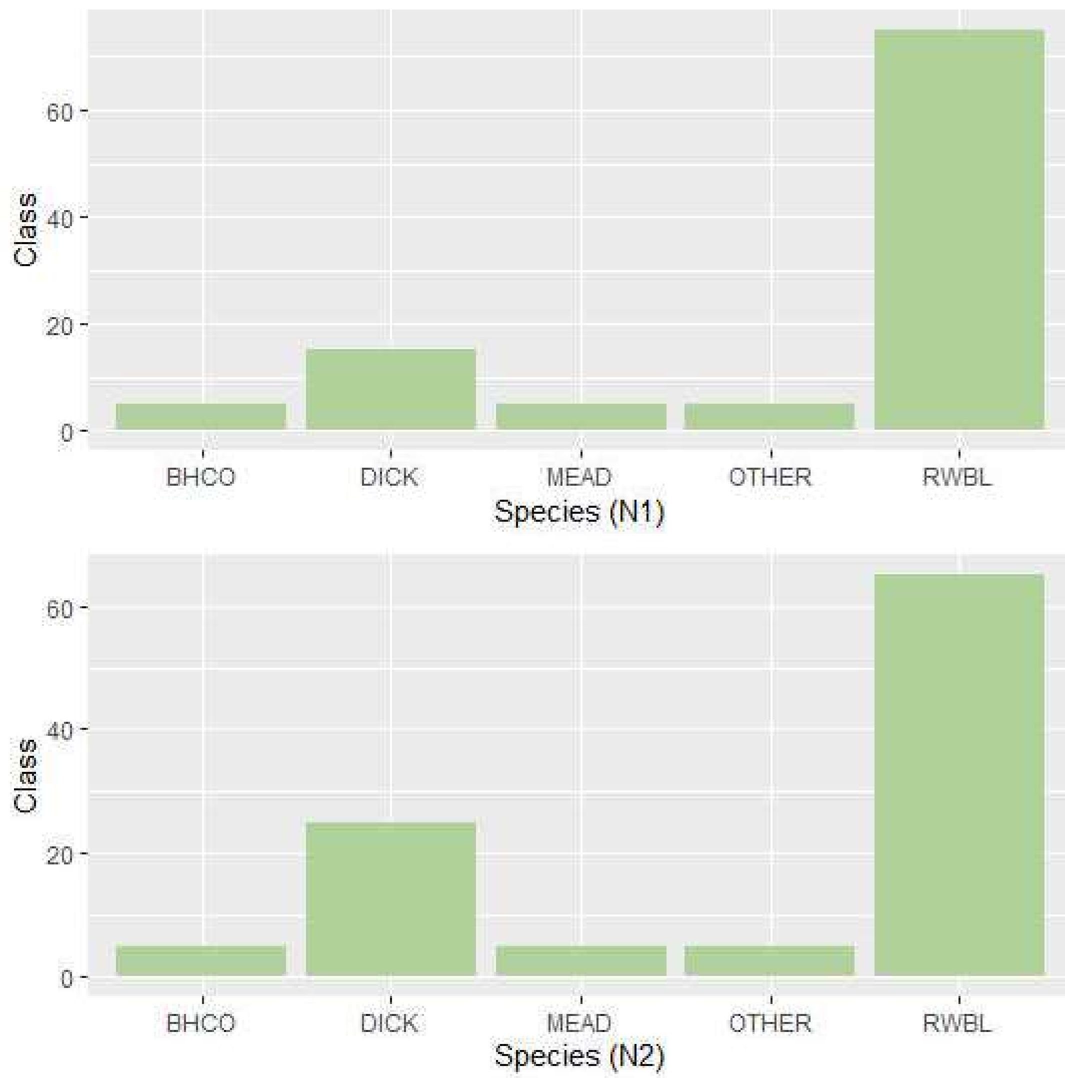

Figure 4: A comparison of average bird species observed during haphazard walking across sites N1 and N2. Values represent the midpoint of percentage classes (e.g., 0-10%, 10-20%, etc.). Refer to Appendix A for a list of all species codes and scientific names. OTHER species for site N1 include blue-winged teal, great-horned owl, grasshopper sparrow, killdeer, mallard, ring-necked pheasant, and western kingbird. OTHER species for site N2 include ring-necked pheasant and yellow-headed blackbird.

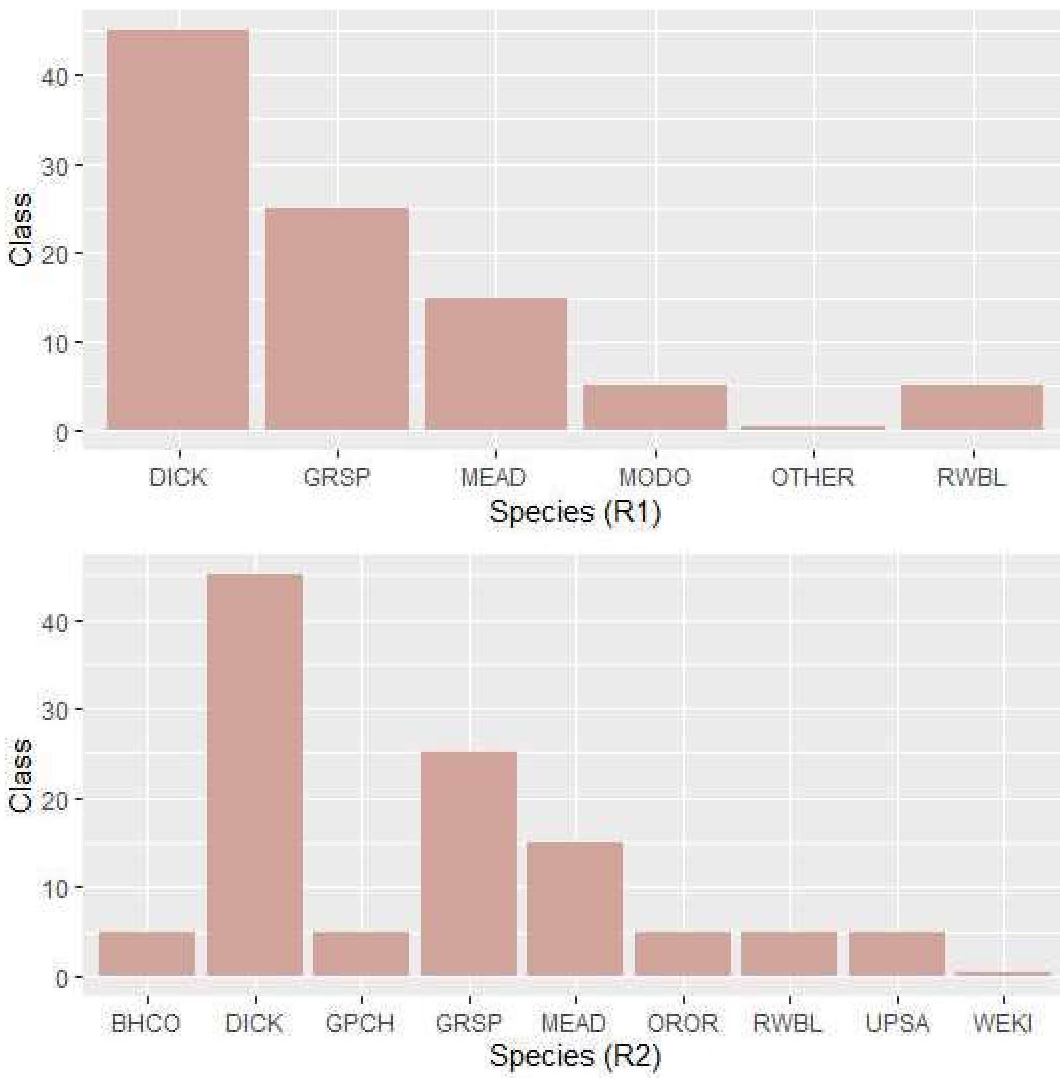

Figure 5: A comparison of average bird species observed during nest-dragging across sites R1 and R2. Values represent the midpoint of percentage classes (e.g., 0-10%, 10-20%, etc.). Refer to Appendix A for a list of all species codes and scientific names. OTHER species for site R1 include brown-headed cowbird and western kingbird.

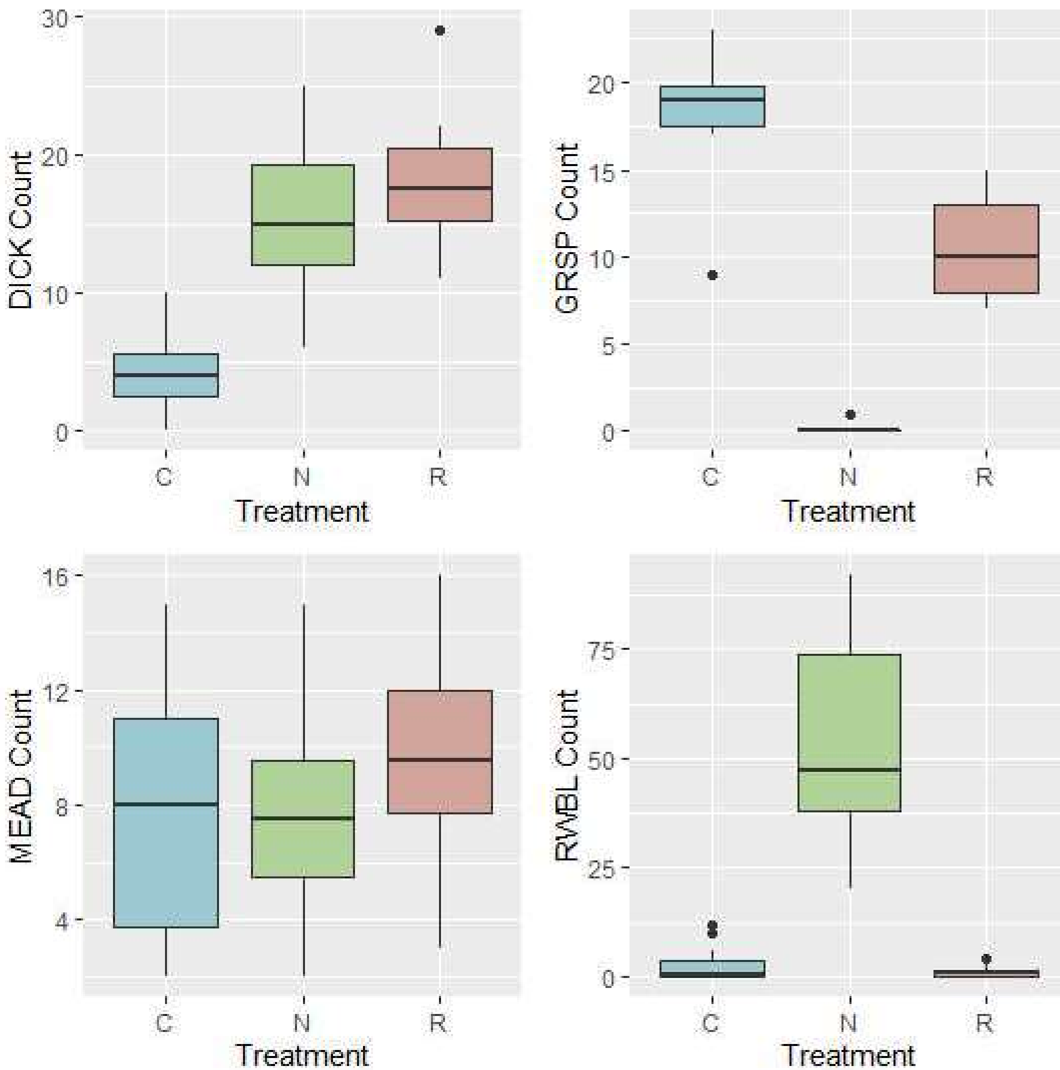

Figure 6: Count distributions for high frequency bird species observed across Continuous (C), Non-grazed (N), and Rotational (R) treatments. Bird species include DICK (Dickcissel, *Spiza americana*), GRSP (Grasshopper sparrow, *Ammodramus savannarum*), MEAD (Meadowlark species, *Sturnella spp.*), and RWBL (Red-winged blackbird, *Agelaius phoenicus*). Site C2 was not included in treatment analysis for GRSP.

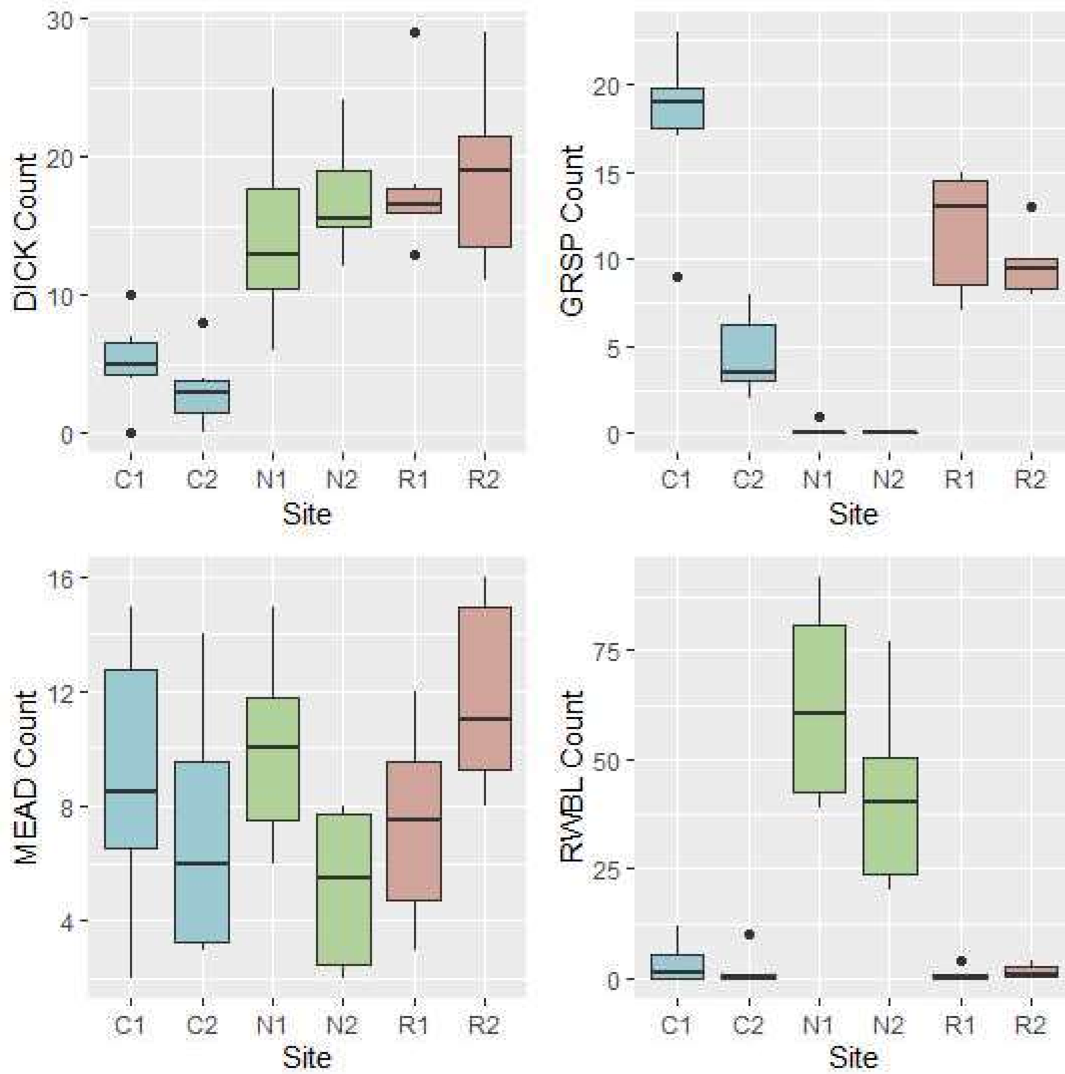

Figure 7: Count distributions for high frequency bird species observed across individual sites for Continuous (C), Non-grazed (N), and Rotational (R) treatments. Bird species include DICK (Dickcissel, *Spiza americana*), GRSP (Grasshopper sparrow, *Ammodramus savannarum*), MEAD (Meadowlark species, *Sturnella spp.*), and RWBL (Red-winged blackbird, *Agelaius phoenicus*).

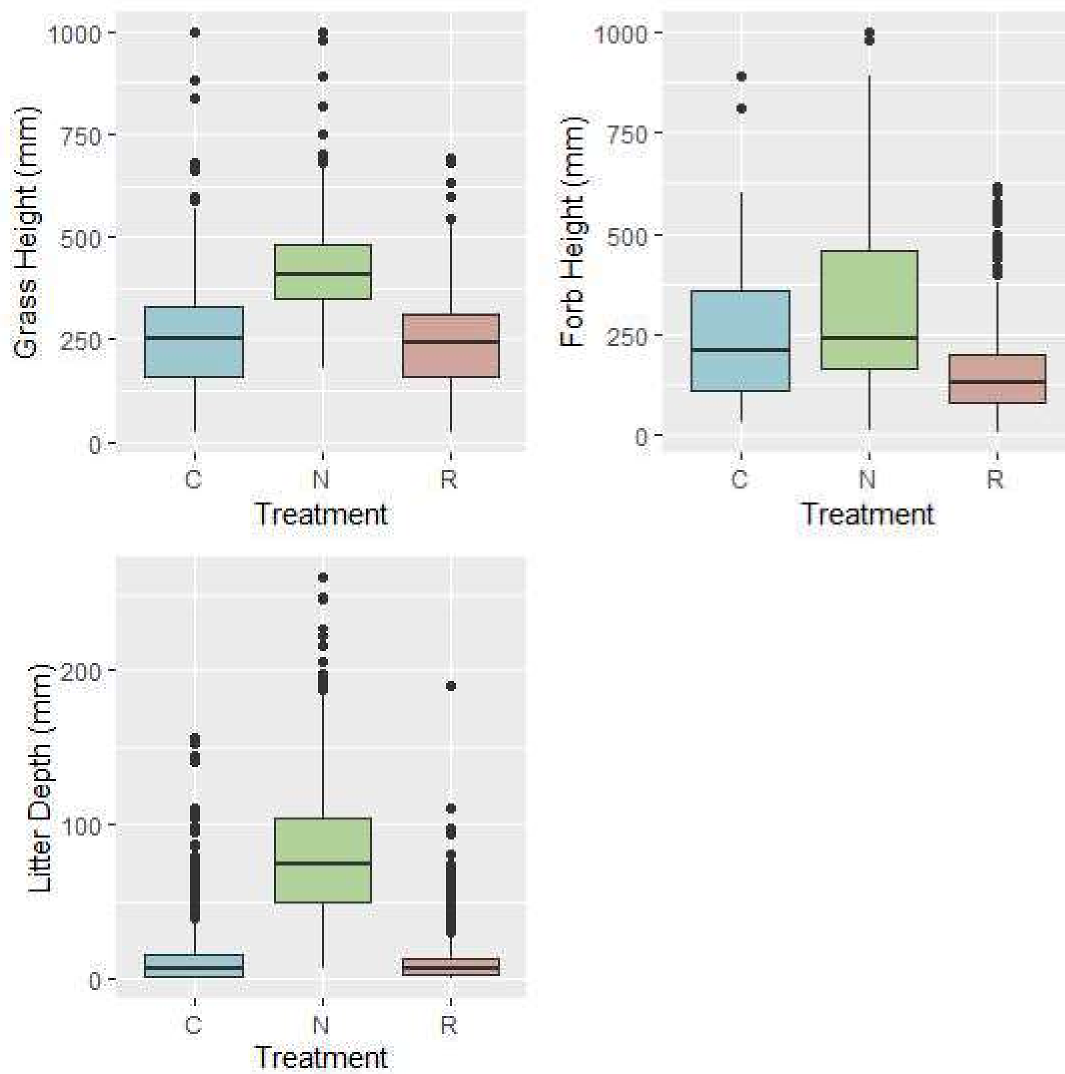

Figure 8: A comparison of grass height, forb height, and litter depth measurements across Continuous (C), Non-grazed (N), and Rotational (R) treatments. Measurements are in millimeters (mm).

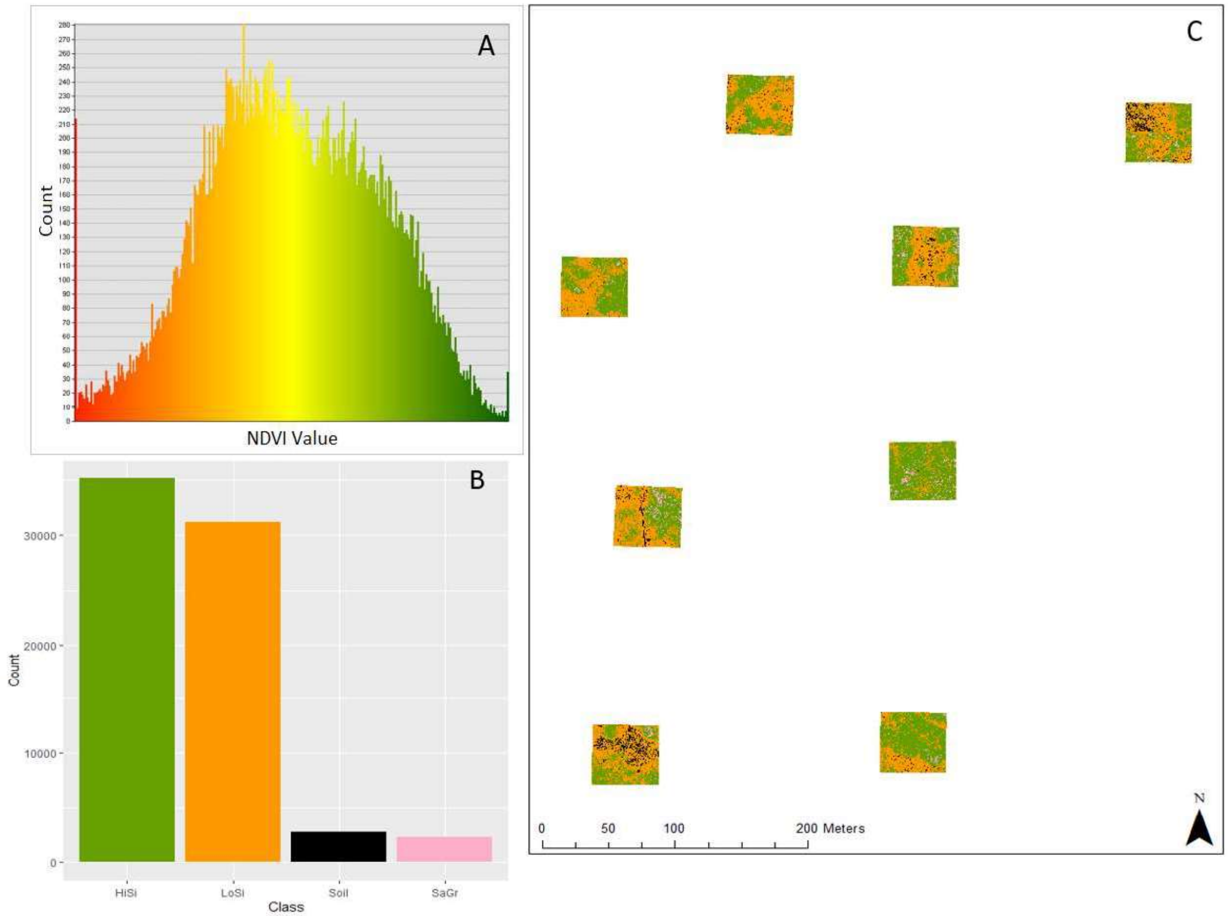

Figure 9:

A) A histogram displaying unclassified raw NDVI value ranges for site C1. Overall ranges span from -0.05 to 0.91.

B) Classification groups for site C1 include Soil (mean = 0.24, SD ± 0.02), LoSi (low signal; mean = 0.43, SD ± 0.03), HiSi (high signal; mean = 0.63, SD ± 0.04), and SaGr (saturated grass; mean = 0.80, SD ± 0.03).

C) A site map of C1 displaying classified groups laid out in space.

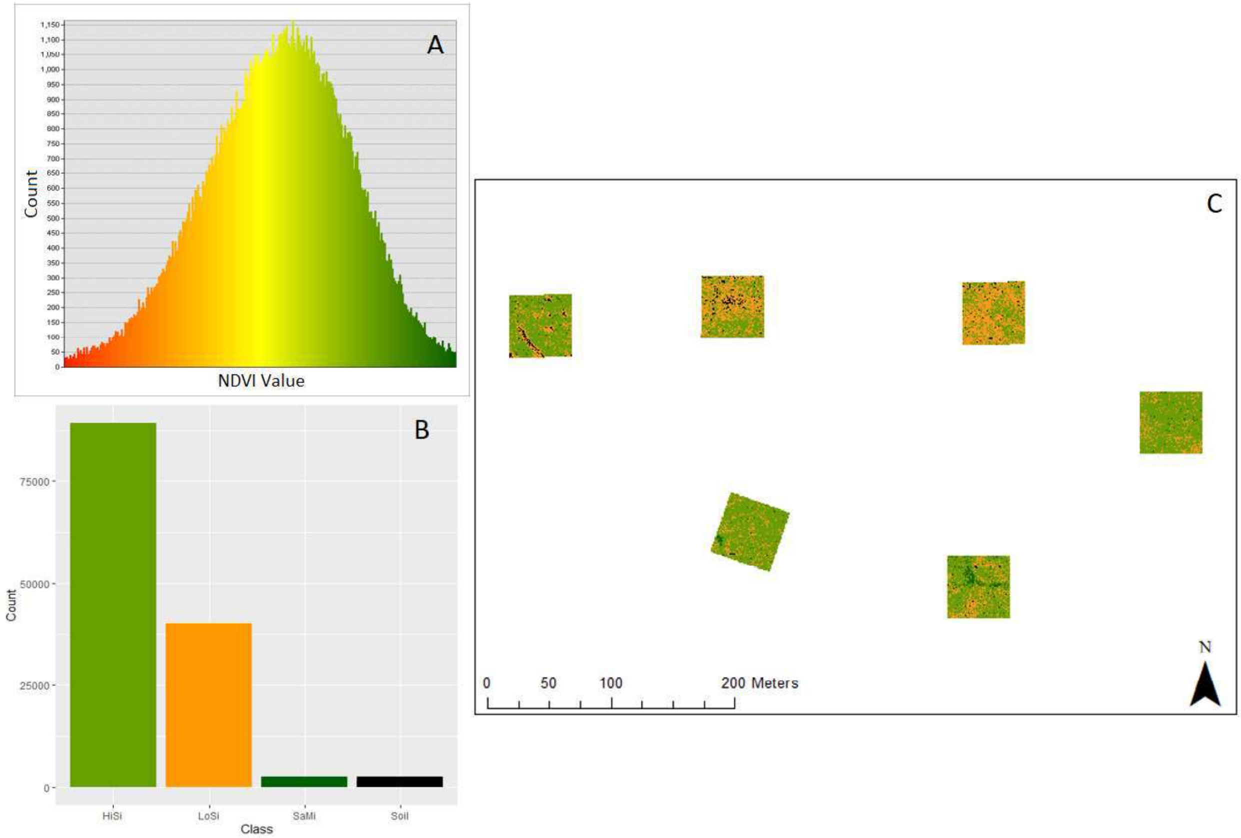

Figure 10:

A) A histogram displaying unclassified raw NDVI value ranges for site C2. Overall ranges span from -0.03 to 0.87.

B) Classification groups for site C2 include Soil (mean = 0.13, SD ± 0.07), LoSi (low signal; mean = 0.37, SD ± 0.03), HiSi (high signal; mean = 0.55, SD ± 0.03), and SaMi (saturated mix; mean = 0.76, SD ± 0.04).

C) A site map of C2 displaying classified groups laid out in space.

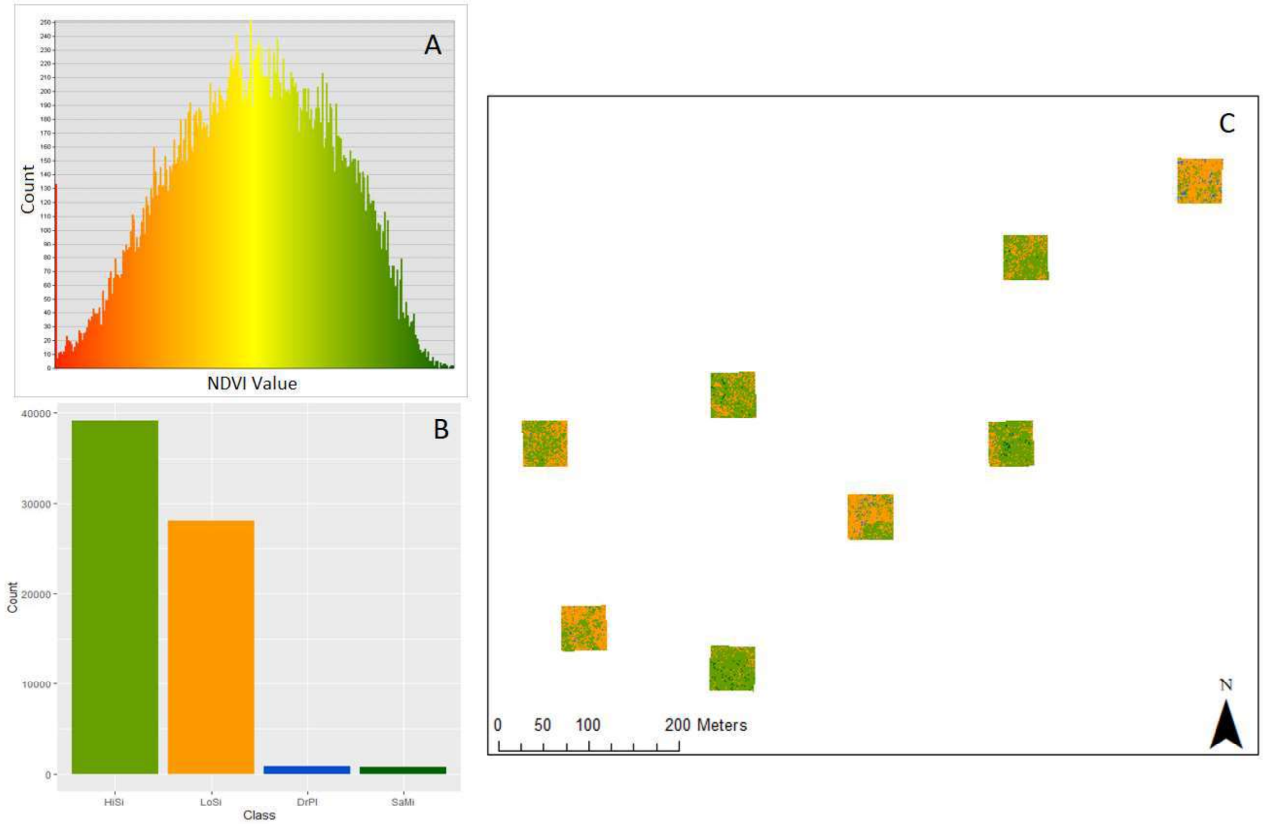

Figure 11:

A) A histogram displaying unclassified raw NDVI value ranges for site N1. Overall ranges span from -0.35 to 0.9.

B) Classification groups for site N1 include DrPl (dry plant; mean = 0.24, SD $\pm$ 0.07), LoSi (low signal; mean = 0.32, SD $\pm$ 0.05), HiSi (high signal; mean = 0.62, SD $\pm$ 0.05), and SaMi (saturated mix; mean = 0.84, SD $\pm$ 0.03).

C) A site map of N1 displaying classified groups laid out in space.

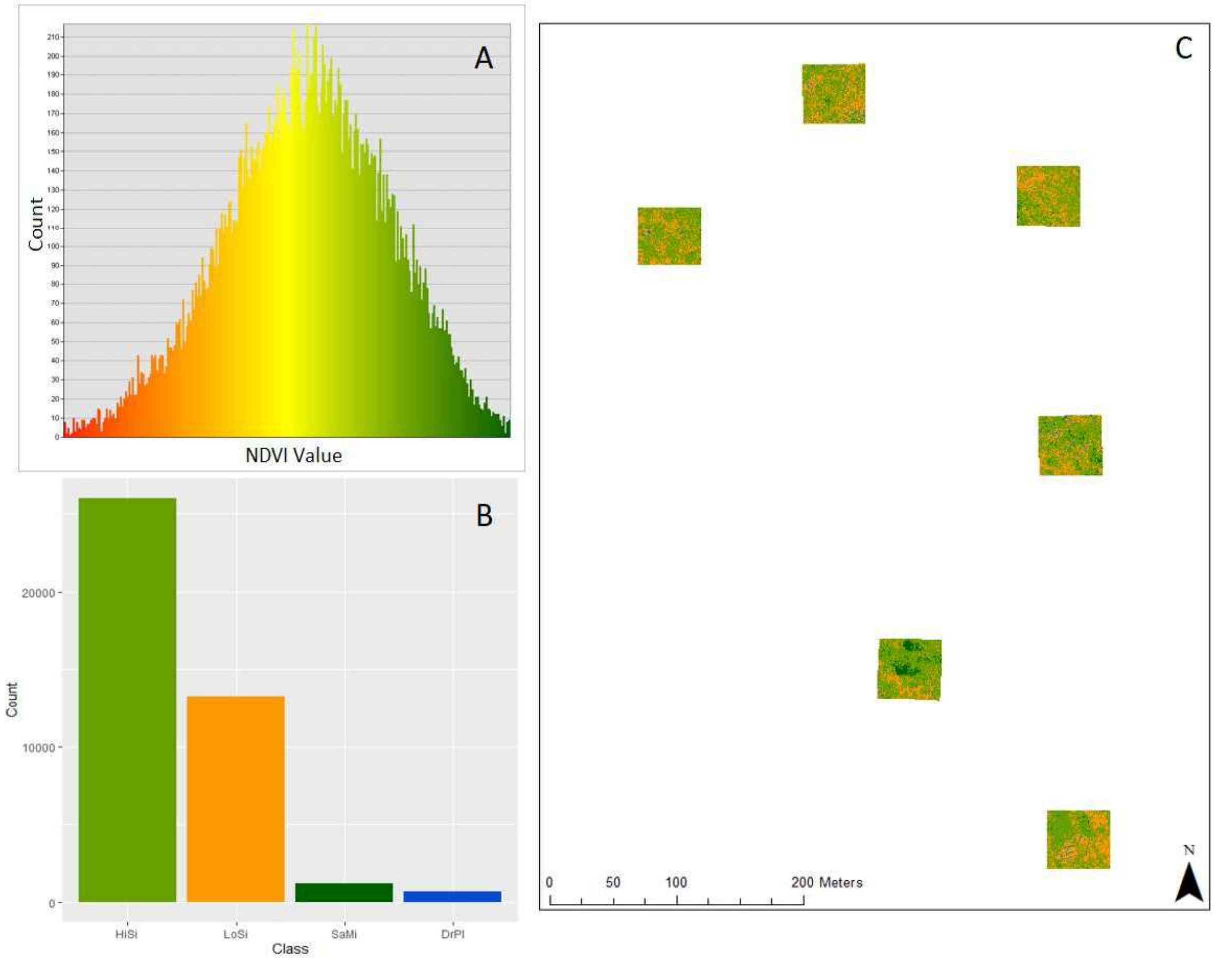

Figure 12:

A) A histogram displaying unclassified raw NDVI value ranges for site N2. Overall ranges span from -0.16 to 0.92.

B) Classification groups for site N2 include DrPl (dry plant; mean = 0.17, SD $\pm$ 0.06), LoSi (low signal; mean = 0.4, SD $\pm$ 0.04), HiSi (high signal; mean = 0.62, SD $\pm$ 0.04), and SaMi (saturated mix; mean = 0.84, SD $\pm$ 0.03).

C) A site map of N2 displaying classified groups laid out in space.

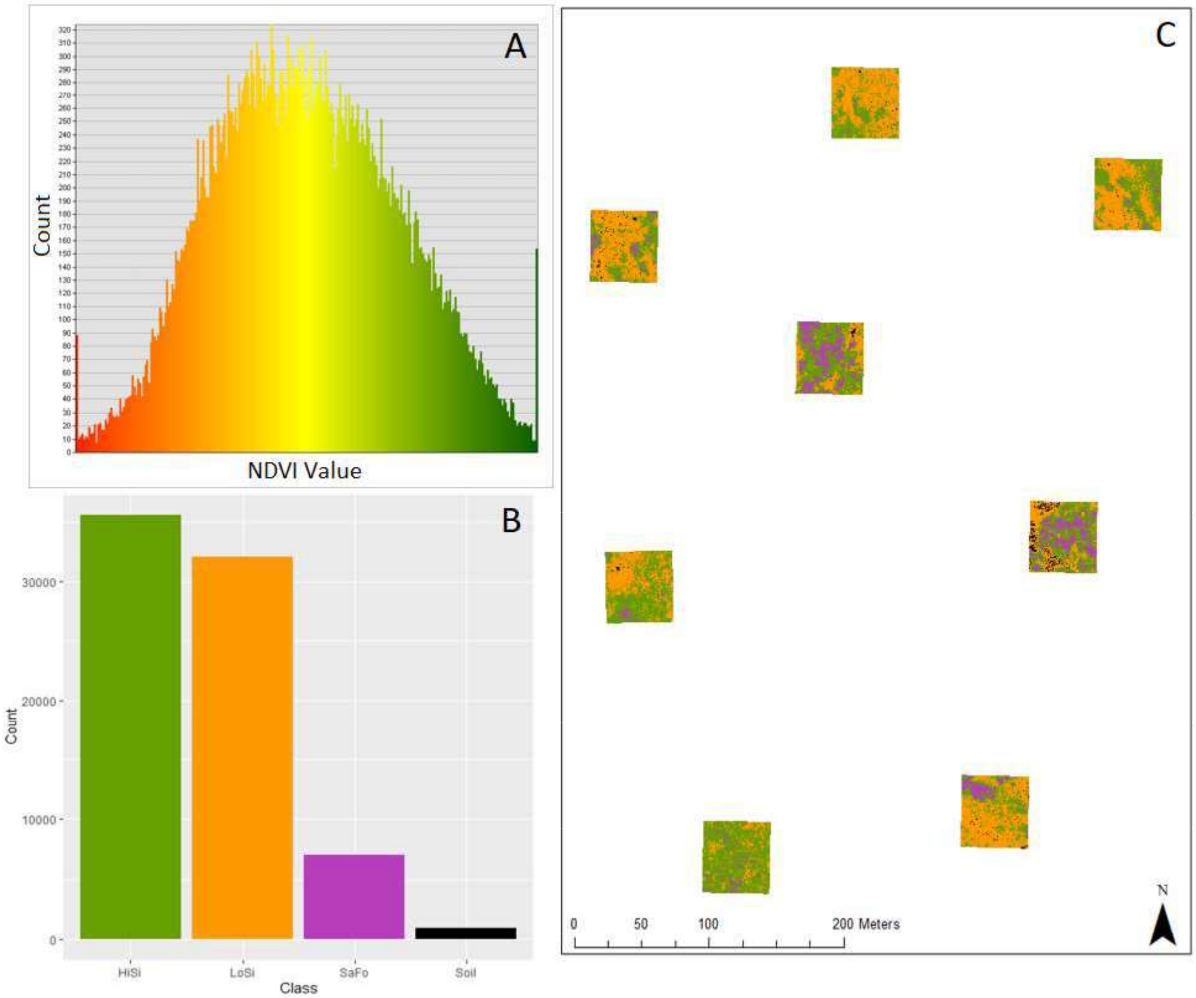

Figure 13:

A) A histogram displaying unclassified raw NDVI value ranges for site R1. Overall ranges span from -0.02 to 0.92.

B) Classification groups for site R1 include Soil (mean = 0.16, SD $\pm$ 0.02), LoSi (low signal; mean = 0.32, SD $\pm$ 0.04), HiSi (high signal; mean = 0.58, SD $\pm$ 0.04), and SaFo (saturated forb; mean = 0.82, SD $\pm$ 0.04).

C) A site map of R1 displaying classified groups laid out in space.

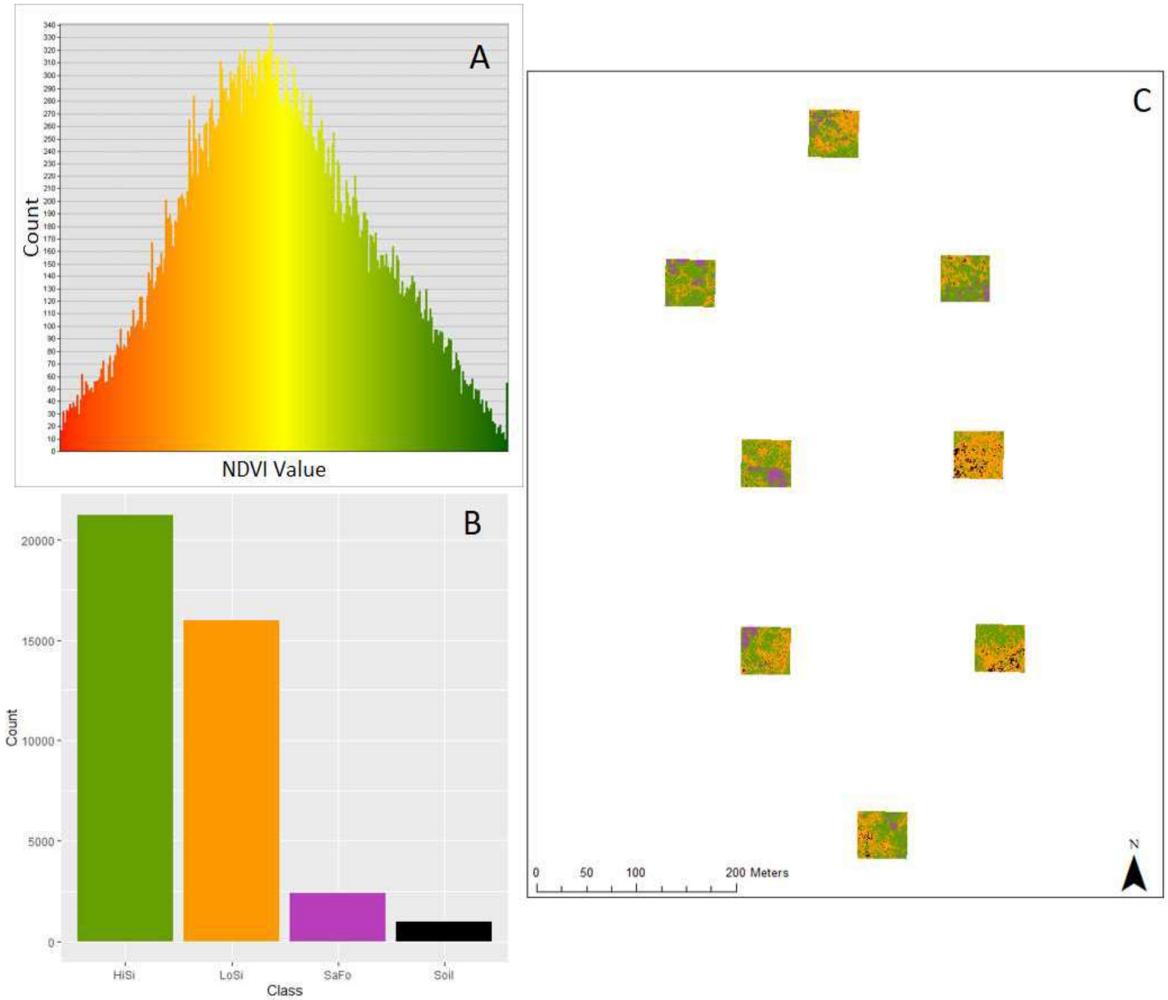

Figure 14:

A) A histogram displaying unclassified raw NDVI value ranges for site R2. Overall ranges span from -0.07 to 0.93.

B) Classification groups for site R2 include Soil (mean = 0.15, SD ± 0.02), LoSi (low signal; mean = 0.40, SD ± 0.04), HiSi (high signal; mean = 0.63, SD ± 0.03), and SaFo (saturated forb; mean = 0.88, SD ± 0.03).

C) A site map of R2 displaying classified groups laid out in space.

APPENDICES

Appendix A: Presence (1) or absence (0) of bird species observed at study sites of Continuous (C), Non-grazed (N), and Rotational (R) treatments during nest dragging, haphazard walking, and bird point count surveys at Cheyenne Bottoms, 2021.

Species Code	Common Name	Scientific Name	C1	C2	N1	N2	R1	R2
BHCO	brown-headed cowbird	*Molothrus ater* (Boddaert, 1783)	1	1	1	1	1	1
BWTE	blue-winged teal	*Spatula discors* (Linnaeus, 1766)	0	0	1	0	0	0
CONI	common nighthawk	*Chordeiles minor* (J. R. Forster, 1771)	0	1	0	0	0	0
COYE	common yellowthroat	*Geothlypis trichas* (Linnaeus, 1766)	0	0	1	1	0	0
DICK	dickcissel	*Spiza americana* (Gmelin, 1789)	1	1	1	1	1	1
EAKI	eastern kingbird	*Tyrannus tyrannus* (Linnaeus, 1758)	0	1	0	1	0	0
GHOW	great horned owl	*Bubo virginianus* (Gmelin, 1788)	0	0	1	0	0	0
GPCH	greater prairie chicken	*Tympanuchus cupido* (Linnaeus, 1758)	0	0	0	0	0	1
GRSP	grasshopper sparrow	*Ammodramus savannarum* (Gmelin, 1789)	1	1	0	0	1	1
GTGR	great-tailed grackle	*Quiscalus mexicanus* (JF Gmelin, 1788)	0	1	0	0	0	0
KILL	killdeer	*Charadrius vociferus* (Linnaeus, 1758)	1	0	1	0	0	1
MALL	mallard	*Anas platyrhynchos* (Linnaeus, 1758)	0	0	1	0	0	0
MEAD	meadowlark species	*Sturnella magna, S. neglecta* (Linnaeus, 1758; Audubon, 1844)	1	1	1	1	1	1
MODO	mourning dove	*Zenaida macroura* (Linnaeus, 1758)	1	1	1	0	1	0
NOBO	northern bobwhite	*Colinus virginianus* (Linnaeus, 1758)	0	0	0	0	1	1
OROR	orchard oriole	*Icterus spurius* (Linnaeus, 1766)	0	0	0	0	0	1
PRFA	prairie falcon	*Falco mexicanus* (Schlegel, 1850)	0	0	1	0	0	0

Appendix A *(continued)*: Presence (1) or absence (0) of bird species observed at study sites of Continuous (C), Non-grazed (N), and Rotational (R) treatments during nest dragging, haphazard walking, and bird point count surveys at Cheyenne Bottoms, 2021.

Species Code	Common Name	Scientific Name	C1	C2	N1	N2	R1	R2
RNPH	ring-necked pheasant	*Phasianus colchicus* (Linnaeus, 1758)	0	0	1	1	0	0
RWBL	red-winged blackbird	*Agelaius phoeniceus* (Linnaeus, 1766)	1	1	1	1	1	1
UPSA	upland sandpiper	*Bartramia longicauda* (Bechstein, 1812)	1	1	0	0	1	1
WEKI	western kingbird	*Tyrannus verticalis* (Say, 1822)	1	1	0	0	1	1
YHBL	yellow-headed blackbird	*Xanthocephalus xanthocephalus* (Bonaparte, 1826)	1	0	0	1	0	0

Appendix B: Presence (1) or absence (0) of plant species and genera observed at study sites of Continuous (C), Non-grazed (N), and Rotational (R) treatments during vegetation surveys at Cheyenne Bottoms, 2021.

Scientific Name	Common Name	C1	C2	N1	N2	R1	R2
Achillea millefolium L.	common yarrow	1	1	0	0	1	1
Acmispon americanus (Nutt.) Rydb.	spanish clover	1	0	1	0	0	0
Aegilops cylindrica Host	jointed goatgrass	0	0	0	0	1	1
Agrostis gigantea Roth, 1788	redtop	0	1	0	0	0	0
Agrostis scabra Willd.	rough bent grass	1	0	0	0	0	0
Ambrosia psilostachya DC.	western ragweed	1	1	1	1	1	1
Ambrosia trifida L. (1753)	giant ragweed	0	0	0	0	1	0
Apocynum cannabinum L.	prairie dogbane	1	0	1	1	0	0
Asclepias fascicularis Dcne.	narrowleaf milkweed	1	1	1	1	1	1
Asclepias speciosa Torr.	showy milkweed	0	0	1	1	1	1
Asclepias sullivantii Engelm. ex A.Gray	prairie milkweed	0	0	1	1	0	0
Asclepias syriaca L.	common milkweed	0	0	0	0	1	0
Asclepias viridis Walter	green milkweed	1	0	0	0	0	0
Atriplex prostrata Boucher ex DC.	triangle orache	0	0	1	1	1	1
Bassia scoparia (L.) A.J.Scott	kochia	1	1	1	0	1	1
Bouteloua dactyloides (Nutt.) Columbus 1999	buffalo grass	1	1	0	0	1	1
Bromus inermis Leyss.	smooth brome	0	0	1	1	1	0
Bromus tectorum L.	cheatgrass	1	1	1	1	1	1
Carduus nutans L.	musk thistle	0	0	0	1	1	0
Carex spp.	sedge species	1	1	1	1	1	1
Chenopodium album L.	lamb's quarters	0	0	0	1	1	0
Chloris verticillata Nutt.	windmill grass	0	1	0	0	1	0
Cirsium vulgare (Savi) Ten.	bull thistle	0	0	0	1	1	0
Convolvulus arvensis L.	field bindweed	0	1	1	1	1	1
Coreopsis lanceolata L.	lance-leaved coreopsis	1	1	0	1	1	0

Appendix B *(continued)*: Presence (1) or absence (0) of plant species and genera observed at study sites of Continuous (C), Non-grazed (N), and Rotational (R) treatments during vegetation surveys at Cheyenne Bottoms, 2021.

Scientific Name	Common Name	C1	C2	N1	N2	R1	R2
Croton monanthogynus Michx.	prairie tea	0	1	0	0	0	0
Desmanthus illinoensis (Michx.) MacMill. ex B. L. Rob. & Fernald	Illinois bundleflower	0	0	0	1	1	0
Dichanthelium oligosanthes var. scribnerianum (Nash) Freckmann & Lelong	Schribner's panic grass	0	0	1	1	0	0
Distichlis spicata (L.) Greene	inland saltgrass	0	1	1	1	0	0
Elymus virginicus L.	Canada wildrye	0	0	0	1	0	0
Erigeron canadensis L.	horseweed	0	1	0	0	1	1
Erigeron strigosus Muhl. ex Willd.	prairie fleabane	1	1	0	0	1	0
Euphorbia maculata L.	spotted spurge	1	1	1	1	1	0
Euphorbia marginata Pursh	snow-on-the-mountain	1	0	0	0	0	0
Gleditsia triacanthos L.	honey locust	0	1	0	1	1	1
*Grindelia squarros*a (Pursh) Dunal	curlycup gumweed	1	1	0	0	1	1
Helianthus annuus L.	annual sunflower	0	1	1	1	0	1
Hordeum jubatum L.	foxtail barley	1	1	1	1	1	1
Hordeum pusillum Nutt. (1818)	little barley	1	1	1	0	1	1
Iva annua L. 1753	annual marsh elder	0	1	1	0	0	1
Juncus spp.	rush species	1	0	0	0	1	0
Juniperus virginiana L.	eastern redcedar	1	0	0	0	0	0
Lactuca serriola L.	prickly lettuce	0	0	1	1	1	1
Lepidium virginicum L.	Virginia pepperweed	1	1	0	0	1	1
Lobelia cardinalis L.	cardinal flower	0	0	0	0	1	0
Lythrum alatum Pursh	winged loosestrife	0	0	0	0	1	1
Marsilea vestita Hooker & Greville	hairy water clover	0	1	0	0	0	0
Medicago sativa L.	alfalfa	0	0	0	0	1	1

Appendix B *(continued)*: Presence (1) or absence (0) of plant species and genera observed at study sites of Continuous (C), Non-grazed (N), and Rotational (R) treatments during vegetation surveys at Cheyenne Bottoms, 2021.

Scientific Name	Common Name	C1	C2	N1	N2	R1	R2
Melilotus albus Medik.	white sweet clover	0	0	0	0	0	1
Melilotus officinalis (L.) Pall.	yellow sweet clover	0	0	0	0	1	1
Opuntia spp.	prickly pear species	1	1	0	0	0	1
Panicum virgatum L.	switchgrass	1	1	1	0	0	0
Pascopyrum smithii (Rydb.) Á.Löve	western wheatgrass	1	1	1	1	1	1
Persicaria maculosa Gray.	lady's thumb	0	0	1	0	0	0
Phlaris arundeacea L.	reed canary	0	0	0	1	0	0
Phragmites australis (Cav.) Trin. ex Steud.	phragmites	0	0	0	1	0	0
Phyla nodiflora (L.) Greene	frogfruit	0	0	0	1	0	0
Physalis virginiana Mill.	Virginia ground cherry	0	1	1	1	1	0
Poa arida Vasey	plains bluegrass	1	1	1	1	1	1
Polygonum spp.	smartweed species	0	0	1	1	0	0
Ratibida columnifera (Nutt.) Wooton & Standl.	upright prairie coneflower	1	0	0	0	0	1
Rhus aromatica L.	aromatic sumac	0	0	0	0	0	1
Rumex crispus L.	curly dock	1	0	1	1	1	1
Schedonnardus paniculatus (Nutt.) Trel.	tumblegrass	1	1	0	0	1	1
Solanum carolinense L.	Carolina horsenettle	0	0	0	0	1	0
Solidago canadensis L.	Canada goldenrod	0	0	1	0	1	0
Sporobolus airoides (Torr.) Torr.	alkali sacaton	1	1	1	1	0	1
Sporobolus cryptandrus (Torr.) A.Gray	sand dropseed	0	0	0	0	1	0
Symphyotrichum ericoides (L.) G.L.Nesom	heath aster	1	1	1	1	1	1
Tamarix spp.	eastern saltcedar species	0	0	0	1	0	1
Taraxacum officinale (L.) Weber ex F.H.Wigg.	dandelion	0	1	0	0	1	1
Teucrium canadense L.	American germander	0	0	0	1	0	0
Tradescantia occidentalis (Britton) Smyth	prairie spiderwort	0	0	0	0	0	0

Appendix B *(continued)*: Presence (1) or absence (0) of plant species and genera observed at study sites of Continuous (C), Non-grazed (N), and Rotational (R) treatments during vegetation surveys at Cheyenne Bottoms, 2021.

Scientific Name	Common Name	C1	C2	N1	N2	R1	R2
Tragopogon dubius Scop.	yellow goatsbeard	1	1	0	0	1	1
Trichostema brachiatum L.	fluxweed	0	0	0	0	1	0
Typha spp.	cattail species	0	0	0	1	0	0
Ulmus pumila L.	Siberian elm	0	0	0	0	1	0
Verbena stricta Vent.	hoary vervain	0	0	1	1	0	1
Vernonia baldwinii Torrey (Shinners, 1950)	western ironweed	1	0	0	1	1	1
Vicia spp.	vetch species	0	0	1	0	0	0
Xanthium strumarium L.	common cocklebur	0	0	1	0	0	1

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Thesis: Influences of grazing on habitat characteristics, avian community composition and nesting bird abundance within Cheyenne Bottoms, KS

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