PLANT COMMUNITY COMPOSITION OF DOUGLAS CREEK TRAINING AREA, NORTH DAKOTA ARMY NATIONAL GUARD: 1999-2015

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

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ABSTRACT

A vegetation monitoring study was conducted from 1999 to 2015 at Douglas Creek Military Reservation (DCMR), Garrison in McLean County, North Dakota to assess how climatic and military training disturbance affects plant community composition. The objectives were to 1) describe the prairie vegetation at DCMR across four plant communities for sixteen years and 2) explore shifts in plant community composition in correlation with time. Sixteen transects were randomly selected on native prairie and classified into four types based on plant communities. Frequency data was collected at each of these sites four times from 1999-2015, with plant communities compared using non-metric multidimensional scaling (NMS) ordination. The NMS ordination showed that the frequency of invasive graminoids Kentucky bluegrass (*Poa pratensis* L.) and smooth brome (*Bromus inermis* Leyss.) increased during the study. Increases in precipitation and growing season days appear to be the primary influence on the changes in plant communities from 1999-2015.

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I would like to recognize the personal who assisted with the collection of data at Douglas Creek Military Reservation. Without this research, this project would not have been possible. I would also like to notably recognize Dennis Whitted and the NDSU range technicians for their knowledge and diligent hard work. I would also extend my gratitude to Peter O'Brien, whose organization, knowledge, and pervious research was indispensable in assisting me during this project.

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INTRODUCTION

Native grasslands in North America have been diminishing over the past five decades due to land conversion. Approximately 70% of the tall-grass prairie, 30% mixed-grass prairie, and 50% short-grass prairie have been lost due to an increased disturbance regime, agricultural conversion, urbanization, and an altered climate (Samson and Knopf 1994; Samson et al. 2004). In some areas, the loss has been up to 99% (Cully et al. 2003). The remaining prairie has been left isolated and disjointed. The fragmentation of prairie has altered the successional pathways in these communities and left them susceptible to invasion by exotic species (Hobbs and Huenneke 1992; Leach and Givnish 1996; Higgins et al. 2002). The loss of these prairies has resulted in negative effects on biodiversity as a broad regional impact as well as on diversity of localized plant and animal communities.

In the Northern Great Plains, Kentucky bluegrass (*Poa pratensis* L.) and smooth brome (*Bromus inermis* Leyss.) are the most prevalent prairie invaders (Cully et al. 2003; Murphy and Grant 2005). Some areas of the North Dakota National Wildlife Refuge system have over 70% frequency of Kentucky bluegrass and smooth brome; conversely, frequencies of native grasses are below 5% (Grant et al. 2009). These invasive grasses have been shown to replace native prairie vegetation and degrade ecosystem services. These species compete against native grasses and are difficult to supplant once established. The suitability of Kentucky bluegrass and smooth brome to the current disturbance and climate regimes in the Northern Great Plains is accelerating the rate at which native grasslands are being reduced (White et al. 2013; Wilson and Pinno 2013). Specific ecological impacts of the loss of native prairie may be highly variable across space and time, but one way to document the effects is through long-term vegetation surveys. Beginning in 1999, vegetation data was collected on the Douglas Creek

Military Reservation (DCMR), found within the Missouri Slope region comprised of mixed-grass prairies in McLean County, North Dakota. The objectives of this study were to 1) describe the vegetation at DCMR across four plant community types starting in 1999, and 2) explore any shifts in plant community composition with time and management.

Climate Variability and Plant Community Composition

Over the past two decades, average precipitation in North Dakota has increased from historic levels. Additionally, temperature averages have been increasing over that same time period, resulting in an extended growing seasons (NOAA, 1948-2013). Forage production and species composition are driven by precipitation and temperature conditions, so the new climate regime in the Northern Great Plains may have significant long-term effects on plant community composition and community stability (Badh et al. 2009; DeKeyser et al. 2013). For example, since 1950, some mesic areas found on North Dakota rangelands have been noted to be dominated by Kentucky bluegrass, a grass species that thrives in high moisture areas. Kentucky bluegrass occurred first in areas of the United States with higher moisture content, and it has been shifting west into traditionally drier climates over the past several decades (Stevens 1950; DeKeyser et al. 2013).

Increases in water availability have been linked with changes in plant community composition and structure on North American prairies (Hautier et al. 2009; Collins et al. 2012) and increases in primary production (Sala et al. 1988; Milchunas et al. 1994). Although annual precipitation trends are increasing, the increasingly more variable climatic conditions often result in fewer, more intense precipitation events. Thus, extended periods without precipitation may also be affecting plant communities. Reduction in precipitation during the growing season reduced total herbaceous production up to 40%, with perennial cool-season grasses being the

most affected (Heitschmidt et al. 2005). While herbaceous production may return to pre-drought levels only two years after the removal of drought conditions, the species composition of the community remains altered (Heitschmidt et al. 2005).

Species richness also shows a direct relationship to precipitation. Many tall-grass and mixed-grass prairies in North America are in a continental climate and subject to extreme fluctuations in precipitation, and species richness follows these fluctuations (O'Brien 2014). Across many types of grasslands, increases in precipitation have been tied to greater species richness, especially in warm season grasses and forbs (Collins et al. 2012). Conversely, reduced precipitation may result in a drastic decline in species richness and a slow recovery from that decline (O'Brien 2014). Additional research has shown a lag time before species diversity or richness is affected, as in the case of a wet year following a dry year (Biondini et al. 1998; Symstad and Jonas 1999; Collins et al. 2012). The variety of conditions and ecosystems make it difficult to generalize the results of these studies across time and space.

In addition to the altered precipitation regime, climate in the Northern Great Plains displays an increase in overall temperature and the number of days in a growing season (Badh et al. 2009). Temperature may play a crucial factor in several stages of plant development. Large temperature fluctuations at the beginning of a growing season may have adverse impacts on plants emerging from dormancy (Malyschev and Henry 2012). High temperatures during the growing season result in rapid evaporation that may reduce available water sources (O'Brien 2014). A lengthening growing season could favor cool-season plants that benefit from the additional growing days in early spring and late fall (Bartholomew and Williams 2005);(DeKeyser et al. 2015).

Frank and Hoffman (1989) found a correlation between the morphological development of several native graminoid species and the number of growing degree days on a native mixed-grass prairie. Four different cool-season perennial grasses were shown to reach certain morphological development stages after a particular number of growing degree days (Frank and Hoffman 1989). The variability of developmental stages that the native grasses reached across a temporal scale reinforces a heterogeneous landscape offers a variety of maturity, height, and cover levels which cannot be found in a monoculture (Frank and Hoffman 1989; Heitschmidt et al. 2005).

Similarly, growing degree days may have a linear relationship with nitrogen content on rangelands. An equation that may estimate the nitrogen content based on growing degree days and green:dead ratios of vegetation has shown some accuracy in the mixed-grass prairies in eastern Montana (Haferkamp et al. 2005). As growing degree days increase and soil nitrogen increases, exotic species like Kentucky bluegrass may become more dominant (Wedin and Tilman 1990; Laungani et al. 2012). While there may be a linear relationship between growing degree days and soil nitrogen, the causation for this increase in nitrogen is likely a result of increased fossil fuel burning and nutrient deposition in agricultural practices (Vinton and Goergen 2006; Norton et al. 2008).

STUDY AREA

This study was conducted on the Army National Guard Training Facility, a military training base centrally located in McLean County, North Dakota, and approximately 16 km west and south of the city of Garrison, North Dakota. This training facility is in Sections 30 and 31, T138N, R85W, and Sections 25, 26, 35, and 36, T148N, R68W, McLean County, North Dakota. It is found on the north shore of Lake Sakakawea (Garrison Reservoir). The study area falls within MLRA 53B, classified as Central Dark Brown Glaciated Plains (USDA, NRCS 2011). The area is rolling upland plains covered by glacial till, with boulders and cobbles exposed on the surface. No large-scale cultivation has occurred within this area, but small areas have been plowed for tree planting for windbreaks. (Barker et al. 2001) The physiographic region is known as the Missouri Plateau, which formed from glaciated sections of the Great Plains (USDA NRCS. 2011).

This region rises from 500 to 600 m increasing gradually from south east to northwest. The nearly level to rolling till plains in this MLRA include kettle holes, kames, moraines, and small glacial lakes. Moderately steep and steel slopes are adjacent to major stream valleys. Streams and rivers are present, as are areas conifers and deciduous trees (USDA NRCS. 2011).

The topography associated with the DCMR is classified as rolling prairie interspersed with finger draws draining into Lake Sakakawea. The shoreline along the training area lies about 560 meters above sea level. The topography rises sharply from the shoreline, reaching 580 m - 50 to 250 meters away from the shore. The interior portion of the peninsula ranges from 580 to 590 m, with two peaks reaching 595 m. The highest points on DCMR are found on the north portion, reaching heights of 605 meters.

The area is in a continental climate zone that experiences extreme temperature fluctuations. The 30-year mean annual temperature at Garrison, approximately 10 km east, and 8 km north of DCMR was 5°C. The 30-year mean annual precipitation was 43.4 cm, up to 75% occurring in the form of rain during the growing season. The growing season, as defined by length of time from the last 0° C day in the spring to the first 0° C day in the fall, averaged 135 days over the past 30 years (NOAA, 1931-2014). The variation in elevation and plant communities in the study area leads to a zonation dominant plant species due to different tolerance ranges. Thus, the DCMR was divided into shoreline, green ash draws, planted trees, and open grassland plant communities.

Historic shoreline plant communities consist of Canada wildrye (*Elymus canadensis*), big bluestem (*Andropogon gerardii*), mountain rush (*Juncus articus*), Kentucky bluegrass (*Poa pratensis*), fowl bluegrass *(P. palustris*), little bluestem (*Schizachyrium scoparium*), prairie dropseed (*Sporobolus heterolepis*), and prairie wedgescale (*Sphenopholis obtusata*). Common forbs include: Canadian anemone (*Anemone canadensis*), common goldstar (*Hypoxis hirsuta*), silverweed cinquefoil (*Argentina anserina*), meadow zizia (*Zizia aptera*), golden zizia (*Z. aurea*), pale agoseris (*Agoseris glauca*), oval-leaf milkweed (*Asclepias ovalifolia*), Canada thistle (*Cirsium arvense*), fiddle-leaf hawksbeard (*Crepis runcinata*), American licorice (*Glycyrrhiza lepidota*), Philadelphia fleabane (*Erigeron philadelphicus*), palespike lobelia (*Lobelia spicata*), (*Rudbeckia hirta)*, white heath aster (*Symphyotrichum ericoides*), smooth blue aster (*S. laeve*), Maximilian sunflower (*Helianthus maximiliani*), Rydberg's sunflower (*H. nuttallii*), Rocky Mountain blazing star (*Liatris ligulistylis*), and Canada goldenrod *(Solidago canadensis*) (Sedivec and Barker 2010).

The green ash tree draw plant communities historically consisted of slender wheatgrass (*Elymus trachycaulus*), western wheatgrass (*Pascopyrum smithii*), prairie sandreed (*Calamovilfa longifolia*), sun sedge (*Carex heliophila*), little bluestem (*Schizachyrium scoparium*), shortbristle needle and thread (*Hesperostipa curtiseta*), porcupinegrass *(H. spartea*), and green needlegrass (*Nassella viridula*). Common forbs include: Labrador buttercup (*Ranunculus rhomboideus*), small-leaf pussytoes (*Antennaria parvifolia*), groundplum milkvetch (*Astragalus crassicarpus*), field chickweed (*Cerastium arvense*), bastard toadflax (*Comandra umbellate*), western wallflower (*Erysimum asperum*), purple locoweed (*Oxytropis lambertii*), white penstemon (*Penstemon albidus*), prairie groundsel (*Packera plattensis*), western yarrow (*Achillea millefolium*), pale agoseris *(Agoseris glauca*), candle anemone (*Anemone cylindrical*), prairie milkvetch (*Astragalus adsurgens*), yellow sundrops (*Calylophus serrulatus*), streamside fleabane (*Erigeron glabellus*), blanketflower (*Gaillardia aristata*), northern bedstraw (*Galium boreale*), curlytop gumweed (*Grindelia squarrosa*), Richardson's alumroot (*Heuchera richardsonii*), lilac penstemon (*Penstemon gracilis*), Pennsylvania cinquefoil (*Potentilla pennsylvanica*), upright prairie coneflower (*Ratibida columnifera*), yellow salsify (*Tragopogon dubius*), large Indian breadroot (*Pediomelum esculentum),* autumn onion *(Allium stellatum*), prairie fleabane (*Erigeron strigosus*), blue lettuce (*Lactuca oblongifolia*), velvety goldenrod *(Solidago mollis*), and prairie goldenrod (*Oligoneuron album*). Western snowberry (*Symphoricarpos occidentalis*), Green Ash (Fraxinus pennsylvanica) and Silveryberry (*Elaeagnus commutata*) are common shrub/treess of the green ash tree draw plant communities (Sedivec and Barker 2010).

The planted tree plant community areas are found on previously cultivated lands and contain a dense graminoid under story. The following tree species are common on the DCMR planted tree areas and include northern hawthorn *(Crataegus rotundifolia*), Russian olive

(*Elaeagnus angustifolia*), green ash (*Fraxinus pennsylvanica*), ponderosa pine (*Pinus ponderosa*), and choke cherry (*Prunus virginiana*) (Sedivec and Barker 2010).

The historic dominant graminoids in open grassland prairie plant communities was western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), prairie sandreed (*Calamovilfa longifolia*), needle-leaf sedge (*Carex duriuscula*), threadleaf sedge (*C. filifolia*), prairie Junegrass (*Koeleria macrantha*), plains muhly (*Muhlenbergia cuspidata*), and needle and thread (*Hesperostipa comata*). Common forbs included: textile onion (*Allium textile*), western rockjasmine (*Androsace occidentalis*), eastern pasqueflower (*Pulsatilla patens*), downy paintedcup (*Castilleja sessiliflora*), prairie violet (*Viola pedatifida*), little rose *(Chamaerhodos erecta*), blacksamson echinacea (*Echinacea angustifolia*), streamside fleabane *(Erigeron glabellus*), scarlet beeblossom (*Guara coccinea*), stiffstem flax *(Linum rigidum*), rush skeletonplant (*Lygodesmia juncea*), silverleaf Indian breadroot (*Pediomelum argophyllum*), tarragon (*Artemisia dracunculus*), prairie sagewort (*A. frigida*), hairy false goldenaster (*Heterotheca villosa*), Flodman's thistle *(Cirsium flodmani*), broom snakeweed (*Gutierrezia sarothrae*), stiff sunflower (*Helianthus pauciflorus*), and stiff goldenrod(*Oligoneuron rigidum*) (Sedivec and Barker 2010).

Although the DCMR is comprised of native rangeland, many invasive plants are found in the area. The most common invasive grasses include smooth bromegrass (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), and quackgrass (*Agropyron repens*). The most common invasive forb plants include sweetclover (*Melilotus officinalis*), leafy spurge (*Euphorbia esula*), Canada thistle (*Cirsium arvense*), field bindweed (*Convolvulus arvensis*) field sowthistle (*Sonchus arvensis*) houndstongue (*Hieracium cynoglossoides*) and wormwood (*Artemisia absinthium*) found on DCMR (Sedivec and Barker 2010). These started out as small areas and

are increasing with time to become a larger problem. Only Russian olive would be classified as an invasive tree found on DCMR.

The management goal for the grasslands at DCMR is "to integrate the relationships of all organisms including human activity and nonliving elements of their environment" (Barker et al. 2001). Guided by this goal, DCMR has been managed for minimal human use. Nearly all military training on DCMR in the past 15 years has been classified as minimum impact training; such as patrolling, terrain/map analysis, and reconnaissance. The DCMR has been predominantly utilized as rangeland not subjected to cattle grazing for a minimum 20 years.

METHODS

Field Sampling

The study area at Douglas Creek Military Reservation was classified into shoreline, green ash tree draw, planted trees, and open grassland prairie sites based on plant community groups and topographic characteristics. Four sites were selected for each plant community group using a randomize design and sampled to determine plant species composition (Figure 1). The DCMR was stratified by plant community and the software Idrisi (Clark Lab, Clark University) utilized to randomly select transect locations from within the designated plant community types, resulting in sixteen transects; four shoreline sites, four Green Ash draw sites, four planted tree sites, four open grassland prairie sites.

To represent peak production on this area and these sites (which should result in finding the majority of plants that grow in the plant community type), vegetation surveys were conducted from 1999-2015 during early to mid-July every five years. The vegetation surveys focused on graminoid and forb species composition. Plant communities were described using a $0.25m^2$ quadrat with a $0.1m^2$ quadrat nested within. Forbs were recorded using the $0.25m^2$ quadrat to determine species composition, density, and frequency. Graminoids were recorded using the $0.1m^2$ quadrat to determine presence/absence frequency data (Prosser et al. 2003).

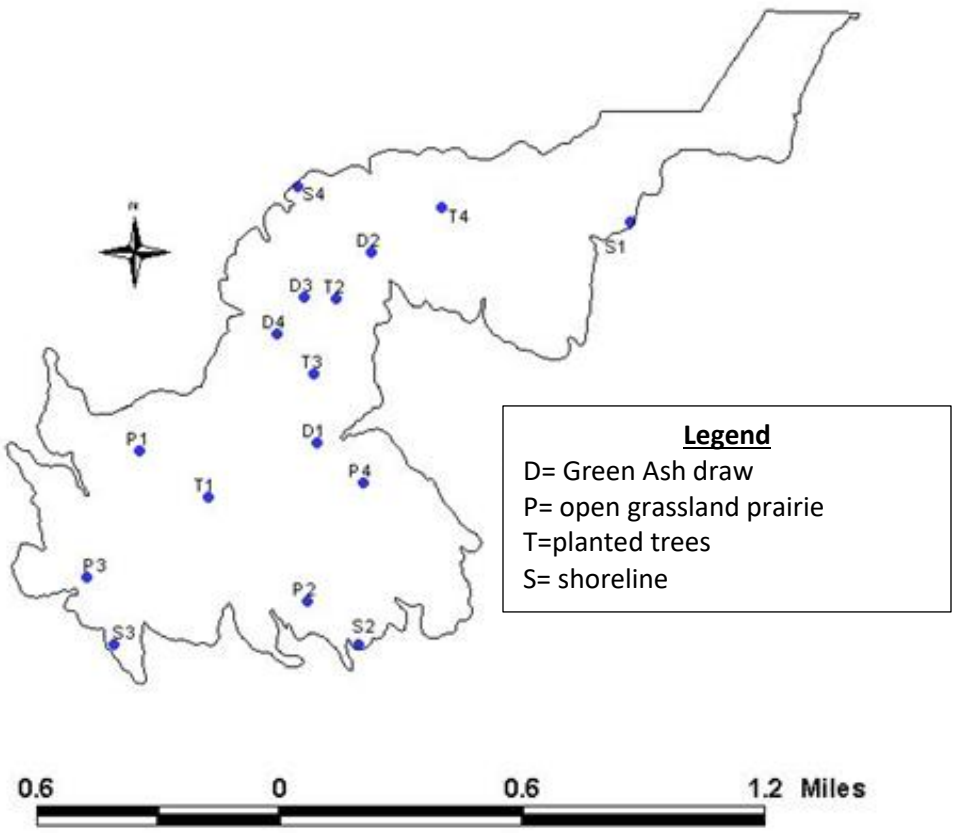

Figure 1. Locations of transects on Douglas Creek Military Reservation, based on plant communities.

Data Analysis

Four sets of data representing different years were utilized from each transect in order to standardize the data for analysis. Each sample period corresponds to a frequency value collected within that year. The first sample period for each transect was taken in 1999, second sample period taken in 2005, third sample period from 2009, and fourth sample period from 2015. Frequency values were subjected to an arcsine-square-root transformation to improve normality by spreading values on the tails of the distribution and compressing the middle (Peck 2010).

Frequency data were analyzed using Nonmetric Multidimensional Scaling (NMS) for graphical display of the similarity of plant species found at all sites. The NMS analysis was completed using PC-ORD Version 6 software (McCune and Medford 2011). The Relative Sorenson Coefficient was the distance measure used. The data was analyzed in PC-ORD using 500 iterations of the data finding one axis or six with an instability criterion of 0.0001. Dimensions and model selection was based on: (1) a model with a stress <25 (2); a significant Monte Carlo test ($p<0.05$); (3) an instability <0.0001; and (4) a selection of axes was discontinued if the next axis did not reduce stress >5. Pearson's Correlation Coefficient $r\geq0.4$ or $r\leq-0.4$ were used to explain the ordination and appropriately reflect an interpretable effect size (McCune and Medford 2011).

The shoreline, green ash tree draw, planted trees, and open grassland transects were analyzed in separate groups to detect temporal trends within each plant community. A multi-response permutation procedure (MRPP) was performed on the sample periods of each transect across all site types. The distance matrix was rank transformed using a relative Sorenson distance measure.

RESULTS

Climate

The thirty-year average for mean annual temperature (MAT) at the Garrison weather station remained relatively stable (p = *0.419)* during the study, with temperatures increasing only 0.085° C compared to the pre-study averages (Table 1). The average minimum temperature decreased by only 0.78° C, from -33.11 C to -33.89° C, while the average maximum temperatures increased by 0.87° C, from 36.60° C to 37.47° C (NOAA, 1948-2014). Similarly, growing season days (GSD) at Garrison increased (p = *0.28*) during the study, with over three more days per year compared to the pre-study averages (NOAA, 1931-2014).

Table 1. The 30-year averages in mean annual temperature (MAT), mean annual precipitation (MAP), and growing season days (GSD) at Garrison, North Dakota, weather station before study (1968-1997) and during study (1984-2013) (NOAA, 1948-2013).

30-year average	MAT (°C)	MAP (cm.)	GSD
Prior to study (1968 – 1997)	5.01	38.14	132.05
During study (1985 – 2014)	5.0	43.45	135.03

The thirty-year averages for mean annual precipitation (MAP) increased (p=*0.03*) during the study period. The 30-year MAP averages during the study were 5.3cm greater than pre-study 30-year averages.

Figure 2 represents the MAP, MAT, and GSD at DCMR from 1931 to 2014. The trend lines indicate that two of the three measures of climate are increasing during this time period, with the MAP fluctuating more than either the GSD or MAT. The MAT shows a gradual decrease; with the GSD increasing averages closely match the MAP averages.

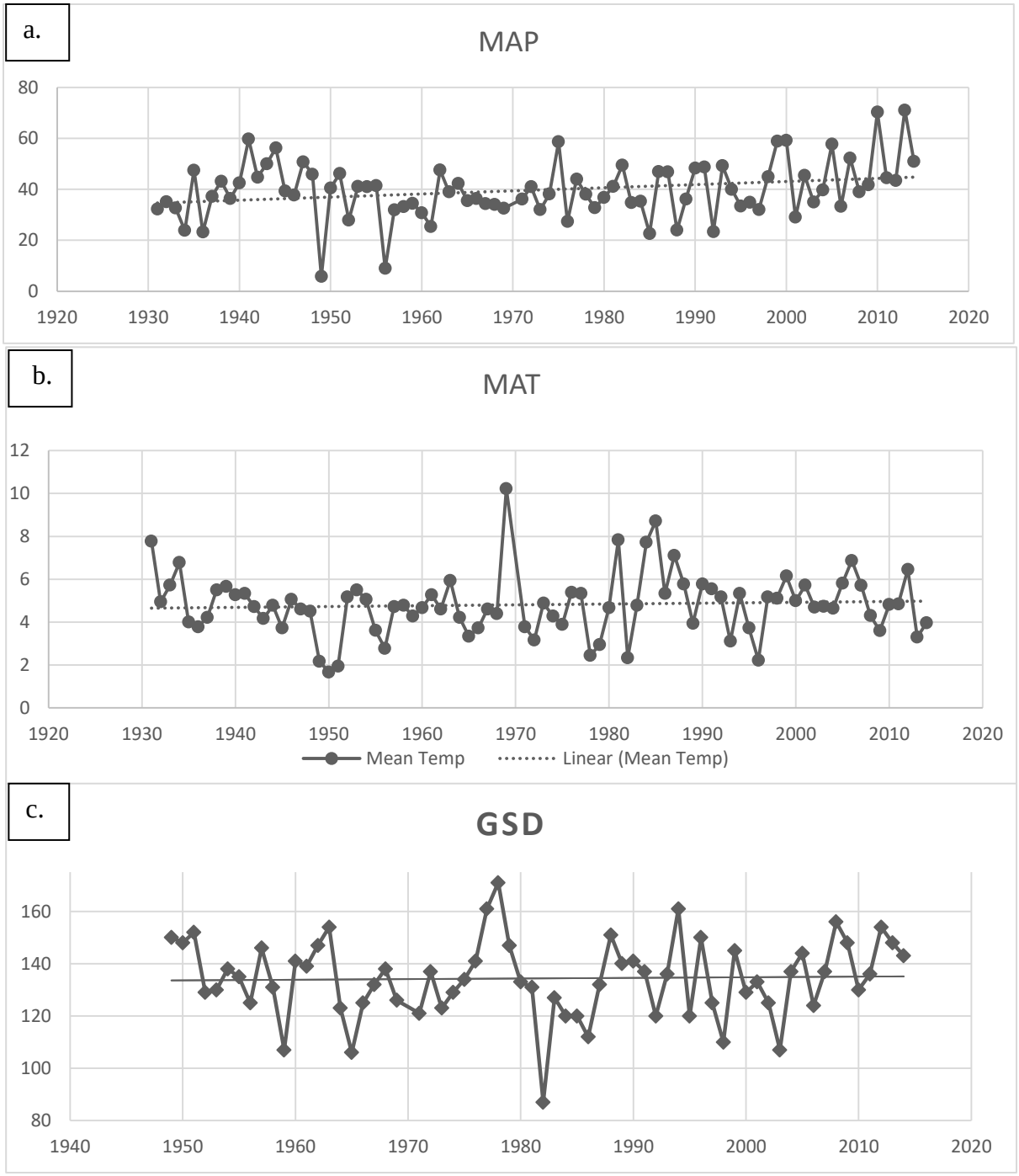

Figure 2. The a) mean annual precipitation (MAP); b) mean annual temperature (MAT) from 1931-2014; and c) growing season days (GSD) at Garrison, ND weather station from 1949-2014 (NOAA, 1931-2014).

Shoreline Plant Community

Non-metric multidimensional scaling (NMS) scores using the relative Sorenson distance measure returned a three-dimensional solution. The first and second axes are presented in Figure 3. Coefficients of determination for the correlations between ordination distances on the axis determined by the NMS scores were calculated for each axis. R-squared value for the first axis was 67.4%. The second axis increment was 15.9%, which had a cumulative value of 83.3%. The third axis increment was 0.9%. Thus, the three-axis cumulative R-squared value was 84.2%.

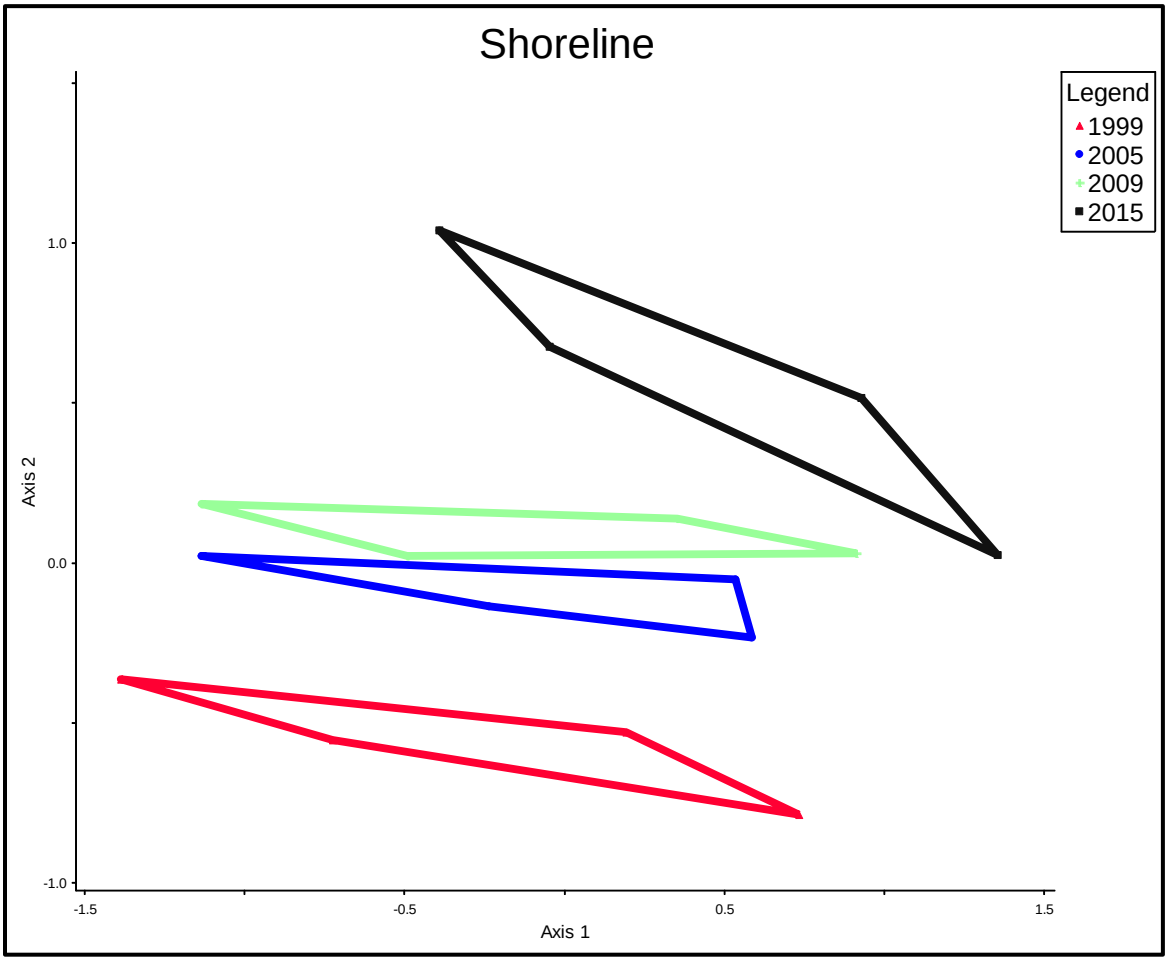

Figure 3. Non-metric multidimensional scaling ordination of the shoreline plant community sites at Douglas Creek Military Reservation for 1999, 2005, 2009, and 2015 near Garrison, North Dakota.

Correlations between species and axis were deemed interpretable at an absolute value greater than 0.4. Table 2 shows the species that had positive correlations on axis 1 and axis 2. Wormwood and white panicle aster had the highest positive correlations with a value greater than 0.7. Table 3 shows the negative correlation among species on both axis. Scarlet beeblossom shows the greatest negative correlation (-0.801) with Missouri goldenrod (-0.772) and green needlegrass (-0.766) closely behind.

Table 2. Positive correlated plant species for the shoreline plant community sites for all years (1999-2015) on the Douglas Creek Military Reservation near Garrison, North Dakota.

Positive correlation		**Axis 1**	**Axis 2**
wormwood	*Artemisia absinthium*	0.711	
American licorice	*Glycyrrhiza lepidota*	0.641	
Canada goldenrod	*Solidago canadensis*	0.642	
Canada thistle	*Cirsium arvense*	0.708	
Canadian anemone	*Anemone canadensis*	0.513	
field sowthistle	*Sonchus arvensis*	0.670	
fowl bluegrass	*Poa palustris*	0.542	
green comet milkweed	*Asclepias viridiflora*		0.594
porcupinegrass	*Hesperostipa spartea*		0.419
clustered field sedge	*Carex praegracilis*	0.434	
reed canarygrass	*Phalaris arundinacea*	0.818	
shortbeak sedge	*Carex brevior*	0.542	
smooth brome	*Bromus inermis*	0.447	
white panicle aster	*Symphyotrichum lanceolatum*	0.729	

Table 3. Negative correlated plant species for the shoreline plant community sites for all years (1999-2015) on the Douglas Creek Military Reservation near Garrison, North Dakota.

Negative Correlation		**axis1**	**axis 2**
autumn onion	*Allium stellatum*	-0.498	
blacksamson echinacea	*Echinacea angustifolia*	-0.793	
blue grama	*Bouteloua gracilis*	-0.694	
blue lettuce	*Lactuca tatarica*	-0.426	
dotted blazing star	*Liatris punctata*	-0.703	
downy paintedcup	*Casteleja sessiliflora*	-0.447	
field chickweed	*Cerastium arvense*	-0.436	

Table 3. Negative correlated plant species for the shoreline plant community sites for all years (1999-2015) on the Douglas Creek Military Reservation near Garrison, North Dakota (continued).

Negative Correlation		**axis1**	**axis 2**
Flodman's thistle	*Cirsium flodmani*		-0.512
green needlegrass	*Nassella viridula*	-0.766	
large Indian breadroot	*Pediomelum esculentum*	-0.535	
lesser spikemoss	*Selaginella densa*	-0.447	
Missouri goldenrod	*Solidago missouriensis*	-0.772	
needle and thread	*Hesperostipa comata*	-0.693	
northern reedgrass	*Calamagrostis canadensis*		-0.540
Norwegian cinquefoil	*Potentilla norvegica*		-0.577
Pasqueflower	*Pulsatilla patens*	-0.544	
plains muhly	*Muhlenbergia cuspidata*	-0.512	
Porcupinegrass	*Hesperostipa spartea*	-0.706	
prairie fleabane	*Erigeron strigosus*	-0.659	
prairie groundsel	*Senecio plattensis*	-0.447	
prairie rose	*Rosa arkansana*		-0.602
prairie sagewort	*Artemisia frigida*	-0.668	
prairie sandreed	*Calamovilfa longifolia*	-0.557	
purple prairie clover	*Dalea purpurea*	-0.630	
purple threeawn	*Aristida purpurea*	-0.514	
Quackgrass	*Elymus repens*		-0.524
rough false pennyroyal	*Hedeoma hispida*		-0.449
Sandberg bluegrass	*Poa sandbergii*		-0.449
scarlet beeblossom	*Gaura coccinea*	-0.801	
sideoats grama	*Bouteloua curtipendula*	-0.716	
silverleaf Indian breadroot	*Pediomelum argophyllum*	-0.637	
smooth blue aster	*Symphyotrichum laeve*	-0.498	
sun sedge	*Carex heliophila*		-0.548
Sweetclover	*Melilotus officinalis*		-0.543
threadleaf sedge	*Carex filifolia*	-0.763	
upright prairie coneflower	*Ratibida columnifera*		-0.421
western snowberry	*Symphoricarpos occidentalis*		-0.684
western wheatgrass	*Pascopyrum smithii*	-0.681	
western yarrow	*Achillea millefolium*	-0.657	
white heath aster	*Symphyotrichum ericoides*	-0.759	
white milkwort	*Polygala alba*	-0.646	
whorled milkwort	*Polygala verticillata*	-0.597	

The overall PerMANOVA test among the different sample periods did find a difference (p= *0.075*), but was not highly significant. All other pairwise comparisons had no difference in sample periods using the Bonferroni's correction. Graminoid and forb frequency change over time is shown in Table 4.

Table 4. Frequency (%) of dominant graminoid and forb species on the shoreline plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
Graminoids					
Kentucky bluegrass	*Poa pratensis*	83.75	97.00	99.00	84.00
fowl bluegrass	*Poa palustris*	0.00	0.00	0.00	72.00
reed canarygrass	*Phalaris arundinacea*	40.00	60.00	14.00	62.67
Porcupinegrass	*Hesperostipa spartea*	25.00	64.00	56.00	30.00
smooth brome	*Bromus inermis*	6.25	41.00	31.00	29.00
needle and thread	*Hesperostipa comata*	31.25	24.00	1.00	24.00
western wheatgrass	*Pascopyrum smithii*	56.25	59.00	32.00	20.00
Quackgrass	*Elymus repens*	23.75	22.00	0.00	18.00
green needlegrass	*Nassella viridula*	15.00	9.33	8.00	16.00
Presl's sedge	*Carex preslii*	0.00	0.00	0.00	16.00
shortbeak sedge	*Carex brevior*	0.00	0.00	0.00	14.00
blue grama	*Bouteloua gracilis*	35.00	28.00	10.00	0.00
creeping bentgrass	*Agrostis stolonifera*	0.00	42.00	0.00	0.00
crested wheatgrass	*Agropyron cristatum*	2.50	4.00	14.00	0.00
fall rosette grass	*Dichanthelium wilcoxianum*	0.00	4.00	4.00	0.00
little bluestem	*Schizachyrium scoparium*	0.00	10.00	0.00	0.00
needleleaf sedge	*Carex eleocharis*	15.00	0.00	0.00	0.00
northern reedgrass	*Calamagrostis canadensis*	17.50	0.00	0.00	0.00
plains muhly	*Muhlenbergia cuspidata*	17.50	0.00	0.00	0.00
prairie Junegrass	*Koeleria macrantha*	21.67	9.33	1.33	0.00
prairie sandreed	*Calamovilfa longifolia*	15.00	22.00	14.00	0.00
purple threeawn	*Aristida purpurea*	0.00	76.00	32.00	0.00
Sandberg bluegrass	*Poa sandbergii*	5.00	0.00	0.00	0.00
sideoats grama	*Bouteloua curtipendula*	15.00	8.00	4.00	0.00
slender wheatgrass	*Elymus trachycaulus*	0.00	0.00	4.00	0.00
sun sedge	*Carex heliophila*	51.25	39.00	2.00	0.00
threadleaf sedge	*Carex filifolia*	65.00	12.00	18.00	0.00
Forbs					
Canada thistle	*Cirsium arvense*	23.33	44.00	32.00	65.00
field sowthistle	*Sonchus arvensis*	25.00	16.00	0.00	53.00
Wormwood	*Artemisia absinthium*	25.00	8.00	1.00	35.00

Table 4. Frequency (%) of dominant graminoid and forb species on the shoreline site at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
white heath aster	*Symphyotrichum ericoides*	28.33	27.00	26.00	32.00
Canada goldenrod	*Solidago canadensis*	0.00	3.00	1.00	29.00
silverleaf Indian breadroot	*Pediomelum argophyllum*	17.50	30.00	10.00	21.00
green comet milkweed	*Asclepias viridiflora*	0.00	0.00	0.00	12.00
white panicle aster	*Symphyotrichum lanceolatum*	20.00	4.00	2.00	11.00
common plantain	*Plantago major*	0.00	0.00	0.00	8.00
blue lettuce	*Lactuca tatarica*	26.25	14.00	8.50	7.50
cudweed sagewort	*Artemisia ludoviciana*	22.50	13.00	17.00	7.00
Canadian anemone	*Anemone canadensis*	12.50	17.00	17.00	6.00
blacksamson echinacea	*Echinacea angustifolia*	22.50	15.00	10.00	5.00
American licorice	*Glycyrrhiza lepidota*	5.00	2.50	1.00	4.50
stiff sunflower	*Helianthus pauciflorus*	15.00	4.50	4.00	4.50
candle anemone	*Anemone cylindrica*	0.00	0.00	0.00	4.00
smooth blue aster	*Symphyotrichum laeve*	5.00	0.00	0.00	4.00
purple prairie clover	*Dalea purpurea*	5.00	0.00	1.00	2.00
Tarragon	*Artemisia dracunculus*	7.50	14.00	4.00	2.00
upright prairie coneflower	*Ratibida columnifera*	7.50	2.00	0.00	2.00
western poison ivy	*Toxicodendron rydbergii*	0.00	0.00	0.00	2.00
dotted blazing star	*Liatris punctata*	10.00	7.00	1.00	1.00
prairie fleabane	*Erigeron strigosus*	5.00	1.00	1.00	1.00
rough bugleweed	*Lycopus asper*	0.00	0.00	0.00	1.00
scarlet beeblossom	*Gaura coccinea*	30.00	6.00	7.00	1.00
stiff goldenrod	*Oligoneuron rigidum*	0.00	0.00	0.00	1.00
tall tumblemustard	*Sisymbrium altissimum*	0.00	0.00	0.00	1.00
wavyleaf thistle	*Cirsium undulatum*	0.00	3.00	1.00	1.00
American vetch	*Vicia americana*	5.00	2.00	3.00	0.00
autumn onion	*Allium stellatum*	5.00	0.00	0.00	0.00
bastard toadflax	*Comandra umbellata*	5.00	0.00	0.00	0.00
blue flax	*Linum perenne*	0.00	0.00	1.00	0.00
Canadian horseweed	*Conyza canadensis*	20.00	0.00	0.00	0.00
common dandelion	*Taraxacum officinale*	5.00	0.00	0.00	0.00
common yellow oxalis	*Oxalis stricta*	5.00	0.00	0.00	0.00
curlycup gumweed	*Grindelia squarrosa*	5.00	0.00	0.00	0.00
downy paintedcup	*Casteleja sessiliflora*	10.00	0.00	0.00	0.00
field bindweed	*Convolvulus arvensis*	0.00	0.00	12.00	0.00
field chickweed	*Cerastium arvense*	5.00	0.00	1.00	0.00
Flodman's thistle	*Cirsium flodmani*	5.00	0.00	0.00	0.00
giant goldenrod	*Solidago gigantea*	5.00	0.00	0.00	0.00
hoary puccoon	*Lithospermum canescens*	0.00	1.00	0.00	0.00

Table 4. Frequency (%) of dominant graminoid and forb species on the shoreline plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
Holboell's rockcress	*Arabis holboellii*	5.00	0.00	0.00	0.00
large Indian breadroot	*Pediomelum esculentum*	0.00	2.00	3.00	0.00
lesser spikemoss	*Selaginella densa*	5.00	0.00	0.00	0.00
Missouri goldenrod	*Solidago missouriensis*	10.00	1.00	1.00	0.00
narrowleaf stoneseed	*Lithospermum incisum*	5.00	0.00	0.00	0.00
Norwegian cinquefoil	*Potentilla norvegica*	41.67	0.00	0.00	0.00
oval-leaf milkweed	*Asclepias ovalifolia*	0.00	2.00	2.00	0.00
pasqueflower	*Pulsatilla patens*	5.00	0.00	4.00	0.00
Philadelphia fleabane	*Erigeron philadelphicus*	15.00	0.00	2.00	0.00
plains milkvetch	*Astragalus gilviflorus*	0.00	0.00	1.00	0.00
prairie groundsel	*Senecio plattensis*	10.00	0.00	0.00	0.00
prairie sagewort	*Artemisia frigida*	20.00	10.00	0.00	0.00
prickly lettuce	*Lactuca serriola*	0.00	0.00	3.00	0.00
prostrate knotweed	*Polygonum aviculare*	0.00	0.00	1.00	0.00
rough false pennyroyal	*Hedeoma hispida*	5.00	0.00	0.00	0.00
spiny phlox	*Phlox hoodii*	0.00	0.00	1.00	0.00
sweetclover	*Melilotus officinalis*	30.00	0.00	0.00	0.00
tall cinquefoil	*Potentilla arguta*	5.00	0.00	0.00	0.00
textile onion	*Allium textile*	0.00	0.00	3.00	0.00
western yarrow	*Achillea millefolium*	12.50	0.00	0.00	0.00
white milkwort	*Polygala alba*	5.00	0.50	0.00	0.00
whorled milkwort	*Polygala verticillata*	5.00	0.00	0.00	0.00
yellow salsify	*Tragopogon dubius*	7.50	3.00	3.00	0.00
Shrubs					
western snowberry	*Symphoricarpos occidentalis*	18.75	20.00	23.00	13.00
Woods' rose	*Rosa woodsii*	0.00	0.00	19.00	9.00
chokecherry	*Prunus virginiana*	5.00	1.00	0.00	0.00
prairie rose	*Rosa arkansana*	16.25	26.00	4.00	0.00

The shifts in dominant vegetation were accompanied with differences in diversity indices (Table 5). Species richness was different ($p > 0.006$) between the second (2005) and fourth (2015), and the third (2009) and fourth sample periods. The first (1999) and fourth sample periods were also different ($p=0.0108$). The Shannon's H also declined ($p > 0.006$) between

sample periods. Additionally, the Simpson's D showed differences (p> *0.009*) between the first and fourth, second and fourth, and third and fourth sample periods.

Table 5. Plant species richness and diversity indices on the shoreline plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

	1999	2005	2009	2015
Species richness	31.25[a]	25.25[b]	22.5[b]	10.5[c]
Shannon's H	3.23525[a]	3.04225[ab]	2.90075[b]	2.23125[c]
Simpson's D	0.951825[a]	0.944[a]	0.93215[a]	0.880975[b]

Green Ash Draw Plant Community

Non-metric multidimensional scaling (NMS) scores using the relative Sorenson distance measure returned a three-dimensional solution. The first and second axes are presented in Figure 4. Coefficients of determination for the correlations between ordination distances on the axis determined by the NMS scores were calculated for each axis. R-squared value for the first axis was 44.3%. The second axis increment was 31.4%, which had a cumulative value of 75.7%. The third axis increment was 13.8%. Thus, the three axis cumulative R-squared value was 89.5%.

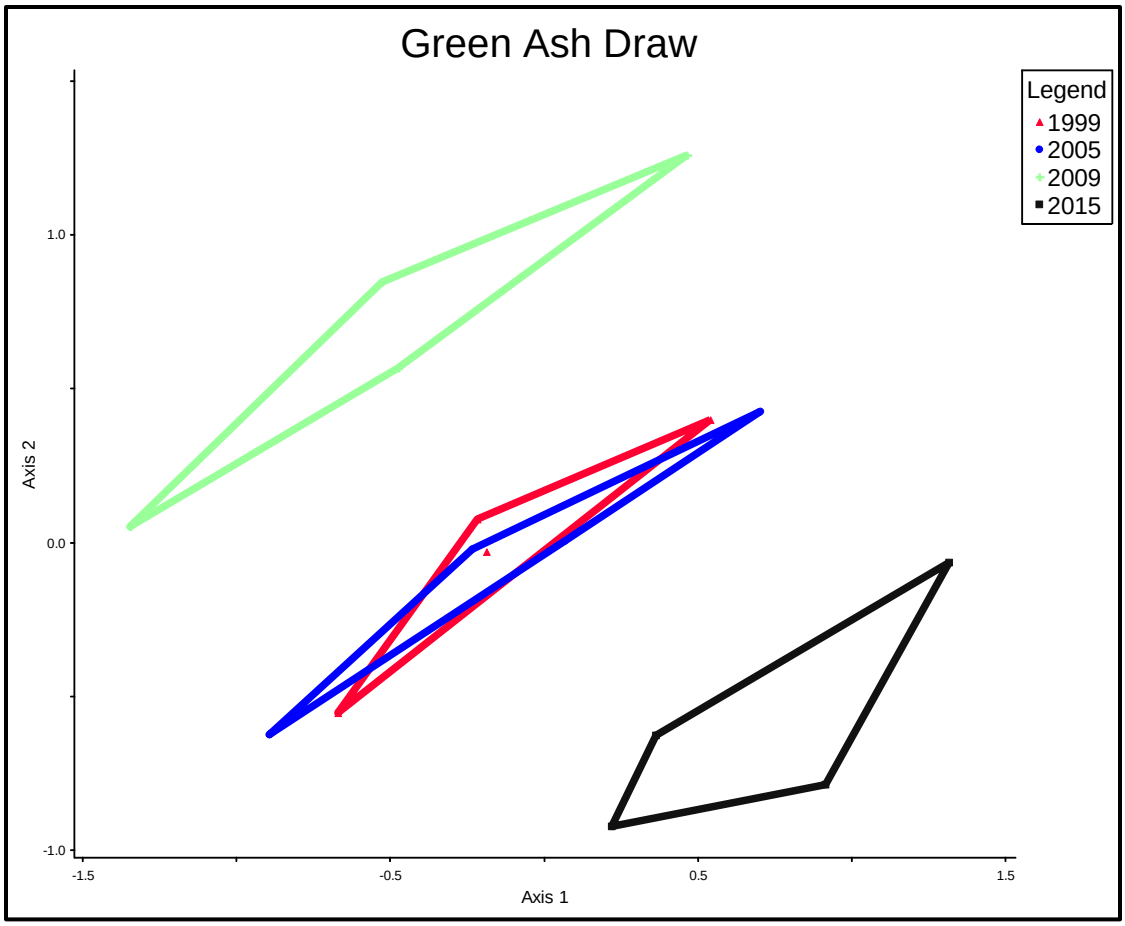

Figure 4. Non-metric multidimensional scaling ordination of the Green Ash draw plant community sites at Douglas Creek Military Reservation for 1999, 2005, 2009, and 2015 near Garrison, North Dakota.

Correlations between species and axis were deemed significant ($p \leq 0.05$) at an absolute value greater than 0.4. Table 6 shows the species that had positive correlations on axis 1 and axis 2. Canadian anemone had highest positive correlations with a value of 0.806 on the second axis. However, American licorice also showed a high positive correlation (0.742). Table 7 shows the negative correlation among species on both axis. Indian hemp showed the greatest negative correlation (0.806).

Table 6. Positive correlated species for the Green Ash draw plant community sites for all years on the Douglas Creek Military Reservation near Garrison, North Dakota.

Positive correlation		**Axis 1**	**Axis 2**
American licorice	*Glycyrrhiza lepidota*	0.742	
American red raspberry	*Rubus idaeus*		0.473
big bluestem	*Andropogon gerardi*		0.495
brook cinquefoil	*Potentilla rivalis*		0.553
Canada goldenrod	*Solidago canadensis*		0.567
Canada thistle	*Cirsium arvense*	0.678	
Canadian anemone	*Anemone canadensis*		0.806
cudweed sagewort	*Artemisia ludoviciana*		0.697
field bindweed	*Convolvulus arvensis*		0.553
Kentucky bluegrass	*Poa pratensis*		0.446
Quackgrass	*Elymus repens*	0.540	
red haw	*Crataegus rotundifolia*		0.648
reed canarygrass	*Phalaris arundinacea*		0.424
serviceberry	*Amelanchier alnifolia*		0.589
silverberry	*Elaeagnus commutata*		0.596
Sprengel's sedge	*Carex sprengelii*	0.408	
western poison ivy	*Toxicodendron rydbergii*	0.473	

Table 7. Negative correlated species for the Green Ash draw plant community sites for all years on the Douglas Creek Military Reservation near Garrison, North Dakota.

Negative Correlation		**axis1**	**axis 2**
blacksamson echinacea	*Echinacea angustifolia*	-0.789	-0.648
Canadian anemone	*Anemone canadensis*		-0.590
chokecherry	*Prunus virginiana*	-0.553	
Indianhemp	*Apocynum cannabinum*	-0.604	-0.806
meadow zizia	*Zizia aptera*	-0.537	
pasqueflower	*Pulsatilla patens*	-0.607	
prairie groundsel	*Senecio plattensis*		-0.473
purple locoweed	*Oxytropis lambertii*	-0.53	
red haw	*Crataegus rotundifolia*		-0.553
silver buffaloberry	*Shepherdia argentea*	-0.527	
silverberry	*Elaeagnus commutata*		
stiffstem flax	*Linum rigidum*		-0.446
blue grama	*Bouteloua gracilis*		-0.698
green needlegrass	*Nassella viridula*	-0.673	-0.596
prairie sandreed	*Calamovilfa longifolia*	-0.514	-0.553
slender wheatgrass	*Elymus trachycaulus*	-0.521	
Spikeoat	*Avenula hookeri*	-0.631	-0.567
threadleaf sedge	*Carex filifolia*	-0.562	

The overall PerMANOVA test show a difference among the different sample periods ($p=0.0004$). All other pairwise comparisons had no difference ($p>0.05$) in sample periods using the Bonferroni's correction. Table 8 shows the fequecy change over time of both graminoid and forbs.

Table 8. Frequency (%) of dominant graminoid and forb species on the Green Ash draw plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
Graminoids					
Kentucky bluegrass	*Poa pratensis*	76.25	86.00	89.00	84.00
Quackgrass	*Elymus repens*	3.33	24.00	10.67	76.00
Porcupinegrass	*Hesperostipa spartea*	21.67	36.00	9.33	59.00
Canada wildrye	*Elymus canadensis*	0.00	19.00	2.00	49.00
sun sedge	*Carex heliophila*	62.50	21.00	6.00	44.00
big bluestem	*Andropogon gerardi*	40.00	54.00	10.00	41.33
needle and thread	*Hesperostipa comata*	45.00	6.67	5.33	38.00
sideoats grama	*Bouteloua curtipendula*	11.67	50.67	14.67	36.00
green needlegrass	*Nassella viridula*	41.25	44.00	14.00	28.00
little bluestem	*Schizachyrium scoparium*	5.00	31.00	4.00	26.67
Sprengel's sedge	*Carex sprengelii*	5.00	0.00	0.00	24.00
crested wheatgrass	*Agropyron cristatum*	0.00	4.00	4.00	20.00
western wheatgrass	*Pascopyrum smithii*	25.00	28.00	13.00	20.00
prairie Junegrass	*Koeleria macrantha*	3.33	10.67	0.00	8.00
reed canarygrass	*Phalaris arundinacea*	0.00	12.00	0.00	8.00
prairie cordgrass	*Spartina pectinate*	5.00	32.00	4.00	4.00
purple threeawn	*Aristida purpurea*	0.00	0.00	4.00	4.00
blue grama	*Bouteloua gracilis*	37.50	0.00	6.00	0.00
Indiangrass	*Sorghastrum nutans*	0.00	0.00	12.00	0.00
marsh muhly	*Muhlenbergia racemosa*	0.00	8.00	0.00	0.00
needleleaf sedge	*Carex eleocharis*	5.00	0.00	0.00	0.00
plains muhly	*Muhlenbergia cuspidata*	2.50	14.00	0.00	0.00
prairie dropseed	*Sporobolus heterolepis*	0.00	0.00	4.00	0.00
prairie sandreed	*Calamovilfa longifolia*	18.33	18.67	16.00	0.00
rough bentgrass	*Agrostis scabra*	0.00	16.00	0.00	0.00
slender wheatgrass	*Elymus trachycaulus*	0.00	26.40	4.80	0.00
smooth brome	*Bromus inermis*	0.00	14.00	6.00	0.00
Spikeoat	*Avenula hookeri*	0.00	8.00	12.00	0.00
Switchgrass	*Panicum virgatum*	0.00	20.00	0.00	0.00
threadleaf sedge	*Carex filifolia*	2.50	0.00	30.00	0.00
woolly sedge	*Carex lanuginose*	2.50	34.00	2.00	0.00

Table 8. Frequency (%) of dominant graminoid and forb species on the Green Ash draw plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	Scientific Name	1999	2005	2009	2015
Forbs					
western poison ivy	*Toxicodendron rydbergii*	60.00	38.00	39.00	57.00
Canada thistle	*Cirsium arvense*	30.00	12.00	6.00	45.00
white heath aster	*Symphyotrichum ericoides*	41.25	59.00	29.00	35.00
northern bedstraw	*Galium boreale*	20.00	23.00	27.00	30.00
wild bergamot	*Monarda fistulosa*	16.67	38.00	20.00	28.00
stiff goldenrod	*Oligoneuron rigidum*	15.00	16.00	15.00	24.00
American licorice	*Glycyrrhiza lepidota*	37.50	18.00	8.50	22.00
cudweed Sagewort	*Artemisia ludoviciana*	32.50	47.00	30.00	17.00
silverleaf Indian breadroot	*Pediomelum argophyllum*	32.50	26.00	10.00	14.00
candle anemone	*Anemone cylindrical*	0.00	14.00	0.00	11.00
smooth blue aster	*Symphyotrichum leave*	0.00	24.00	8.00	11.00
stiff sunflower	*Helianthus pauciflorus*	7.50	12.50	10.50	11.00
blacksamson Echinacea	*Echinacea angustifolia*	20.00	12.00	12.00	9.00
Canadian anemone	*Anemone canadensis*	23.33	24.00	19.00	9.00
prairie fleabane	*Erigeron strigosus*	0.00	18.00	0.00	8.00
blue lettuce	*Lactuca tatarica*	5.63	4.00	3.50	7.00
stinging nettle	*Urtica dioica*	0.00	0.00	0.00	7.00
Wormwood	*Artemisia absinthium*	0.00	1.00	2.00	6.00
giant sunflower	*Helianthus giganteus*	0.00	0.00	0.00	6.00
purple milkvetch	*Astragalus agrestis*	5.00	9.00	2.00	6.00
white milkwort	*Polygala alba*	0.00	0.00	0.00	6.00
Indianhemp	*Apocynum cannabinum*	6.25	0.00	7.00	5.50
blue flax	*Linum perenne*	0.00	0.00	7.00	4.00
dwarf false indigo	*Amorpha nana*	0.00	1.00	0.00	4.00
starry false lily of the valley	*Maianthemum stellatum*	2.50	0.00	0.50	3.50
Canada goldenrod	*Solidago canadensis*	0.00	1.00	11.00	3.00
dotted blazing star	*Liatris punctata*	0.00	5.00	1.00	2.00
houndstongue hawkweed	*Hieracium cynoglossoides*	0.00	0.00	0.00	2.00
Pasqueflower	*Pulsatilla patens*	25.00	7.00	15.00	2.00
upright prairie coneflower	*Ratibida columnifera*	0.00	0.00	0.00	2.00
yellow sundrops	*Calylophus serrulatus*	0.00	0.00	1.00	2.00

Table 8. Frequency (%) of dominant graminoid and forb species on the Green Ash draw plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	Scientific Name	1999	2005	2009	2015
scarlet beeblossom	*Gaura coccinea*	15.00	0.00	0.00	1.50
bastard toadflax	*Comandra umbellata*	15.00	0.00	8.00	1.00
false boneset	*Brickellia eupatorioides*	0.00	0.00	0.00	1.00
Tarragon	*Artemisia dracunculus*	25.00	1.00	0.00	1.00
American vetch	*Vicia americana*	32.50	7.00	1.00	0.00
autumn onion	*Allium stellatum*	5.00	0.00	0.00	0.00
black bindweed	*Polygonum convolvulus*	5.00	0.00	0.00	0.00
brook cinquefoil	*Potentilla rivalis*	0.00	0.00	1.00	0.00
common dandelion	*Taraxacum officinale*	2.50	0.50	0.00	0.00
common sunflower	*Heliathus annuus*	5.00	0.00	0.00	0.00
field bindweed	*Convolvulus arvensis*	0.00	0.00	1.00	0.00
field sowthistle	*Sonchus arvensis*	5.00	3.00	0.00	0.00
Fireweed	*Epilobium angustifolia*	0.00	2.00	0.00	0.00
giant goldenrod	*Solidago gigantean*	7.50	3.00	0.00	0.00
gray goldenrod	*Solidago nemoralis*	0.00	1.00	0.00	0.00
grooved flax	*Linum sulcatum*	5.00	13.00	0.00	0.00
Holboell's rockcress	*Arabis holboellii*	5.00	0.00	0.00	0.00
meadow zizia	*Zizia aptera*	5.00	11.00	3.00	0.00
Missouri goldenrod	*Solidago missouriensis*	0.00	0.00	3.00	0.00
Missouri milkvetch	*Astragalus missouriensis*	0.00	0.00	1.00	0.00
mountain deathcamas	*Zigadenus elegans*	5.00	0.00	0.00	0.00
Nuttall's violet	*Viola nuttallii*	0.00	0.00	1.00	0.00
old man's whiskers	*Geum triflorum*	0.00	0.00	1.00	0.00
oval-leaf milkweed	*Asclepias ovalifolia*	5.00	3.00	0.00	0.00
Philadelphia fleabane	*Erigeron philadelphicus*	0.00	0.00	1.00	0.00
prairie groundsel	*Senecio plattensis*	20.00	0.00	0.00	0.00
purple locoweed	*Oxytropis lambertii*	0.00	9.00	3.00	0.00
purple meadow-rue	*Thalictrum dasycarpum*	15.00	0.00	5.00	0.00
purple prairie clover	*Dalea purpurea*	0.00	4.00	0.00	0.00
red haw	*Crataegus rotundifolia*	5.00	1.00	3.00	0.00
rough false pennyroyal	*Hedeoma hispida*	40.00	0.00	0.00	0.00
Rydberg's sunflower	*Helianthus rydbergii*	0.00	1.00	0.00	0.00

Table 8. Frequency (%) of dominant graminoid and forb species on the Green Ash draw plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
smooth carrionflower	*Smilax herbacea*	25.00	0.00	0.00	0.00
smooth horsetail	*Equisetum laevigatum*	5.00	0.00	0.00	0.00
stiffstem flax	*Linum rigidum*	25.00	0.00	0.00	0.00
Sweetclover	*Melilotus officinalis*	5.00	0.00	0.00	0.00
tall cinquefoil	*Potentilla argute*	0.00	3.00	0.00	0.00
Unknown forb	*Unknown forb*	0.00	0.00	1.00	0.00
velvety goldenrod	*Solidago mollis*	20.00	2.00	0.00	0.00
white panicle aster	*Symphyotrichum lanceolatum*	5.00	0.00	2.00	0.00
yellow salsify	*Tragopogon dubius*	0.00	2.00	4.00	0.00
Shrubs					
western snowberry	*Symphoricarpos occidentalis*	86.25	95.00	81.00	90.00
Woods' rose	*Rosa woodsia*	0.00	21.00	17.00	26.00
silver buffaloberry	*Shepherdia argentea*	0.00	6.00	1.00	6.00
Chokecherry	*Prunus virginiana*	13.33	27.00	19.00	3.00
American red raspberry	*Rubus idaeus*	5.00	4.00	5.00	0.00
prairie rose	*Rosa arkansana*	16.25	22.00	5.00	0.00
Serviceberry	*Amelanchier alnifolia*	5.00	0.00	3.00	0.00
Silverberry	*Elaeagnus commutata*	10.00	1.00	2.00	0.00

The shifts in dominant vegetation were accompanied with differences in diversity indices (Table 9). Species richness was different ($p > 0.006$) between the first and fourth, second and fourth, and third and fourth sample periods. No difference ($p > 0.05$) was found between the other sample periods. The Shannon's H also declined ($p > 0.006$) between these three sample periods with the greatest change occurring between the third to fourth periods ($p = 0.008$). Additionally, the Simpson's D showed a difference between the second and fourth ($p > 0.008$), third and fourth ($p = 0.016$), and first to fourth ($p = 0.020$) sample periods

Table 9. Plant species richness and diversity indices on the Green Ash draw plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

	1999	2005	2009	2015
Species richness	30.75[a]	35.75[a]	32.25[a]	15.25[b]
Shannon's H	3.2425[a]	3.42975[a]	3.3027[a]	2.62975[b]
Simpson's D	0.95345[a]	0.962925[a]	0.955325[a]	0.922275[b]

Planted Tree Plant Community

Non-metric multidimensional scaling (NMS) scores using the relative Sorenson distance measure returned a two-dimensional solution. The first and second axes are displayed in Figure 5. Coefficients of determination for the correlations between ordination distances on the axis determined by the NMS scores were calculated for each axis. R-squared value for the first axis was 46.9%. The second axis increment was 32.9%, which had a cumulative value of 79.8%.

Correlations between species and axis were deemed significant ($p \leq 0.05$) at an absolute value greater than 0.4. Table 10 shows the species that had positive correlations on axis 1 and axis 2. Wormwood, Canada thistle and smooth brome had the highest positive correlations with a value greater than 0.7. Table 11 shows the negative correlation among species on both axis. Green needle grass had the greatest negative correlation (-0.813).

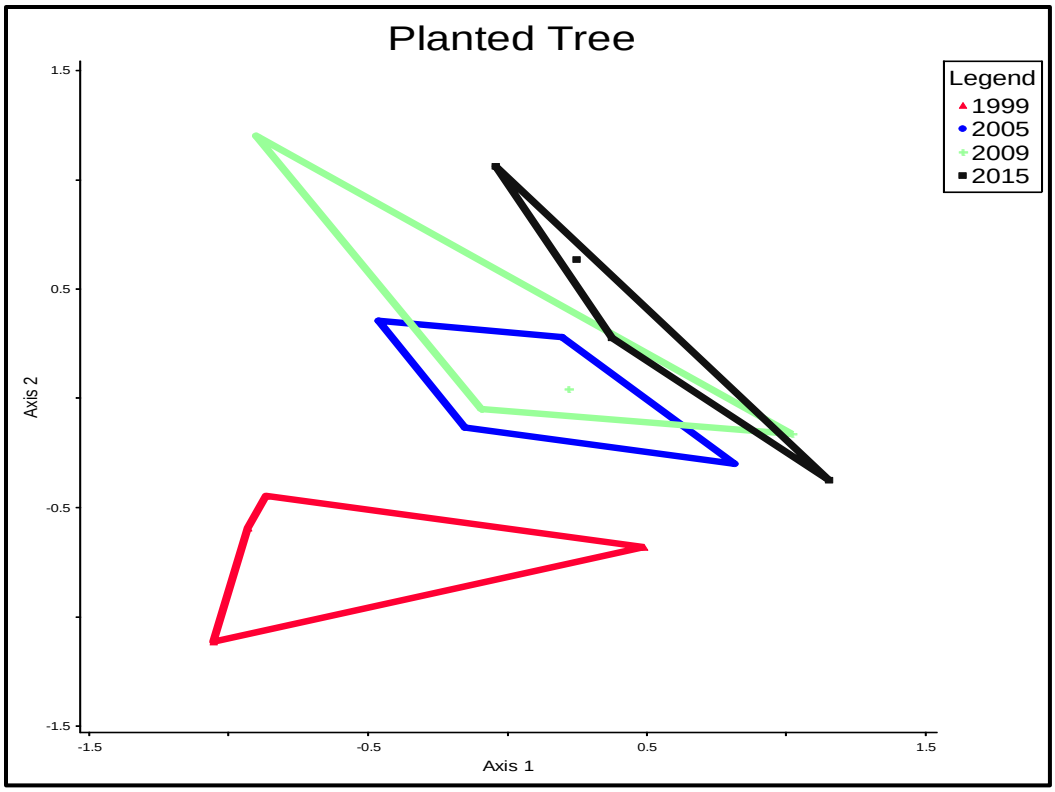

Figure 5. Non-metric multidimensional scaling ordination of the herbaceous understory of the planted tree plant community at Douglas Creek Military Reservation for 1999, 2005, 2009, and 2015 near Garrison, North Dakota.

Table 10. Positive correlated species for the planted tree plant community sites for all years on the Douglas Creek Military Reservation near Garrison, North Dakota.

Positive correlation		**Axis 1**	**Axis 2**
Wormwood	*Artemisia absinthium*		0.715
blue lettuce	*Lactuca tatarica*		0.505
Canada thistle	*Cirsium arvense*		0.799
flatspine stickseed	*Lappula occidentalis*		0.456
Kentucky bluegrass	*Poa pratensis*	0.486	
Lambsquarters	*Chenopodium album*		0.547
Quackgrass	*Elymus repens*	0.700	
scarlet globemallow	*Sphaeralcea coccinea*	0.493	
silverleaf Indian breadroot	*Pediomelum argophyllum*		0.516
smooth brome	*Bromus inermis*	0.772	
textile onion	*Allium textile*		0.516
western snowberry	*Symphoricarpos occidentalis*		0.457
white panicle aster	*Symphyotrichum lanceolatum*		0.516

Table 11. Negatively correlated species for the planted tree plant community sites for all years on the Douglas Creek Military Reservation near Garrison, North Dakota.

Negative Correlation		**axis1**	**axis 2**
American vetch	*Vicia americana*	-0.602	-0.699
autumn onion	*Allium stellatum*	-0.640	-0.527
black bindweed	*Polygonum convolvulus*	-0.547	-0.516
blue grama	*Bouteloua gracilis*	-0.402	-0.479
common dandelion	*Taraxacum officinale*	-0.683	
desert biscuitroot	*Lomatium foeniculaceum*	-0.650	
dotted blazing star	*Liatris punctata*	-0.402	-0.479
green needlegrass	*Nassella viridula*	-0.813	
large Indian breadroot	*Pediomelum esculentum*	-0.402	-0.479
northern bedstraw	*Galium boreale*	-0.402	-0.479
Nuttall's violet	*Viola nuttallii*	-0.525	-0.522
Sweetclover	*Melilotus officinalis*	-0.451	
threadleaf sedge	*Carex filifolia*	-0.402	-0.479
western wheatgrass	*Pascopyrum smithii*	-0.718	-0.537
yellow salsify	*Tragopogon dubius*	-0.514	

The overall PerMANOVA test among the different sample periods found no significant difference (p=*0.103).* All other pairwise comparisons had no difference in sample periods using

the Bonferroni's correction. Graminoid and forb frequency change over time is shown in Table 12.

Table 12. Frequency (%) of dominant graminoid and forb species on the planted tree plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
Graminoids					
Kentucky bluegrass	*Poa pratensis*	83.75	100.00	87.00	95.00
quackgrass	*Elymus repens*	80.00	80.00	100.00	44.00
crested wheatgrass	*Agropyron cristatum*	45.00	65.00	42.00	43.00
smooth brome	*Bromus inermis*	13.33	38.67	41.33	42.67
western wheatgrass	*Pascopyrum smithii*	78.75	53.00	39.00	31.00
green needlegrass	*Nassella viridula*	13.33	6.67	2.67	6.00
blue grama	*Bouteloua gracilis*	5.00	0.00	0.00	0.00
needle and thread	*Hesperostipa comata*	15.00	0.00	0.00	0.00
needleleaf sedge	*Carex eleocharis*	70.00	0.00	0.00	0.00
prairie Junegrass	*Koeleria macrantha*	5.00	0.00	0.00	0.00
sun sedge	*Carex heliophila*	7.50	0.00	0.00	0.00
threadleaf sedge	*Carex filifolia*	15.00	0.00	0.00	0.00
Forbs					
Canada thistle	*Cirsium arvense*	5.00	21.00	19.00	49.00
absinthium	*Artemisia absinthium*	0.00	6.00	7.00	22.00
white heath aster	*Symphyotrichum ericoides*	27.50	12.00	4.00	18.00
flatspine stickseed	*Lappula occidentalis*	0.00	0.00	0.00	12.00
blue lettuce	*Lactuca tatarica*	0.00	3.00	0.50	7.00
showy milkweed	*Asclepias speciose*	0.00	0.00	0.00	7.00
western poison ivy	*Toxicodendron rydbergii*	0.00	1.00	0.00	7.00
stinging nettle	*Urtica dioica*	0.00	0.00	0.00	5.00
houndstongue hawkweed	*Hieracium cynoglossoides*	0.00	0.00	0.00	3.00
American vetch	*Vicia americana*	56.25	10.00	22.00	2.00
common dandelion	*Taraxacum officinale*	5.00	0.00	2.00	2.00
field bindweed	*Convolvulus arvensis*	0.00	1.00	4.00	2.00
tall tumblemustard	*Sisymbrium altissimum*	0.00	0.00	0.00	2.00
lambsquarters	*Chenopodium album*	0.00	1.00	1.00	1.00
oval-leaf milkweed	*Asclepias ovalifolia*	0.00	0.00	0.00	1.00
upright prairie coneflower	*Ratibida columnifera*	0.00	1.00	0.00	1.00

Table 12. Frequency (%) of dominant graminoid and forb species on the planted tree plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
velvety goldenrod	*Solidago mollis*	0.00	1.00	0.00	1.00
yellow salsify	*Tragopogon dubius*	12.50	5.00	0.00	1.00
autumn onion	*Allium stellatum*	8.33	0.00	0.00	0.00
black bindweed	*Polygonum convolvulus*	12.50	0.00	0.00	0.00
black medick	*Medicago lupulina*	0.00	0.00	7.00	0.00
blacksamson echinacea	*Echinacea angustifolia*	0.00	2.00	0.00	0.00
Canadian milkvetch	*Astragulus canadensis*	5.00	0.00	0.00	0.00
cudweed sagewort	*Artemisia ludoviciana*	5.00	0.00	0.00	0.00
desert biscuitroot	*Lomatium foeniculaceum*	17.50	0.00	1.00	0.00
dotted blazing star	*Liatris punctata*	5.00	0.00	0.00	0.00
Flodman's thistle	*Cirsium flodmani*	30.00	0.00	0.00	0.00
great ragweed	*Ambrosia trifida*	5.00	0.00	0.00	0.00
large Indian breadroot	*Pediomelum esculentum*	5.00	0.00	0.00	0.00
northern bedstraw	*Galium boreale*	5.00	0.00	0.00	0.00
Nuttall's violet	*Viola nuttallii*	3.75	0.00	0.50	0.00
prairie sagewort	*Artemisia frigida*	10.00	2.00	0.00	0.00
purple meadow-rue	*Thalictrum dasycarpum*	0.00	0.00	1.00	0.00
rush skeletonplant	*Lygodesmia juncea*	0.00	3.00	0.00	0.00
scarlet beeblossom	*Gaura coccinea*	0.00	1.00	0.00	0.00
scarlet globemallow	*Sphaeralcea coccinea*	0.00	2.00	1.00	0.00
silverleaf Indian breadroot	*Pediomelum argophyllum*	0.00	0.00	1.00	0.00
smooth blue aster	*Symphyotrichum laeve*	0.00	1.00	0.00	0.00
stiff sunflower	*Helianthus rigidus*	5.00	0.50	0.00	0.00
sweetclover	*Melilotus officinalis*	17.50	2.00	1.00	0.00
tarragon	*Artemisia dracunculus*	7.50	3.00	0.00	0.00
textile onion	*Allium textile*	0.00	0.00	3.00	0.00
wavyleaf thistle	*Cirsium undulatum*	0.00	1.00	0.00	0.00
western yarrow	*Achillea millefolium*	0.00	6.00	0.00	0.00
white milkwort	*Polygala alba*	5.00	0.00	0.00	0.00
white panicle aster	*Symphyotrichum lanceolatum*	10.00	0.00	1.00	0.00
wild bergamot	*Monarda fistulosa*	5.00	1.00	0.00	0.00

Table 12. Frequency (%) of dominant graminoid and forb species on the planted tree plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	**Scientific Name**	**1999**	**2005**	**2009**	**2015**
Shrubs					
western snowberry	*Symphoricarpos occidentalis*	22.50	20.00	27.00	41.00
prairie rose	*Rosa arkansana*	0.00	1.00	0.00	0.00
Serviceberry	*Amelanchier alnifolia*	0.00	1.00	1.00	0.00

The shifts in dominant vegetation were accompanied with differences in diversity indices (Table 13). Species richness was different ($p > 0.009$) between the first and fourth, second to fourth ($p=0.017$), and third to fourth ($p=0.031$) sample periods. The Shannon's H also declined between these three sample periods, declining between the first to fourth periods ($p=0.014$). Additionally, the Simpson's D only different ($p= 0.032$) between the first and fourth sample periods. No significant difference was found between the other sample periods.

Table 13. Plant species richness and diversity indices on the planted tree community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

	1999	2005	2009	2015
Species richness	16^{a}	11^{b}	11.5^{b}	7^{c}
Shannon's H	2.51475^{a}	2.137^{b}	2.1965^{b}	1.80825^{c}
Simpson's D	0.897825^{a}	0.855225^{b}	0.867^{b}	0.816125^{b}

<u>Open Grassland Prairie Community</u>

Non-metric multidimensional scaling (NMS) scores using the relative Sorenson distance measure returned a two-dimensional solution. The first and second axes are displayed in Figure 6. Coefficients of determination for the correlations between ordination distances on the axis determined by the NMS scores were calculated for each axis. R-squared value for the first axis was 70.9%. The second axis increment was 14.5%, which had a cumulative value of 85.4%.

Correlations between species and axis were deemed significant ($p \leq 0.05$) at an absolute value greater than 0.4. Table 14 shows the species that had positive correlations on axis 1 and axis 2. Kentucky bluegrass and purple milkvetch had the highest positive correlations values greater than 0.6. Table 15 shows the negative correlation among species on both axis. Prairie sagewort, blue grama, and silver-leaf Indian breadroot showed the greatest negative correlation with values greater than -0.6.

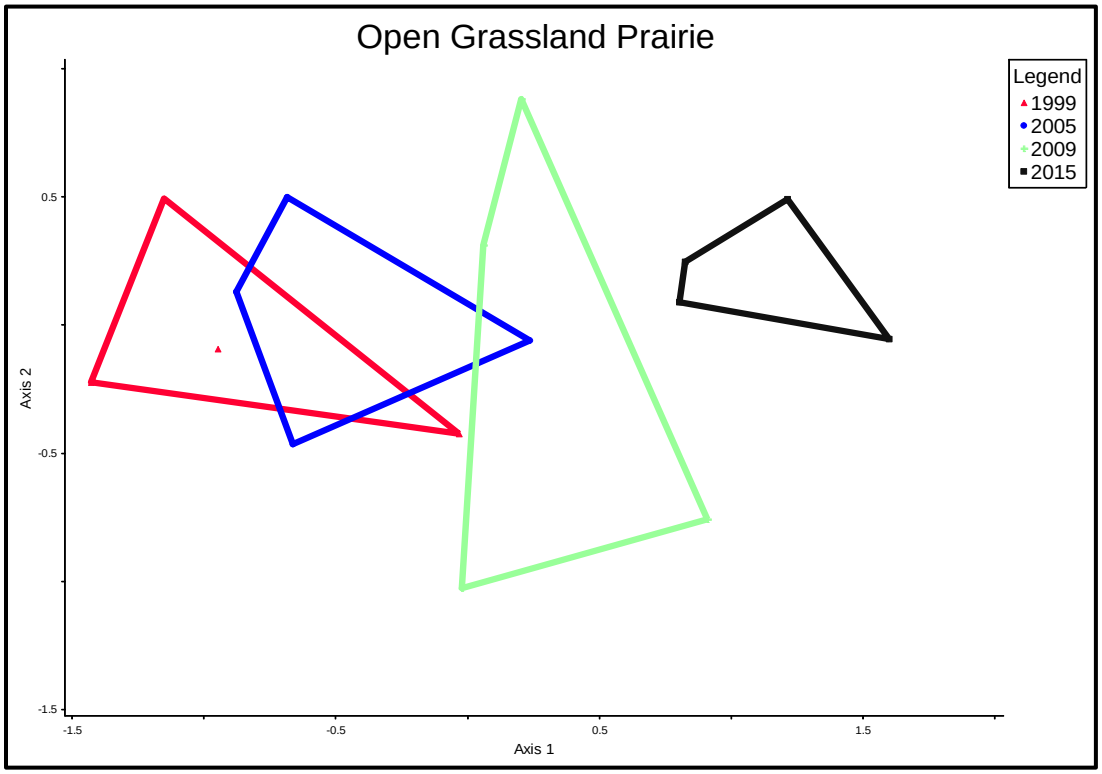

Figure 6. Non-metric multidimensional scaling ordination of the open grassland prairie plant community sites at Douglas Creek Military Reservation for 1999, 2005, 2009, and 2015 near Garrison, North Dakota.

Table 14. Positive correlated species for the open grassland prairie plant community sites for all years on the Douglas Creek Military Reservation near Garrison, North Dakota.

Positive correlation		**axis 1**	**axis 2**
common milkweed	*Asclepias syriaca*		0.535
Kentucky bluegrass	*Poa pratensis*	0.628	
leafy spurge	*Euphorbia esula*		0.552
purple milkvetch	*Astragalus agrestis*		0.641
purple prairie clover	*Dalea purpurea*		0.550
textile onion	*Allium textile*		0.467
velvety goldenrod	*Solidago mollis*		0.467

Table 15. Negative correlated species for the open grassland prairie plant community sites for all years on the Douglas Creek Military Reservation near Garrison, ND.

Negative Correlation		**axis1**	**axis 2**
autumn onion	*Allium stellatum*	-0.415	
bastard toadflax	*Comandra umbellata*	-0.476	-0.565
blacksamson echinacea	*Echinacea angustifolia*	-0.668	
blue grama	*Bouteloua gracilis*		-0.780
common dandelion	*Taraxacum officinale*	-0.452	
cudweed sagewort	*Artemisia ludoviciana*		-0.615
desert biscuitroot	*Lomatium foeniculaceum*		-0.500
dotted blazing star	*Liatris punctata*	-0.528	
Flodman's thistle	*Cirsium flodmani*	-0.644	
hairy false goldenaster	*Heterotheca villosa*	-0.515	
Holboell's rockcress	*Arabis holboellii*	-0.559	
Missouri goldenrod	*Solidago missouriensis*		-0.495
narrowleaf goosefoot	*Chenopodium leptophyllum*	-0.423	
needle and thread	*Hesperostipa comata*		-0.449
needleleaf sedge	*Carex eleocharis*	-0.509	
northern bedstraw	*Galium boreale*	-0.515	
Nuttall's violet	*Viola nuttallii*	-0.559	
Philadelphia fleabane	*Erigeron philadelphicus*		-0.546
plains muhly	*Muhlenbergia cuspidata*		-0.600
prairie groundsel	*Senecio plattensis*	-0.423	
prairie Junegrass	*Koeleria macrantha*	-0.662	
prairie rose	*Rosa arkansana*	-0.511	
prairie sagewort	*Artemisia frigida*	-0.798	
prairie sandreed	*Calamovilfa longifolia*	-0.482	
prickly Russian thistle	*Salsola iberica*	-0.505	
scarlet beeblossom	*Gaura coccinea*	-0.645	
silverleaf Indian breadroot	*Pediomelum argophyllum*	-0.736	
stiff goldenrod	*Oligoneuron rigidum*		-0.546
sun sedge	*Carex heliophila*		-0.615
Tarragon	*Artemisia dracunculus*	-0.418	-0.649
threadleaf sedge	*Carex filifolia*	-0.569	
wavyleaf thistle	*Cirsium undulatum*	-0.411	
western rockjasmine	*Androsace occidentalis*	-0.515	
western yarrow	*Achillea millefolium*		-0.76
yellow salsify	*Tragopogon dubius*	-0.660	

The overall PerMANOVA test among the different sample periods found a difference ($p = 0.0004$). All other pairwise comparisons had no difference ($p > 0.05$) in sample periods using the Bonferroni's correction, though the fourth sample period is most different from all the others if a less conservative statistical procedure was done. Graminoid and forb frequency change over time is presented in Table 16.

Table 16. Frequency (%) of dominant graminoid and forb species on the open grassland prairie plant community site at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

Common Name	**Scientific name**	**1999**	**2005**	**2009**	**2015**
Graminoids					
Kentucky bluegrass	*Poa pratensis*	91.25	100.00	100.00	100.00
western wheatgrass	*Pascopyrum smithii*	66.25	90.00	78.00	60.00
smooth brome	*Bromus inermis*	0.00	0.00	0.00	20.00
green needlegrass	*Nassella viridula*	20.00	20.00	15.00	18.00
needle and thread	*Hesperostipa comata*	46.25	57.00	3.00	13.33
Porcupinegrass	*Hesperostipa spartea*	7.50	10.00	0.00	12.00
purple threeawn	*Aristida purpurea*	0.00	13.33	1.33	8.00
crested wheatgrass	*Agropyron cristatum*	3.33	12.00	1.33	6.67
Canada wildrye	*Elymus canadensis*	0.00	0.00	0.00	4.00
little bluestem	*Schizachyrium scoparium*	5.00	0.00	8.00	4.00
prairie sandreed	*Calamovilfa longifolia*	3.33	14.67	1.33	4.00
blue grama	*Bouteloua gracilis*	38.75	26.00	1.00	0.00
fall rosette grass	*Dichanthelium wilcoxianum*	5.00	0.00	0.00	0.00
needleleaf sedge	*Carex eleocharis*	13.33	0.00	0.00	0.00
plains muhly	*Muhlenbergia cuspidata*	10.00	7.00	0.00	0.00
prairie Junegrass	*Koeleria macrantha*	30.00	2.00	0.00	0.00
Quackgrass	*Elymus repens*	0.00	22.00	0.00	0.00
slender wheatgrass	*Elymus trachycaulus*	0.00	6.00	0.00	0.00
sun sedge	*Carex heliophila*	35.00	46.00	3.00	0.00
threadleaf sedge	*Carex filifolia*	10.00	13.33	4.00	0.00
Forbs					
white heath aster	*Symphyotrichum ericoides*	31.25	45.00	26.00	47.00
blue lettuce	*Lactuca tatarica*	20.63	18.50	13.50	30.50
American vetch	*Vicia americana*	43.33	5.00	15.00	13.00

Table 16. Frequency (%) of dominant graminoid and forb species on the open grassland prairie plant community site at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	Scientific name	1999	2005	2009	2015
silverleaf Indian breadroot	*Pediomelum argophyllum*	10.00	9.00	2.00	12.00
Canada thistle	*Cirsium arvense*	0.00	2.00	2.00	10.00
Tarragon	*Artemisia dracunculus*	20.00	23.00	6.00	10.00
blacksamson echinacea	*Echinacea angustifolia*	20.00	16.00	10.00	8.00
oval-leaf milkweed	*Asclepias ovalifolia*	0.00	1.00	0.00	5.00
dotted blazing star	*Liatris punctata*	7.50	4.00	2.00	4.00
cudweed Sagewort	*Artemisia ludoviciana*	0.00	2.00	1.00	3.00
field Sagewort	*Artemisia campestris*	0.00	0.00	0.00	3.00
scarlet beeblossom	*Gaura coccinea*	16.67	1.00	2.00	3.00
stiff sunflower	*Helianthus pauciflorus*	0.00	0.00	0.00	3.00
yellow salsify	*Tragopogon dubius*	6.67	6.00	1.00	3.00
western yarrow	*Achillea millefolium*	5.00	0.00	1.00	2.50
bastard toadflax	*Comandra umbellata*	17.50	4.00	1.00	2.00
field bindweed	*Convolvulus arvensis*	0.00	0.00	0.00	2.00
purple prairie clover	*Dalea purpurea*	0.00	1.00	1.00	2.00
velvety goldenrod	*Solidago mollis*	0.00	0.00	1.00	2.00
western poison ivy	*Toxicodendron rydbergii*	0.00	0.00	0.00	2.00
Wormwood	*Artemisia absinthium*	0.00	3.00	0.00	1.00
field sowthistle	*Sonchus arvensis*	0.00	0.00	0.00	1.00
large Indian breadroot	*Pediomelum esculentum*	10.00	2.00	0.00	1.00
leafy spurge	*Euphorbia esula*	0.00	1.00	1.00	1.00
prairie Sagewort	*Artemisia frigida*	18.75	21.00	0.00	1.00
rush skeletonplant	*Lygodesmia juncea*	0.00	3.00	0.00	1.00
showy milkweed	*Asclepias speciosa*	0.00	0.00	0.00	1.00
upright prairie coneflower	*Ratibida columnifera*	5.00	5.00	0.00	1.00
wavyleaf thistle	*Cirsium undulatum*	0.00	4.00	0.00	1.00
wild bergamot	*Monarda fistulosa*	0.00	0.00	0.00	1.00
common dandelion	*Taraxacum officinale*	11.25	0.00	1.00	0.50
autumn onion	*Allium stellatum*	6.67	0.00	0.00	0.00
common milkweed	*Asclepias syriaca*	0.00	1.00	1.00	0.00
desert biscuitroot	*Lomatium foeniculaceum*	42.50	0.00	3.00	0.00
field pussytoes	*Antennaria neglecta*	5.00	0.00	0.00	0.00
flexile milkvetch	*Astragalus flexuosus*	5.00	0.00	0.00	0.00

Table 16. Frequency (%) of dominant graminoid and forb species on the open grassland prairie plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015 (continued).

Common Name	**Scientific name**	**1999**	**2005**	**2009**	**2015**
Flodman's thistle	*Cirsium flodmani*	5.00	5.00	0.00	0.00
hairy false goldenaster	*Heterotheca villosa*	5.00	0.00	0.00	0.00
Holboell's rockcress	*Arabis holboellii*	7.50	0.00	0.00	0.00
lacy tansyaster	*Machaeranthera pinnatifida*	0.00	1.00	0.00	0.00
Missouri goldenrod	*Solidago missouriensis*	5.00	2.00	1.00	0.00
narrowleaf goosefoot	*Chenopodium leptophyllum*	5.00	0.00	0.00	0.00
northern bedstraw	*Galium boreale*	5.00	0.00	0.00	0.00
Nuttall's violet	*Viola nuttallii*	10.00	0.00	0.00	0.00
Pasqueflower	*Pulsatilla patens*	5.00	0.00	0.00	0.00
Philadelphia fleabane	*Erigeron philadelphicus*	0.00	0.00	1.00	0.00
prairie groundsel	*Senecio plattensis*	5.00	0.00	0.00	0.00
prickly Russian thistle	*Salsola iberica*	5.00	1.00	0.00	0.00
purple milkvetch	*Astragalus agrestis*	7.50	1.00	4.00	0.00
rough false pennyroyal	*Hedeoma hispida*	5.00	0.00	0.00	0.00
scarlet globemallow	*Sphaeralcea coccinea*	5.00	6.00	0.00	0.00
smooth blue aster	*Symphyotrichum laeve*	0.00	1.00	0.00	0.00
Spinystar	*Escobaria vivipara*	5.00	0.00	0.00	0.00
stiff goldenrod	*Oligoneuron rigidum*	0.00	0.00	1.00	0.00
textile onion	*Allium textile*	0.00	0.00	1.00	0.00
western rockjasmine	*Androsace occidentalis*	10.00	0.00	0.00	0.00
white milkwort	*Polygala alba*	0.00	1.00	0.00	0.00
Shrubs					
Woods' rose	*Rosa woodsii*	0.00	0.00	0.00	2.00
prairie rose	*Rosa arkansana*	5.00	4.00	6.00	0.00
western snowberry	*Symphoricarpos occidentalis*	10.00	10.00	12.00	0.00

The individual species changed in abundance and the plant communities also changed ($p>0.003$). These findings are further exhibited by the diversity indices (Table 17). Species richness had the greatest different ($p > 0.009$) between the second and fourth sample periods. There was also a decline in species richness between the first and third, first and fourth ($p=0.007$), third and fourth ($p=0.031$), and second to third ($p=0.08$) sample periods. The

Shannon's H also showed declines between all sample periods except the first and second ($p=0.008$). Simpson's D showed similar difference to the Shannon's H, with the greatest difference ($p= 0.009$) between the second and fourth sample periods. No significant difference was found between the first and second sample periods for either parameter tested.

Table 17. Plant species richness and diversity indices on the open grassland prairie plant community sites at Douglas Creek Military Reservation, near Garrison, North Dakota from 1999-2015.

	1999	2005	2009	2015
Species richness	27.75[a]	26.5[a]	17[b]	8.25[c]
Shannon's H	3.115[a]	3.01575[a]	2.5225[b]	1.8325[c]
Simpson's D	0.94485[a]	0.936575[ab]	0.8933[b]	0.792675[c]

DISCUSSION

The plant communities at DCMR are trending towards lower species richness and dominance by introduced cool-season grasses. Overall, the strongest driver of all plant communities is Kentucky bluegrass. Native cool-season grasses, like needle-and-thread, are decreasing in the open grassland prairie and shoreline sites, while the invasive cool-season smooth brome is increasing. In all sites, native forbs and warm season grasses are decreasing. The sites were dominated by Kentucky bluegrass at the beginning of the study, continue to increase in Kentucky bluegrass, accumulate litter and loose species richness and diversity.

All plant communities on DCMR are undergoing a transition, and decreasing in species richness and diversity, with the exception of shoreline plant communities having the least amount of lost diversity. When comparing the planted tree, open prairie, woody draw, and shoreline sites, the vegetation compositions were different from one another throughout the study period. This difference is expected because of the variability in soil types, water infiltration and holding capacity, and light availability across the landscape (Abrams and Hulbert 1987; Knapp et al. 1993; Hook and Burke 2000). However, transects at each of these location types showed increases in Kentucky bluegrass and smooth brome, as well as decreases in frequency of warm season grasses and native forbs. Despite these similarities, the NMS ordination did not clearly indicate that plant community composition was moving toward a single invaded state. Eventually, Kentucky bluegrass and smooth brome may create monocultures that erase the species differences across the topographic gradient. However, the variety of soil characteristics and light availability at the microsite level dictate plant community composition more strongly than the presence of other species (Smeins and Olsen 1970; Hook and Burke 2000; Kolb 2002).

Thus, sites at different location types that are invaded by the same exotic species still retain unique species composition when compared across the landscape.

The effects of these invaders on measures of species richness and diversity are unclear. A general trend across all transects is that the greatest highest measures in Shannon's H and Simpson's D occurred during the second sampling period and lowest during the fourth sampling period. The corresponding increases in exotic species frequency may partially explain these changes in diversity (Kolb 2002); however, increasing precipitation, temperature, and growing season days over the course of the sampling periods may also be impacting the change in diversity (Frank and Hoffman 1989; Adler and Levin 2007). These climate shifts, in combination with the increased exotic species, have reduced species diversity over time.

Although the 15 year period encompasses a wet cycle when compared to historical averages, the years between the third and fourth sample period had a decline in precipitation from previous years (NOAA, 1948-2013). The open grassland prairie plant community is driven by an increase in Kentucky bluegrass and smooth brome, and a decline in needle-and-thread and blue grama. The rising frequencies of these two invasive cool-season grasses may be a result of a shifting climate. While precipitation declined, the average temperature and growing season days were both much higher in the final years of the study than the beginning years. Because the additional growing season days extend the spring and fall, these cool-season grass species may be benefiting from the increase growing season days (Bartholomew and Williams 2005; DeKeyser et al. 2015).

With only frequency data, it is difficult to make conclusions about species abundance and diversity. A major drawback to using only frequency data is that it cannot account for production of each plant counted, nor can it account for landscape structure, such as vegetation

height, cover, or a measurement of bare ground. For example, Kentucky bluegrass occurred at 100% frequency throughout the study period at several transects, but it most likely increased in biomass through that time. The inability of frequency data to account for production changes in ubiquitous species makes measurements of diversity based on frequency data alone limited. These drawbacks notwithstanding, the frequency data is an excellent method to get a complete vegetation census on a site. Even if increases in biomass of invaders like Kentucky bluegrass and smooth brome occur, the frequency data will still highlight the existence, or subsequent loss, of rare species (Prosser et al. 2003).

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