Summer 7-26-2018

PLANT COMMUNITY COMPOSITION, FLORISTIC QUALITY, AND ESTABLISHMENT OF ROADSIDE REVEGETATION IN NEBRASKA, USA.

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by

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Agronomy

Under the supervision of Professor Walter H. Schacht

Lincoln, Nebraska

August, 2018

Plant community composition, floristic quality, and establishment of roadside revegetation in Nebraska, USA

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University of Nebraska, 2018

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Roadside revegetation poses a challenge and opportunity for biodiversity conservation, as the land area occupied by roadsides is not expected to decline in the future. In the context of roadside revegetation activities in rural regions dominated by agricultural land uses, revegetation efforts can establish plant communities that offer unique species that would otherwise be absent on the landscape. To determine the efficacy of roadside revegetation efforts in 1) providing plant communities of high biodiversity value and 2) meeting the expectations of roadside revegetation managers for establishment, we quantified botanical composition, floristic quality, and success in seeding efforts to meet manager expectations. We evaluate the outcome of roadside revegetation conducted by Nebraska Department of Transportation for five regions across Nebraska, USA: Loess hills and Glacial drift sites within the tallgrass prairie region, central Loess plains region, Sandhills region, and High Plains Panhandle region. Hereafter, we refer to these geographical areas as Northeast, Southeast, Central, Sandhills, and Panhandle regions, respectively. We found species richness and biodiversity of roadsides was greatest in the western regions of Nebraska. Biomass production on roadsides declined on an east to west gradient, but the component species responsible for this gradient were unique to each region. Manager expectations for established plant communities along roadsides were met at five of our 10 study sites, where significant correlations between managers' expected communities and actual plant communities were observed. Our assessment occurred on average 13.2 years (range: 10-17) post-revegetation, thus,

providing insight into what established roadside vegetation communities can be expected after a decade or more.

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ACKNOWLEDGEMENTS

I would like to thank Dr. Walter Schacht for presenting this opportunity to me and encouraging me to complete my M.S. I have really appreciated your guidance and relentless optimism for myself and other students. I would also like to thank Dr. Edward Raynor, without your effort and input, this manuscript would never have been completed. Additionally, I would like to thank Dr. Mitchell Stephenson and Dr. Jerry Volesky for their willingness to serve as committee members and helping to strength this thesis.

Thank you to Dr. Heidi Hillhouse for your willingness to discuss the state of my thesis and offering suggests to help me be productive. I would like to thank Kelly Brink, Ben Schiltz, Ben Beckman and Justin Hladik for assistance in the field and friendship away from campus.

I owe my parents a big thank you for instilling in me a work ethic, showing me the value of education, and a love of grasslands. And to my wife, Abby, for always offering me encouragement to finish. You knew what it would take for me to finish and you never waived in your support.

GENERAL INTRODUCTION

Ullman (1956), in his contribution to Man's Role in Changing the Face of the Earth (1956), stated that "Few forces have been more influential in modifying the earth than transportation." Highways and interstates, in particular, are a common form of transportation infrastructure that are physical manifestations of the social connections and the economic and political decisions that lead to land use change in terrestrial ecosystems. These transportation corridors intersect both urban and rural landscapes, with each area having unique management concerns. In both urban and rural areas, revegetated roadsides can help to reduce soil erosion (Forman and Alexander, 1998) and provide wildlife habitat and landscape connectivity (Gardiner et al., 2018; Hunter and Hunter, 2008; Ries et al., 2001; Tormo et al., 2007a). In the United States, roadsides provide 4 million ha of potential habitat (Wojcik and Buchmann, 2012). With the future development of transportation infrastructure highly likely (Ibisch et al., 2016), the area available for potential habitat will only increase. In Nebraska, the Nebraska Department of Transportation (NDOT) currently has 16,000 km of interstates and highway, which translates to 20,250 ha of roadside area (J. Soper, unpublished data). This land area covers a large geographic region, with climatic and soil conditions spanning semiarid climates with clay and sandy soils to subhumid climates with loamy soils. This diversity in abiotic conditions can greatly restrict the success of seed mixtures that do not conform to these condition.

The Nebraska Department of Transportation has worked to revegetate roadsides for a number of years. However, the conditions found along roadsides can be inhospitable to plants (Coffin, 2007), primarily due to the heavily compacted soils (artifact of construction activity) and high salinity from de-icing salts applied during winter (Trombulak and Frissell, 2000; US Environmental Protection Agency, 1996). Early revegetation efforts were primarily focused on reducing soil erosion on recently constructed roadsides. These early seeding mixtures were primarily exotic cool-season grasses and leguminous forbs, which quickly established on roadside substrate. In the early 1980's, NDOT began to include native warm-season grasses and forbs as managers realized native species would be better adapted to the diverse abiotic site conditions and that forbs would provide visually appealing roadside. By the early 2000's NDOT moved to seeding mixtures that were dominated by native species, with exotic species rarely being included.

Currently, NDOT develops seeding mixtures with species that: 1) reduce soil erosion by providing soil surface vegetation and sod-forming coverage, 2) are tolerant of poor soil conditions, 3) are tolerant of frequent mowing (this is important for visual safety and snow removal operations), 4) create a visually appealing roadside, 5) provide habitat for pollinators, and 6) are economical, meaning selected species can provide the above characteristics without substantially increasing costs of revegetation efforts. Based on these criteria, seeding mixtures have been developed for each of the major ecological regions of Nebraska. Seeding mixtures are developed for both roadside shoulders (0 to 3 meters from road edge) and backslopes/foreslopes (remaining area of highway right-of-way beyond the shoulder). However, there has been limited documentation of the effectiveness of the species used in these mixtures. Discerning the plant species that are successful in establishing and persisting in the local, inhospitable roadside environments would be invaluable in determining species composition for future roadside seed mixtures (e.g., Grant et al., 2011; Tormo et al., 2007b). The shift to higher diversity mixture has increased the cost of revegetation for NDOT. Thus, by identifying those species that perform poorly, the species mixtures can be adjusted and costs associated with revegetation efforts can likely be reduced.

The objectives of this project were twofold. First, we evaluated seeded roadsides segments statewide to determine what species from the seed mixture are currently represented and/or what volunteer species occur. Secondly, we assessed whether current seeded roadside communities were associated with the expectations of the managers that developed the seeding mixtures used in a given region. The results of the project will inform roadside managers of the current state of the plant communities of revegetated roadsides and facilitate adaptation of roadside seeding mixtures moving forward.

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ABSTRACT

Roadside revegetation poses a challenge and opportunity for biodiversity conservation, as the land area occupied by roadsides is not expected to decline in the future. In the context of roadside revegetation activities in rural regions dominated by agricultural land uses, revegetation efforts can establish plant communities that offer unique species that would otherwise be absent on the landscape. To determine the efficacy of roadside revegetation efforts in 1) providing plant communities of high biodiversity value and 2) meeting the expectations of roadside revegetation managers for establishment, we quantified botanical composition, floristic quality, and success in seeding efforts to meet manager expectations. We evaluate the outcome of roadside revegetation conducted by Nebraska Department of Transportation for five regions across Nebraska, USA: Loess hills and Glacial drift sites within the tallgrass prairie region, central Loess plains region, Sandhills region, and High Plains Panhandle region. Hereafter, we refer to these geographical areas as Northeast, Southeast, Central, Sandhills, and Panhandle regions, respectively. We found species richness and biodiversity of roadsides was greatest in the western regions of Nebraska. Biomass production on roadsides declined on an east to west gradient, but the component species responsible for this gradient were unique to each region. Manager expectations for established plant communities along roadsides were met at five of our 10 study sites, where significant correlations between managers' expected communities and actual plant communities were observed. Our assessment occurred on average 13.2 years (range: 10-17) post-revegetation, thus, providing insight into what established roadside vegetation communities can be expected after a decade or more.

Keywords: backslope, floristic quality, invasive species, revegetation expectations, roadsides, Sandhills,

INTRODUCTION

Establishing and maintaining a diverse and vigorous vegetation community on roadsides has the potential to provide erosion control, wildlife and pollinator habitat, and landscape connectivity (Gardiner et al., 2018; Hunter and Hunter, 2008; Ries et al., 2001; Tormo et al., 2007). In rural areas, roadsides represent landscape features which offer opportunities for biodiversity conservation through the provision of habitat for rare plants and some birds and mammals (Hopwood, 2008; Munguira and Thomas, 1992; Noss et al., 1995). Indeed, roadside vegetation in regions dominated by agricultural land use can be manipulated to create islands of high biodiversity relative to surrounding agricultural lands (Forman and Alexander, 1998) and act as replacement habitat for species experiencing habitat loss.

Roadsides are challenging environments to restore. A myriad of factors, including site microclimate, soil composition, and soil chemistry (Forman, 2003), contribute to the success of seedling establishment. For example, the level of compaction of soils and the origin of roadside soils can affect seedling establishment. Moreover, following establishment, roadside soils in temperate environments usually become laden with de-icing salts (Jodoin et al., 2008). The excess nutrients can facilitate invasion by salt-tolerant species and promote the spread of nitrogen-capitalizing invasive plants. Roadsides can also serve as conduits for rapid dispersal of invasive species (Von Der Lippe and Kowarik, 2007). These management and environmental factors can threaten the longevity of seeded plant communities on roadsides (Trombulak and Frissell, 2000).

The role of roadside establishment and management activities for conservation goals has long been recognized in western Europe and Australia, where roadsides are managed for a broad range of ecosystem services including provisioning of floral diversity (Forman, 2003; Gardiner et al., 2018). In the United States, the potential habitat area along roads is estimated to be almost 4 million ha, an area roughly equal in size to the Netherlands (Wojcik and Buchmann, 2012). This expansive coverage suggests that roads represent a potentially huge and underexploited opportunity for the delivery of ecosystem services (Potts et al., 2016). Furthermore, in the United States, roadside vegetation management commonly includes native species-based restoration and, less commonly, preservation of existing native vegetation (National Research Council 2005). In Midwestern states, where only a small percentage of natural prairies remain, states maintain hundreds of thousands of ha of roadsides as grasslands (Noss et al., 1995). These roadsides are seen as sites for biodiversity conservation by seeding a diversity of flower species (Hopwood, 2008) that also provide for stabilized soil stratum and prevent erosion (Bochet and García- Fayos, 2004). Establishment of diverse mixtures of native, flowering plants on roadsides increases the diversity of plants in the areas in which they occur, thus increasing habitat diversity and making pollen and nectar sources for pollinators more abundant compared to adjacent areas (Forman, 2003; Hopwood et al., 2015).

The Nebraska Department of Transportation (NDOT) switched their roadside seeding mixture from rapidly-establishing, exotic cool-season grasses (e.g., smooth bromegrass, *Bromus inermis*, and tall fescue, *Festuca arundinacea*) and legumes (e.g., red clover, *Trifolium pretense*) to complex mixtures of slower-establishing, native grasses and wildflowers in the early 1980s. The move to complex mixtures of native species (20 species or more) was in response to interest expressed by the general public and other state and federal agencies in native plant communities because of the desirable characteristics of native grasses (e.g., drought resistance and deep root systems) (C. Weinhold, NDOT, personal communication). Overall, NDOT's objectives for seeding mixtures required managers to select species that were 1) native, 2) showy and attractive to the general public, 3) adapted to roadside conditions, 4) established relatively rapidly, 5) provided a relatively dense cover, and 6) contributed to permanent cover. To meet these objectives, NDOT developed separate seeding mixtures to be used on roadside shoulders and backslopes (Fig. 1). Shoulder soils are highly compacted while backslope soils are not compacted and usually have different seeding mixtures. Mixtures containing species that are adapted to local site conditions exhibit the highest levels of establishment (Hufford and Mazer, 2003); thus, seed mixtures adapted to local site conditions were in-part involved in NDOT's revegetation initiative.

In this study, roadside managers used backslope mixtures composed of tall and mid-grasses and forbs (i.e., wildflowers; Table 1). This mixture was reflective of local site conditions changing from predominately tall-grass species for eastern sites to mid-grasses in the western half of Nebraska (Fig. 2) (Dunn et al., 2016). The efficacy in meeting this initiative's goals of plant community establishment has not been evaluated, and how roadside revegetation activities could provide habitat with conservation value has not been assessed in an agriculturally-dominated grassland region of the United States' Central Great Plains. An understanding of conservation value for roadside vegetation communities can provide insight for roadside managers seeking to enhance ecosystem services, such as the provisioning of pollinator habitat, to the surrounding landscape (Wojcik and Buchmann, 2012). Because biodiversity conservation value of grassland communities in this region is correlated with pollinator abundance (Farhat et al., 2014), we assessed biodiversity conservation value of our study sites in efforts to gauge the success of the revegetation efforts that used multiple forb and grass species in seeding mixtures.

Our objectives were twofold. First, we tested whether roadside vegetation communities on backslopes met restoration managers' expectations for seeding success, and determined if species richness, frequency of desired and undesired species, and the floral quality of revegetated sites differed across our study regions approximately 10 years after seeding. Second, we assessed whether roadside communities were associated with expected responses of restored grassland habitat to the predominant land use in this agriculturally-dominated region. Cropland areas generally have reduced seed source richness and higher susceptibility to invasion by non-native species; whereas, rangeland areas have more diverse native plant species. We predicted that roadsides in proximity to cropland would have lower species richness, native species presence, and biodiversity conservation value than roadsides near native rangeland. Because the presence of such association can provide insight into guiding restoration activities in agro-ecosystems of the Central Great Plains, we asked three questions: (1) to what extent do vegetation communities on revegetated roadsides resemble the composition of the initial seeding mixture planted to revegetate the sites in our study regions? (2) does species richness vary in roadside vegetation management sites across the state? and (3) do roadsides vary in biodiversity conservation value across the state?

METHODS

We sampled 10 re-vegetated roadside sites in Nebraska, with two sites within each of the five NDOT landscape regions (Table 1; Fig. 2). The Northeast and Southeast sites were in the Tallgrass Prairie region of eastern Nebraska; the Central and Sandhills sites were in the Mixed Prairie region; and the Panhandle sites were in the Shortgrass Prairie of western Nebraska (Rolfsmeier and Steinauer, 2010; Schneider et al., 2011). The Northeast region is characterized by rolling hills of loess soils with average precipitation of 580 to 700 mm per year, whereas the Southeast region has the highest average precipitation, generally greater than 700 mm per year. Topography and soils of the Southeast region are predominately rolling hills and tablelands of loess soils. The Central region is primarily loess tablelands, with areas of dissected loess hills, with average annual precipitation of the Central region ranging from 500 to 580 mm. Soils of the Sandhills region are primarily sand, with limited soil organic material. Precipitation in the Sandhills region has the greatest variability of all regions evaluated in our study, ranging from 430 to 580 mm of precipitation per year, whereas the Panhandle region has the lowest precipitation of the state, ranging from 350 to 430 mm of precipitation per year. The Panhandle is generally loess tablelands, with areas of eroded canyons.

The Northeast and Southeast sites and one of the Central sites were adjacent to crop fields (mostly corn and soybeans) and the Sandhills and Panhandle sites and one of the Central sites were surrounded by grazed rangeland from the time of roadside seeding to the time of data collection. Study sites were seeded by NDOT between 1990 and 1998 (a minimum of 10 years before the time of data collection), were located on a level landscape positions with road length minimum of 400 m to avoid topographic effects, were on highways with an east-west orientation for consistency purposes, and had minimum roadside width of 10 m. Following road construction activities, each site was seeded with a mixture of native forbs and grasses known to stabilize soil (Table 1). In the years of vegetation sampling, NDOT maintenance staff marked sites with signage to remove areas from annual mowing.

Data collection

To determine the species richness of re-vegetated roadsides, we conducted modified-step point surveys (Owensby, 1973) at each site in June and August of 2008 and 2009. At each sampling event, 200 modified-step points were collected for ground cover and plant basal cover at an interval of every 5 m. When a plant base was not encountered at a point, the nearest plant within the 180° arc in front of the point was identified to species level and recorded. Surveys were conducted on warm (≥20°C), sunny (<60% cloud cover) days with average wind speeds less than 5 m s^{-1}.

In August 2009, standing crop (kg ha^{-1}) was determined by clipping all current year, herbaceous plant material at ground level in 16 randomly-placed quadrats (0.25 x 1.0 m) at each site. Samples were separated by species, plant material was placed in paper bags, oven-dried at 60°C to a constant weight, and weighed at the nearest 0.01 g.

Data Analysis

Development of Expected and Actual Ranks

Roadside managers are interested in understanding the current species composition of revegetated roadside and how current species composition compares to composition of the species seeded. The seeding mixtures used in the different regions of the state were similar but not identical at the study sites. As these sites were planted over 7 years, seed of a given species may not have been available, so another species was substituted into the seeding mixture. To allow for an evaluation of the seeding mixtures used within a region, the list of seeded species was standardized. To standardize the seeding lists of a given region, a list of all seeded species for both sites was determined. If an individual species was only seeded at a single site, within this region, it was added to one of the following categories: seeded other forbs or seeded other grasses. An additional group of non-seeded species was added and termed 'volunteer' species. The list of species seeded at both sites, other seeded grasses, other seeded forbs, and volunteer species was ranked in order from what was expected to be the most commonly occurring species/group to the least commonly occurring species/group by the restoration manager (NDOT: Carol Wienhold and Ronald Poe, 2009, personal communication).

At an individual site, relative species composition was determined using the modified step-point data. For species that were assigned into one of the composite groups, those species' data were combined to produce a relative composition for each group. Ranks were assigned to the common species, other seeded grasses, other seeded forbs, and volunteer species in order from the most frequently to the least frequently occurring botanical composition. To evaluate the current species composition of revegetated sites compared to the seeded species of a region, we used Kendall's tau rank correlation analysis (Kendall, 1938). A rank near 1 indicates the measured community was similar to the community that managers expected; whereas, a rank near -1 indicates dissimilarity between measured and expected plant communities.

Species Richness, FQI, and Botanical Composition of Functional Groups

We calculated species richness based on the August 2009 modified step-point data at each site for total, seeded, volunteer, and by origin (native or exotic) for forbs, grasses, and other plant forms in each region. Next, we conducted a floristic quality assessment (Swink and Wilhelm, 1979; Taft et al., 1997) to evaluate restoration success and identify plant communities of conservation interest. Floristic quality indices (FQI) were calculated for each re-vegetated site and averaged to provide a measure of floristic quality for each region. Calculation of FQI starts by applying a Coefficient of Conservatism (*C*) to each species (Swink and Wilhelm, 1979; Taft et al., 1997). Values range from 0 to 10 and represent the degree to which a plant species is tolerant of disturbance and the species' fidelity to the native vegetation of a region. Non-native plants receive a value of 0 and a plant that is indicative of the intact flora of the area and is not tolerant of disturbance would receive a *C* = 10. For our sites we used the mean of *C* values developed for Nebraska by the Nebraska Natural Heritage Program (G. Steinauer, pers. comm.). FQI is then calculated based as the mean *C* for species present at a site times the square root of the number of native species. We calculated FQI for forbs, native species, and total species. To account for abundance or proportion of biomass of a species at each site (sensu Bourdaghs et al., 2006), we calculated biomass FQI (*b*FQI) using our August 2009 standing crop data. To calculate *b*FQI, Proportional Coefficient of Conservatism indices were calculated from the general formula

$$bC = \sum_{j=1}^{S} \mathrm{p}_j C_j$$

where bC is the proportional Coefficient of Conservatism index, which is equal to the product of the proportional abundance (p; expressed as percent of a site's total standing crop) and the *C*-value of the j^{th} species, summed for all species detected in standing crop (S). Weighted Floristic Quality indices were computed by multiplying weighted Coefficient of Conservatism indices by the square root of S. Plants that were observed but could not be identified to species level were excluded from all of the various index calculations because assigning C-values to higher taxonomic levels was considered inappropriate.

T-tests were conducted to determine if establishment of plant functional groups, based on standing crop, varied (1) by region, (2) whether a group was seeded or was a volunteer, and (3) by origin (native or exotic). In all cases, we report exact P values to allow readers to distinguish between significant effects ($P < 0.05$) and marginally significant effects that may still warrant attention ($0.05 < P < 0.1$). Previous revegetation research has demonstrated that forb species are established and stable after 4 to 6 years since seeding (Larson et al., 2017; Piper et al., 2007); we assumed vegetation communities in our study represent established roadsides communities because the mean age since revegetation was 13.2 years (range 10-17).

RESULTS

Meeting manager expectations

The results of rank correlation indicated a positive correlation of the expected and actual ranks in the Sandhills and Southeast regions and one site in the Northeast region ($P < 0.05$; Fig. 3), suggesting these established plant communities were similar to what the NDOT restoration managers expected. Grasses were the most common plant functional group on revegetated roadsides and were ranked higher than forbs for all regions. The level to which seeded grasses established and persisted has a much greater influence on whether or not there was a positive correlation. Additionally, if a site had a higher level of volunteer species (primarily smooth bromegrass and Kentucky bluegrass (*Poa pratensis*)) than expected, that appeared to result in a non-significant rank correlation. In general, few seeded forbs persisted after 10 years and the influence of this group was minimal. Although the tau-test for statistical dependence was not significant for Central site 1, the negative correlation indicates this community tended to be dissimilar from the plant community expectations of roadside managers.

Plant community and ground cover

Total species richness based on the modified step-point in August 2009 was relatively constant across all regions, except for the Sandhills and the Panhandle (Table 3). The total richness of grass species was similar across all regions, while the total richness of forbs was much higher in the Sandhills region. The richness of seeded grasses and forbs did not vary among regions. Differences in overall richness was driven by volunteer species establishing in seeded roadsides. Distributions of conservatism rankings varied among regions, but each region had a mode $C = 0$ (Fig. 4), indicating exotic species were the most common species at each site.

The Sandhills region appeared to have the greatest number of species with relatively high C values. Percentage bare ground was 5% or less on all sites except for the two Sandhills sites and one of the Panhandle sites (Table 2). Even though species richness was relatively high on these Sandhills and Panhandle sites, individual plants were widely distributed and litter cover was low.

Floristic quality

The floristic quality of total grasses, forbs, and natives based on the modified step-point in August 2009 did not differ among regions, except for the Sandhills region (Table 4). Total floristic quality score of the Sandhills region for all methods of detection (i.e., modified step point or clipped biomass based) was 1.5 to 2 times greater than the other regions of Nebraska. However, the floristic quality from biomass clipping, proportionally weighted on mass, shows a large increase in the Northeast region. This increase in floristic quality is likely because eastern gamagrass (*Tripsacum dactyloides*), a highly productive seeded species, was abundant, thereby, increasing the Northeast region's floristic quality score. From a biomass perspective, the Southeast region had the lowest total FQI scores of all sites (Table 4), likely because of the inclusion of numerous exotic species in the seeding mixture as well as the invasion of exotic cool-season grasses (e.g., smooth bromegrass).

Establishment

Collectively across all regions, total biomass of all seeded species compared to all volunteer species did not differ ($t_{1,18} = 0.34$, $p = 0.63$). Similarly, biomass of seeded forbs compared to volunteer forbs did not differ across all regions ($t_{1,18} = 0.52$, $p = 0.69$); however, eastern regions had greater establishment of seeded forbs (67.6% and 68.0%) (Fig. 5a). Biomass of seeded grasses compared to volunteer grasses was not different when pooled across all sites

($t_{1,18}$ 0.33, p = 0.63, Fig. 5b); although, the proportion of seeded grass species was high in the Northeast and Panhandle, the proportion of seeded grass species was clearly less in the other regions.

Biomass of native forbs was greater than exotic forb biomass ($t_{1,18}$ = -2.78, p = 0.01), especially in the Southeast (94.6 % native and 6.4% exotic) and Sandhills (97.5% native and 2.5%) regions (Fig 5c). Total biomass of exotic grasses compared to native grasses was not different across regions ($t_{1,18}$ = 0.27, p = 0.39); this likely was a result of the high production of native grasses in the Northeast region (Fig. 5d).

Total biomass of all seeded native species was greater than all seeded exotic species across regions ($t_{1,18}$ = -1.67, p = 0.06). Biomass of seeded native forbs was greater than that of exotic seeded forbs ($t_{1,18}$ = -1.55, p = 0.07, Fig. 6a) with this result being most pronounced in the Northeast (87.4% native and 12.6% exotic) and Southeast (95.5% native and 4.5% exotic) regions. This implies establishment of native species can be dominant over non-native species in Nebraska roadside communities. Biomass of seeded native grasses was greater (57.5 to 100% for all sites) than exotic seeded grasses ($t_{1,18}$ = -1.62, p = 0.06; Fig. 6b). In the Northeast, Central, and Sandhills regions, the biomass of seeded native grasses composed more than 97% of the total seeded grass biomass.

Volunteer native species biomass was greater than the biomass of exotic volunteer species ($t_{1,18}$ = 3.10, p = 0.003). Specifically, the biomass of volunteer native forbs (31 to 98.6%) was greater than volunteer exotic forbs ($t_{1,18}$ = -2.09, p = 0.03, Fig. 6c) across all regions, and 99% of Sandhills volunteer forbs were native. Biomass of volunteer exotic grasses (62.5 to 100%) was greater than biomass of volunteer native grasses ($t_{1,18}$ = -3.32, p = 0.002, Fig. 6d) with Central and Eastern regions producing 3 to 6 times more volunteer biomass than western regions.

Additionally, 77 to 100% of this biomass, in the Central and Eastern regions, was exotic cool-season grasses, including smooth bromegrass, Kentucky bluegrass, and tall fescue.

DISCUSSION

In this study, seeding mixtures used at our study sites were considered by NDOT restoration managers to be the most appropriate combination of species to quickly establish and to persist while concomitantly providing soil coverage (to minimize erosion) and plant diversity. To measure success, the seeding mixture and the existing community was evaluated against one another; essentially, to determine the level of similarity between the current revegetated roadside community and the expected plant community. To achieve this comparison, we used rank correlation analysis to identify the regions that supported plant communities similar to the initial seeding mixture. Expected rankings of the plant communities were developed by consulting with roadside managers based on seeding rates used and their observation of plant communities on other roadside revegetation projects. From our results, the current plant communities of the eastern regions were highly correlated with the expected ranks. The eastern regions were commonly seeded with warm-season tallgrasses, exotic cool-season grasses, and native forbs, and those species responded favorably to the higher precipitation received in those regions. The Sandhills region was also highly correlated to the managers' expected ranking. The Sandhills region has very sandy soils and relatively low precipitation; these two environmental factors likely mediate resistantance to invasion by other species (Stubbendieck and Tunnell, 2008). As the seeding mixture was primarily species native to the region (Kaul et al., 2006), the positive correlation of the current plant community to the expected ranking is further evidence that the seeding mixture (primarily sand bluestem (*Andropogon hallii*), sand dropseed (*Sporobolus cryptandrus*), sand lovegrass (*Eragrostis trichodes*), and prairie sandreed (*Calamovilfa longifolia*)) is well adapted to growing conditions of the Sandhills region. We surmise that the regions with significant similarity with manager expectations appear to be seeding mixtures that are well suited to the conditions common to those regions.

While grasses and forbs are both included in seed mixtures, grasses are expected to be dominant in roadside seedings. Generally, roadside managers acknowledge that re-vegetated roadsides will shift from the initial grass and forb matrix to become dominated by grasses over time (Bochet et al., 2010). Grasses flourish in seeded roadsides in the absence of defoliation (i.e., grazing or mowing) during the growing season; therefore, forbs species are outcompeted for resources and the site becomes dominated by grasses (Safford and Harrison, 2001). While backslopes are occasionally mowed, most backslope mowing occurs in fall, which allows grasses to complete their entire growth cycle for the growing season. If high abundance of forbs is a priority for roadsides, managers will need to utilize alternative methods to reduce the abundance of grasses on roadsides.

Species richness generally was highest in the western regions of Nebraska, with the highest richness occurring in the Sandhills, a region known for resilient native-dominated plant communities (Arterburn et al., 2018; Stubbendieck and Tunnell, 2008). Biodiversity conservation value as revealed by FQI derived from modified step-point data had a higher score in the Sandhills than elsewhere. However, the biomass-weighted FQI had the greatest score in the Northeast region where a grass species of high biodiversity conservation value, eastern gamagrass, became well-established and dominated the biomass of the revegetated area. The differences in results of the FQI analysis is likely due to methodology in determining FQI, as observed by Bourdaghs et al. (2006). Traditionally, FQI is calculated using species richness data, which uses the richness of the site to evaluate the quality of the plant community present (Mushet et al., 2002), and ignores the proportion of the plant community that an individual plant species physically occupies. The biomass-weighted FQI allows the species with greatest mass (i.e., greatest proportion of the plant community) to wield a greater influence on the site's biodiversity conservation value.

In the Northeast region, eastern gamagrass produced a large amount of biomass. For instance, it was the second highest percentage (16%) of biomass of any native species for a region (Appendix Table 1). Thus, due to that species' coefficient of conservatism ranking, the biomass-weighted FQI was much higher in the Northeast region. Because biomass production varied by region and with plant functional group, it is not surprising that species with large coefficient of conservatism values, such as eastern gamagrass, can magnify the biodiversity conservation value of a region when biomass is part of the FQI calculation. When using the biomass-weighted FQI, the sites with higher scores shift to the Northeast region. Even when eastern gamagrass was removed from the calculation (Table 4), the shift in FQI was largely the result of the large proportion of the biomass being produced by other native warm-season grasses; switchgrass biomass was similar to that of eastern gamagrass (Appendix Table 1). These grasses produce so much more biomass than forbs, that the overall FQI score is weighted in favor of the productive warm-season grass guild.

From a species richness-based calculation of biodiversity conservation value, floristic quality scores were greatest when the surrounding land use was rangeland (Fig. 3). This result further supports the claim that roadside plant communities can be landscape dependent or, in other words, result from neighboring seed sources (Forman and Godron, 1986). Despite studies of roadside plant species composition being limited in number (Gardiner et al., 2018), it is evident that native species are moving onto roadsides from the surrounding landscape and assisting in the stabilization of the plant communities when sites are located near native-dominated seed sources and far from croplands (Gelbard and Belnap, 2003; Spooner and Lunt, 2004). Further, the greater number of plant species found in the Sandhills and Panhandle regions when compared to the more mesic regions was likely driven by volunteer species rather than better establishment of seeded species. Of the 78 species found in the Sandhills and 56 species found in the Panhandle, 90% and 88% were volunteer species, respectively (Table 3). Volunteer species in the other regions composed 69% to 78% of the total species. The Sandhills and Panhandle sites were surrounded by diverse native rangeland (Kaul et al., 2006), so the increased richness is likely a result of seed rain, vegetative tillering of grasses, and concomitant dispersal onto roadsides. Furthermore, the relatively high richness in the Sandhills was likely a result of the availability of native species, which dominate this region (Bleed and Flowerday, 1998; Dunn et al., 2017; Schneider et al., 2011; Stubbendieck et al., 2017). Bare, sandy soils of the Sandhills do not provide adequate growing conditions for most invasive species, thus favoring the native species adapted to the region's conditions (Bleed and Flowerday, 1998). An additional point is that the species moving onto roadsides from rangelands are unlikely to be included in seeding mixtures as these species often are not available commercially or are cost-prohibitive. In the regions dominated by cropland, species richness was generally lower and the proportion of plant species detected on adjacent roadsides were as much as 43% exotic. Evidence from prairie restoration research has found that proximity to cropland results in higher levels of invasion by exotic plants in both restored and remnant prairies (Rowe et al., 2013).

Floristic quality assessment is an important tool to determine the impact of biodiversity on roadsides. The evaluation of biodiversity can help roadside managers gauge the success of a revegetation project in providing ecosystem services to the landscape. Past research in Iowa and Nebraska has shown that floristic quality is positively associated with diverse butterfly communities (Farhat et al. 2014). Moreover, floristic quality assessments in Kansas show FQI of 17 to 41 for remnant sites and 13 for USDA Conservation Reserve Program (CRP) sites (Jog et al., 2006), meaning sites with higher FQI are more similar to native plant communites. The FQI results from most roadsides in our study are similar to the floristic quality scores for Kansas CRP sites, likely due to the low number of species included in the NDOT seeding mixture. The Sandhills region, however, is an exception. The roadsides of the Sandhills resembled the remnant sites from Kansas, likely because of the large number of plant species that appeared to have moved-in from the surrounding rangeland.

If biodiversity is a priority for roadside managers, habitat improvement efforts should focus in the regions of the state that have limited biodiversity; primarily, the regions dominated by highly productive grasses in the eastern half of Nebraska. Once the seeded species have established, altering the structure and density of the vegetation will facilitate a greater suite of different plant species (Dickson and Busby, 2009). Further, such efforts to enhance the level of plant diversity on revegetated roadsides can positively impact bees (Hopwood 2008) and other pollinators (Ries et al., 2001). From these results, the effort of planting native forbs on roadsides surrounded by rangelands is perhaps unnecessary. Native forbs appear to move onto roadsides from surrounding rangelands, thus calling to question the need to seed expensive forbs into roadsides. Seeding native forbs on roadsides in regions where croplands dominate likely is a more effective use of resources.

Roadside revegetation is often focused on the establishment of perennial species to reduce the likelihood of soil erosion rather than focused on plant and animal diversity which commonly is the goal of prairie or wetland restoration (Schacht and Soper, 2012). Therefore, the emphasis on reducing soil erosion, in conjunction with the limited species mixtures, makes roadside seedings similar to CRP plantings. CRP sites often have similar issues with plant invasion by non-seeded species (Baer et al., 2009). One critical difference is that CRP plantings typically are completed in a block and have a relatively low perimeter:area ratio. Roadsides are long and linear plantings with a high perimeter:area ratio; therefore, the entire roadside stand is exposed to a high level of pressure of invasion from the surrounding land.

To better assess roadside seedings' ability to reduce soil erosion, plant cover or biomass is a better indicator of the ability of the vegetation to protect the soil surface (Kort et al., 1998). The aboveground plant biomass on roadsides declined on a gradient from east to west, but the ratio of biomass of seeded species to that of volunteer species did not differ among regions. However, the species that produced the greatest proportion of the biomass varied between regions. For example, the Northeast region had a high proportion of seeded grass species (69.7%), while the Southeast and Central regions had much lower proportions of seeded species (31.2% and 14.0%, respectively) (Fig 5A). The difference in the proportions of seeded species compared to volunteer species was primarily driven by the invasion of smooth bromegrass and Kentucky bluegrass onto roadsides in the Southeast and Central regions. The Northeast region did have both invasive species present, but the high productivity of eastern gamagrass and switchgrass (*Panicum virgatum*) (Appendix Table 1) was adequate for the seeded native species to dominate the biomass production of this region. The difference of total biomass between native species and exotic species was not significant at the state-level; however, biomass of native forbs was greater than exotic forbs. This result suggests that the native forbs that establish themselves are better suited to the conditions of roadsides than non-native forbs. This follows the general trend among roadside managers to utilize more native forbs in roadside mixtures, as the native species are better adapted to site conditions (Carol Wienhold and Ronald Poe, 2009, personal communication).

Of the percentage of total plant species detected on revegetated roadsides across the landscape regions, 46 to 64% were forbs (Table 3); yet; by weight, forbs generally composed less than 10% of the total biomass (Fig. 5 and 6). Forbs commonly are at low densities and/or small in size but are major contributors to biodiversity conservation values when FQI scores are based on species richness; however, forbs are minor contributors to plant diversity when based on biomass. Even with a high number of forb species, FQI scores were relatively low due to a high percentage (19 to 43%) of the forb species being exotic. Interestingly, most of the forbs found were not seeded (71 to 98% volunteer) and likely originated from neighboring areas. A majority of these volunteer species were not the showy forbs that are preferred by NDOT (e.g., sweetclover (*Melilotus officinalis*), kochia (*Kochia scoparia*) and Russian thistle (*Salsola tragus*)). Even though the number of seeded native forb species was low, these forbs composed a majority of the total forb biomass across all regions. This was especially evident in the eastern regions of Nebraska where Maximillian sunflower (*Helianthus maximiliani*) had high production of biomass (Appendix 1). Overall, a few seeded forb species were prevalent (by weight) 10-years post-seeding but a majority of the forbs were volunteer species (mostly natives) that lack the aesthetic value of the desired seeded species. The low persistence of seeded forb species calls to question the forb species selected to be included in the seeding mixture and/or the inclusion of forbs in the seeding mixtures because of the high cost of most forb species.

Furthermore, past studies utilizing a weighting approach to gauge a site's floristic quality employ canopy cover estimates for a proxy of abundance (e.g., Bourdaghs et al., 2006). Because cover estimates are based on a plant's areal extent and can be misleading relative to abundance estimates from clipped vegetation (Catchpole and Wheeler, 1992), we argue that our clipped biomass-weighted FQI scores reveal unparalleled estimates of a site's biodiversity conservation value, and our regional comparisons across functional groups, their origin, and whether they were seeded provide a new perspective on the success of revegetation efforts for biodiversity conservation. Interestingly, the results of establishment based on biomass from forbs and grasses were different based on whether functional groups were seeded or not. Biomass of volunteer native forbs was greater than exotic forbs, but biomass of volunteer exotic grasses was greater than volunteer native grasses. The volunteer native forbs were much more prevalent in the western regions, likely because of the proximity to native rangelands. The volunteer exotic grasses were more prevalent in the eastern regions, most likely because of the higher precipitation in the east and proximity to cropland edges, which were typically dominated by invasive grass species and had few native forb species (Dunn et al., 2017; Rolfsmeier and Steinauer, 2010).

By utilizing two separate sampling techniques, we present differing perspectives of the plant communities on roadsides. In one perspective, the modified step-point presents plant communities in terms of species frequency and accounts for the prevalence of understory species (less conspicuous), such as Kentucky bluegrass. Understory species can appear to dominate a plant community from a frequency perspective even though they represent a minor part of total plant canopy cover and biomass. Furthermore, per unit time, the number of points sampled when using the modified step-point is multiple times greater than when using a quadrat in arriving at an estimate of biomass. This increase in the number of sampling points increases the number of species encountered which then provides for a better measure of richness and biodiversity. In the second perspective, biomass presents the plant community in terms of coverage of the site. This is critically important for roadsides, as the coverage of the soil surface is the primary goal of revegetation efforts. Combined, these two techniques offer a better perspective of the reality of a roadside plant community. Biomass presents the perspective of the large grasses and forbs that visually dominate the site, while the modified step-point provides a metric of both the frequently-occurring understory species and the larger overstory species. The combination of the two perspectives is necessary to understand the plant communities of roadsides in Nebraska.

CONCLUSION

The primary motivations of roadside revegetation is to reduce soil erosion and to add biodiversity to the landscape. Our results indicate that after at least 10 years, the eastern sites were dominated by grass species and these species were commonly volunteer grass species. The combination of high grass productivity and the proximity to invasive species from cropland areas reduced the abundance of seeded forbs on roadsides. If a roadside objective is diversity and an abundance of showy forbs, management of these areas should be altered to improve forb persistence. Mowing during the growing season could reduce foliar canopy of grasses, which allows for greater persistence of forb species (Williams et al., 2007). Roadsides across the state had relatively moderate biodiversity, when compared to inventories in nearby states (i.e., Kansas), but biodiversity was greatest in the western regions where the roadsides were surrounded by native rangeland. The proximity to native rangeland likely facilitates seed rain and migration of native species onto roadsides. Overall, the plant diversity of revegetated roadside appears to be greatly influenced by the surrounding land use. Surrounding land use should be considered a critical part of planning roadside revegetation and not simply for plants moving onto roadsides, but also seeded species moving off roadsides into surround landscape.

Furthermore, of the 4 million ha of potential roadside habitat in the United States (Wojcik and Buchmann, 2012), as much as 20,250 ha occurs in Nebraska (J. Soper, unpublished data), where soil conservation, diversity/habitat, and aesthetic objectives are not consistently achieved. Our findings contribute new insight into the success of revegetation efforts for these understudied habitats; and in contrast to the areal extent of most natural habitats worldwide (Ibisch et al., 2016), the size of the area occupied by roadsides is not expected to decline in the future.

ACKNOWLEDGEMENTS

We thank employees of the Nebraska Department of Transportation for their field work and help in assembling expected rank of regional plant communities. Kelly Brink, Ben Schiltz, Jessica Shortino, Ryan Brock, Ben Beckman, Justin Hladik, and Samantha Bray for their assistance with data collection. Mitch Stephenson and Jerry Volesky for reviewing this document. This project as possible with funding from the Nebraska Department of Transportation.

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TABLES

Table 1. Representative seeding mixtures for roadside backslopes for each study region in Nebraska, USA.

	Landscape Region				
Species	**Northeast**	**Southeast**	**Central**	**Sandhills**	**Panhandle**
Big Bluestem (*Andropogon gerardii* Vitman)	X	X			
Blackeyed Susan (*Rudbeckia hirta* L.)	X	X	X		
Blanket Flower (*Gillardia pulchella* Foug.)					X
Blue Flax (*Linum prenne* L.)	X				
Canada Wildrye (*Elymus canadensis* L.)	X				
Crested Wheatgrass (*Agrogyron cristatum* (L.) Gaertn.)					X
Dames Rocket (*Hesperis matronalis* L.)	X	X	X		X
Evening Primrose (*Oenothera bienis* L.)	X				
False Sunflower (*Heliopsis helianthoides* (L.) Sweet var. *scabra* (Dunal) Fernald	X				
Grayhead Prairie Coneflower (*Ratibida pinnta* (Vent.) Barnhart)		X			
Hairy Vetch (*Vicia villosa* Roth)		X		X	X
Indiangrass (*Sorghastrum nutans* (L.) Nash)	X	X	X		
Intermediate Wheatgrass (*Elymus hispidus* (Opiz) Meld.)	X	X	X		X
Lance-leaved Coreopsis (*Coreopsis lanceolata* L.)					X
Leadplant (*Amorpha canescens* Nutt. ex Pursh)	X		X		
Little Bluestem (Schizachyrium scoparium (Michx.) Nash)	X	X	X	X	X
Maximillian Sunflower (*Helianthus maximiliani* Schrad.)		X			
Mexican Red-Hat (*Ratibida columnifera* forma *pulcherrima* (DC.) Fernald					X
Oats (*Avena fatua* L.)	X				X
Ox-Eye Daisy (*Leucanthemum vulgare* Lam.)		X			
Partridge Pea (*Chamaecrista fasciculate* (Michx.) Greene)	X	X			
Pitcher Sage (*Salvia azuera* Michx.)	X				
Plains Coreopsis (*Coreopsis tinctoria* Nutt.)		X			
Prairie Sandreed (*Calamovilfa longifolia* (Hook) Scribn.)				X	
Purple Prairie Clover (*Dalea purpurea* Venten.)	X	X	X		X
Red Clover (*Trifolium pretense* L.)	X	X			
Reed Canarygrass (*Phalaris arundinacea* L.)		X			
Rocky Mountain Penstemon (*Penstemon strictus* Benth.)					X
Rye (*Secale cereale* L.)				X	
Sand Bluestem (*Andropogon gerardii* subsp. *hallii* (Hack.) J. Wipff)				X	

Sand Dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray)				**X**	
Sand Lovegrass (*Eragrostis trichodes* (Nutt.) A. W. Wood)	**X**		**X**	**X**	
Shell-leaf Penstemon (*Penstemon grandiflorus* Nutt.)	**X**		**X**		
Sideoats Grama (*Boutelous curtipendula* (Michx.) Torr)	**X**	**X**	**X**		**X**
Sweetclover (*Melilotus officinalis* (L.) Pallas)			**X**	**X**	
Switchgrass (*Panicum virgatum* L.)	**X**	**X**	**X**	**X**	
Upright Prairie Coneflower (*Ratibida columnifera* (Nutt.)Wooton & Standl.)	**X**		**X**		**X**
Western Wheatgrass (*Elymus smithii* (Rydb.) Gould)			**X**	**X**	**X**

Table 2. Environmental factors for each sampling location within our five study regions in Nebraska, USA.

NDOT Landscape Region	Average Annual Precipitation (mm)	Maximum Average Temperature (°C)	Minimum Average Temperature (°C)	Growing Degree Days (>10°C)	Soil Type	Bare ground cover (%)	Latitude	Longitude	Age of Seeding (years)	Surrounding Land Use
Northeast										
Site 1	578	16.3	2.7	3290	Orwet loam	1	42°27'59.26" N	97°57'22.90" W	10	crop
Site 2	637	15.6	2.2	3290	Bazile silt loam	0.25	42°21"03.75" N	97°44"15.34" W	14	crop
Southeast										
Site 1	662	17.4	3.8	3541	Hastings silt loam	0.50	40°52'20.58" N	97°56'53.99" W	10	crop
Site 2	757	17.8	4.4	3541	Crete silt loam	1.5	40°11'24.43" N	97°01'14.85" W	16	crop
Central										
Site 1	546	62.8	1.6	2938	Valentine loamy fine sand	0.05	41°25'20.96" N	100°24'31.90" W	10	rangeland
Site 2	585	17.1	4.6	2938	Holdrege silt loam	0.25	40°17'33.20" N	99°10'45.82" W	13	crop
Sandhills										
Site 1	463	15.9	0.7	4798	Valentine fine sand	29.00	42°55'38.59" N	100°45'39.68" W	17	rangeland
Site 2	463	15.9	0.7	4798	Valentine fine sand	52.50	42°55'12.25" N	101°01'5394" W	15	rangeland
Panhandle										
Site 1	462	16.7	0.6	4147	Munjour fine sandy loam	5.25	42°46'38.55" N	102°49'41.37" W	15	rangeland
Site 2	352	16.2	-0.2	4147	Valent loamy fine sand	47.75	41°38'25.69" N	103°44'48.39" W	12	rangeland

Table 3. Species richness (number of species) including forbs and grasses at each region sampled in Nebraska, USA in 2008 and 2009. The number of seeded species for each region is within parentheses.

Region	Total	Exotic	Native	Volunteer	Seeded
Total					
Northeast	39	13	26	28	11(27)
Southeast	42	18	24	29	13(22)
Central	41	8	33	32	9(17)
Sandhills	78	15	63	70	8(9)
Panhandle	56	19	37	49	7(17)
Forbs					
Northeast	20	6	14	17	3(18)
Southeast	21	8	13	15	6(14)
Central	19	3	16	17	2(10)
Sandhills	50	9	41	49	1(2)
Panhandle	32	12	20	30	2(11)
Grasses					
Northeast	17	7	10	10	7(9)
Southeast	19	10	9	12	7(8)
Central	19	5	14	12	7(7)
Sandhills	23	6	17	16	7(9)
Panhandle	22	7	15	17	5(6)
Other[1]					
Northeast	2	0	2	1	1
Southeast	2	0	2	2	0
Central	3	0	3	3	0
Sandhills	5	0	5	5	0
Panhandle	2	0	2	2	0

1. Other includes sedges, shrub and cactus species.

Table 4. Floristic quality index (FQI) averaged across the two study sites within each region. FQI was based on species detected in August 2009 biomass clippings, biomass-weighted (*b*FQI), modified step-point for August 2009 and all species detections from modified step point surveys from 2008 and 2009 at five regions in Nebraska, USA.

	*b*FQI –Proportional Biomass			FQI-Modified Step Point			All detections 2008-2009		
Region	Total *b*FQI	Forb *b*FQI	Native *b*FQI	Total FQI	Forb FQI	Native FQI	Total FQI	Forb FQI	Native FQI
Northeast	20.38*	4.40	44.86*	9.84	7.60	12.72	12.80	10.89	23.57
Southeast	7.96	7.49	14.35	13.18	7.98	16.89	12.39	10.85	19.30
Central	12.18	1.24	20.72	10.39	3.03	11.92	17.39	14.35	23.71
Sandhills	17.76	9.40	20.47	21.35	14.70	22.16	30.72	21.83	32.71
Panhandle	12.01	7.49	18.92	12.35	8.34	15.65	14.11	9.77	20.27

* Northeast Total bFQI and Native bFQI without eastern gamagrass is 9.78 and 23.18

FIGURES

Figure 1. Example of shoulder and backslope locations along a roadside revegetation site. Near Nenzel, Cherry county, Nebraska. March 2008, credit: J. Soper.

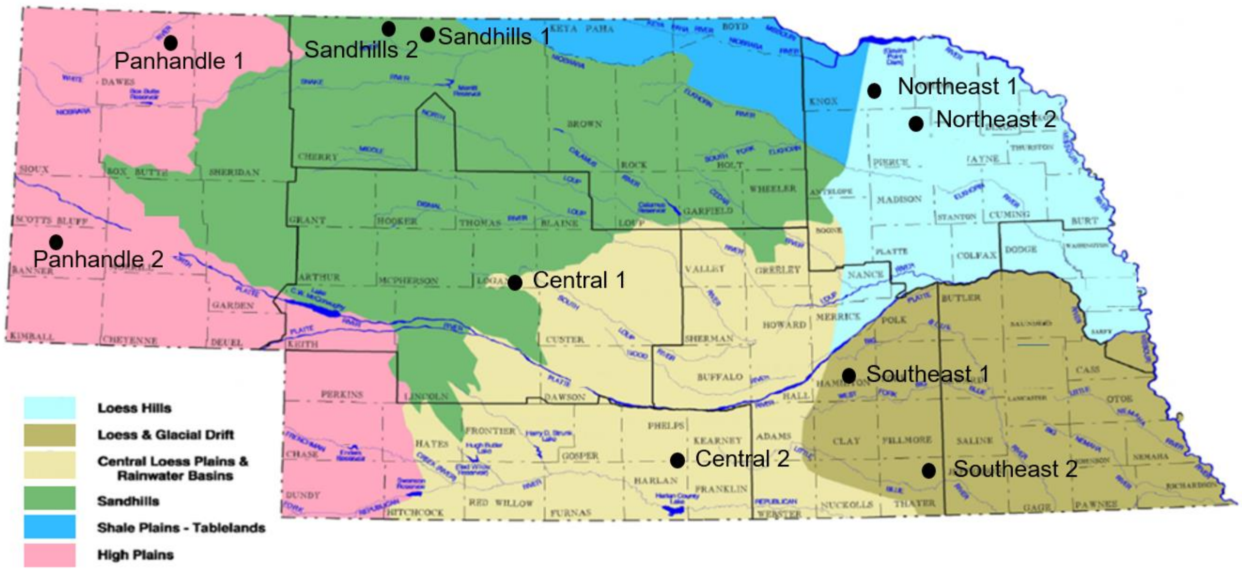

Figure 2. Location of study sites in Nebraska, USA within landscape regions, as depicted by color. Bold lines depict Nebraska Department of Transportation district boundaries.

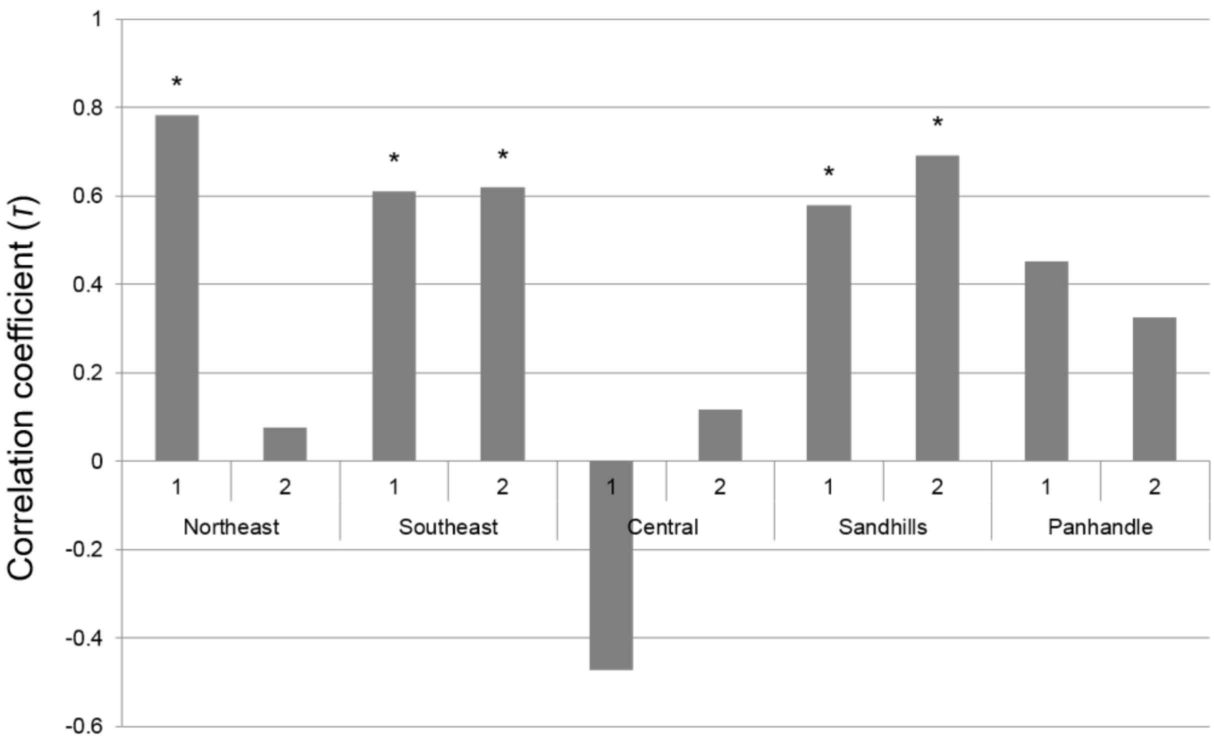

Figure 3. Kendall rank correlation of expected and actual ranks of establishment of revegetated sites derived from August 2009 modified step point data, Nebraska, USA. An asterisk indicates correlation is statistically significant at $\alpha=0.05$.

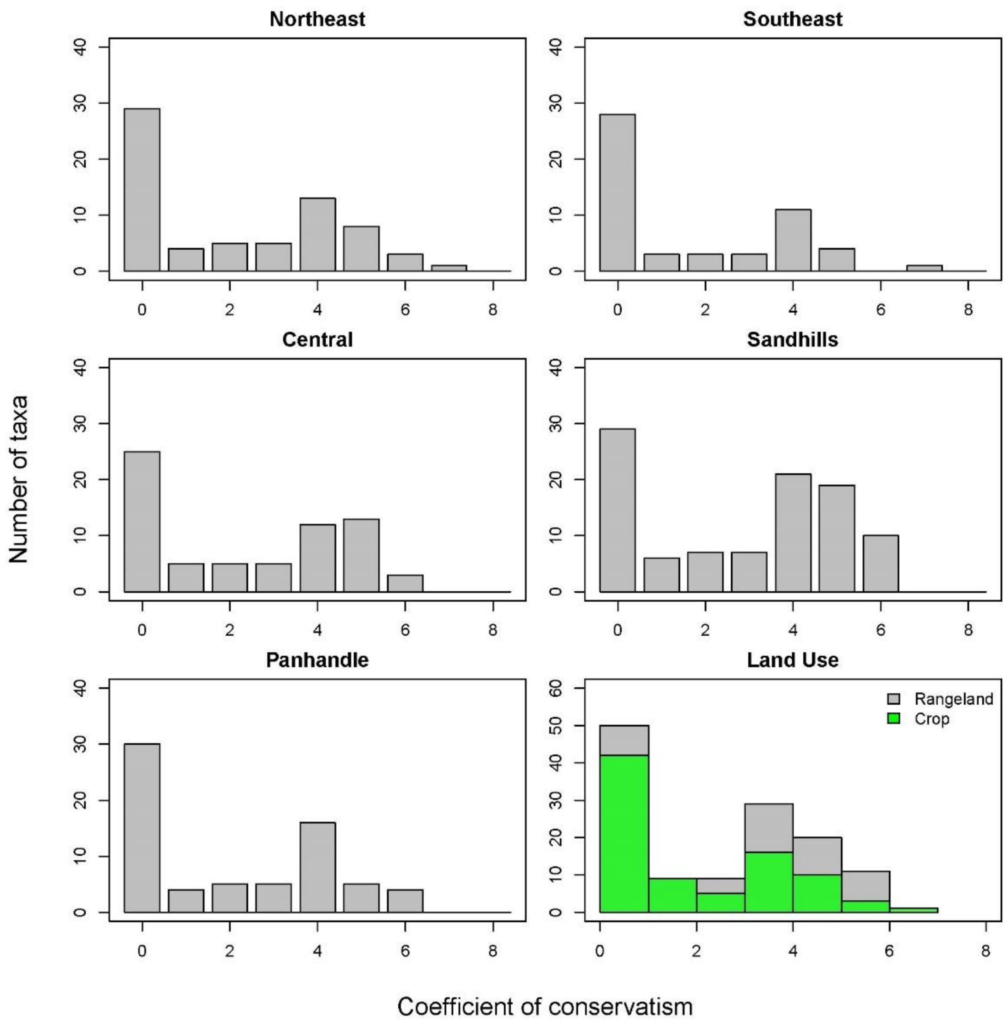

Figure 4. Frequency distribution of coefficient of conservatism by number of all taxa detected at study regions, and frequency distribution of coefficient of conservatism by number of taxa within rangeland and cropland across study area, Nebraska, USA.

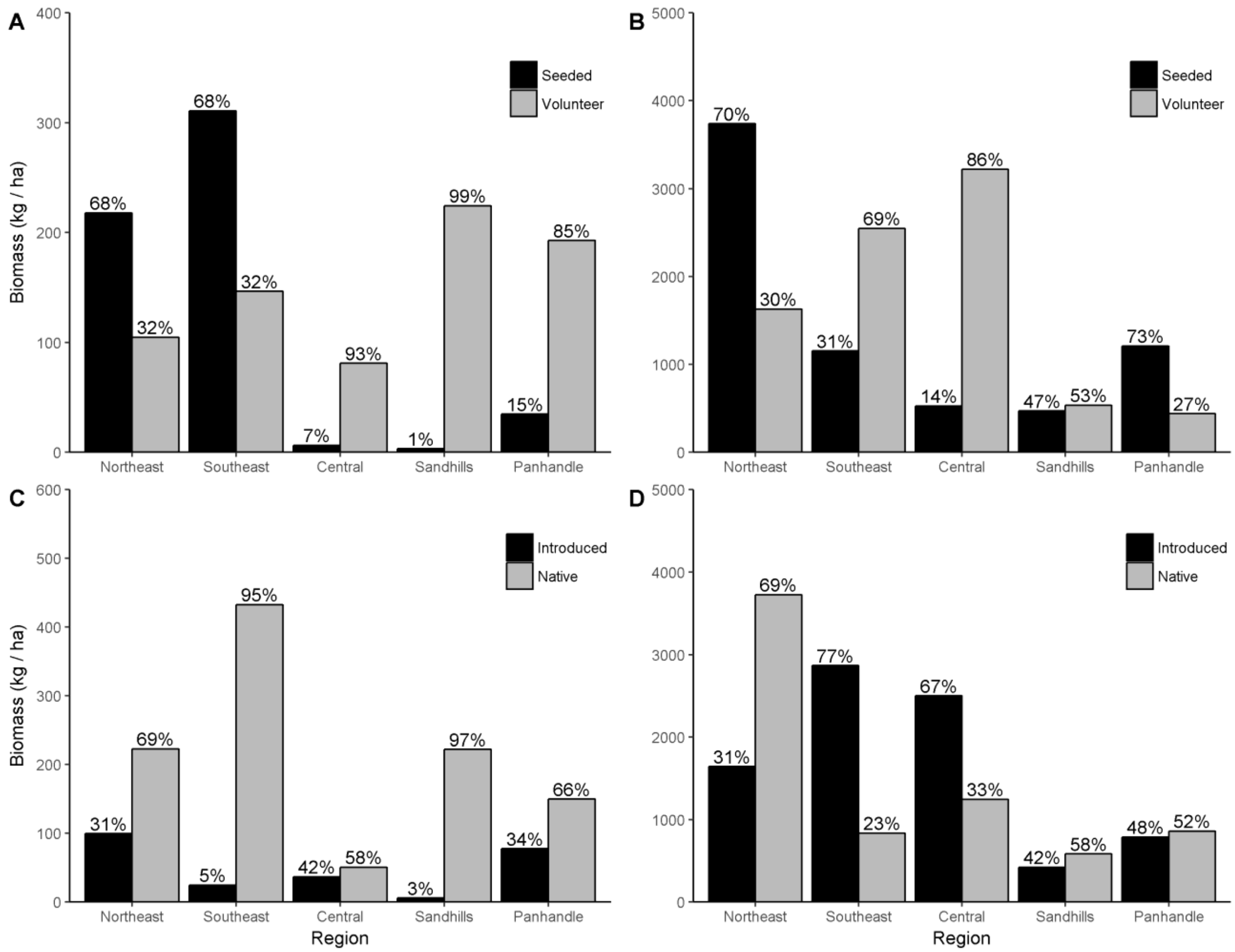

Figure 5. A) Seeded and volunteer forb biomass, B) seeded and volunteer grass biomass, C) introduced and native forb biomass, and D) introduced and native grass biomass clipped in August 2009 in each study region, Nebraska, USA. Numbers above bars indicate percentage of weight per region.

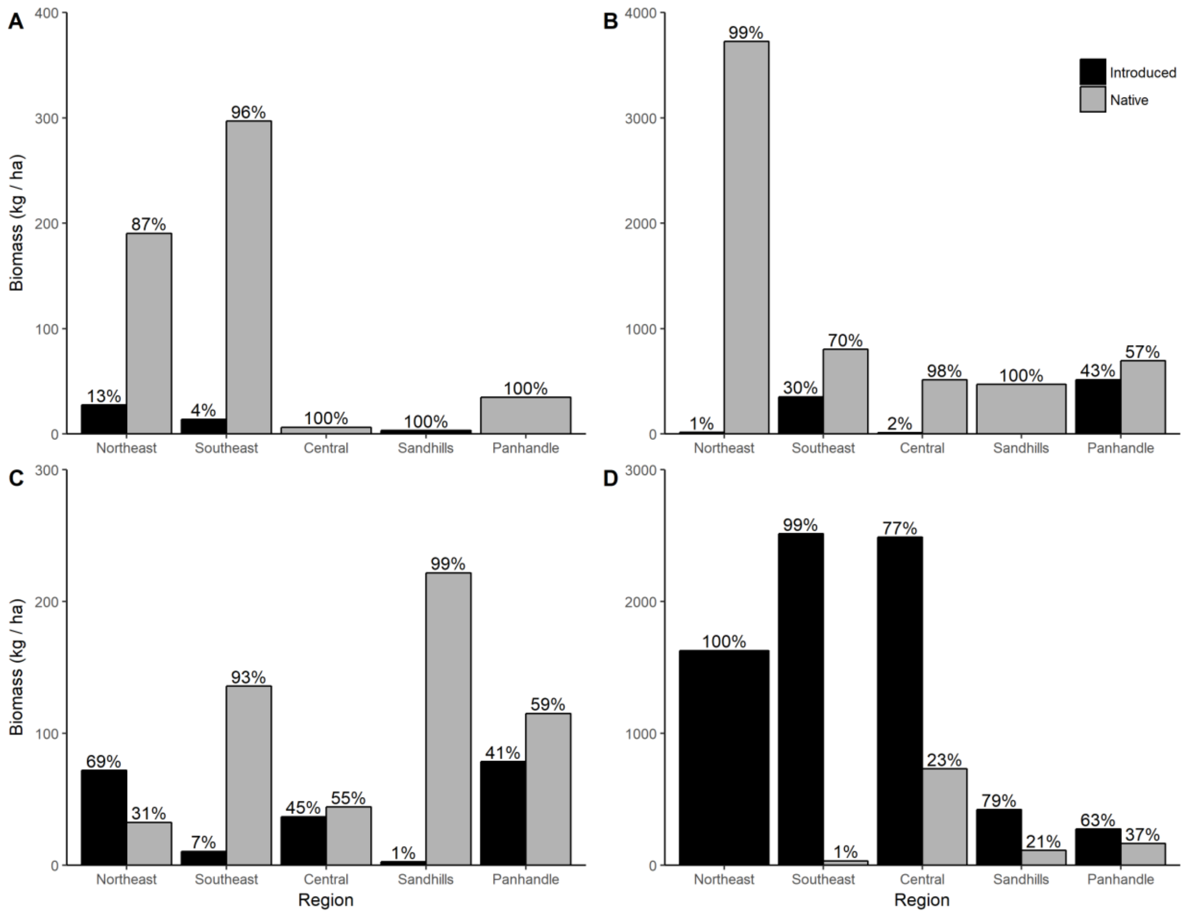

Figure 6. Aboveground biomass of A) seeded introduced and seeded native forb, B) seeded introduced and seeded native grass, C) volunteer introduced and native forb, and D) volunteer introduced and native grass clipped in August 2009 in each study region, Nebraska, USA. Numbers above bars indicate percentage of weight per region.

APPENDIX

APPENDIX Table 1. Relative species composition (based on biomass) for each region. Data collected in August 2009, Nebraska, USA. Last column is percent of biomass of grand total.

	Region					
Common name	Northeast	Southeast	Central	Sandhills	Panhandle	Total
Alfalfa (*Medicago sativa* L.)	0	0	1	0	1	0
American Deervetch (*Lotus purshianus* (Benth.) F. Clements & E. Clements *ex* Otley)	0	0	0	0	0	0
Annual Sunflower (Helianthus annuus L.)	0	0	0	5	2	1
Barnyardgrass (*Echinochla crus-galli* (L.) P. Beauv.)	0	0	0	0	0	0
Big Bluestem (*Andropogon gerardii* Vitman)	2	3	2	0	0	2
Birds-Foot Trefoil (*Lotus corniculatus* L.)	0	2	0	0	0	0
Black Medic (*Medicago lupulina* L.)	0	0	0	0	0	0
Blackeyed Susan (*Rudbeckia hirta* L.)	0	0	0	0	0	0
Blue Grama (*Bouteloua gracilis* (Willd. *ex* Kunth) Lag. *ex* Griffiths)	0	1	0	0	2	0
Blue Salvia (*Salvia azuera* Michx.)	1	0	0	1	0	1
Brittle Cactus (*Opuntia fragilis* (Nutt.) Haw.)	0	0	0	0	0	0
Buffalograss (*Buchloe dactyloides* (Nutt.) Englem.)	0	1	11	0	6	3
Canada Bluegrass (*Poa compressa* L.)	0	0	0	0	0	0
Canada Goldenrod (*Solidago canadensis* L.)	0	0	0	0	0	0
Canada Thistle (*Cirsium arvense* (L.) Scop.)	0	0	0	0	0	0
Common Knotweed (*Polygonum aviculare* L.)	1	0	0	0	0	0
Crested Wheatgrass (*Agrogyron cristatum* (L.) Gaertn.)	0	0	0	0	2	0
Cudweed Sagewort (*Artemisia ludoviciana* Nutt.)	0	0	0	1	0	0
Curlycup Gumweed (*Grindelia squarrosa* (Pursh) Dunal)	1	0	0	0	2	0
Daisy Fleabane (*Erigeron strigosus* Muhl *ex* Willd.)	0	0	0	0	0	0
Dandelion (*Taraxacum officinale* G.H. Weber *ex* F.H. Wigg.)	0	0	0	0	0	0

Dogwood (*Cornus dummondii* C. A. Mey.)	0	1	2	0	0	1
Downy Bromegrass (*Bromus tectorum* L.)	0	0	0	0	2	0
Eastern Gamagrass (*Tripsacum dactyloides* (L.) L.)	16	0	0	0	0	7
Fetid-Marigold (*Dyssodia papposa* (Vent.) A. S. Hitchc.)	0	0	0	0	0	0
Fourpoint Evening Primrose (*Oenothera bienis* L.)	0	0	0	0	0	0
Goatsbeard (*Tragopogon dubius* Scop.)	0	0	0	0	0	0
Grayhead Coneflower (*Ratibida pinnta* (Vent.) Barnhart)	0	0	0	0	0	0
Green Sagewort (*Artemisia dracunculus* L.)	0	0	0	0	0	0
Hairy Goldaster (*Heterotheca villosa (*Pursh) Shinners)	0	0	0	0	2	0
Hairy Grama (*Bouteloua hirsuta* Lag.)	0	0	0	0	0	0
Hairy Vetch (*Vicia villosa* Roth)	0	0	0	0	0	0
Heath Aster (*Aster ericoides* L.)	0	0	0	1	3	1
Hoary Puccoon (*Lithospermum incisum* Lehm.)	0	0	0	0	0	0
Horseweed (*Conyza canadensis* (L.) Cronquist)	0	0	0	0	0	0
Indiangrass (*Sorghastrum nutans* (L.) Nash)	0	6	4	0	0	2
Intermediate Wheatgrass (*Elymus hispidus* (Opiz) Meld.)	0	4	0	0	12	3
Junegrass (*Koeleria macrantha* (Ledeb.) Schult.)	0	0	0	2	0	0
Kentucky Bluegrass (Poa pratensis L.)	13	8	11	8	1	10
Kochia (*Kochia scoparia* (L.) Schrad.)	0	0	0	1	1	0
Lambsquarters (*Chenopodium album* L.)	0	0	0	0	0	0
Lemon Scurfpea (*Psoralidium lanceolatum* (Pursh) Rydb.)	0	0	0	0	0	0
Little Barley (*Hordeum pusillum* Nutt.)	0	0	0	0	0	0
Little Bluestem (Schizachyrium scoparium (Michx.) Nash)	1	0	1	14	13	4
Maximilian Sunflower (*Helianthus maximiliani* Schrad.)	0	6	0	0	0	1
Missouri Goldenrod (*Solidago missouriensis* Nutt.)	0	0	0	0	0	0
Narrow-Leaf Four-O'Clock (*Mirabilis linearis* (Pursh) Heimerl)	0	0	0	0	0	0
Needleandthread (*Stipa comata* Trin. & Rupr.)	0	0	0	1	0	0
Orchardgrass (*Dactylis glomerata* L.)	2	7	0	0	0	2

Partridge Pea (*Chamaecrista fasciculate* (Michx.) Greene)	0	0	0	0	0	0
Pepper Weed (*Lepidium densiflorum* Schrader)	0	0	0	0	0	0
Prairie Cordgrass (*Spartina pectinata* Link)	0	0	2	0	0	0
Prairie Rose (*Rosa arkansana* Porter *ex* Porter & J.M. Coult.)	1	0	0	1	0	1
Prairie Sandreed (*Calamovilfa longifolia* (Hook) Scribn.)	0	0	0	3	2	1
Purple Lovegrass (*Eragrostis spectabilis* (Pursh) Steud.)	0	0	0	0	0	0
Purple Prairieclover (*Dalea purpurea* Venten.)	0	0	0	0	1	0
Purple Sandgrass (*Triplasis purpurea* (Walter) Chapm.)	0	0	0	1	0	0
Purpletop (*Tridens flavus* (L.) A. S. Hitchc.)	0	0	0	0	0	0
Redclover (*Trifolium pretense* L.)	1	0	1	2	0	1
Redroot Pigweed (*Amaranthus retroflexus* L.)	0	0	0	0	0	0
Reed Canarygrass (*Phalaris arundinacea* L.)	1	0	0	0	0	0
Rush Skeletonplant (*Lygodesmia juncea* (Pursh) D. Don *ex* Hook)	0	0	0	0	0	0
Russian Thistle (*Salsola tragus* L.)	0	0	0	3	0	0
Sand Bluestem (*Andropogon gerardii* subsp. *hallii* (Hack.) J. Wipff)	0	0	0	3	0	0
Sand Dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray)	0	0	0	3	13	2
Sand Lovegrass (*Eragrostis trichodes* (Nutt.) A. W. Wood)	0	0	0	2	0	0
Sand Paspalum (*Paspalum setaceum* Michx. var. *stramineum* (Nash) D. J. Banks)	0	0	0	0	0	0
Scribner's Panicum (*Panicum oligosanthes* Schult. var. *scribnerianum* (Nash) Fernald)	0	0	0	1	0	0
Sedge (*Carex* sp.)	0	0	0	0	0	0
Sideoats Grama (*Bouteloua curtipendula* (Michx.) Torr.)	0	2	0	0	6	1
Silky Prairieclover (*Dalea villosa* (Nutt.) Sprengel.)	0	0	0	0	0	0
Silver Sagebrush (*Artemisia cana* Pursh)	0	0	0	0	1	0
Sixweeks Fescue (*Vulpia octoflora* (Walter) Rydb.)	0	0	0	0	0	0
Smooth Bromegrass (*Bromus inermis* Leyess.)	15	11	40	18	9	20

Smoothseed Wildbean (*Strophostyles leiosperma* (Torr. & A. Gray) Pipper).	0	0	0	0	0	0
Spurge (*Euphorbia* sp.)	0	0	0	0	0	0
Stiff Flax (*Linum rigidum* Pursh)	0	0	0	1	0	0
Stiff Sunflower (*Helianthus pauciflorus* Nutt.)	0	0	0	0	0	0
Sulfur Cinquefoil (*Potentilla recta* L.)	0	0	0	0	0	0
Sweetclover (*Melilotus officinalis* (L.) Pallas)	1	0	0	0	5	1
Switchgrass (*Panicum virgatum* L.)	15	15	13	21	0	15
Tall Fescue (*Lolium arundinaceum* (Schreb.) S. J. Darbyshire)	11	20	5	0	0	7
Tenpetal Mentzelia (*Mentzilla decapetala* (Pursh *ex* Sims) Urban & Gilg *ex* Gilg)	0	0	0	0	0	0
Texas Croton (*Croton texensis* (Klotzsch) Mull. Arg.)	0	0	0	0	0	0
Timothy (*Phleum pretense* L.)	2	0	0	0	0	0
Unknown Annual	0	0	0	0	1	0
Unknown Forb	0	0	0	0	0	0
Upright Prairie Coneflower (*Ratibida columnifera* (Nutt.)Wooton & Standl.)	0	0	0	0	0	0
Virginia Groundcherry (*Physalis virginiana* P.Mill.)	0	0	0	1	0	0
Western Ragweed (*Ambrosia psilostachya* DC.)	1	1	0	1	6	1
Western Wheatgrass (*Elymus smithii* (Rydb.) Gould)	12	11	3	0	6	6
White Prairieclover (*Dalea candida* Michx *ex* Willd.)	0	0	0	0	0	0
Wild Licorice (*Glycyrriza lepidota* Pursh)	1	0	0	2	0	0
Wooly Plantain (*Plantago patagonica* Jacq.)	0	0	0	0	0	0
Yarrow (*Achillea millefolium* Piper)	0	0	0	0	0	0
Yellow Foxtail (*Setaria pumila* (Poir.) Roem. & Schult.)	0	0	0	0	0	0
Total ($\bar{\boldsymbol{x}}$)	4384	3534	3140	1694	1850	29203

FINAL REPORT

Adapting NDOR's Roadside Seed Mixture for Local Site Conditions

Walter Schacht and Jon Soper

Introduction

The Nebraska Department of Roads (NDOR) has considerable challenges with its objectives of rapidly establishing and maintaining a diverse and vigorous vegetation cover on roadsides. Establishing vegetation quickly on NDOR roadsides is important because the vegetation cover will stabilize the slopes and reduce the rate of soil erosion. In the last three decades, the seeding mixture for roadsides has switched from rapidly-establishing, exotic cool-season grasses to complex mixtures of slower-establishing, native grasses and wildflowers. The move to the newer, complex mixture(s) has been in response to interest expressed by the general public and other state and federal agencies in native plant communities and because of the desirable characteristics of native grasses (e.g., drought resilience and deep root systems). Overall, NDOR seeding mixture objectives are to select species that 1) are native, 2) are showy and attractive to the general public, 3) are adapted to roadside conditions, 4) establish relatively rapidly, 5) provide a relatively dense cover, and 6) contribute to permanent cover. The seeding mixtures should tolerate poor soil conditions and repeated mowing, while still producing a roadside that is visually appealing and diverse.

To meet these objectives, NDOR has developed separate seeding mixtures to be used on roadside shoulders (Type B) and backslopes (Type A). The shoulder mixture is dominated by short growth-form grass species and mixtures for this seeding area have been similar across the state. The backslope mixture is more diverse than the shoulder mixture and is composed of tall and mid-grasses and forbs (a.k.a., wildflowers). The backslope mixture changes from predominately tall-grass species in the eastern sections of Nebraska to mid-grasses in the western section of Nebraska.

When selecting species for mixtures, it is generally best to select species that are adapted to local site conditions. The backslope mixtures have had some consideration in regard to local conditions when selecting species, by changing the types and amounts of tall and mid-grasses or cool-season and warm-season grasses. The same does not hold true for the shoulder mixture, which was the uniform for the sites tested across the state. With the expense of seeding projects, the use of species adapted to local site conditions become even more important. Currently, NDOR has not investigated the suitability of species in existing mixtures. If the species that demonstrate limited adaptability to local conditions could be identified and removed, then the remaining species should be more effective at rapidly establishing and stabilizing the site over the long-term.

Objectives

The primary objectives of this study are to evaluate roadside seeding segments statewide to determine what species from the seeding mixtures are currently represented and/or what non-seeded (volunteer) species occur. With this information, NDOR can develop site-specific seeding mixtures that will succeed in stabilizing the disturbed roadside, while supporting NDOR Environmental Section's long-term plan for roadside landscapes.

Study Design and Sampling Methodology

Study Design

At the initiation of the project, a list of possible research sites was developed by NDOR staff using the following criteria. Sites were selected: (1) that had both shoulders (Type B) and backslopes (Type A) and preferably an erosion control seeding, (2) that had seeding project completion dates between 1990 and 1998, and (3) that were located on highways with an east-west orientation. From this list, UNL staff conducted site visits to evaluate appropriateness of individual sites for inclusion in the study. Sites were further evaluated on the following criteria for shoulders and backslopes: (1) located on a level landscape position, (2) were a minimum of 400 meters in length and (3) seeded species were present. In 2008, two sites were selected in each of 5 NDOR landscape regions (Table 1; Figure 1). No sites were found in landscape region E that met the criteria for study site selection. Representative seeding mixtures used on backslopes in the other landscape regions are given in Table 2. After site selection was completed, NDOR maintenance staff marked sites with signage to remove areas from annual mowing during project duration.

Data collection

Relative species composition of sites was determined using the modified-step point (MSP) method (Owensby 1957) in June and August of 2008 and 2009. Two hundred points were sampled on both the shoulders and backslopes on each of the four sampling dates. Relative species composition was determined of both seeded and non-seeded on each of the sampling dates.

Standing crop was determined by destructive harvest (clipping) of herbaceous plant material on all sites for both shoulders and backslopes in August 2009. Samples were separated by species and placed into individual sample bags. Samples were dried in a forced-air oven at

60°C for 48 hours and weighed. Weight of the individual species was used to calculate relative species composition by weight for the individual species at each site.

Data Analysis

The species included in the Type B mixture were uniform for the entire state, which allowed all Type B data to be analyzed with ANOVA (Analysis of Variance) for landscape region effect on relative species composition. ANOVA was applied to relative species composition data from the MSP and standing crop sampling.

Seeding mixtures used on backslopes (Type A) differed among landscape regions; therefore, using ANOVA to compare site botanical composition among landscape regions was not possible. Each site within landscape region was analyzed separately. The actual botanical composition at the time of sampling each site was compared to the expected botanical composition using Kendall's tau rank correlation analysis. The rank order was based on botanical composition, the species with the highest percentage composition was ranked highest and the species with the lowest percentage composition was ranked lowest. The expected botanical composition was developed by NDOR staff based on seeding rates and likelihood of a species to persist after 10 years post seeding. The expected rank and actual rank (based on vegetation sampling at the sites) of seeded and non-seeded species for the Jansen backslope is given in Table 3 as an example of the basis for the Kendall's tau rank correlation analysis.

Results

Type B Mixtures

Results from MSP sampling indicated that there were no differences in the relative species composition of seeded species among the landscape regions (p=0.05) for the Type B seeding mixture (Table 4). Seeded species composed 25 to 38% of botanical composition during 2008 and 2009, with western wheatgrass (*Elymus smithii* [Rybd.] Gould), buffalograss (*Buchloe dactyloides* [Nutt.] Engelm.) and tall fescue (*Lolium arundinaceum* [Schreb.] S.J. Darbyshire) as the dominant seeded species. Western wheatgrass composed 8.3 to 19.8% of botanical composition and was the most common of the seeded species. Relative species composition of tall fescue and buffalograss was 8.7 to 11.2% and 4.5 to 8.6%, respectively. Blue grama (*Bouteloua gracilis* [Willd. ex Kunth]) and birdsfoot trefoil (*Lotus corniculatus* L.) were uncommon. Relative species composition of blue grama and birdsfoot trefoil was 0 to 1.9% and 0 to 0.3%, respectively. Oats (*Avena sativia* L.) and perennial ryegrass (*Lolium perenne* L.) were seeded on all sites, but were not detected during sampling in 2008 and 2009.

Overall, the results of the MSP sampling indicate that shoulders were dominated by non-seeded seeded species (Table 4). Smooth bromegrass (*Bromus inermus* Leyss) and Kentucky bluegrass (*Poa pratensis* L.) were the most common non-seeded species and accounted for 23 to 35% of the total botanical composition. Intermediate wheatgrass (*Elymus hispidus* [P.Opiz] Meldris) was detected, but was limited to less than 10% of botanical composition. Relative species composition of sand dropseed (*Sporobolus cryptandrus* [Torr.] A. Gray) and warm-season tall grasses was 2.7 to 5.7% and 4.2 to 7.9%, respectively. Common weedy species in Nebraska were not frequently detected on the shoulders. Downy brome (*Bromus tectorum* L.), kochia (*Kochia scoparia* [L.] Schrad.), Russian thistle (*Salsola tragus* L.), and western ragweed (*Ambrosia psilostachya* DC.) generally composed less than 10% of total botanical composition. As an entire group, non-seeded species composed 64.2 to 75.6% of the botanical composition of the shoulders.

There was no difference ($p>0.05$) in the ground cover of the shoulders among the landscape regions (Table 5). Ground cover was comprised of 66.6 to 76.3% litter, 22.6 to 31.4% bare ground, and 1.1 to 3.9% plant basal area.

Results from the standing crop analysis indicated that there was a difference ($p<0.05$) in relative species composition of seeded species among landscape regions (Table 6). Relative species composition of buffalograss (26.6%) in landscape region C and tall fescue (20.4%) in landscape region B was significantly greater than that in the other landscape regions. Based on weight, the seeded species composed 28.1 to 50.3% of botanical composition in all regions, except in landscape region D. The seeded species were nearly non-existent on the shoulders of the two sites in landscape region D (Nenzel and Crookston).

Non-seeded species were dominant on the shoulders of landscape regions A, D, and F and composed about 50% of the vegetation biomass in landscape regions B and D by weight (Table 6). Introduced, cool-season grasses composed 30 to 53% of the botanical composition on shoulders in landscape regions A and C. Relative species composition of smooth bromegrass was greater than 27% in regions A and C, while relative species composition of Kentucky bluegrass was 21.8% in region A. In regions B and D, relative species composition of the native, warm-season tall grasses was 36% or greater. The botanical composition of shoulders in region F also was dominated by non-seeded species but not by a particular species or group of species. The diversity of non-seeded species on region F shoulders appeared to be considerably more than in other regions. Other grasses and forbs within the non-seeded category, primarily weedy annuals, composed 5.8 to 27.3% of the botanical composition over all study sites.

Type A Mixtures

Results from the rank correlation analysis from the MSP sampling on the backslopes demonstrated that the expected and actual ranks of botanical composition were significantly correlated at a number of sites (Table 7). Actual and expected ranks at both sites in landscape region B, Aurora and Jansen, were significantly correlated at all sampling dates (Tables 8 and 9). The actual and expected ranks at the Creighton site, located in landscape region A, were significantly correlated in June 2008 and August 2009 (Table 10). In landscape region D, actual and expected ranks were correlated at the Nenzel site at all sampling dates (Table 11). Actual and expected ranks at the other sites were not significantly correlated because a seeded species (e.g., switchgrass at Jansen) became dominant over the years or non-seeded species invaded and dominated the site. The actual relative species composition of the backslopes of each site based on MSP are in Tables 12 through 21 and will be reviewed in the Discussion section.

The rank correlation analysis results for the Type A mixture based on weight indicated that there was limited correlation between expected and actual botanical composition (Table 22). There were significant correlations at Aurora and Jansen, in landscape region B, and Nenzel, in landscape region D (Tables 23 through 25). As was seen in the MSP analysis, most sites became dominated by some seeded species or invaded by non-seeded species over time (Tables 26 through 35), thus greatly reducing the occurrence of significant correlations between the expected and actual ranks.

Discussion

Botanical composition of the stands on shoulders based on MSP varied greatly within landscape regions (between sites) and among landscape regions; therefore, significant differences among landscape regions were not detected even though numeric differences were great. Averaged over all dates, seeded species composed only 30% of shoulder stands (Table 4) which is probably a concern; however, the harsh conditions of shoulders on roadsides (e.g., periodic passing of snow plows/graders, spreading of road de-icer material, little or no top soils) create poor conditions for a solid stand of the seeded species and make for situations favorable for invasive, non-seeded species. Based on weight, seeded species composed as much as 50% and as little as 0.3% of the standing biomass (Table 6).

Landscape Region A

Seeded species were common on the shoulders in landscape region A but non-seeded grasses were a major component as well. Modified step-point sampling indicated that the relative species composition of seeded and non-seeded species were similar to that of the other landscape regions (Table 4). The standing crop sampling indicated that relative species composition of smooth bromegrass and Kentucky bluegrass (two non-seeded grasses) was greater on region A sites than on sites in the other regions (Table 6). Along with western wheatgrass, these two non-seeded grasses were dominant on region A shoulders.

The results from the Plainview Type A sampling indicated that the backslope was primarily comprised of switchgrass and eastern gamagrass based on MSP and weight (Tables 12 and 26). Both of these species were seeded on the site, although eastern gamagrass is no longer seeded by NDOR. Little bluestem (Schizachyrium scoparium [Michx.] Nash), indiangrass (*Sorghastrum nutans* [L.] Nash) and intermediate wheatgrass were expected to be major components of this site, but they composed only a small percentage of the botanical composition. All species of forbs were limited on the site and the group accounted for less than 10% of the total species composition. The Plainview site was dominated by two seeded, warm-season grass species, switchgrass and eastern gamagrass, suggesting that the grasses were highly adapted to the site and that a lower seeding rate could have been used. A reduction in seeding rate of these species might have allowed for an increase in the other seeded grass species.

The Type A sampling at the Creighton site demonstrated that the site is dominated by non-seeded species, primarily tall fescue (Tables 13 and 27). Tall fescue was not included in the Type A seeding mixture, but tall fescue was a component of the Type B mixture. In addition to the Type B mixture as a source, NDOR staff suggested that tall fescue was used, as a supplemental species in Type A mixtures, if seed of some species in the mixture was unavailable at the time of seeding. Seeded grass species were common, but as a whole were less than 20% of botanical composition. Tall fescue usually establishes rapidly and can be an effective competitor of the seeded species used in NDOR mixtures, thus limiting establishment of these seeded species. Seeded forbs were not common on the site and accounted for less than 10% of botanical composition by MSP or weight.

Type A seeding mixtures on backslopes in landscape region A generally did not achieve the objective of a diverse stand of seeded species. The reduction or outright exclusion of these species (e.g., switchgrass and eastern gamagrass) at the Plainview site might have resulted in greater site diversity and perhaps could have effected stand longevity. The dominance of tall fescue on the Creighton backslopes suggests that tall fescue should not be used in Type A mixtures and/or seeding rates of tall fescue be reduced in Type B mixtures. However, the low diversity stands at Plainview and Creighton dominated by a few perennial grasses appeared to be effective in stabilizing the sites.

Landscape Region B

Seeded species were common on shoulders in landscape region B, but non-seeded grasses were a strong component as well. Modified step-point sampling indicated that the percentage composition of seeded and non-seeded species on shoulders in region B was similar to the other landscape regions (Table 4). Unlike the other landscape regions, however, seeded species based on weight composed a majority of the shoulder vegetation with western wheatgrass and tall fescue being the most common (Table 6). Warm-season tall grasses (switchgrass, big bluestem (*Andropogon gerardii* Vitman and indiangrass) were the principal non-seeded species on the shoulders. Inclusion of warm-season tall grasses in the Type B seeding mixture could be considered as a means to reduce invasion potential of smooth bromegrass and Kentucky bluegrass.

The backslope at Aurora was dominated by tall fescue and orchardgrass (*Dactylis glomerata* L.) based on both MSP and weight (Tables 14 and 28). Tall fescue was not included in the Type A mixture for the site, but it was a component of the Type B mixture. In addition to the Type B mixture as a source, NDOR staff suggested that tall fescue was used, as a supplemental species in Type A mixtures, if seed of some species in the mixture were unavailable at the time of seeding. Orchardgrass was not seeded but could have been present in the hay mulch after seeding. Intermediate wheatgrass was recorded during sampling, but was generally less than 10% of botanical composition by MSP or weight. Seeded warm-season grasses were present on the site, but generally composed less than 10% of the botanical composition by MSP. However, warm-season grasses accounted for 20% of the biomass sampled at the site. Switchgrass and indiangrass were the dominant seeded warm-season grasses, with very little sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.) and little bluestem. Seeded forbs were sampled at the site, but percentage composition was low based on both MSP and weight.

Cool-season grasses were dominant on the backslope of the Jansen site (Tables 15 and 29). Intermediate wheatgrass was the most common seeded species based on either MSP (22.4 to 50.0%) or weight (26.5%). Switchgrass was the second most common grass, composing 5.8 to

16.7% of botanical composition based on MSP and 20.9% based on weight. The other seeded warm-season grasses were detected during sampling, but were generally less than 20% of botanical composition by MSP or weight. Percentage composition of seeded forbs was generally less than 15% based on MSP, but was much greater based on weight (27.1 %) with a relative species composition of 23.2% for Maximilian sunflower (*Helianthus maximiliani* Schrad.). Maximilian sunflower can grow to over one meter in height, with numerous stems radiating from one basal point. An individual plant can produce a large amount of biomass even though its relative species composition based on MSP is low.

Overall, cool-season grasses dominated region B backslopes with limited amounts of warm-season grasses and forbs. A reduction in the seeding rate of cool-season grasses might be advantageous to warm-season grasses and increase warm-season grass populations. Removing the cool-season grass canopy by mowing in late spring and early summer could weaken cool-season grasses and help increase the competitive capabilities of warm-season grasses. Specifically, mowing at the elongation stage of the cool-season grasses would be stressful to cool-season grasses and would open the canopy in the early summer for warm-season grass growth.

Landscape Region C

As in the other landscape regions, both seeded and non-seeded species were common on shoulders in landscape region C. Modified step-point sampling indicated that the percentage composition of seeded and non-seeded species on shoulders in region C was similar to the other landscape regions (Table 4). Similar to landscape region B, seeded species accounted for around 50% of the vegetation biomass (Table 6). However, unlike the other regions, buffalograss was the principal seeded species observed in the stand. Western wheatgrass and tall fescue also were common on the shoulders. Even though region C sites had good stands of the seeded species, non-seeded species composed about 50% of stand by weight with Kentucky bluegrass being the most common.

Backslopes at Arnold and Ragan were dominated by non-seeded species (smooth brome and Kentucky bluegrass) and warm-season tall grasses (switchgrass, big bluestem and indiangrass) based on MSP and weight (Tables 16, 17, 30, and 31). Percentage composition of non-seeded species (40 to 60%) was not surprising, given results from other sites, but the percentage composition of warm-season tall grasses (30 to 60%) was greater than expected. The backslope seeding mixture in landscape region C was comprised primarily of mid-height grasses (little bluestem, sideoats grama, and western wheatgrass) but relative species composition of warm-season tall grasses was relatively high based on MSP and weight. Increasing or adding warm-season tall grasses to the Type A mixture might improve the resistance of sites to invasion by exotic cool-season grasses. The seeded mid-height grasses were on the site, but were limited to less than 10% of botanical composition by MSP and weight. Seeded forbs were not common. American deervetch (*Lotus purshianus* F.E. & E.G. Clem. *ex* Otley), an annual native forb, had moved onto the site from the surrounding rangeland and the presence of this species indicated its adaptability to the site.

Landscape Region D

Seeded species were common on the shoulders at the Crookston and Nenzel sites but non-seeded grasses also were prevalent. Modified step-point sampling indicated that the percent composition of seeded and non-seeded species was similar to the other landscape regions (Table 4). By weight, tall and mid-height warm-season grasses (sand bluestem [*Andropogon hallii* Hack.] and little bluestem) composed as much as 46.2% of the shoulder vegetation (Table 6). These species likely moved onto the shoulders from the backslopes or surrounding native rangeland. The inclusion of these species could improve site resistance to invasion from annual species. Buffalograss, tall fescue, and birdsfoot trefoil are not adapted to the sandy, semi-arid conditions of the Sandhills. Blue grama and western wheatgrass also did not establish and persist well on the sites in region D. Modifying the Type B seeding mixture for landscape region D needs to be considered.

The Nenzel site was the most representative of the seeding mixture for all sites sampled (Tables 7 and 18). Warm-season grasses were 45.9 to 59.1% of the botanical composition by MSP. Little bluestem was the most common warm-season grass with a relative species composition of 20.3 to 35.1% by MSP. By weight, relative species composition of little bluestem was 43.7% (Table 32). Relative species composition of the other seeded warm-season species was generally 10% or less by MSP and weight. The non-seeded species on the site were not the exotic cool-season grasses seen at the other sites sampled. At the Nenzel site, prairie junegrass (Koeleria macranantha [Ledeb.]) and native perennial forbs were the most common non-seeded species. These species likely established on the site from hay mulch or the surrounding rangeland.

Non-seeded species were dominant on backslopes of the Crookston site (Table 19). Percentage composition of non-seeded species based on MSP was 55.5 to 76.6%. Downy brome was the most common of the non-seeded species with a relative species composition of 9.6 to 26.5% of botanical composition. Seeded warm-season grasses based on MSP were common with sand bluestem composing the greatest proportion at 9.6 to 27.0%. Relative species composition of other warm-season grasses generally was less than 10%. By weight, sand bluestem and switchgrass were the most common seeded species while an assortment of native grasses, forbs, and shrubs composed most of the non-seeded species. Overall, seeded warm-season grasses composed 40.7% of biomass produced at the site (Table 33). The differences in results between the sampling methods indicate that the seeded warm-season grasses, while lower in number of individuals, actually produced more biomass, and the numerous individuals of non-seeded species filled the space between the large warm-season grass plants.

Results from the Nenzel and Crookston sites indicate that the Type A mixture used is adapted to the landscape region. Results at Crookston indicate that annual species can become an issue on these sites (Tables 19 and 33). Soils of landscape region D are primarily sand and susceptible to disturbance. Limiting the amount of disturbance on these sites could help to reduce the open soil that allows annual species to invade and thus limit the establishment of perennial grasses.

Landscape Region E

Possible sites in landscape region E were very limited and the site that was available failed to meet the minimum site requirements.

Landscape Region F

The seeded grasses of the Type B seeding mixture established and were present at the time of sampling at the Chadron and N-71 sites but the non-seeded species were dominant. Modified step-point sampling indicated that the percentage composition of seeded and non-seeded species for landscape region F was similar to the other landscape regions (Table 4). Blue grama, buffalograss, and western wheatgrass were the only seeded species that persisted, and combined to make up 28.8% of the botanical composition by weight (Table 6). Sand dropseed was the principal non-seeded species (18.7%) by weight although western ragweed (10.4%) and a number of other grasses and forbs were present. Sand dropseed is a native, short to mid-height grass that provides good ground cover. It appears to be adapted to the shoulder in landscape region F and could be considered for inclusion in the Type B seeding mixture.

The backslope at the Chadron site was dominated by little bluestem, sideoats grama and pubescent intermediate wheatgrass and combined to compose 60 to 75% of the backslope vegetation based on MSP and weight (Tables 20 and 34). The other seeded grasses were much less common. Seeded forbs were limited on the site and generally were less than 10% of botanical composition by MSP or weight. Non-seeded species occurred on the site, and composed 6.1-32.6% of botanical composition by MSP but were less than 5.0% based on weight.

Seeded species were not common on the backslope of the N-71 site (Tables 21 and 35). Non-seeded species composed 86.3 to 95.9% of botanical composition by MSP whereas they composed 69.3% by weight. Pubescent intermediate wheatgrass was the principal seeded species by weight (15.6%); other seeded species composed less than 10% of the total vegetation by weight. Based on MSP, non-seeded species were predominantly annuals while sand dropseed and fringed sagebrush (*Artemisia frigida* Willd) were major non-seeded components based on weight.

Results from the Chadron site indicate that the mid-height grasses in the Type A seeding mixture are adapted to conditions in landscape region F (Tables 20 and 34). The mid-height grasses were found on the N-71 site but at low amounts (Tables 21 and 35). Mid-height grasses are likely well suited to region F although establishment and persistence of these grasses cannot be certain because of the relatively high variability (i.e., unpredictability) of climatic conditions (e.g., rainfall) at the time of seeding.

Recommendations

Shoulders

As already stated, botanical composition of the sampled sites was extremely variable. The differences in botanical composition between sites within landscape region were surprisingly high and likely resulted from such things as differences in date of seeding (e.g., spring vs. fall) and year of seeding, last-minute changes in the seeding mixture, and differences in seeding contractors. Variable conditions between sites at seeding make it difficult to draw strong conclusions about the adaptability of the Type B seeding mixture to roadside conditions. However, the following are some conclusions that can be made about seeding mixtures for shoulders.

***Type B Seeding Mixture Adaptability**.* The Type B seeding mixture appeared to be well adapted to landscape region B and C where the seeded species composed about 50% of the vegetation. The seeding mixture was only moderately or marginally adapted to regions A and F where the seeded species composed only 25 to 30% of the standing vegetation. The Type B seeding mixture was totally unsuccessful in region D. *Recommendations:*

- Continue with the Type B seeding mixture in landscape regions B and C.
- Modify Type B seeding mixture in regions A and F.
    - Remove or greatly reduce the seeding rate of blue grama because it has very low stand persistence in regions A and F as well as in the other landscape regions. Increase the seeding rate of buffalograss and western wheatgrass and/or experiment with other shortgrasses such as hairy grama.
    - Reduce the seeding rate of tall fescue because it can spread onto the backslopes and/or become dominant on the shoulders. Following seeding, tall fescue tends to emerge and establish relatively rapidly –

providing for an early vegetation cover. The other seeded perennial grasses are slower in establishment but are native and do not require as frequent mowing as tall fescue. Tall fescue, as a rapidly establishing species, could be replaced largely by annual or short-lived perennial grasses such as perennial ryegrass. These grasses would disappear from the site in a couple of years and not invade the backslopes.

- Develop a new seeding mixture for landscape region D.
    - Buffalograss is native to Nebraska but is not adapted to sandy soils and is not found in the Sandhills. Tall fescue and birdsfoot trefoil also are not adapted to the sandy, semi-arid conditions of the Sandhills. Remove these three species from the seeding mixture and experiment with other short to mid-height grasses such as hairy grama and sand dropseed.
    - The native warm-season grasses in the Type A seeding mixture appear to be adapted to the shoulder conditions. They were found on the shoulders of the sites in region D and should be considered for inclusion in the Type B mixture.
- Consider removal of birdsfoot trefoil in the Type B seeding mixture.

Management of Shoulder Vegetation. A number of management tools exist that could be used to manipulate botanical composition of roadside vegetation following establishment. However, NDOR does not commonly apply management practices once the project has been closed; therefore, management practices such as prescribed burning or herbicide application are not considered as means to control invasive, non-seeded plants and to favor seeded plants.

Recommendations:

- Current practice is to mow vegetation on the shoulders periodically through the growing season. Because most of the invasive, non-seeded species are cool-season grasses, timing of mowing could be used to suppress non-seeded cool-season grasses, to open the canopy, and to favor growth of warm-season grasses. Mowing should be timed so that the prevalent cool-season grasses are in elongation stage and the warm-season grasses have just started growing. In most years, this would be in late May. In years with good late summer/early fall growing conditions, mowing in early September could suppress cool-season grasses.
- Interseeding native warm-season grasses into degraded roadside stands of vegetation (where cool-season grasses are prevalent) should be considered. In 2012 and 2013, we are conducting field studies to evaluate interseeding as a management technique to increase wildflowers in roadside vegetation cover.
- Herbicides could be used as a stand maintenance tool to control the invasive, cool-season grasses on the shoulders. Proper herbicides and timing would be effective in controlling the invasive, cool-season grasses but seeded cool-season grasses and legumes would also be suppressed. Although the use of herbicides would reduce plant diversity and require periodic application, the invasive, cool-season grasses could be effectively controlled.

Backslopes

Similar to the shoulders, botanical composition of the sampled sites was extremely variable, and the variable conditions among sites at seeding make it difficult to draw strong conclusions about the adaptability of Type A seeding mixtures to roadside conditions. Below are several recommendations coming from field observations and a review of study results.

Type A Seeding Mixture Adaptability. Most of the plant species included in the Type A seeding mixtures across the state appear to be adapted to regional growing conditions and commonly establish as part of these diverse stands (15+ species in the seeding mixtures). However, as might be expected, most species do not persist because there is little to no management during the life of the stand to create conditions favorable to the entire set of seeded species; thus diversity of the desired species declines over time. This certainly works against NDOR's goal of having a diverse stand of native species on the backslopes of roadsides. The backslopes of most sites in this study had good ground cover and were stable – there were very few indicators of soil loss; therefore, the plant communities that developed on these sites were meeting the purpose of the vegetation cover in minimizing soil erosion on the site. These simple plant communities, however, were often dominated by invasive, non-seeded species and were not the diverse, native plant communities that are expected/envisioned based on the complex seeding mixtures used. The following recommendations are based on the assumptions that the goals and management practices of NDOR will not change. *Recommendations:*

- Minimize the inclusion of perennial forbs/wildflowers in the Type A seeding mixture. Even if perennial forbs establish following seeding, most of them do not persist. They are the most expensive components of the Type A seeding mixture and are the least likely to establish and persist. Based on observations and results of this study, we recommend including the following perennial forbs in the five landscape regions studied:

Forb Species	**Landscape Region A**	**Landscape Region B**	**Landscape Region C**	**Landscape Region D**	**Landscape Region F**
Upright Prairie Coneflower	X	X	X	X	X
Purple Prairie Clover	X	X	X	X	X

Maximillian Sunflower	X	X			
Red Clover	X	X			
Pitcher Sage	X	X			

- Consider inclusion of more annual forbs in Type A seeding mixtures. They establish relatively well and the seeds are relatively inexpensive. Many of them are showy and conspicuous in the first year or two following seeding and show up again when growing conditions are favorable. Annual forbs to consider: American deervetch, partridge pea, plains coreopsis, and low lupine.
- Several species of native, warm-season tallgrasses were not included in Type A seeding mixtures used in the various landscape regions, especially in the eastern part of the state. Even when not seeded, several of these warm-season tallgrasses were found on backslopes when sampling. We recommend including big bluestem, indiangrass, switchgrass, little bluestem, and sideoats grama in all Type A seeding mixtures in landscape regions A, B, and C.
- A few seeded species, such as switchgrass and eastern gamagrass, became dominant in some cases, especially in eastern Nebraska. There may not be anything that can be done at the time of seeding, but keeping seeding rates of these species low may be a means of avoiding their dominance.
- Tall fescue should not be included in Type A seeding mixtures even when seeds of other perennial grasses are not available. Tall fescue establishes relatively rapidly and appears to be aggressive and persistent once established on backslopes.
- Seeding mixture in landscape region D seems appropriate.

- Seeding mixture in landscape region F seems appropriate although sand dropseed appeared to be well adapted to sites in this region and should be included in the mixture.

Management of Backslope Vegetation. As with the shoulders, there are a number of management tools that could be used to manipulate botanical composition of backslope vegetation following establishment. However, NDOR does not commonly apply management practices once the project has been closed; therefore, management practices such as prescribed burning or herbicide application are not considered as means to control invasive, non-seeded plants and to favor seeded plants. *Recommendations:*

- Current practice is to mow vegetation on the backslopes every third year in August or September. Because most of the invasive, non-seeded species are cool-season grasses, timing of mowing could be used to suppress non-seeded cool-season grasses, to open the canopy, and to favor growth of warm-season grasses. Mowing should be timed so that the prevalent cool-season grasses are in elongation stage and the warm-season grasses have just started growing. In most years, this would be in late May. In years with good late summer/early fall growing conditions, mowing in early September could suppress cool-season grasses.
- Interseeding forbs/wildflowers (and perhaps warm-season grasses) into degraded roadside stands of vegetation (where cool-season grasses are prevalent) should be considered. In 2012 and 2013, we are conducting field studies to evaluate interseeding as a management technique to increase wildflowers in roadside vegetation cover.

- Herbicides could be used as a stand maintenance tool to control the invasive, cool-season grasses on backslopes. Proper herbicides and timing would be effective in controlling the invasive, cool-season grasses but seeded cool-season grasses and legumes would also be suppressed. Although the use of herbicides would reduce plant diversity and require periodic application, the invasive, cool-season grasses could be effectively controlled.

Table 1. Location of research sites by landscape region.

NDOR Landscape Region	Location	Year of seeding
A	Creighton (Highway 59)	1998
	Plainview (Highway 20)	1994
B	Aurora (Highway 34)	1998
	Jansen (Highway 136)	1992
C	Arnold (Highway 92)	1998
	Ragan (Highway 4)	1995
D	Crookston (Highway 20)	1991
	Nenzel (Highway 20)	1993
F	Chadron (Highway 20)	1993
	N-71 (Highway 88)	1996

Figure 1. Location of study sites within landscape regions, as depicted by color.

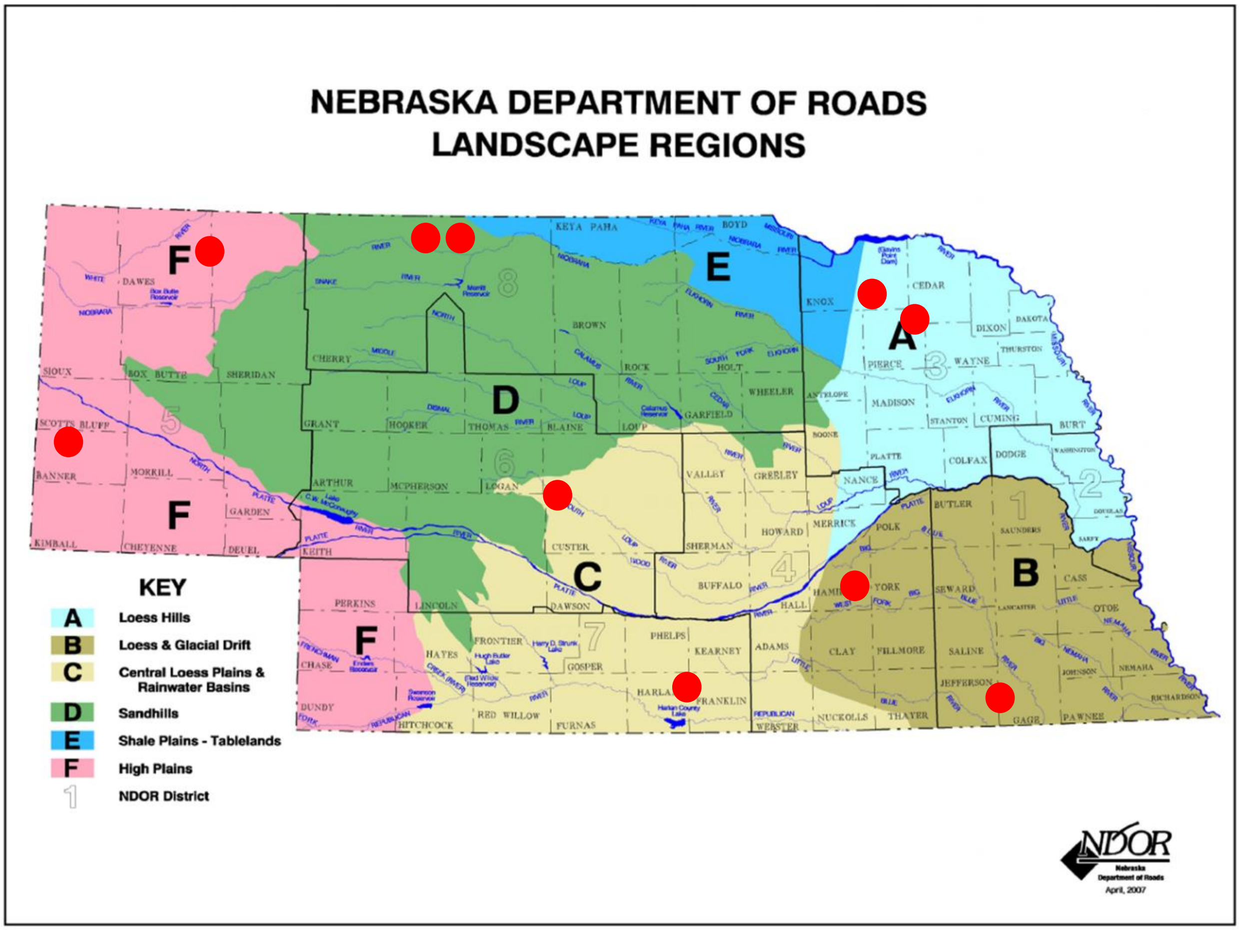

Table 2. Seeded species on backslope locations at Creighton, Jansen, Arnold, Nenzel and Chadron.

	Landscape Region				
Species	A (Creighton)	B (Jansen)	C (Arnold)	D (Nenzel)	F (Chadron)
Big Bluestem	X	X			
Blackeyed Susan	X	X	X		
Blanket Flower					X
Blue Flax	X				
Canada Wildrye	X				
Crested Wheatgrass					X
Dames Rocket	X	X	X		X
Evening Primrose	X				
False Sunflower	X				
Grayhead Prairie Coneflower		X			
Hairy Vetch		X		X	X
Indiangrass	X	X	X		
Intermediate Wheatgrass	X	X	X		
Lance-leaved Coreopsis					X
Leadplant	X		X		
Little Bluestem	X	X	X	X	X
Maximillian Sunflower		X			
Mexican Red-Hat					X
Oats	X				X
Ox-Eye Daisy		X			
Partridge Pea	X	X			
Pitcher Sage	X				
Plains Coreopsis		X			
Prairie Sandreed				X	
Pubsecent Wheatgrass					X
Purple Prairie Clover	X	X	X		X
Red Clover	X	X			
Reed Canarygrass		X			
Rocky Mountain Penstemon					X
Rye				X	

Sand Bluestem				**X**	
Sand Dropseed				**X**	
Sand Lovegrass	**X**		**X**	**X**	
Shell-leaf Penstemon	**X**		**X**		
Sideoats Grama	**X**	**X**	**X**		**X**
Sweetclover			**X**	**X**	
Switchgrass	**X**	**X**	**X**	**X**	
Upright Prairie Coneflower	**X**		**X**		**X**
Western Wheatgrass			**X**	**X**	**X**

Table 3. Representative example of Expected rank and actual rank for seeded species at the Jansen backslope, June 2008. (Some non-seeded species were expected to invade and establish on the site.)

Species	Expected Rank	Actual Rank
Little Bluestem	1	4
Intermediate Wheatgrass	2	2
Indiangrass	3	6
Switchgrass	4	5
Sideoats Grama	5	12.5
Grayhead Coneflower	6	12.5
Non-seeded species	7	1
Red Clover	8	3
Other seeded grasses	9	8
Purple Coneflower	10	12.5
Blackeyed Susan	11	12.5
Other seeded forbs	12	7
Partridge Pea	13	12.5
Plains Coreopsis	14	12.5
Hairy Vetch	15	12.5
Dames Rocket	16	12.5

Table 4. Relative species composition of shoulder sites in Nebraska for all landscape regions.

Species	Seeding Rate (lbs of PLS/acre)	June 2008	August 2008	June 2009	August 2009
		%			
Seeded		**25.8**	**30.8**	**32.6**	**38**
Western Wheatgrass	4 to 8	8.3	12.2	13.9	19.8
Blue Grama	2	0	1.9	1.8	1.3
Buffalograss	3 to 6	8.9	12.1	8.7	11
Tall Fescue	8 to 20	8.6	4.5	7.9	5.9
Birdsfoot Trefoil	4 to 5	0	0.1	0.3	0
Oats	10	0	0	0	0
Perennial Rye	8 to 10	0	0	0	0
Non-seeded		**75.6**	**71.5**	**70.9**	**64.2**
Downy Brome		3.1	1.4	1.1	0.4
Kentucky Bluegrass		17.3	9.1	17.8	12.1
Intermediate Wheatgrass		9.2	5.2	0.9	0.9
Sand Dropseed		4.5	2.7	3.2	5.7
Smooth Bromegrass		17.9	14.2	16.8	13.8
Warm-Season Tall Grasses		4.2	7.9	6.4	7.8
Kochia		6.3	6.4	7.3	2.9
Russian Thistle		1.5	2.1	1.8	2.2
Western Ragweed		2.5	7.9	1.9	5.7
Other Grasses and Forbs		9.1	14.6	13.7	12.7

Table 5. Relative ground cover of shoulder sites in Nebraska for all landscape regions based on MSP method.

	2008		2009	
	June	August	June	August
	%			
Litter	73.3	66.6	76.3	67.9
Bare Ground	22.8	31.4	22.6	30.6
Plant Hits	3.9	2	1.1	1.5

Table 6. Relative species composition by standing crop of shoulder sites in Nebraska, August 2009, based on weight.

		Landscape Region				
Species	**Seeding Rate (lbs of PLS/acre)**	**A**	**B**	**C**	**D**	**F**
				%		
Seeded		**28.1**	**54.1**	**46.8**	**0.3**	**28.8**
Western Wheatgrass	4 to 8	27.5	26.7	7.9	0.3	10.1
Blue Grama	2	0.5	1.5	0	0	5.2
Buffalograss	3 to 6	0[b]	1.7[b]	26.6[a]	0[b]	13.5[b]
Tall Fescue	8 to 20	0.1[b]	20.4[a]	12.4[b]	0[b]	0[b]
Birdsfoot Trefoil	4 to 5	0	3.8	0	0	0
Oats	10	0	0	0	0	0
Perennial Rye	8 to 10	0	0	0	0	0
Non-seeded		**71.9**	**45.9**	**53.2**	**99.7**	**71.2**
Downy Brome		0	0	0.3	0	0.2
Kentucky Bluegrass		21.8[a]	2.0[b]	5.4[b]	5.3[b]	0.8[b]
Intermediate Wheatgrass		0	0	0	0	1.3
Sand Dropseed		0	0	0.5	3.7	18.7
Smooth Bromegrass		31.1[a]	0.9[b]	27.2[a]	16.6[b]	7.7[b]
Warm Season Tall Grasses		2.1[b]	36.0[a]	3.3[b]	46.2[a]	4.7[b]
Kochia and Russian Thistle		0.1	0	0	6.1	0.1
Western Ragweed		3	1.3	0	1.5	10.4
Other Grasses and Forbs		13.9	5.8	16.4	20.2	27.3

Table 7. Kendall's tau rank correlation scores based on MSP.

Region	Site	June 2008	August 2008	June 2009	August 2009
A	**Creighton**	**0.5201***	0.38191	0.34171	**0.56097***
	Plainview	0.17056	0.08528	0.08528	0.04264
B	**Aurora**	**0.4949***	**0.39451***	**0.4111***	**0.55201***
	Jansen	**0.52296***	**0.4949***	**0.39973***	**0.47216***
C	**Arnold**	0.32757	0.18257	0.38103	0.03616
	Ragan	0.0252	0.24343	0.18257	0.03616
D	**Crookston**	0.22111	0.25042	0.22111	0.42212
	Nenzel	**0.62312***	**0.54272***	**0.62312***	**0.5201***
F	**Chadron**	0.12792	0.25042	0.44877	0.040452
	N-71	0.185	0.32375	0.25584	0.17056

***Indicates significant correlation (p=0.05)**

Table 8. Comparison of the actual and expected rank order at Aurora backslope location based on MSP.

		Actual Rank			
Species	**Expected Rank**	**June 2008**	**August 2008**	**June 2009**	**August 2009**
Little Bluestem	1	3	7	10.5	4
Intermediate Wheatgrass	2	1	2	4	2
Indiangrass	3	5	5	1	1
Switchgrass	4	4	4	3	5
Sideoats Grama	5	11.5	12	10.5	6
Grayhead Coneflower	6	11.5	8	5	11.5
Red Clover	7	2	3	2	3
Other Seeded Grasses	8	7	1	10.5	11.5
Purple Coneflower	9	11.5	12	10.5	11.5
Blackeyed Susan	10	11.5	12	10.5	11.5
Other Seeded Forbs	11	6	6	10.5	7
Partridge Pea	12	11.5	12	10.5	11.5
Plains Coreopsis	13	11.5	12	10.5	11.5
Hairy Vetch	14	11.5	12	10.5	11.5
Dames Rocket	15	11.5	12	10.5	11.5

Table 9. Comparison of the actual and expected rank order at Jansen backslope location based on MSP.

Species	Expected Rank	Actual Rank June 2008	August 2008	June 2009	August 2009
Little Bluestem	1	6	2	8	2
Intermediate Wheatgrass	2	1	1	1	1
Indiangrass	3	5	8	5	7
Switchgrass	4	2	5	2	3
Sideoats Grama	5	7	6	7	9
Grayhead Coneflower	6	8	7	6	6
Red Clover	7	12.5	9	9	10
Other Seeded Grasses	8	3	3	3	4
Purple Coneflower	9	10	10	10	11
Blackeyed Susan	10	11	11	11	12
Other Seeded Forbs	11	4	4	4	5
Partridge Pea	12	12	12	12	13
Plains Coreopsis	13	13	13	13	14
Hairy Vetch	14	14	14	14	8
Dames Rocket	15	15	15	15	15

Table 10. Comparison of the actual and expected rank order at Creighton backslope location based on MSP.

Species	Expected Rank	Actual Rank	
		June 2008	August 2009
Little Bluestem	1	3	2
Indiangrass	2	1	1
Intermediate Wheatgrass	3	2	4
Other seeded grasses	4	4	3
Other Forbs	5	5	5
Switchgrass	6	8.5	7
Pitcher Sage	7	8.5	9
Red Clover	8	6	6
Partridge Pea	9	8.5	9
Dames Rocket	10	8.5	9

Table 11. Comparison of the actual and expected rank order at Nenzel backslope location based on MSP.

		Actual Rank			
Species	**Expected Rank**	**June 2008**	**August 2008**	**June 2009**	**August 2009**
Switchgrass	1	2	3	2	3
Little Bluestem	2	1	1	1	1
Prairie Sandreed	3	3	4	3	5
Sand Bluestem	4	4	2	4	2
Sand Dropseed	5	5	5	5	4
Western Wheatgrass	6	8	8	8	8.5
Sand Lovegrass	7	8	8	8	6
Sweetclover	8	8	8	8	8.5
Hairy Vetch	9	8	8	8	8.5
Rye	10	8	8	8	8.5

Table 12. Relative species composition of Plainview backslope, Region A, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**94.3**	**66.7**	**89.0**	**90.9**
Big Bluestem	1.9	13.3	0.0	0.0
Eastern Gamagrass	11.3	6.7	41.1	39.8
Indiangrass	3.8	6.7	0.0	0.0
Intermediate Wheatgrass	0.0	0.0	0.0	1.1
Little Bluestem	0.0	0.0	0.0	0.0
Switchgrass	67.9	33.3	39.7	44.3
Pitcher sage	0.0	0.0	4.1	1.1
Wild Rose	9.4	6.7	4.1	4.5
Non-seeded	**5.7**	**33.3**	**11.0**	**9.1**
Canada Goldenrod	0.0	13.3	2.7	2.3
Other Grasses and Forbs	5.7	20.0	8.2	6.8

Table 13. Relative species composition of Creighton backslope, Region A, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
		%		
Seeded	**19.3**	**23.9**	**10.3**	**22.1**
Big Bluestem	2.8	5.1	2.9	4.1
Indiangrass	5.5	0.0	1.5	7.6
Intermediate Wheatgrass	5.5	6.5	0.0	3.4
Little Bluestem	2.8	8.7	3.7	4.8
Switchgrass	0.0	0.0	0.0	0.7
Red Clover	0.7	0.7	0.7	0.7
Other Seeded Forbs	2.1	2.9	1.5	0.7
Non-seeded	**80.7**	**76.1**	**89.7**	**77.9**
Tall Fescue	65.5	68.1	67.7	66.9
Orchardgrass	1.4	5.1	16.2	6.2
Other Grasses and Forbs	13.8	2.9	5.9	4.8

Table 14. Relative species composition of Aurora backslopes, Region B, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**24.68**	**18.30**	**14.38**	**23.97**
Big Bluestem	1.3	3.9	0.0	0.0
Indiangrass	2.5	2.6	2.6	8.2
Intermediate Wheatgrass	5.7	3.3	3.3	5.5
Little Bluestem	4.4	0.7	0.7	2.1
Sideoats Grama	0.0	0.0	0.0	1.4
Switchgrass	3.2	2.6	2.6	2.1
Grayhead Coneflower	0.0	0.7	0.7	0.0
Maximillian Sunflower	2.5	1.3	1.3	0.7
Red Clover	5.1	3.3	3.3	4.1
Non-seeded	**75.3**	**81.7**	**85.6**	**76.0**
Tall Fescue	62.0	60.7	55.6	56.2
Orchardgrass	7.6	15.7	18.8	17.8
Other Grasses and Forbs	5.7	5.3	11.3	2.1

Table 15. Relative species composition of Jansen backslopes, Region B, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**91.5**	**89.4**	**69.7**	**76.5**
Big Bluestem	8.5	7.1	10.6	9.4
Indiangrass	4.3	0.0	7.6	2.4
Intermediate Wheatgrass	50.0	45.9	22.7	22.4
Little Bluestem	3.2	16.5	0.0	14.1
Sideoats Grama	2.1	5.9	1.5	1.2
Switchgrass	14.9	5.9	16.7	10.6
Black-eyed Susan	0.0	0.0	0.0	3.5
Grayhead Coneflower	1.1	1.2	1.5	3.5
Maximillian Sunflower	7.4	7.1	9.1	9.4
Non-seeded	**8.5**	**10.6**	**30.3**	**23.5**
Western Wheatgrass	0.0	0.0	19.7	1.2
Carex sp.	0.0	1.2	3.0	4.7
Bindweed	3.2	0.0	0.0	2.4
Stiff Sunflower	2.1	4.7	4.6	2.4
Other Grasses and Forbs	3.2	4.7	3.0	12.9

Table 16. Relative species composition of Arnold backslope, Region C, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**37.5**	**41.1**	**69.2**	**66.7**
Indiangrass	3.1	1.8	9.6	0.0
Intermediate Wheatgrass	3.1	0.0	0.0	0.0
Little Bluestem	3.1	1.8	3.8	0.0
Sideoats Grama	1.6	0.0	0.0	0.0
Switchgrass	26.6	37.5	53.8	66.7
Western Wheatgrass	0.0	0.0	1.9	0.0
Non-seeded	**62.5**	**58.9**	**30.8**	**33.4**
American Deervetch	15.6	19.6	1.9	10.0
Big Bluestem	3.1	3.6	0.0	3.3
Lemon Scurfpea	3.1	1.8	7.7	0.0
Prairie Sandreed	4.7	7.1	0.0	3.3
Sand Dropseed	4.7	0.0	3.8	0.0
Scribner's Panicum	1.6	1.8	5.8	3.3
Carex sp.	6.3	3.6	0.0	0.0
Western Ragweed	4.7	5.4	0.0	0.0
Other Grasses and Forbs	18.68	16.0	11.6	13.4

Table 17. Relative species composition of Ragan backslope, Region C, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**45.2**	**62.5**	**59.0**	**51.4**
Indiangrass	6.5	20.0	30.8	17.1
Little Bluestem	3.2	7.5	0.0	0.0
Switchgrass	25.8	35.0	23.1	34.3
Western Wheatgrass	0.0	0.0	5.1	0.0
Sweetclover	3.2	0.0	0.0	0.0
Upright Prairie Coneflower	6.5	0.0	0.0	0.0
Non-seeded	**54.8**	**37.5**	**41.0**	**48.6**
Big Bluestem	16.1	20.0	5.1	22.9
Prairie Cordgrass	12.9	15.0	23.1	20.0
Stiff Sunflower	6.5	0.0	7.7	0.0
Other Grasses and Forbs	19.4	2.5	5.1	5.7

Table 18. Relative species composition of Nenzel backslope, Region D, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**49.3**	**50.6**	**45.9**	**59.1**
Little Bluestem	20.3	23.5	26.4	35.1
Prairie Sandreed	8.1	3.6	4.4	3.5
Sand Bluestem	8.1	10.2	3.8	9.4
Sand Dropseed	4.1	3.6	2.5	4.1
Sand Lovegrass	0.0	0.0	0.0	0.6
Switchgrass	8.8	9.6	8.8	6.4
Non-Seeded	**50.7**	**49.5**	**54.2**	**41.0**
Fourpoint Eveningprimrose	2.0	2.4	0.0	0.0
Green Sagewort	6.1	4.8	3.0	3.5
Indiangrass	0.7	0.0	3.8	2.3
Lemon Scurfpea	0.0	0.0	10.1	0.6
Missouri Goldenrod	2.7	3.6	0.0	0.0
Purple Prairie Clover	1.4	3.0	1.3	3.5
Prairie Junegrass	15.5	8.4	9.4	10.5
Carex sp.	0.0	1.2	5.7	1.8
Six-weeks Fescue	3.4	1.2	0.0	0.0
Western Ragweed	4.1	3.0	1.9	7.0
Other Grasses and Forbs	14.8	21.8	18.9	11.7

Table 19. Relative species composition of Crookston backslopes, region D, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**23.4**	**25.3**	**37.3**	**44.6**
Little Bluestem	2.1	2.4	2.4	1.4
Prairie Sandreed	4.3	0.0	8.4	6.8
Sand Bluestem	9.6	10.8	14.5	27.0
Sand Dropseed	3.2	6.0	2.4	4.1
Sand Lovegrass	0.0	0.0	0.0	0.0
Switchgrass	0.0	1.2	0.0	5.4
Western Wheatgrass	4.3	4.8	9.6	0.0
Non-Seeded	**76.6**	**74.8**	**62.7**	**55.5**
Annual Sunflower	4.3	1.2	2.4	4.1
Carex sp.	7.4	4.8	3.6	0.0
Clammy Groundcherry	4.3	0.0	0.0	0.0
Cudweed Sagewort	3.2	6.0	6.0	2.7
Downy Brome	18.1	26.5	9.6	12.6
Intermediate Wheatgrass	6.4	1.2	0.0	0.0
Needleandthread	3.2	3.6	9.6	6.8
Prairie Junegrass	4.3	1.2	4.8	6.8
Six-weeks Fescue	2.1	0.0	0.0	0.0
Wild Rose	3.2	3.6	3.6	5.4
Western Rageweed	5.3	0.0	3.6	6.8
Other Grasses and Forbs	14.9	26.6	19.3	10.4

Table 20. Relative species composition of Chadron backslopes, region F, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**67.4**	**72.7**	**86.3**	**93.9**
Blue Grama	0.0	0.5	0.5	0.6
Crested Wheatgrass	0.0	0.0	1.6	0.0
Little Bluestem	19.8	31.1	27.5	30.0
Pubescent Wheatgrass	25.7	17.5	22.0	38.9
Sideoats Grama	16.0	11.5	22.0	23.3
Western Wheatgrass	0.0	4.4	9.3	0.6
Purple Prairie Clover	5.9	7.7	3.3	0.6
Non-seeded	**32.6**	**27.3**	**13.7**	**6.1**
Downy Brome	13.9	4.4	3.9	1.7
Sand Dropseed	2.7	1.5	0.5	0.0
Western Ragweed	1.6	1.1	0.5	0.3
White Clover	5.9	1.6	0.0	0.0
Yellow Sweetclover	1.6	2.7	2.2	1.1
Other Grasses and Forbs	7.0	16.0	6.6	3.0

Table 21. Relative species composition of N-71 backslopes, Region F, based on MSP.

Species	June 2008	August 2008	June 2009	August 2009
	%			
Seeded	**4.1**	**9.8**	**8.9**	**13.8**
Crested Wheatgrass	0.7	3.7	1.9	1.9
Little Bluestem	0.0	0.6	0.6	0.0
Pubescent Wheatgrass	2.7	5.5	3.8	8.1
Sideoats Grama	0.0	0.0	0.0	0.6
Western Wheatgrass	0.7	0.0	2.5	3.1
Purple Prairie Clover	0.0	0.0	0.0	0.0
Non-seeded	**95.9**	**90.2**	**91.1**	**86.3**
Downy Brome	31.5	28.8	14.0	6.9
Sand Dropseed	11.0	18.4	21.7	28.1
Curlycup Gumweed	8.2	8.6	1.9	5.0
Russian Thistle	0.0	0.0	0.0	7.5
Slender Greenthread	0.0	0.0	7.6	0.0
Snow-on-the-Mountian	4.8	0.6	3.2	5.6
Western Ragweed	6.2	3.7	2.5	3.8
Kochia	18.5	18.4	22.9	15.6
Yellow Sweetclover	6.2	3.7	4.5	1.3
Other Grasses and Forbs	9.6	8.0	12.7	12.5

Table 22. Kendall's tau rank correlation based on species composition by weight in August, 2009.

Region	Site	August 2009
A	Creighton	0.18699
	Plainview	0.18091
B	Aurora	**0.41876***
	Jansen	**0.47001***
C	Arnold	0.31032
	Ragan	0.24343
D	Crookston	0.36599
	Nenzel	**0.48617***
F	Chadron	0.40452
	N-71	0.28894

***Indicates significant correlation**

Table 23. Comparison of the actual and expected rank order at Aurora backslope location, based on weight during August, 2009.

Species	Expected Rank	Actual Rank
Little Bluestem	1	6
Indiangrass	2	1
Switchgrass	3	5
Intermediate Wheatgrass	4	4
Partridge Pea	5	12.5
Grayhead Coneflower	6	12.5
Red Clover	7	3
Other Seeded Forbs	8	2
Hairy Vetch	9	12.5
Purple Coneflower	10	12.5
Other Seeded Grasses	11	12.5
Sideoats Grama	12	7
Blackeyed Susan	13	12.5
Dames Rocket	14	12.5
Plains Coreopsis	15	12.5

Table 24. Comparison of the actual and expected rank order at Jansen backslope location, based on weight during August, 2009.

Species	Expected Rank	Actual Rank
Little Bluestem	1	9
Indiangrass	2	5
Switchgrass	3	3
Intermediate Wheatgrass	4	1
Partridge Pea	5	14
Grayhead Coneflower	6	8
Red Clover	7	7
Other Seeded Forbs	8	2
Hairy Vetch	9	14
Purple Coneflower	10	14
Other Seeded Grasses	11	4
Sideoats Grama	12	6
Blackeyed Susan	13	10
Dames Rocket	14	14
Plains Coreopsis	15	14

Table 25. Comparison of the actual and expected rank order at Nenzel backslope location, based on weight during August, 2009.

Species	Expected Rank	Actual Rank
Little Bluestem	1	1
Switchgrass	2	2
Prairie Sandreed	3	7
Western Wheatgrass	4	10
Sand Bluestem	5	3
Sweetclover	6	10
Hairy Vetch	7	6
Sand Lovegrass	8	5
Sand Dropseed	9	4
Rye	10	10

Table 26. Relative species composition of Plainview backslopes, Region A, based on weight.

Species	August 2009
	%
Seeded	**98.7**
Eastern Gammagrass	50.4
Indiangrass	0.5
Switchgrass	38.4
Pitcher sage	5.1
Wildrose	4.3
Non-seeded	**1.3**
Other Grasses and Forbs	1.3

Table 27. Relative species composition of Creighton backslopes, Region A, based on weight.

Species	August 2009
	%
Seeded	**26.2**
Big Bluestem	7.5
Indiangrass	0.6
Intermediate Wheatgrass	1.4
Little Bluestem	5.0
Switchgrass	8.1
Purple Prairie Clover	1.3
Red Clover	2.3
Non-seeded	**73.8**
Orchardgrass	8.3
Tall Fescue	45.0
Timothy	11.6
Other Grasses and Forbs	9.0

Table 28. Relative species composition of Aurora backslopes, Region B, based on weight.

Species	**August 2009**
	%
Seeded	**33.4**
Indiangrass	18.0
Intermediate Wheatgrass	2.2
Little Bluestem	1.0
Sideoats Grama	0.7
Switchgrass	1.0
Maximillian Sunflower	6.6
Red Clover	3.9
Non-seeded	**66.6**
Tall Fescue	38.8
Orchardgrass	25.6
Other Grasses and Forbs	2.2

Table 29. Relative species composition of Jansen backslopes, Region B, based on weight.

Species	August 2009
	%
Seeded	**96.5**
Big Bluestem	12.3
Indiangrass	6.0
Intermediate Wheatgrass	26.5
Little Bluestem	0.6
Sideoats Grama	2.3
Switchgrass	20.9
Blackeyed Susan	0.3
Dames Rocket	0.0
Grayhead Coneflower	1.7
Hairy Vetch	0.0
Maximillian Sunflower	23.2
Red Clover	1.9
Non-seeded	**4.5**
Other Grasses and Forbs	4.5

Table 30. Relative species composition of Arnold backslopes, Region C, based on weight.

Species	August 2009
	%
Seeded	**86.6**
Indiangrass	1.3
Intermediate Wheatgrass	2.0
Little Bluestem	2.9
Switchgrass	77.2
Sideoats Grama	2.2
Purple Prairie Clover	1.1
Non-seeded	**13.4**
Other Grasses and Forbs	13.4

Table 31. Relative species composition of Ragan backslopes, Region C, based on weight.

Species	August 2009
	%
Seeded	**74.1**
Indiangrass	38.2
Little Bluestem	3.5
Switchgrass	32.4
Non-seeded	**26.9**
Big Bluestem	21.9
Other grasses and forbs	4.2

Table 32. Relative species composition of Nenzel backslopes, Region D, based on weight.

Species	August 2009
	%
Seeded	**64.0**
Hairy Vetch	0.6
Little Bluestem	43.7
Prairie Sandreed	0.3
Sand Bluestem	7.3
Sand Dropseed	3.2
Sand Lovegrass	1.3
Sweetclover	0.0
Switchgrass	7.6
Non-seeded	**36.0**
American Licorice	5.5
Clammy Groundcherry	6.9
Pitcher Sage	4.6
Prairie Junegrass	10.1
Other Grasses and Forbs	9.1

Table 33. Relative species composition of Crookston backslopes, Region D, based on weight.

Species	August 2009
	%
Seeded	**40.7**
Little Bluestem	0.5
Sand Bluestem	14.3
Sand Dropseed	4.0
Sand Lovegrass	7.6
Switchgrass	14.3
Non-seeded	**59.3**
American Licorice	10.6
Cudweed Sagewort	5.2
Wild Rose	11.1
Needleandthread	10.4
Prairie Junegrass	10.1
Other Grasses and Forbs	11.9

Table 34. Relative species composition of Chadron backslopes, Region F, based on weight.

Species	August 2009
	%
Seeded	**95.6**
Crested Wheatgrass	1.3
Little Bluestem	37.8
Pubescent Wheatgrass	32.6
Sideoats Grama	18.7
Western Wheatgrass	3.6
Purple Prairie clover	1.6
Non-seeded	**4.4**
Other Grasses and Forbs	4.4

Table 35. Relative species composition of N-71 backslopes, Region F, based on weight.

Species	August 2009
	%
Seeded	**30.7**
Crested Wheatgrass	7.6
Little Bluestem	3.2
Pubescent Wheatgrass	15.6
Purple Prairie clover	2.9
Sideoats Grama	1.4
Non-seeded	**69.3**
Annual Sunflower	6.9
Downy Brome	8.7
Curlycup Gumweed	6.2
Fringed Sagebrush	7.8
Prairie Sandreed	10.4
Sand Dropseed	16.1
Other Grasses and Forbs	13.3