PRAIRIE RESTORATION OUTCOMES IN THE NORTHERN TALLGRASS AND MIXED GRASS PRAIRIE ECO-REGION

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

MASTER OF SCIENCE

ABSTRACT

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Prairie restorations have been implemented using a variety of seeding methods and techniques. The outcomes of these prairie restorations have not been surveyed on United States Fish and Wildlife Service lands in eastern North Dakota and western Minnesota. A survey was initiated to determine the outcomes of these restorations and to provide guidance on what restoration methods and techniques produce desired results. A total of 123 sites were sampled across the area in various upland positions. Data collection took place during June, July, and August in 2009 and 2010. Information collected from the field and from restoration plans included plant community data, physical data, seed mixtures, planting methods, planting age, and invasive/undesirable species information. Plant composition sampling was conducted using ocular estimation of plant cover percent (%) within three randomly placed 2 m^2 quadrats placed in a triangular fashion 12 meters apart. A non-metric multi-dimensional scaling analysis was utilized, featuring correlations of restoration characteristics based on groupings from cluster analysis and multi-response permutation procedures. Logistic regressions were also performed to determine probabilities of membership to certain groups and Akaike's Information Criterion (AIC) was used to compare among factors and models. From these analyses it was found that prairie restorations in the study area can be placed into three significantly different groups ($p<0.05$). One group (Group 1) consisted of younger restorations that had high variability, which are likely to diverge into one of two other groups. One of the other two groups

(Group 2) consists of older restorations, lacking in diversity and high in undesirable grass species. The last group (Group 3) had a variable age, moderate to high diversity, and low invasive/undesirable species which tend to be those most desired characteristics for restorations. A high probability of membership to Group 3, greater than 8 out of ten restorations, occurred when: 1) a minimum of 9 grass species was seeded, 2) ten forb species were included in the seed mix, and 3) broadcast seeding was utilized. Dormant season was the most dependable planting season for membership in Group 3, with winter (10/21 – 4/14) being a hundred percent predictor. The results of this survey will guide restoration practitioners as to the probability of their planned restorations developing into the two dominant groups and the characteristics of restorations that have a high probability of meeting desired restoration conditions. Knowledge of these probabilities will assist managers in developing efficient and self-sustainable prairie restorations and can help in the planning of conservation under increasingly high costs and constraints on management.

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INTRODUCTION

The tallgrass and mixed grass prairie ecosystems are degraded and fragmented. The remaining tallgrass prairie in North Dakota is less than 1% of pre-settlement conditions. Less than 9% remains unaltered in Minnesota. Mixed grass prairies have also declined as much as 30.5% to 99.9% (NPWRC 2006 a). This trend is very common throughout Midwestern prairies. The decline has spurred interest and implementation of the protection, conservation, and restoration of native prairie.

The Prairie Pothole Region (Figure 1) supports over 300 species of migratory birds

Figure 1. Map of the Prairie Pothole Region of North America (NPWRC 2006 b).

and is the primary breeding areas for the continent's waterfowl (USFWS 2010 a). The mission of the Prairie Pothole Joint Venture is to implement conservation programs that sustain populations of waterfowl, shorebirds, other water birds and prairie land birds at objective levels through targeted wetland and grassland protection, restoration and enhancement programs. The vision of the United States Fish and Wildlife Service

(USFWS) Prairie Pothole Joint Venture is to have abundant populations of wetland and grassland birds that can be sustained in perpetuity for the benefit of all people who enjoy these species.

Prairie restoration outcomes of today are not well documented. However, some theories and methodical insights of progressive restoration techniques have been suggested or documented (Tilman 1997, Weber 1999, Wilson 2002, Martin et al. 2005, USDA-NRCS 2005, Biondini 2007, Dailey 2008, Grygiel et al. 2009). Most research has been restricted to relatively small, localized areas created for this sole purpose. This study provides a landscape wide approach in identifying past to present restoration method outcomes. The sites are all unique in relation to the natural environment which they are found. Sites are found to be similar, never the same.

Most of the research on restored prairies is conducted in a fairly uniform environment. Typically, data are collected from sites that are in the same general vicinity, small scale, and limited representation of natural settings. There is little knowledge based on actual past to current restorations, in use today. Restored prairies are developed on heterogeneous landscapes in a variety of conditions. Further research is needed in "field" conditions from actual working restorations.

The objective of this study was to investigate the outcomes and results of prior restorations and the methods used to create the restorations. This study was specifically designed to provide guidance on restoration techniques based on probabilistic outcomes. The study also provides information from a large survey of different restorations in the field using common restoration theories. The results will provide insight on restoration methods and direction for future restorations. Increases in effectiveness and efficiency of prairie restorations should be expected from this study.

LITERATURE REVIEW

A restoration, in the simplest form, is a method of accelerating natural succession (Luken 1990). Stepping back to historic patterns, it is realized that prairie ecosystems are a result of periodic disturbance and succession from natural occurring physical processes (Axelrod 1985, Hobbs et al. 2007). Landscape manipulation and fragmentation suppress these processes (Sampson et al. 2004). Therefore, it is unlikely to create a prairie restoration that can simply be left alone. Remnant prairies are the closest to restoration objectives, although most are a poor representation of past conditions.

Prairie restorations are a product of trying to mimic remnant conditions and/or satisfy objectives of the restorer. There are two general forms of restorations. An ecological restoration is the recovery of any natural system that has been degraded, damaged or destroyed (SER 2004). In contrast to an ecological restoration is a functional restoration. These functions include increases in productivity, ecosystem services, erosion control, wildlife habitat, grazing lands, and other economic resource objectives (Prach et al. 2007). Usually, these restoration types are significantly different in terms of species diversity, composition, and structure (Wilson 2002).

Goals of ecological restorations may include: 1) returning degraded ecosystems to more historical natural conditions with the anticipation of recovering biodiversity, inhibiting invasion, and long term self sustainability; and 2) promoting functional equivalency to native ecosystems, meaning that function and structure found in undisturbed ecosystems develops within restored ecosystems (Zedler and Lindig-Cisneros 2000). There is a difference between restoring an ecosystem and creating one for objective needs. Conservation needs and marketable demands have a part in this concept.

Confirmed suspicions show that many prairies in North Dakota are substantially invaded by introduced species of grasses and forbs and overrun by native shrubs (Grant et. al. 2009). However, there are instances where a successful prairie community requires low management to obtain favorable results. These qualities included high diversity, self-sustainability, invasion resistance, and adequate habitat needs.

Typical Restoration Characteristics

Patterns of species richness and composition have been the objective of many studies (Tilman 1997, Sluis 2002, Hooper et al. 2005, Guo et al. 2006, Biondini 2007, Brudvig et al. 2007, Grygiel et al. 2009). Restorations have, thus far, been unable to reproduce or mimic the patterns of native grasslands (Schott and Hamburg 1997, Sperry 1994). So far, restored prairies have fallen short of resembling remnant standards (Kindscher and Tieszen 1998, Sluis 2002, Martin et al. 2005, Polley et al. 2005).

Restored prairies are not similar to remnant prairies (similarity index = 28.9 - 25.9%), primarily because restored prairies tend to have fewer prairie forbs (Dailey 2008). Seedling emergence of rare prairie forbs and grasses is consistently greater when seed diversity is increased. Study results suggest that tallgrass prairie restorations are primarily seed limited and, by adding seeds to grassland restorations, seedling emergence of rare species can be increased (Martin and Wiley 2006).

Species composition may be equally or more important in the assessment of restoration and management success (Henderson 1999). Differences among plant characteristics in physiology, morphology, resource requirements, and life histories enable multiple species to coexist using limiting resources (Hooper 1998). A single species may not fully utilize these resources, thus opening opportunities for others. The invasion of a plant community by non-seeded species is influenced by species composition and generally decreases with increasing species and functional form richness. An increase in number of species added and functional group diversity increases species richness and diversity (Hooper et al. 2005, Biondini 2007).

Most restored prairies are dominated by just a few species, which are composed mostly of grasses. It has long been realized that a reduction of dominant species, results in an increase of rare species, increasing local species richness (Howe 1999, Polley et al. 2007). Emergence of prairie seedlings is a diversity limiting factor, when there is competition with dominant species. Dominant species may also limit the introduction or, emergence of conservative species (Weber 1999). In fact, there are native species that become dominant in many restorations. Species richness in long-term restored prairies generally persists at levels lower than native remnants, largely as a result of C4 grass dominance (Kindscher and Tieszen 1998, Sluis 2002). Studies suggest that competition between dominant grasses, such as *Andropogon gerardii* and *Panicum virgatum*, and subordinant forbs limits plant diversity in restored tallgrass prairie (McCain and Schmitt 2008).

Many restored prairies are also faced with a consistent trend of decreasing species richness and species compositional changes with time. These changes in restorations are in a different direction than in the remnant prairies (Sluis 2002).

Suspected Methods for Success

Currently, restored prairie seeding techniques vary widely. The diversity, evenness, and patchiness of establishment are often highly variable (Wilson et al. 2004, Martin et al. 2005, Polley et al. 2005). The "right" methods are unknown and progress is by trial and error. This trial and error approach could be associated with adaptive management. Adaptive management is a systematic approach for improving resource management by learning from management outcomes (Williams et al. 2007 b). Adaptive management is currently being used as a management tool, to promote replication of native prairies, or obtain successful objective results. Adaptive management can also be a useful tool for restoration implementation as well.

Composition of species in seed mixtures and variations in combinations can determine the probable state of a restoration (Piper and Pimm 2002). Species richness is considered a possible indicator of overall system status (Woodward et al.1999). Increases in the number of species and functional forms in the seed mixture, increases the diversity and heterogeneity of the restoration (Wilson 2000, del Moral et al. 2007). High diversity may also compensate for species loss. The lost species structure and function can more easily be replaced with a highly diverse species pool (Biondini 2007). Replacement with favorable species can be especially important with increased propagule pressure from invasive species. However, with a more diverse seed mixture the chances of dominant species out-competing subdominants are increased (Piper and Pimm 2002). The number of species established is increased, but often the diversity is much less, than in the initial seed mixture.

It is thought, to achieve aboveground biomass variability, which is less than that of growing-season precipitation, the seed mixtures need to have a minimum of nine species and three functional forms (Biondini 2007). Levang-Brilz and Biondini (2002) found that there were three groups of grasses and three groups of forbs, which could be placed into separate functional groups based on growth rate, root development, and nutrient uptake.

Another study suggested that at least 16 species must be seeded to achieve maximum productivity within the mixed grass prairie region of North Dakota (Guo et al. 2006).

High seed densities result in higher coverage and possibly higher production (Kindscher and Tieszen 1998, Wilson et al. 2004, Guo et al. 2006). However, seed density effectiveness is limited due to competition (Piper and Pimm 2002). The conditions that promote the establishment of a diverse and patchy composition are currently unknown (Wilson et al. 2004, Williams et al. 2007 a).

Methods of planting are suspected to have some effect on the success of a restoration. Seasonal climatic variations can contribute to diverse moisture levels. Higher available moisture results in high germination and establishment percentage, while low available moisture can reduce germination and establishment (Wilson 2002). Mechanical planting methods are conducted using two methods, drill or broadcast seeding. Drilling tends to promote grasses, while broadcasting tends to promote forbs (Wilson 2002). However, both grasses and forbs can be established with either.

METHODS

Survey Sites

The survey sites for this study were located in the Northern Tallgrass and Mixed Grass Prairie landscape within the Prairie Pothole Eco-region (NPWRC 2006 b). The focus area consisted of the eastern half of North Dakota and northwestern Minnesota. The sites consisted of US Fish and Wildlife Service property, including waterfowl production areas and wildlife refuges. A portion of the refuge study sites were located on land established by cooperative conservation among 26 agencies led by The Nature Conservancy (USFWS 2010 b). Specific district locations in North Dakota included the Devils Lake Wetlands Management District, Valley City Wetlands Management District, and Tewaukon National Wildlife Refuge. Districts included in Minnesota were the Detroit Lakes Wetlands Management District and Glacial Ridge National Wildlife Refuge. The survey was spread across 14 counties in North Dakota including Benson, Cavalier, Grand Forks, Nelson, Ramsey, Ransom, Richland, Sargent, Towner, Barnes, Cass, Griggs, Steele, and Traill. In Minnesota, Clay, Becker, Polk, and Mahnomen Counties were included in the study.

A total of 123 sites were included in the study (See Appendix A). Sites ranged from 0.5 acres to 400 acres. The year of the establishment ranged from the early 1960's to 2009. Site characteristics were typical of the tallgrass prairie pothole region and the mixed grass prairie pothole region, composed of a mosaic of upland and wetland communities. Each of the survey sites was unique and displayed a variety of soil types and topography. Individual site characteristics and management was not included in consideration for restoration outcomes. Although important factors, site specific characteristics and management is highly variable and very timely to produce results. The survey of a large number of restoration sites compared to a small number prevents any distortion of these factors and gives a respective representation of all sites combined.

Each restoration was managed uniquely in relation to individual variations and demands. Each district may have used different strategies but shared many as well. Based on the available information, the restorations of this study incorporated fire every 3-5 years. There was sporadic grazing and haying taking place if needed and available. Undesirable species were generally managed on a spot treatment basis with mechanical and chemical processes if needed. Bio-control, such as herbivorous weevils, was being used sporadically as well. There were some cases of reseeding, an addition of glyphosphate, mowing early growing stages, and over-spraying to meet objectives. (Personal communication with district employees, Draft Weed Management Plan 2010)

The sample area is considered to have a continental type climate with cold winters and hot summers. The study was conducted over a large area and annual temperatures and precipitation varied geographically. Northeast North Dakota has a 10 year average of 4°C annual mean temperature and an annual mean rainfall of 398.14 mm. East central ND averages 5°C and 387.71 mm of rainfall annually, on a 15 year average. Southeast ND has an average of 6°C and 473.39 mm annually on a 20 year average. Northwest Minnesota averaged 4°C and 418.67 mm annually on a 10 year average (NDAWN 2010).

Northwestern Minnesota and eastern North Dakota have a near average temperature trend during the sampling period. The comparison of the short term temperature trend to the charted time period shows a decreasing average temperature (Figure 2). The Palmer Drought Severity Index (Figure 3) is in a short term decreasing trend but, in comparison to

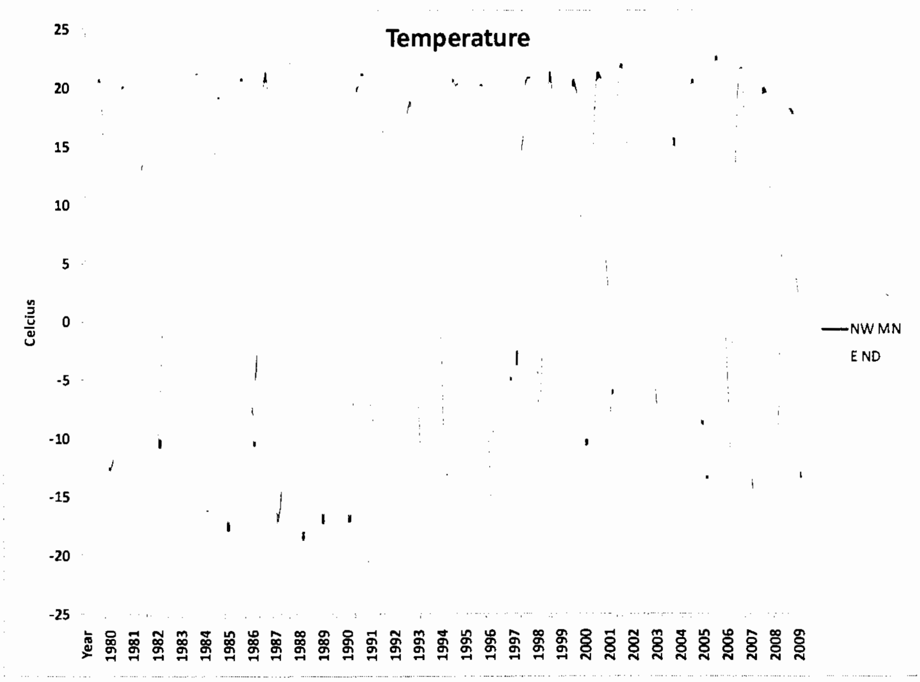

Figure 2. The monthly average temperature (C°) from 1980 to 2010 in Northwestern Minnesota and Eastern North Dakota (NOAA 2010).

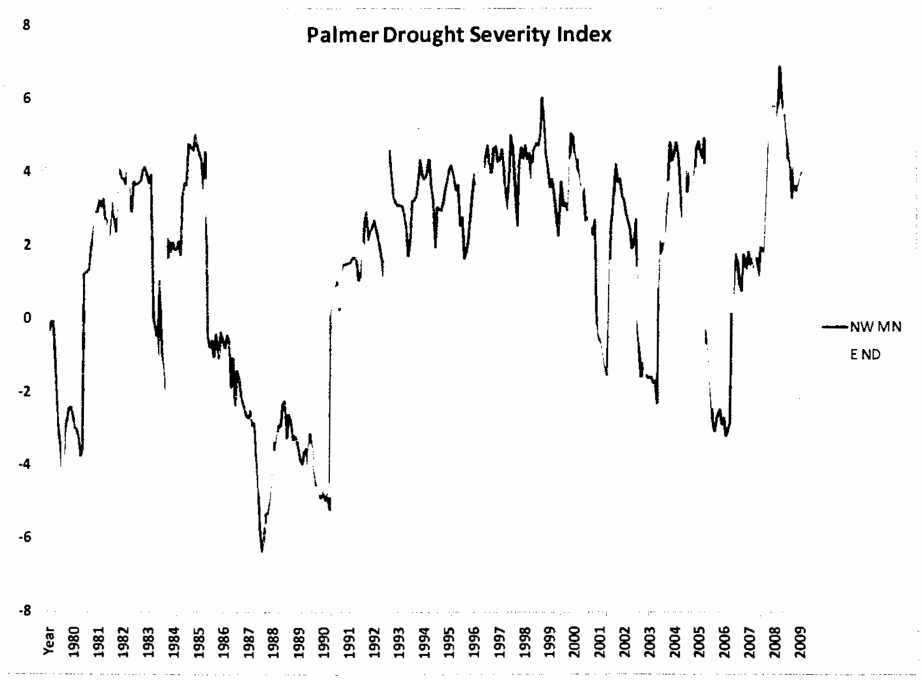

Figure 3. The monthly Palmer Drought Severity Index from 1980 to 2010 in Northwestern Minnesota (NW MN) and Eastern North Dakota (E ND). The values are as follows: 2 or higher = extremely wet, 1.5 to 1.99 = very wet, 1 to 1.49 = moderately wet, -.99 to .99 = near normal, -1 to -1.49 = moderately dry, -1.5 to -1.99 = severely dry, -2 or less = extremely dry. (NOAA 2010).

the long term, are still within all time high precipitation records in relation to the restoration timeline. (NOAA 2010)

Survey Design

The information for the survey was obtained by visiting established tallgrass and mixed grass prairie restorations. Various data from the field were collected in the summers of 2009 and 2010, during the months of June, July, and August. This data collection involved plant community data, physical data, seed mixtures, planting methods, planting age, and invasive/undesirable weed information. The data were analyzed to classify different states and the probability of achieving those states. Expected outcomes of various restoration methods and goals were developed.

Vegetation Sampling

Three methods of vegetative field sampling were conducted to provide information on plant communities. The field sampling methods are shown in 1, 2, and 3 as follows:

1) Plant composition

Sampling for plant composition was accomplished using visual estimation of plant cover percent (%) within 2 m^2 quadrats. The use of the large quadrats, 2 m^2, is designed to estimate the cover of dominant species and occurrence of infrequent species. Smaller quadrats tend to miss the occurrence of infrequent species unless large numbers of quadrats are used and, in this case, 20 smaller Daubenmire quadrats would be needed to equal one 2 m^2 quadrat. The time needed to sample 20 quadrats is much longer than sampling one large quadrat (Stohlgren 2007). Sample points were selected on a restricted random fashion. Aerial photos were used to target approximate spatially separate locations of uplands in each site. Once in the general area, random positioning was used for non-bias selection. The samples were restricted to different spatial sections of the site to ensure adequate spatial distribution of samples and they were restricted to primarily upland ecological sites. All ecological sites compromising of more than 10% of the total restoration had at least one sample point within it. Larger restoration sites had points restricted to being more than 150 m apart within the eco-site. The ecological sites that compromised more than 10,000 m^2 may have had several points located within. A restriction was applied to have no more than 30 points within any given restoration. All restoration sites had at least 2 points within them. Some restorations were composed of homogenous vegetative patterns which required a reduced number of sample points. The number of points within a site was adjusted to account for different observed plant communities for accurate representation of each restoration.

Each sample point within a restoration site had three 2 m^2 quadrats arranged in a triangular fashion 15 m apart (Figure 4). Within these quadrats, all species were identified and estimated for ocular plant cover to the nearest percent. An ocular estimation of bare ground percentage and both litter and invasive litter were estimated in weight per gram as accurately as possible to decipher into categories of low, medium, and high litter in the analysis. Within this triangular pattern, species presence was noted in an effort to account for rare and infrequent species.

2) Vegetative structure

At each point randomly selected for species composition sampling, a Robel transect was sampled. Each sample included 12 Robel readings with 20 m between

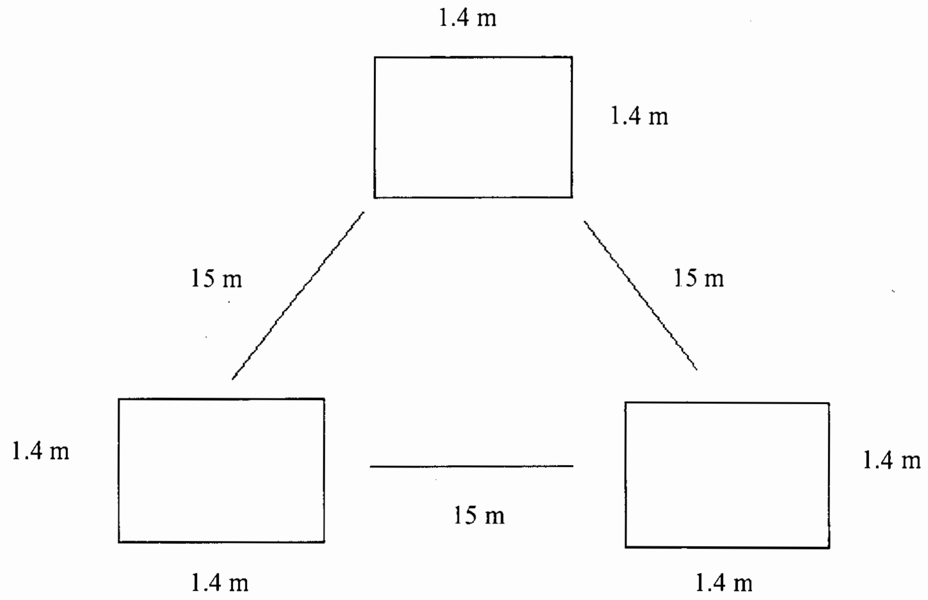

Figure 4. Design of the method used to sample plant composition.

each measure. These readings were sampled using standard Robel sample methods (Robel et al. 1970). This method included pole readings in centimeters from the base of the Robel pole, to the first visible mark of the vegetative height observed from a distance of 4 m and 1 m in height to the pole.

3) Invasive/undesirable species survey

Invasive/undesirable species' locations were observed and estimated densities were recorded throughout each restoration in entirety. Invasive species inventoried were: *Cirsium arvense* (Canada Thistle), *Carduus acanthoides* (Plumeless Thistle), *Carduus nutans* (Musk Thistle), *Linaria vulgaris* (Yellow Toadflax), *Euphorbia esula* (Leafy Spurge), *Lotus corniculatus* (Birds foot Trefoil), *Coronilla varia* (Crown Vetch), *Elaeagnus angustifolia* (Russian Olive), *Ulmus pumila* (Siberian Elm), and *Artemisia absinthium* (Wormwood). The observations were mapped onto aerial photos which were then converted to digital maps displaying invasive species locations and their associated densities. These maps were then dispersed to the appropriate offices for management purposes.

Statistical Analysis

Statistical analysis was conducted on the average of all the 2 m^2 quadrats within a site for species cover, litter, and percent bare ground. The percentage data from the ocular estimation of cover were arcsine square- root transformed for subsequent analysis.

Vegetation composition was analyzed using Non-metric Multi-dimensional Scaling (NMS). The NMS ordination was analyzed using the PC−ORD version 5.32 software. This method can be used both as an ordination technique and as a method for assessing the dimensionality of a data set. NMS is increasingly being used in community ecology and is currently one of the most defensible techniques during peer review (McCune and Grace 2002).

NMS advantages include (McCune and Grace 2002):

- Avoids assumption of linear relationships among variables
- Ranked distances tend to linearize the relationship between distances measured in species space and distances in environmental space. This relieves the "zero truncation problem", a problem that plagues all ordinations of heterogeneous community data sets.
- Allows the use of any distance measure or relativization

NMS disadvantages include:

- Failing to find the best solution (minimum stress) because of intervening local minima

NMS is the most generally effective ordination method for ecological community data and should be the method of choice, unless a specific analytical goal demands another method (McCune and Grace 2002).

The NMS ordination used several options for analysis:

1) A Relative Sorenson similarity measure

2) 50 runs of real data, 250 runs of randomized data

3) Tests of the stress from the real data to a randomized dataset

4) Varimax rotation

5) Random supplier seed of 586

The best solution was selected based on the following:

1) The highest dimensions with a reduction of 5 in the stress of real data

2) A $p \leq 0.05$ for the Monte Carlo test comparing stress for the real data to a randomized dataset

3) Final solutions with a final stress < 20, number of iterations < 300, and instability of < 0.001

Categories were developed to facilitate analysis based on field data and on restoration characteristics of each individual site (Table 1). Categories were

Table 1. Analysis categories of both restoration development data and field data for tallgrass and mixed grass prairie restorations surveyed.

Restoration Development Data		Field Data	
Age	Forb Diversity	Litter (g)	Invasive Grass (%)
Season Planted	Grass Diversity	Invasive Litter (g)	Invasive Forb (%)
Method Planted	Grass Percent (pls)	Bareground (%)	Richness
Geographic Location	Forb Percent (pls)	Robel (cm)	Grass (%)
Seed Mix Diversity		Grass Diversity	Forb (%)
		Forb Diversity	

implemented into the analysis as a secondary matrix to suggest grouping amongst the sites in the NMS graphical outputs. Observations from these categorical outputs assisted in site to group comparisons of like or unlike characteristics. Because information on the restoration factors was incomplete for many of the restorations there were variable sample sizes used in the analyses.

Further examination of grouping was conducted using a Cluster Analysis approach. The Cluster analysis was performed in PC-ORD using a distance measure option of Euclidean (Pythagorean) and Ward's chaining method. The results were displayed using a dendrogram. The dendrogram from the cluster analysis was trimmed at 3 groups and 25% information remaining. This level of grouping was a good compromise between loss of information and ecological affinities among restoration sites. Multi-Response Permutation Procedures (MRPP) were used to test if the groups from the cluster analysis were significantly different. MRPP is a nonparametric procedure for testing the hypothesis of no difference between two or more groups of entities (McCune and Grace 2002).

Once the groups were defined, logistic regressions between the groups and the categories were used to determine which categories had a significant relationship to the groups. Logistic regressions were performed using SAS software Version 9.1.3 (Copyright © 2000-2004 SAS Institute Inc.). Those relationships with a significant likelihood ratio test ($p<0.05$) were then examined to find characteristics common among the sites in separate groups and differences between the groups in whole using the graphical displays. A logistic regression describes the relationship between a categorical variable and a set of predictor variables (UCLA 2010).

Logistic regressions were also performed to determine probabilities of membership to certain groups based on restoration implementation factors. The factors tested included seed mix diversity, seed mix grass diversity, seed mix forb diversity, and method of planting. A full model of all the significant restoration factors was also analyzed with a logistic regression. Akaike's Information Criterion (AIC) was used to compare among factors and models. The AIC with the lowest Δ AIC (AIC – Min AIC) value is used for choosing among competing statistical models for the best predictor variable.

An analysis of species recruitment was conducted to see if restorations gain or lose species overtime. This was conducted by comparing the species richness sampled and the total species diversity of the seed mix.

Invasive/undesirable forb and grass species composition was considered as a characteristic of group membership. A correlation of these grasses and forbs percent with restoration age was produced to display the progressive nature of invasive/undesirable species in the restoration sites sampled. A graphical display was also conducted for invasive forb and invasive grass progression.

RESULTS

Vegetation Composition

The NMS ordination of the 123 different sites found that a 3-dimensional solution was superior for this data set. The final stress was 15.25689, final instability was 0.00072, and the number of iterations was 250. The NMS ordination found that sites were best represented by axis 1 and axis 3. The variability of axis 1 was 19% and axis 3 was 52.8% with the total variation of the axes 1, 2, and 3 being 84.1%.

The cluster analysis shows three obvious groupings displayed in the dendrogram with a chaining of 1.82 (Figure 5). The MRPP analysis found that the three groups were significantly different (p<0.05). Combining the NMS analysis with the cluster analysis reveals the sites within cluster groups, 1, 2, and 3, are grouped in different areas of the NMS graph (Figure 6). Group 1is located at the bottom left of the axes, group 2 mostly at the upper right, and group 3 mostly at the upper left of the axes.

Correlations between plant species and the axes scores revealed that eighteen significant species were the driving forces for the NMS results (Table 2). Species that were associated with group 3 were *Andropogon gerardii*, *Dalea purpurea*, *Helianthus maximiliani*, *Monarda fistulosa*, *Sorghastrum nutans*, and *Taraxacum officinale*. All of the significant species were associated with group 1 except, *Bromus inermis* and *Poa pratensis*. Group 2 included the species *Bromus inermis*, *Poa pratensis*, and *Andropogon gerardii*.

A variety of categories were used to characterize the groups 1, 2, and 3 from the cluster analysis. Some categories were found to be significantly related to the groups from the logistic regression analysis (Table 3). Other characteristics of the groups were

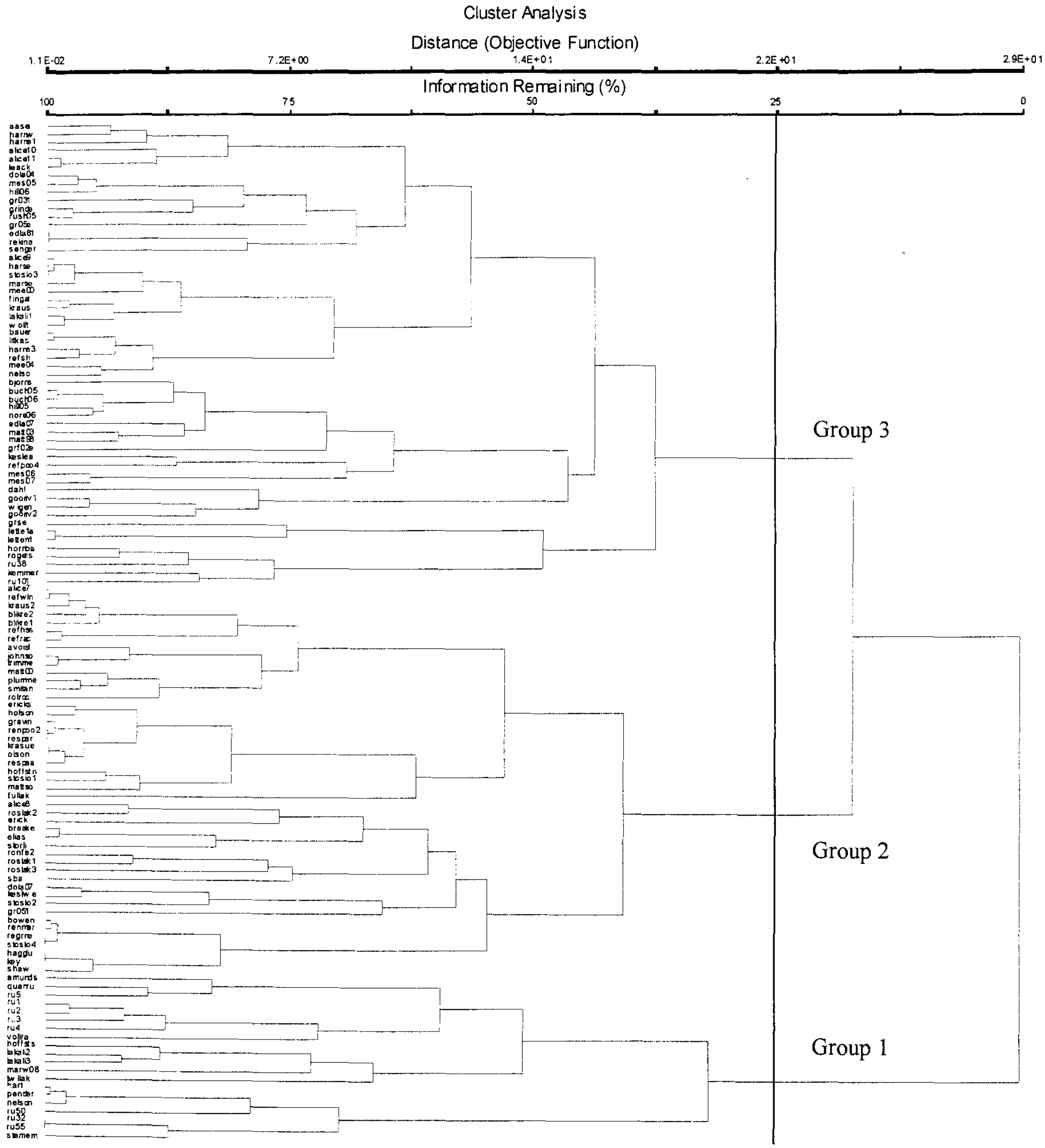

Figure 5. Cluster analysis dendrogram of tallgrass and mixed grass prairie restoration sites surveyed. The vertical line at the 25 % of information remaining level is where the dendrogram was cut resulting in the three groups.

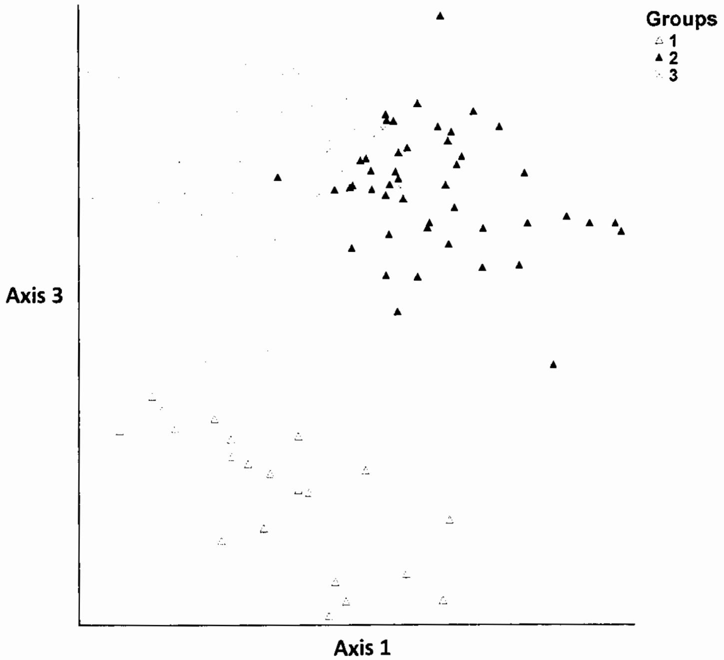

Figure 6. NMS ordination with the groupings from the cluster analysis of the tallgrass and mixed grass prairie restoration sites surveyed.

determined by examining 2- dimensional graphical displays (See Appendix B). The result from the logistic regressions and examinations of the graphs reveals that each group 1, 2, and 3 had a unique set of factors that differentiated them.

Group 1 consisted of new or younger plantings. The restorations in this group were planted with moderate diversity, high grass percent, variable forb percent, high grass diversity, and moderate forb diversity. Group 1, had highly variable restoration characteristics. In addition, this group commonly had low litter and low invasive/undesirable grass percentage. However, this group had the highest invasive/undesirable forb percentage.

Group 2 was composed of older restorations. These restorations were planted with moderate diversity seed mixtures composed of high grass percentage and low forb

Table 2. Species found within the restorations that are correlated with the two NMS axes from the NMS analysis of restorations in the tallgrass and mixed grass prairie eco-region. Correlation coefficients with values of *r* > 0.4 or < -0.4 were considered.

Significant Species		r	
common name	scientific name	axis 1	axis 3
Crested Wheat	*Agropyron cristatum*	0.503 (-)	
Western Wheat	*Agropyron smithii*	0.759 (-)	
Slender Wheat	*Agropyron trachycaulum*	0.724 (-)	
Big Bluestem	*Andropogon gerardii*	0.645 (+)	0.450 (-)
Smooth Brome	*Bromus inermis*		0.783 (+)
Canada Thistle	*Cirsium arvense*	0.490 (-)	
Purple Prairie Clover	*Dalea purpurea*		0.527 (-)
Canada Wild Rye	*Elymus canadensis*	0.465 (-)	
Maximilian Sunflower	*Helianthus maximiliani*		0.542 (-)
Foxtail Barley	*Hordeum jubatum*	0.482 (-)	
Alfalfa	*Medicago sativa*	0.603 (-)	
Wild Bergomot	*Monarda fistulosa*		0.440 (-)
Kentucky Bluegrass	*Poa pratensis*		0.693 (+)
Prairie Coneflower	*Ratibida columnifera*	0.429 (-)	
Sowthistle	*Sonchus arvensis*	0.455 (-)	
Indian Grass	*Sorghastrum nutans*		0.455 (-)
Green Needle Grass	*Nassella viridula*	0.696 (-)	
Common Dandelion	*Taraxacum officinale*		0.405 (-)

percentage. Dense stands of grass with low forb diversity seemed to be characteristic at these sites. However, there was moderate grass diversity in the seed mixture. Invasive/undesirable forb percentage was quite low in this group. However, group 2 did have a high invasive/undesirable grass percentage and high litter amounts.

Group 3 restorations were composed of a variety of ages. These restorations were planted with moderate to high diversity composed of both grass and forbs with moderate

Table 3. Cluster analysis group characteristics from both seeding data and field data of the surveyed tallgrass and mixed grass prairie restorations. Significant factors from the logistic regression are in bold face ($p < 0.05$) (*seeding data, **field data).

Group 1		Group 2	
Restoration Factors*	Characteristics**	Restoration Factors*	Characteristics**
Young Age	*Low Litter*	*Old Age*	*Variable Litter*
Moderate Diversity	**Low Invasive Litter**	**Moderate Diversity**	**High Invasive Litter**
High Grass % (pls)	*Variable Bare Ground %*	*High Grass % (pls)*	*Low Bareground %*
Variable Forb % (pls)	**Variable Richness**	*Low Forb % (pls)*	**Low to Moderate Richness**
High Grass Diversity	*Variable Grass %*	**Moderate Grass Diversity**	*Moderate to High Grass %*
Moderate Forb Diversity	**Variable Forb %**	**Low Forb Diversity**	**Low Forb % Dominated**
Drill Planting Method	**Variable Grass Diversity**	**Drill Dominated**	**Low to Moderate Grass Diversity**
Spring Plantings Dominated	*Variable Forb Diversity*	*Spring and Summer Plantings*	*Low to Moderate Forb Diversity*
NW Geographically	**Low Invasive Grass %**	*NW & SW Geographically*	**Moderate to High Invasive Grass %**
	Moderate to High Invasive Forb %		**Low Invasive Forb %**
	Variable Robel		*Variable Robel*
Group 3			
Restoration Factors*	Characteristics**		
Variable Age	*Moderate to Low Litter*		
Moderate to High Diversity	**Low Invasive Litter**		
High Grass % (pls)	*Low Bare Ground %*		
Moderate Forb % (pls)	**Moderate to High Richness**		
Moderate to High Grass Diversity	*Variable Grass %*		
Moderate To High Forb Diveristy	**Low to Moderate Forb %**		
Drill & Broadcast Planting Method	**Variable Grass Diversity**		
Winter & Spring Planting	*Moderate to High Forb Diversity*		
Variable Geographic Location	**Low Invasive Grass %**		
	Low Invasive Forb %		
	Variable Robel		

diversity. This group was planted with high grass percentage and moderate forb percentage. Like the planting mixture, this group had moderate to high richness and moderate to high forb diversity. The group had grass percentages that were highly variable. The forb percentage ranged from low to moderate and the grass diversity was variable among the restorations. This group typically had low invasive/undesirable grass species in general. Also, the litter amount averaged lower in this group.

Restoration Outlook

Each group was analyzed using logistic regressions for probabilistic outcomes based on seeding information and techniques. Group 1 was not considered in the probabilistic outcome analysis of a restoration because of the group's youthfulness and highly variable characteristics. This suggests that the restoration sites from group1 are in a transitional state leading to either group 2 or group 3. Group 2 and group 3 were considered typical directions a given restoration could develop. Probability of being in group 3, based on seeding techniques, was calculated in percentage of 0 to 100, with 100 being certainty of belonging to the group and zero having no chance of belonging to group 3. The inverse was true for membership to group 2. Seeding techniques that were considered controllable were seed mix diversity, seed mix grass percent (pure live seed (pls)), seed mix forb percent (pls), seed mix grass species diversity, seed mix forb species diversity, method of planting, and season of planting. The logistic regression found all techniques significant ($p < 0.05$) except forb and grass seed mix percentages (pls). Season of planting was significant when winter (10/21 – 4/14) was included ($p = 0.0007$), but not significant when winter was excluded. This suggested that winter was a reliable (approximately 100% probability) predictor for membership to group 3, while the other seasons of planting were not a determinant in the probability of membership to group 3. The planting method of broadcast seeding predicted a 74% probability of membership to group 3 (upper confidence level (CI) = 89%, lower = 50%). Drilling produces a predicted probability of 45% chance of membership to group 3 (upper CI = 59%, lower = 33%). Seed mix diversity was significantly related ($p = 0.0013$) with an increasing predicted probability of membership to group 3 with increasing diversity (Figure 7). Seed mix forb species diversity was significantly related ($p = 0.0041$) with an increasing predicted probability of membership to group 3 with increasing diversity (Figure 8). Seed mix grass species diversity was significantly related ($p = 0.0004$) with an increasing predicted probability of membership to group 3 with increasing diversity (Figure 9). A logistic regression was performed using all of the previous significant restoration factors excluding season of planting. The full model was significant ($p = 0.0055$) with a combination of broadcast seeding, grass species diversity > 9, forb species diversity > 10, and seed mix diversity > 20 having a predicted 80% probability of membership to group 3 (See Appendix D). The Akaike's Information Criterion (AIC) comparison found the full model was not the best predictor but was ranked 3rd (Table 4). Because information on these factors was incomplete for some of the

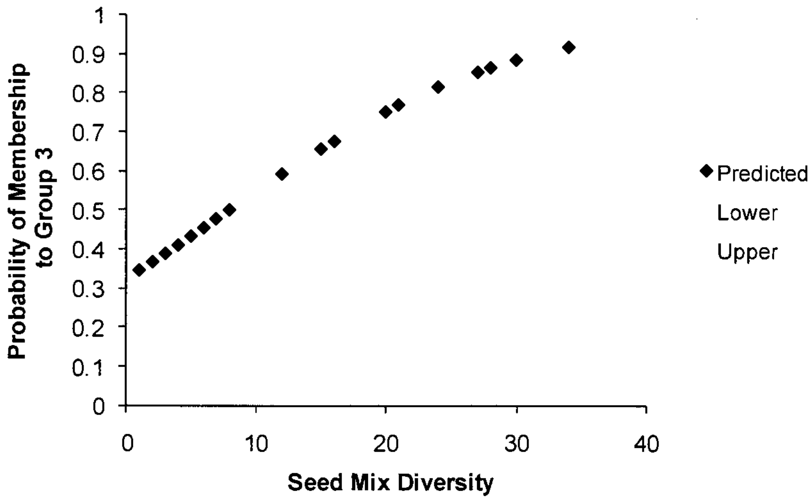

Figure 7. Logistic regression of seed mix diversity and probability of membership to group 3 based on a survey of restoration sites in the tallgrass and mixed grass prairie eco-region. Predicted probabilities are shown with upper and lower confidence intervals.

restorations, sample size varied among logistic regressions. This variability in sample size makes the AIC comparisons less reliable when sample size did not vary.

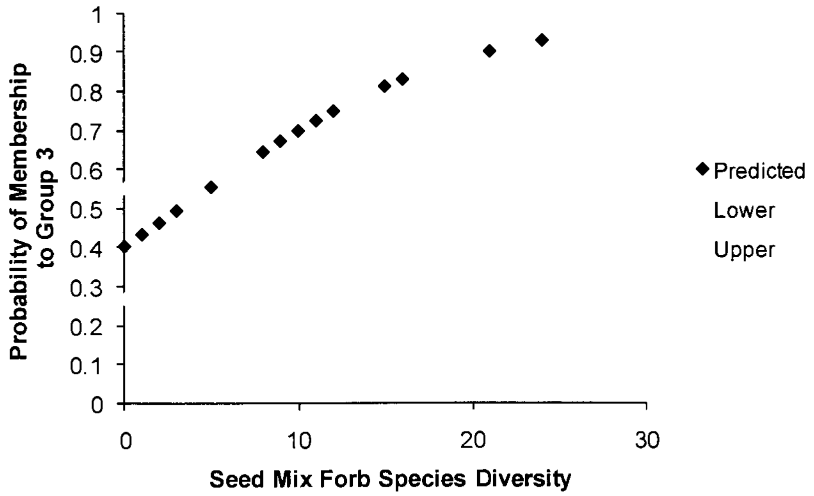

Figure 8. Logistic regression of seed mix forb species diversity and probability of membership to group 3 based on a survey of restoration sites in the tallgrass and mixed grass prairie eco-region. Predicted probabilities are shown with upper and lower confidence intervals.

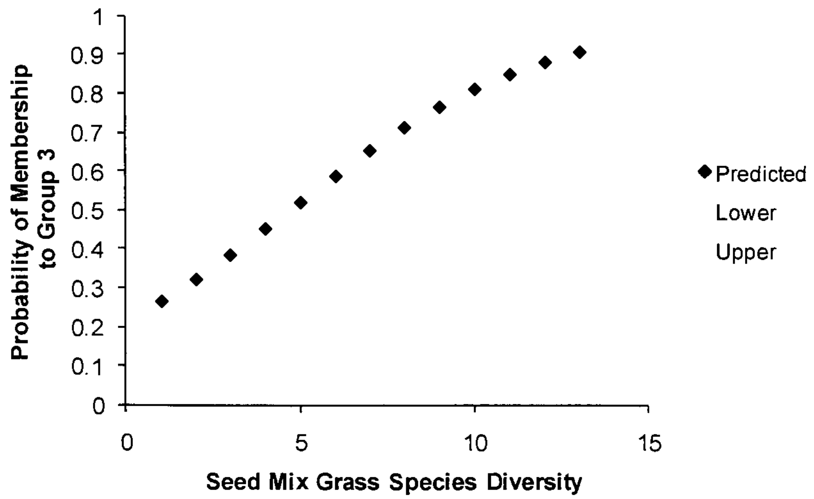

Figure 9. Logistic regression of seed mix grass species diversity and probability of membership to group 3 based on a survey of restoration sites in the tallgrass and mixed grass prairie eco-region. Predicted probabilities are shown with upper and lower confidence intervals.

Table 4. Akaike's Information Criterion levels from logistic regressions of significant restoration factors of group 3 memberships based on a survey of restoration sites within the tallgrass and mixed grass prairie eco-region.

Restoration Factors	AIC	Δ AIC	Predictor
Grass species diversity	85.589	0	1
Seed mix diversity	87.647	2.058	2
Full model	88.098	2.509	3
Forb species diversity	89.774	4.185	4
Method	98.902	13.313	5

Robel Results

Robel transects were conducted at every random point in each restoration site. There were no correlations between the average Robel readings and the groups. A logistic regression showed that the average Robel readings from the restoration sites and membership to the groups were not significant ($p > 0.05$). The coefficient of variation (cv) of the Robel reading within the transect was also found to be a not significant predictor to membership to the groups ($p > 0.05$).

Additional Restoration Recruitment

In addition to species diversity in the seed mix, analysis was conducted on species loss or gain in relation to restoration age. A simple plotting of restorations with grouping preferences was displayed using the correlation of seed mix and year class. Positive and negative species recruitment was plotted (Figure 10). The results show that older restorations gain the most species in addition to the original seed mix. In contrast, the newest restorations gain the least amount of species in addition to the original seed mix. Overall, most restorations have a positive species gain rather than a negative species loss.

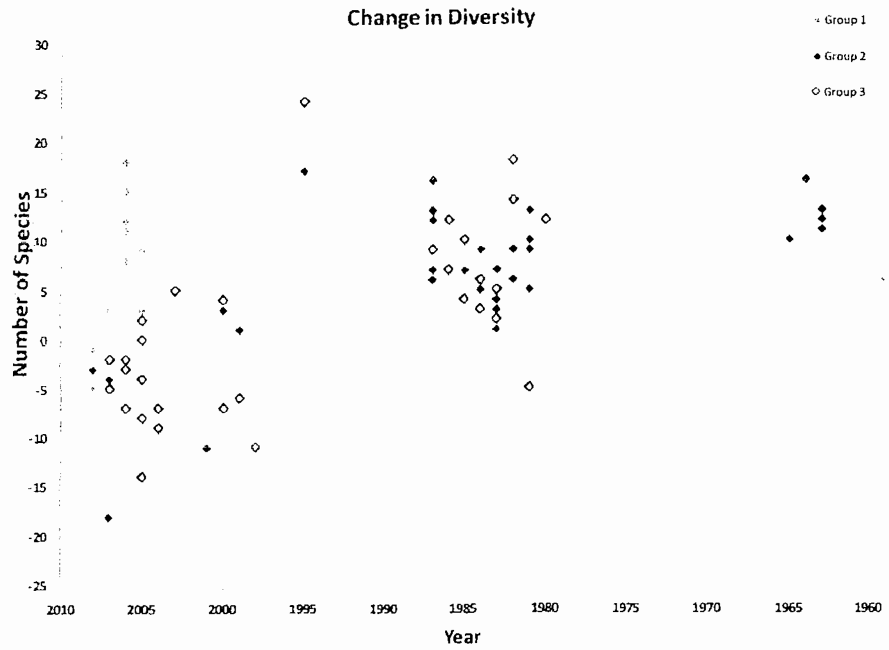

Figure 10. Change in diversity with age class in relation to the original seed mix diversity (zero) of tallgrass and mixed grass restorations. Species gain or species loss is demonstrated by each point and is labeled corresponding to the grouping from the cluster analysis.

Invasive/Undesirable Species Patterns

Invasive/undesirable species patterns were also recognized in the analysis. Invasive/undesirable species were separated into two separate groups, forbs and grasses. Each invasive undesirable species group was plotted in a graph with total percent vs. age class of restorations (Figure 11, Figure 12). Invasive/undesirable forbs had more of a cyclical pattern, not indicative of group membership. Total forb percent is relatively high within the 3-5 years after planting then begins to decline. There is a common pattern of invasive/undesirable forb decline in a 3-4 year trend before bottoming out. The trending peaks and lows are on approximately a 20 year cycle. The invasive/undesirable grasses have more of an increasing trend with age class. However, like invasive/undesirable forbs, grasses also experience a higher percent at the onset of the restoration for about 3 years

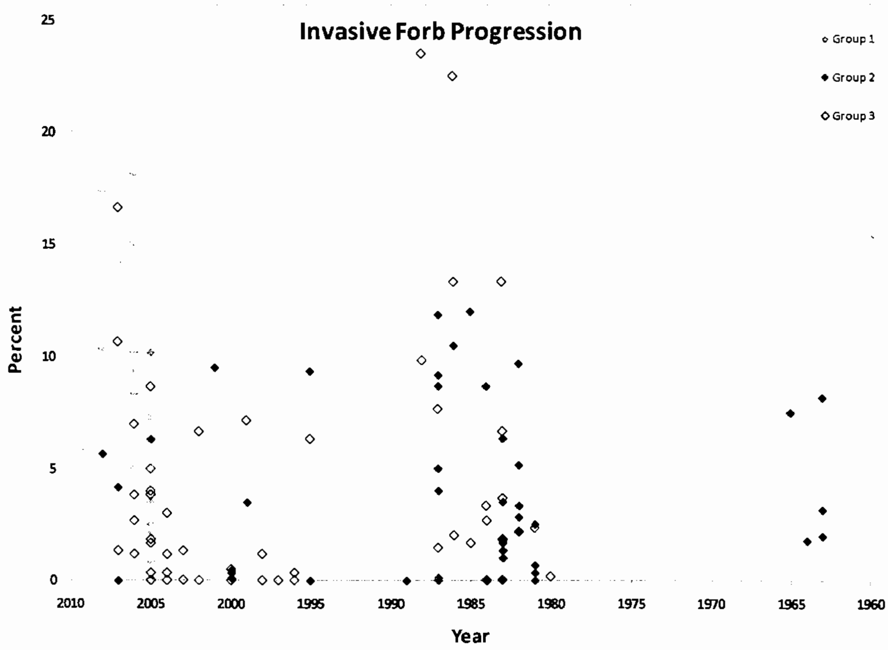

Figure 11. Invasive forb progression in tallgrass and mixed grass prairie restorations. The results are based on correlations between total invasive forb percentage and age classes of the restorations.

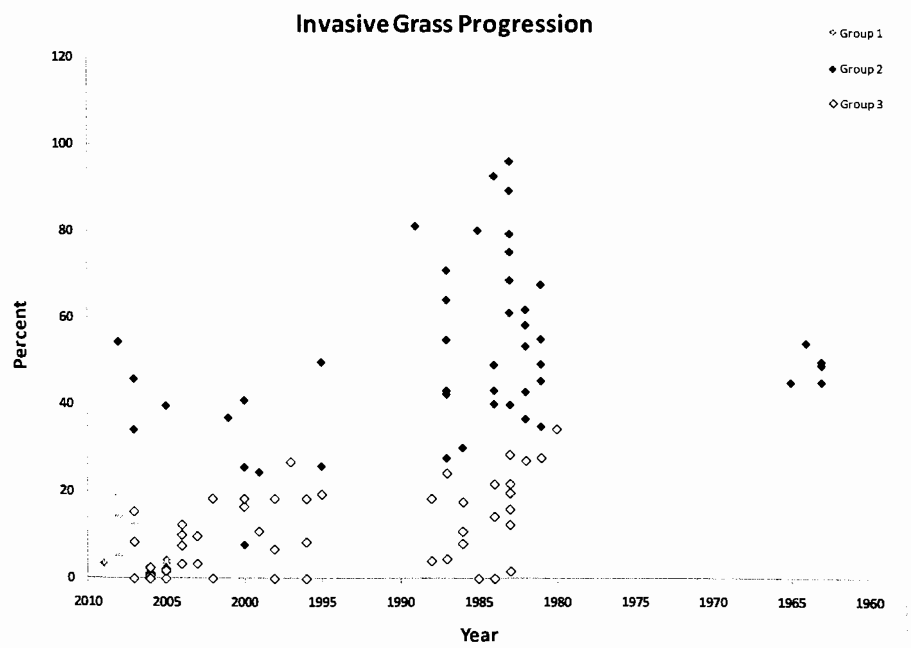

Figure 12. Invasive grass progression in tallgrass and mixed grass prairie restorations. The results are based on correlations between total invasive grass percentage and age classes of the restorations.

before bottoming out. Restorations of 4 to 5 years of age begin a gradual trend of increasing invasive/undesirable grasses, most noticeable in group 2. Group 2, in comparison with group 3, have a higher invasive/undesirable grass percentage.

DISCUSSION

Group Variability

Based on the NMS ordination and cluster analysis, three distinct groups were found among the 123 different restorations. Each group occupied separate locations in relation to axis 1 and axis 3. Each axis and corresponding groups had separate significant species as driving forces. Big bluestem, a C4 grass, was found to be a major factor in all of the groups. This suggests that Big Bluestem is a dominant species and is unrelated to the defining of group status. Group 3 has significant populations of Big Bluestem and Indian grass, which are dominant C4 warm season grass species. Group 3 is also defined by three native forb species and one non-native forb species. Smooth brome and Kentucky bluegrass, which are C3 cool season invasive/undesirable grasses, were associated with group 2, which is specifically dominated by grasses, and not associated with the other groups. Group 1 has the largest pool of significant species. The composition of this group is a variation of multiple functional forms of both grass and forb species. This group contains four introduced forb species. Group 1's significant species diversity is the result of a new restoration. New restorations tend to have higher weed species percentages and species dominance has not established in the short time period (Camill et al. 2004). Considering the significant species results for group 2 and 3, low forb presence and specifically, high invasive/undesirable grass presence are the major determinants of group membership. Other factors, inherent to the site, which are not related to the restoration methods, are historical land use, nutrient levels, management, or seed banks. Physical and biological factors, such as these, are likely responsible for any variability in the groups and account for the outliers.

Group 1 consists of new or younger plantings. The restorations in this group were planted with moderate diversity, high grass percent, variable forb percent, high grass diversity, and moderate forb diversity. This group displays some common trends of current planting methods where there is a tendency towards higher diversity in both forbs and grasses. Group 1, had highly variable characteristics likely related to establishment. This group commonly has low litter and low invasive grass percentage. However, this group usually has the highest invasive forb percentage.

Group 2 was composed of older restorations. These restorations were planted with moderate diversity seed mixes composed of high grass percent and low forb percent. Dense stands of grass with low forb diversity seemed to be characteristic at these sites. However, there was moderate grass diversity in the seed mix. Outcomes of these restorations were very similar to the planting methods used. Invasive/undesirable forb percent was quite low in this group. However, the high invasive/undesirable grass percent seemed to be dominating everything else, leaving a dense, high litter layer.

Group 3 restorations were composed of a variety of ages. These restorations were planted with moderate to high diversity of both grasses and forbs. This group was planted with high grass percentage and moderate forb percentage. Like the planting mix, this group had moderate to high richness and moderate to high forb diversity. Most of these restorations have a trend of higher diversity. The group had grass percentages that were highly variable. The forb percentage ranged from low to moderate and the grass diversity was variable among the restorations. This group typically had low invasive/undesirable grass and forb species in general. Also, the litter amount averaged lower in this group.

Overall, group 3 seemed to have "healthier" restorations and ones that would be deemed successful by the USFWS (personal communication with cooperating USFWS managers). The choice of which groups are favorable is based on the restorer's preferences. The most favored, based on typical preferences, is group 3 (Zedler and Lindig-Cisneros 2000, USFWS 2010 c), meaning that there seemed to be higher invasion resistance, higher diversity retention, and lower litter build- up. These qualities suggest less management and higher self-sustainability (Tilman 1997, Hector et. al 2001). There seems to be a close correlation with seed mix richness for both grass and forbs and group 3 membership and higher species richness in the outcomes. As seen in group 3, on average the overall forb percentage dropped from the planting to the outcomes. Also, the grass diversity on average was variable as opposed to the high diversity in the planting. It is likely that overall seedling emergence is somewhat influenced by resource availability and niche fulfillment among other variables (Biondini 2007). Variable age is another positive quality of group 3. It is thought that many restorations progressively decline with age (Sluis 2002), this disputes that concept. This means that these restorations on average are sustaining their richness overtime.

Group 2 restorations could be considered "unhealthy". Due to past planting methods, seed choices, and undesirable management techniques, the age of these restorations inadvertently control the outcomes of today. The highest concern in this group is the invasive/undesirable grass influence. Most of these restorations are being overtaken by either smooth brome (*Bromus inermis*) or Kentucky bluegrass (*Poa pratensis*) and have high litter accumulations. There are also species dominance issues and homogeneous conditions in this group resulting in low overall diversity.

Group 1, is composed of young and highly variable restorations. This group could diverge into group 2 or group 3. Based on the current planting methods used, there is a high probability that these restorations will be similar to group 3 or, diverge into an entirely separate group.

Restoration Outlooks

Seeding techniques are the controlling factors of group membership. Theoretically, a restoration can develop into group 2, or group 3. Based on predicted probabilities, there is an 8 out of 10 chance of a restoration belonging to group 3 when planting a minimum of 9 grass species, a minimum of 10 forb species, and using broadcast seeding methods. Based on the logistic regression AIC scores of significant restoration factors, the best predictors in order starting with the best is 1) grass diversity, 2) seed mix diversity, 3) all significant factors combined (full model), 4) forb diversity, and 5) planting method. These results show each variables importance in achieving membership to group 3. However, method of planting does highly influence predictability, like all of these factors, and should be considered in restoration planning. In fact, it is known that some techniques and seasons present higher probabilities than others (Doerr and Redente 1983, Wilson 2002). Planting a seed mix with high grass diversity and moderate forb diversity, in conjunction with broadcast seeding methods seems to substantially increase probabilities and tends to be very successful when utilized. Drill seeding methods promotes grass germination but, tends to have an inverse effect when forb diversity is increased (Wilson 2002). Furthermore, excessive forb diversity of more than 20 species did not increase the predicted probability of group 3 membership. As diversity in the seed mixture increases the chances of dominant species out-competing subdominants are increased (Piper and Pimm 2002). Therefore, excessively high diversity and the extra addition of numerous rare species at low densities eventually leads to absence from the restoration and replaced with dominant species. Other methods like the Precision Prairie Reconstruction method may be a more viable method to introduce uncommon and rare plants to increase diversity (Grygiel et al. 2009).

Robel Results

Based on the Robel results, group membership was not a predictor of variations in Robel readings. Individual restoration sites varied in average Robel height and Robel cv, this variation was scattered throughout each of the groups. There were no relationships or correlations to predict the probability of Robel characteristics. It is likely that Robel variation among restoration sites is derived by planting techniques and species selection (Martin et al. 2005). Variable Robel structure within a restoration site is a function of patchiness and variable plant communities.

Species Recruitment

Results show restored prairies generally gain species over time. This addition of species is most dramatic in older plantings, likely because there was very low diversity in the original seed mix. This low diversity mix, likely leaves windows of opportunity for additional non-seeded species to take advantage of unused resources (Hooper et al. 2005, Biondini 2007). Newer restorations tend to recruit less additional species. Most new restorations are composed of moderate to high diversity seed mixes, therefore leaving less resource opportunity for additional species. Seed mixes with high diversity may already contain species similar to the surrounding area. The surrounding seed sources and seed banks likely have much influence on species additions (Platt 1975, Kalamas and Zobel 2002). It is possible that seed sources such as wetlands, roadways, waterways, spoil piles, and adjacent lands are responsible for importing species. Many of the species found in these source sites seem to be found migrating into the restorations (Platt 1975).

Invasive/Undesirable Species Progression

Invasive/undesirable species are of great concern and problematic in prairie restorations (Grant et. al. 2009). Most of the surveyed restoration sites had some composition of these species. Many of the sites that were not represented by the analysis had “weed spots”. These spots, pockets of undesirable species, were only referenced in the weed maps for management and not taken into consideration for analysis because they did not represent the entire site. The percentages were based on invasive/undesirable species presence within the vegetation plots. Only restorations with uniform or significant populations were represented with this analysis.

It is well known that restorations can have a high level of undesirable species during the initial establishment. These early years for a restoration can include both native and non-indigenous species. Invasive/undesirable forbs in this study are shown to have natural cycles of high and low presence. These cycles suggest that invasive/undesirable forb dominance may be influenced by planting succession (Rothrock and Squiers 2003). Environmental influences of prairie restorations could also be factors in the dominance trends of these forbs. As the results show, invasive/undesirable forb presence is not distinguishable between groups 2 and 3. This suggests that seeding techniques in this study are unrelated to invasive/undesirable forb progression. As stated earlier, some restorations are more resistant to invasive/undesirable species invasions. After the initial weed period, these tolerant restorations maintain a lower invasive/undesirable species presence, than the other less tolerant restorations. This explains the high variation of invasive/undesirable grass in older restorations. These invasive/undesirable grasses present a clear picture in the progression graph results. Invasive/undesirable grasses seem to gradually increase in dominance with increasing age of a restoration. Group 2 restorations have the least resistance to these grass invasions. Once introduced, invasive/undesirable grasses dominate the site by slowly increasing their dominance over time. Group 3 restorations maintain a much lower percentage of these invasive/undesirable grasses though time. Management techniques that reduce or slow invasive/undesirable grass dominance, such as grazing and fire, may be required less frequently in group 3 vs. group 2 sites (Blankespoor and Larson 1994, Bowles et al. 2003, Brudvig et al. 2007).

Management Direction

To achieve healthy and successful restorations on USFWS lands in eastern North Dakota and northwest Minnesota these criteria will ensure a high probability of success:

- Plant a high diversity seed mix (minimum of 19 species)
- Recommendation of at least 9 grass species and 10 forb species
- Include a diverse forb component
- Dormant planting season
- Use planting equipment that will adequately disperse variable seed sizes
- Control litter build up

Suggested avoidance:

- 5 or less grass species
- Avoid excessively low (<10) and excessively high (>30) forb species
- Summer plantings (6/08 – 9/01)
- High litter build up

Seeding method approach:

- Broadcast seeding tends to produce higher predicted probabilities per species of grasses and forbs than drill seeding
- Winter planting (10/21 - 4/14), based on the probabilities, is a high predictor of success

Further Research

This study represents a survey of a portion of the tallgrass and mixed grass prairie. Additional locations should also be assessed, to find common trends in these ecosystems and the associated restorations. Further research is needed for determining the outcomes of younger, state of the art, restorations of today. This is necessary to determine if they, too, will diverge into one of the two different groups or, will they remain a distinct group of their own. As our knowledge of prairie restorations increases, further progress is made in beneficial implementation techniques. Therefore, long-term and continuing examination is needed. Further progress of breaking down seed diversity numbers and ratios also need to be studied, with higher sample numbers. Management techniques should be incorporated as well, because of the strong influence it has on plant communities. Also, a breakdown of environmental, historical, and physical property conditions should be assessed to further the understanding of successful restoration progress. Nutrient levels on the restoration sites may have a significant effect on restorations (Biondini 2007). There also seems to be some diversity recruitment, associated with site specific seed banks, such as wetlands, adjacent lands, waterways, rock piles, homes sites, spoil piles, and right of ways. Further studies should be conducted to acknowledge this dispersal and resource. Functional groups should also be considered in further research, to add understanding of plant communities, in relation to working restorations and the success.

CONCLUSION

This study is not a comparison of restorations to remnant native prairies; it is a survey of what has been restored and the associated outcomes. This study found that the use of appropriate seed mixes and planting techniques can enhance the probability of achieving a successful restoration as determined by the USFWS. Variations in species numbers of grasses and forbs and percent ratios of grasses and forbs in these seed mixes, affect the outcome of a restoration. This study also served as a means of solidifying ideas and opinions of restoration concepts.

The preferred outcomes are based solely on current restorations and the associated qualities of these restorations. A successful restoration is one that meets the restorer's objectives, resists invasion, eases management, and is more capable of self-sustainment. The study's goals were to aid in adaptive management and provide useful concepts to further prairie restoration progress. These concepts should assist in managerial decisions increasing efficiency and decreasing management needs.

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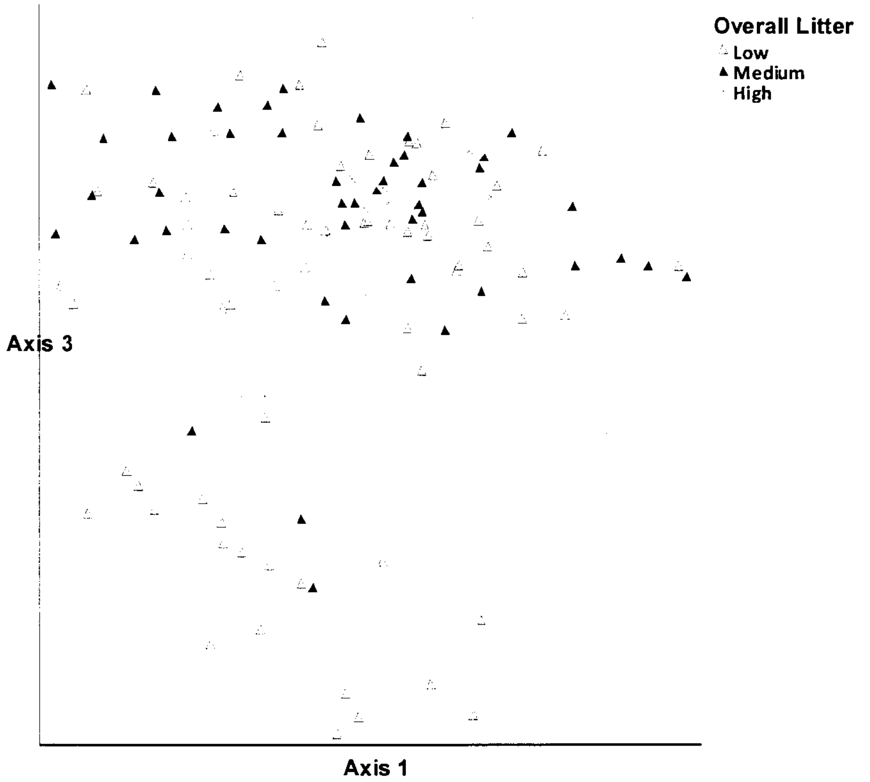
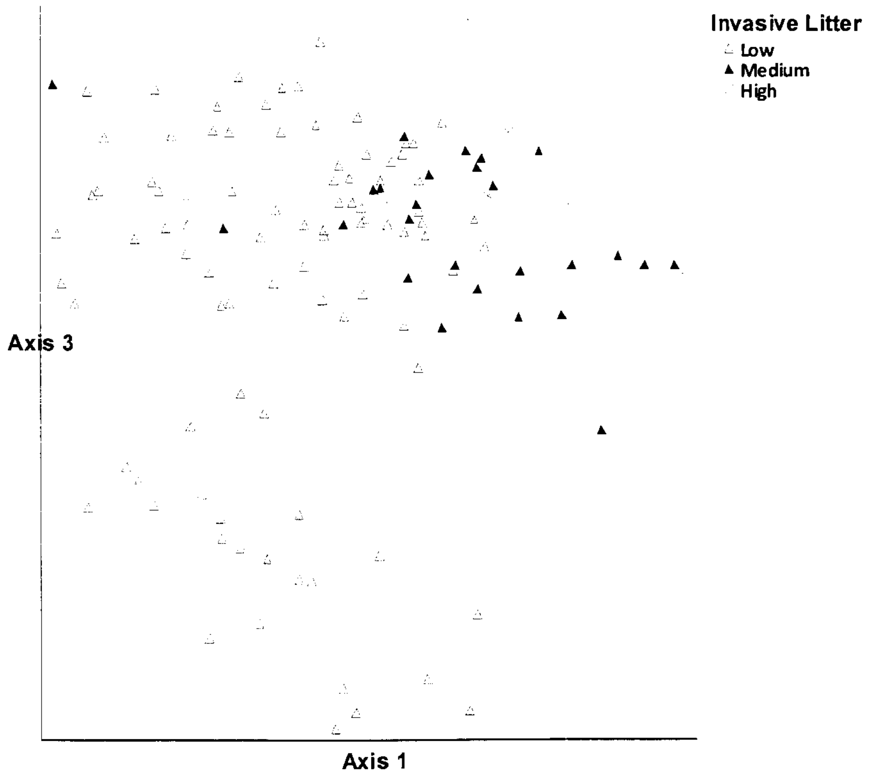
APPENDIX A. RESTORATION SURVEY SITES

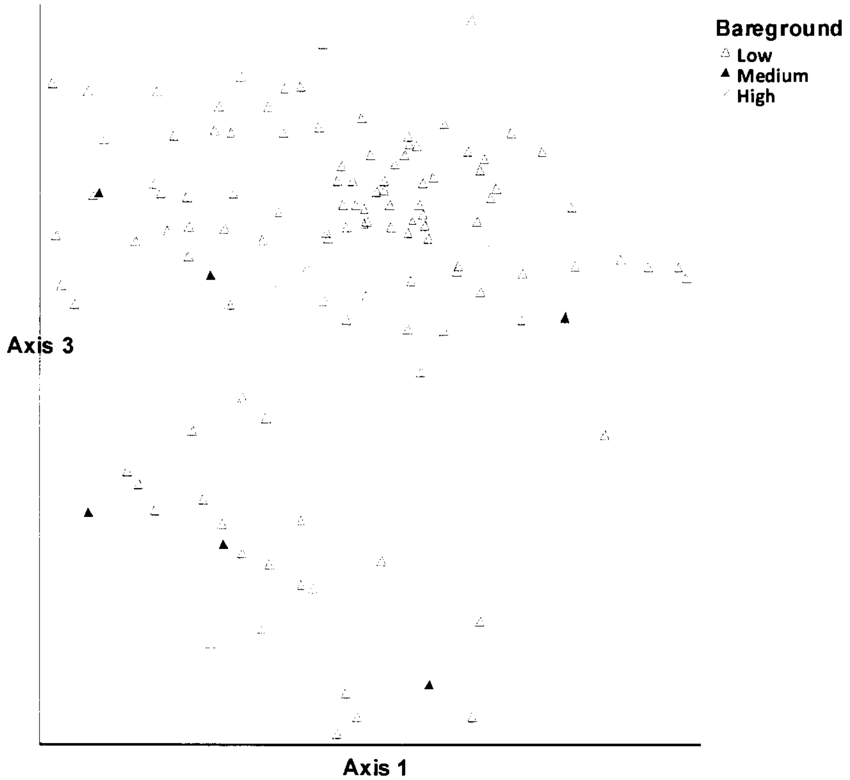
Restoration Survey Sites

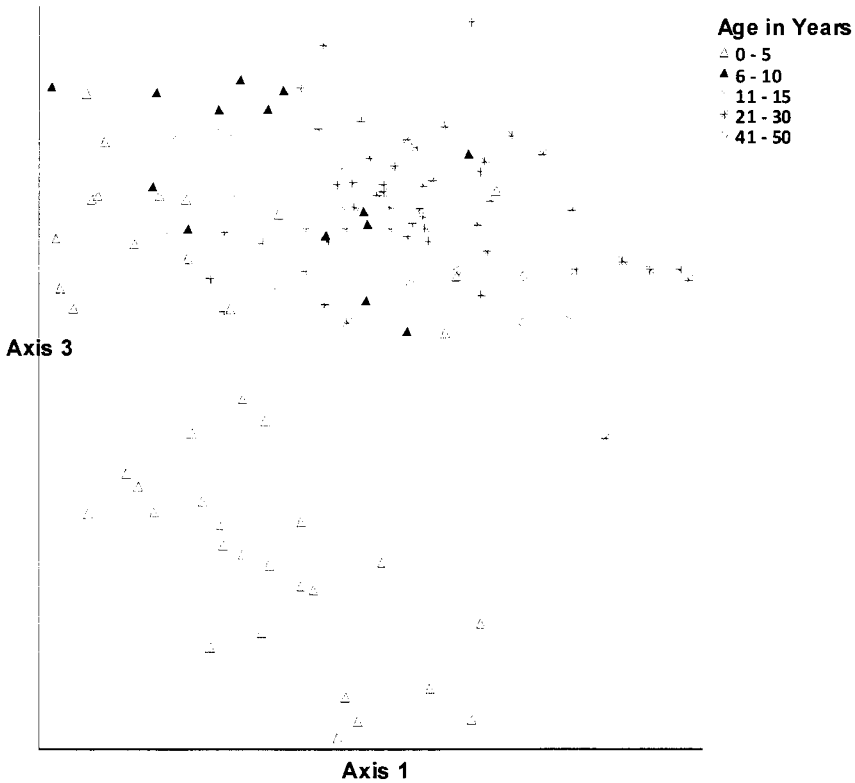
Minnesota		**North Dakota**			
Site	County	Site	County	Site	County
Buchl 05	Becker	Blikre 1	Barnes	Lake Alice 1	Ramsey
Buchl 06	Becker	Blikre 2	Barnes	Lake Alice 2	Ramsey
Mattson 00	Becker	Bowen	Barnes	Lake Alice 3	Ramsey
Mattson 03	Becker	Fingal	Barnes	Martinson East	Ramsey
Mattson 98	Becker	Hagglund	Barnes	Martinson W 08	Ramsey
Bjornson	Clay	Key	Barnes	Little Kasperi	Ransom
Doran Lake 04	Clay	Lettemaier 1a	Barnes	Smith-Tanner	Ransom
Doran Lake 07	Clay	Lettenmaier 1	Barnes	Aaser	Richland
Hillestad 05	Clay	Olson	Barnes	Hartleben NE 1	Richland
Hillestad 06	Clay	Stoney Slough 1	Barnes	Hartleben NE 3	Richland
Noreen 06	Clay	Stoney Slough 2	Barnes	Hartleben NW	Richland
Rushfeldt 05	Clay	Stoney Slough 3	Barnes	Hartleben SE	Richland
Edwin Lake 07	Mahnomen	Stoney Slough 4	Barnes	Leack	Richland
Edwin Lake 81	Mahnomen	Hoffstrand N	Benson	Wollitz	Richland
Glacial Ridge 03 1	Polk	Hoffstrand S	Benson	Bauer	Sargent
Glacial Ridge 05 1	Polk	Mattson	Benson	H. Olson	Sargent
Glacial Ridge 05 E	Polk	Plummer	Benson	Krasue	Sargent
Glacial Ridge Fall 02 E	Polk	Rolling Rock	Benson	Nelson	Sargent
Glacial Ridge SE	Polk	Senger	Benson	Refuge Green Needle	Sargent
MEE 00	Polk	Trimmer	Benson	Refuge HSS	Sargent
MEE 04	Polk	Twin Lake	Benson	Refuge Kiefer Natives	Sargent
Melvin Slough 05	Polk	Alice 10	Cass	Refuge N. Marquette	Sargent
Melvin Slough 06	Polk	Alice 11	Cass	Refuge N. Pool 2	Sargent
Melvin Slough 07	Polk	Alice 7	Cass	Refuge Pool 4	Sargent
		Alice 8	Cass	Refuge Racetrack	Sargent
		Alice 9	Cass	Refuge S. Peanut	Sargent
		Kemmer	Cass	Refuge S. Picnic Area	Sargent
		Kraus	Cass	Refuge SLN	Sargent
		Kraus 2	Cass	Refuge WLN	Sargent
		Dahl	Cavalier	Fuller's Lake	Steele
		Storlie	Cavalier	Hornbacher	Steele
		Amundson	Grand Forks	Rogers	Steele
		Hart	Grand Forks	Shaw	Steele
		Kelly's Slough East	Grand Forks	Wigen	Steele
		Kelly's Slough West	Grand Forks	Grinde	Towner
		Nelson	Grand Forks	Register Unit 1	Towner
		Pender	Grand Forks	Register Unit 101	Towner
		Quanrud	Grand Forks	Register Unit 2	Towner
		Graving	Griggs	Register Unit 3	Towner
		Johnson	Griggs	Register Unit 32	Towner
		Ronnigen Field 2	Griggs	Register Unit 38	Towner
		Erickson	Nelson	Register Unit 4	Towner
		Goose River 1	Nelson	Register Unit 5	Towner
		Goose River 2	Nelson	Register Unit 50	Towner
		Rose Lake 1	Nelson	Register Unit 55	Towner
		Rose Lake 2	Nelson	SBA	Towner
		Rose Lake 3	Nelson	Stephen's Memorial	Towner
		Avocet Island	Ramsey	Vollrath	Towner
		Breakey	Ramsey	Erickson	Traill
		Elias	Ramsey		

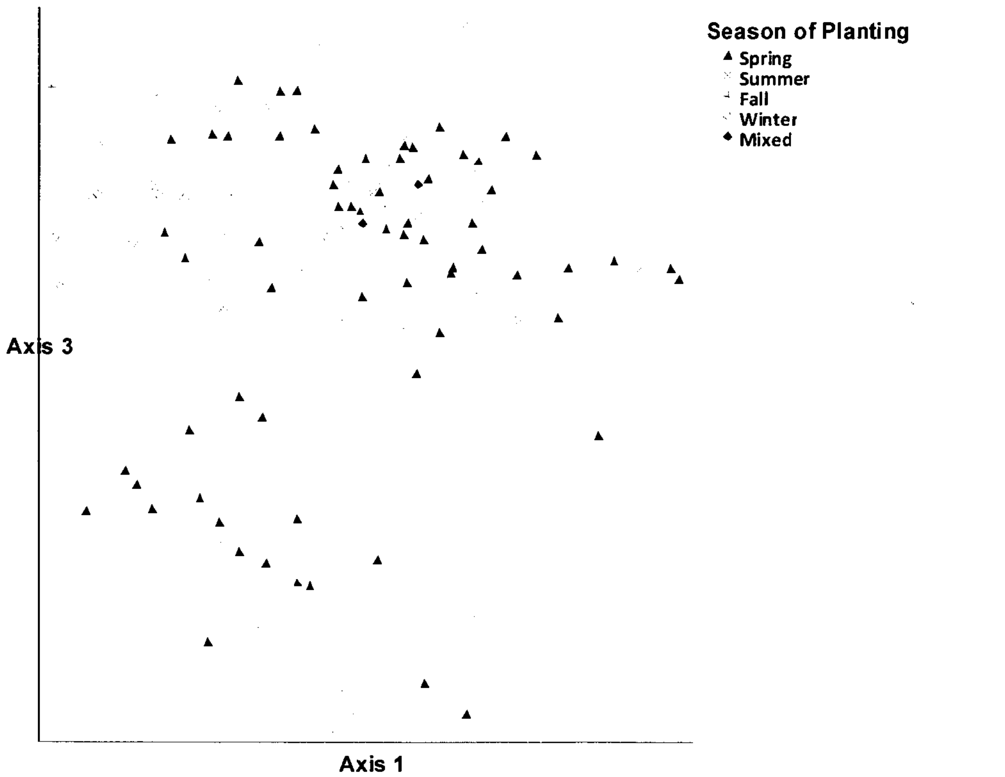
APPENDIX B. NMS 2D GRAPHS OF CATEGORIES

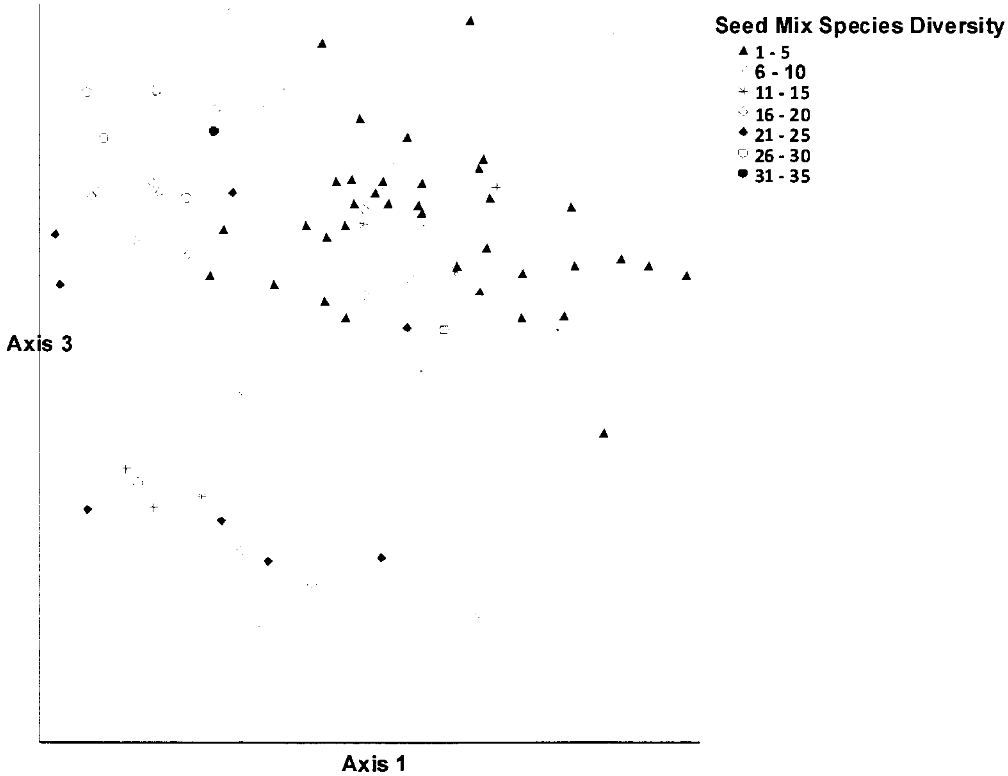


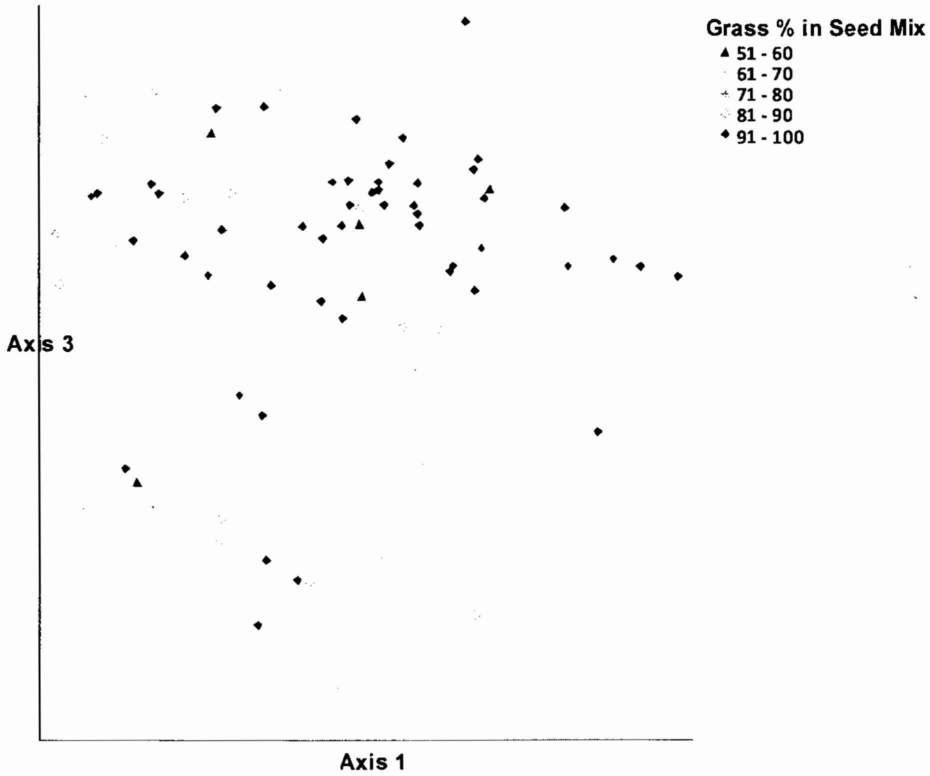


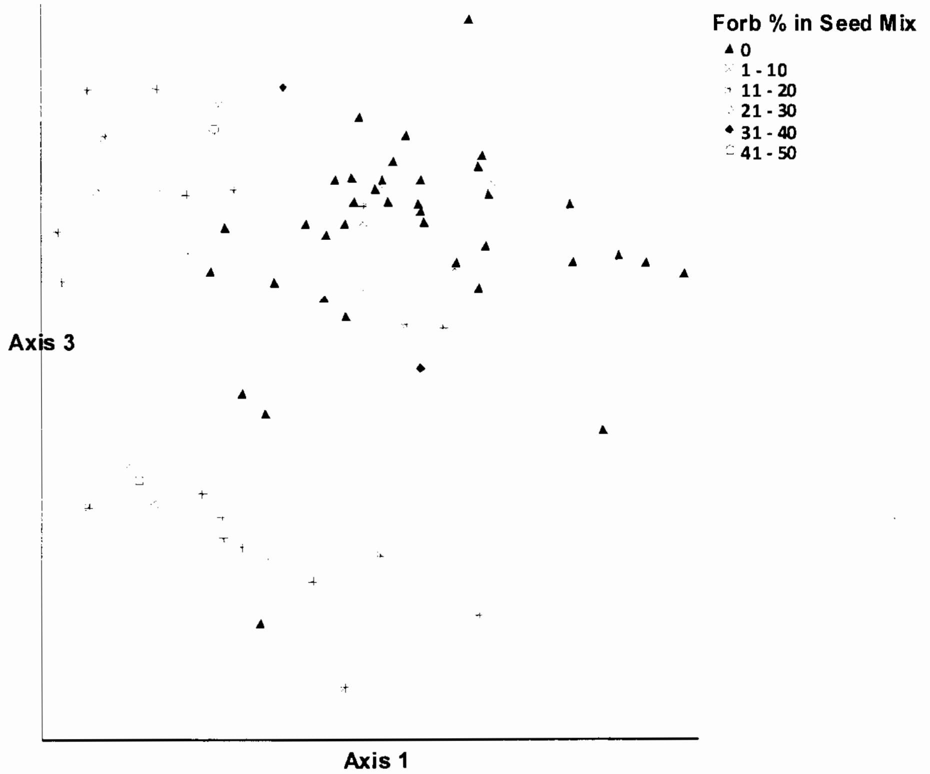

Bareground
Low
Medium
High
Axis 3
Axis 1

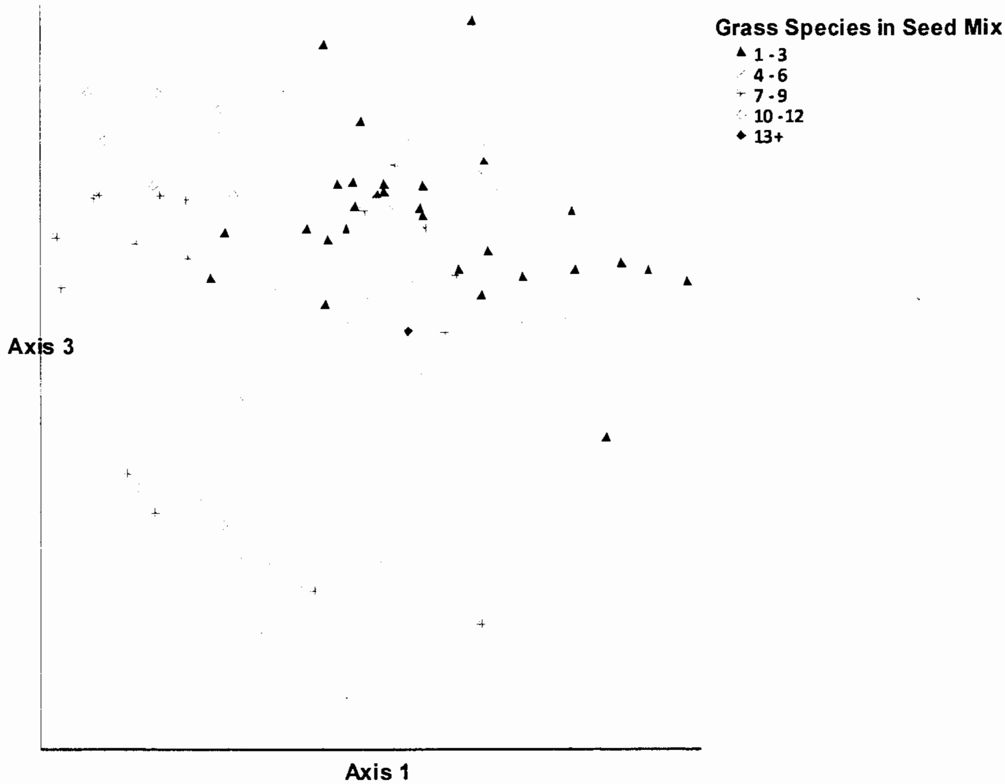

Age in Years
0 - 5
6 - 10
11 - 15
21 - 30
41 - 50
Axis 3
Axis 1

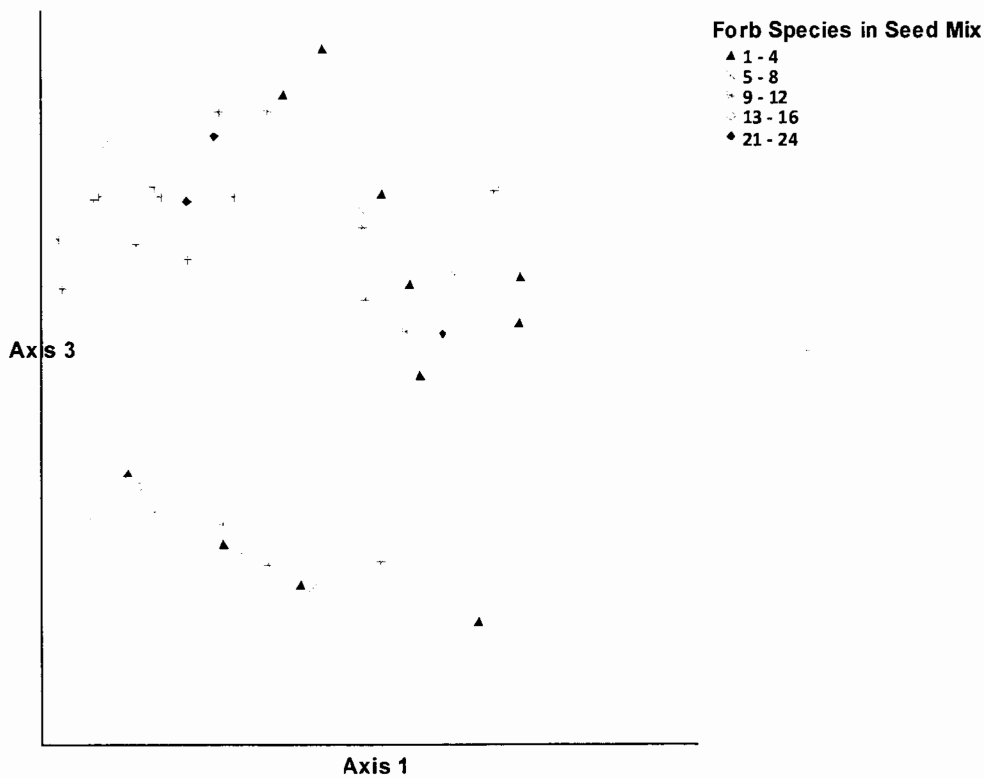

Season of Planting
Spring
Summer
Fall
Winter
Mixed
Axis 3
Axis 1

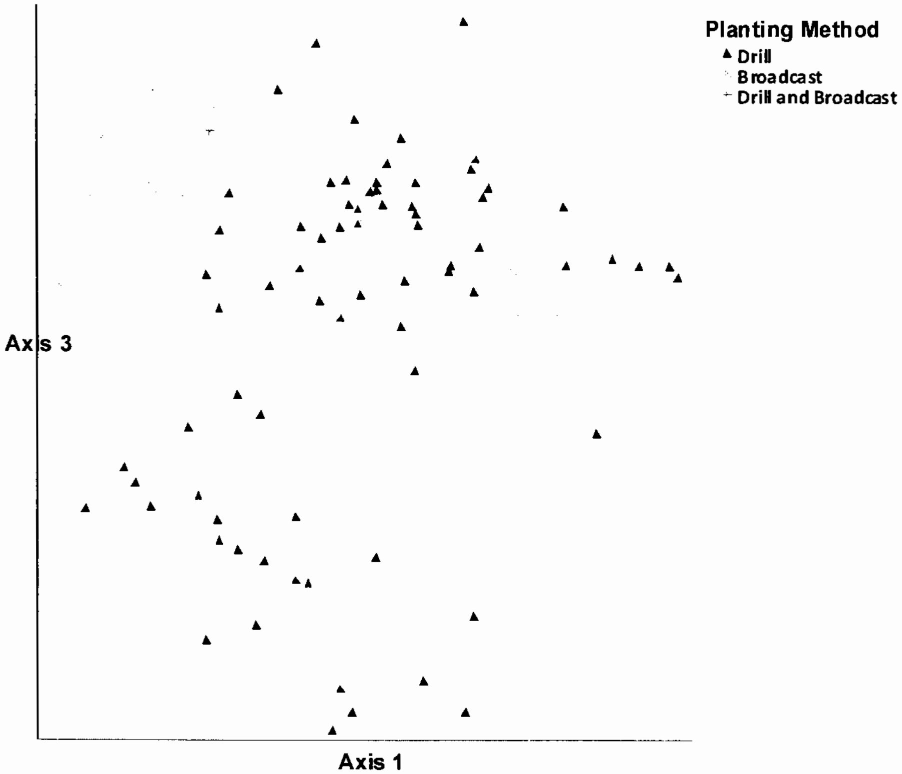

Seed Mix Species Diversity
1 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 35
Axis 3
Axis 1

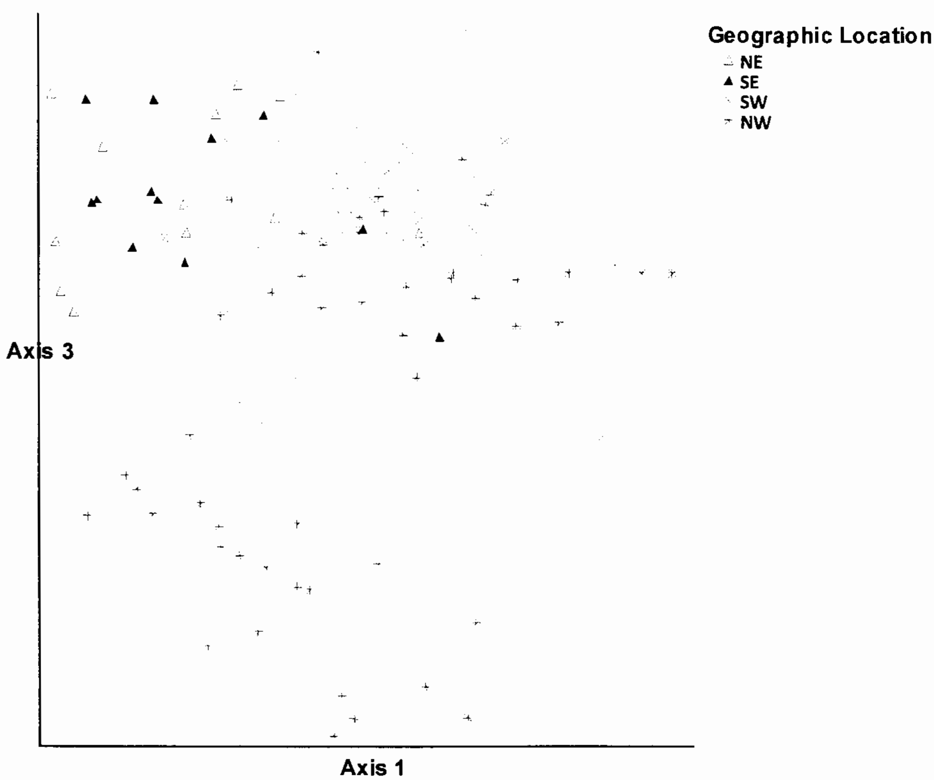

Grass % in Seed Mix
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
Axis 3
Axis 1

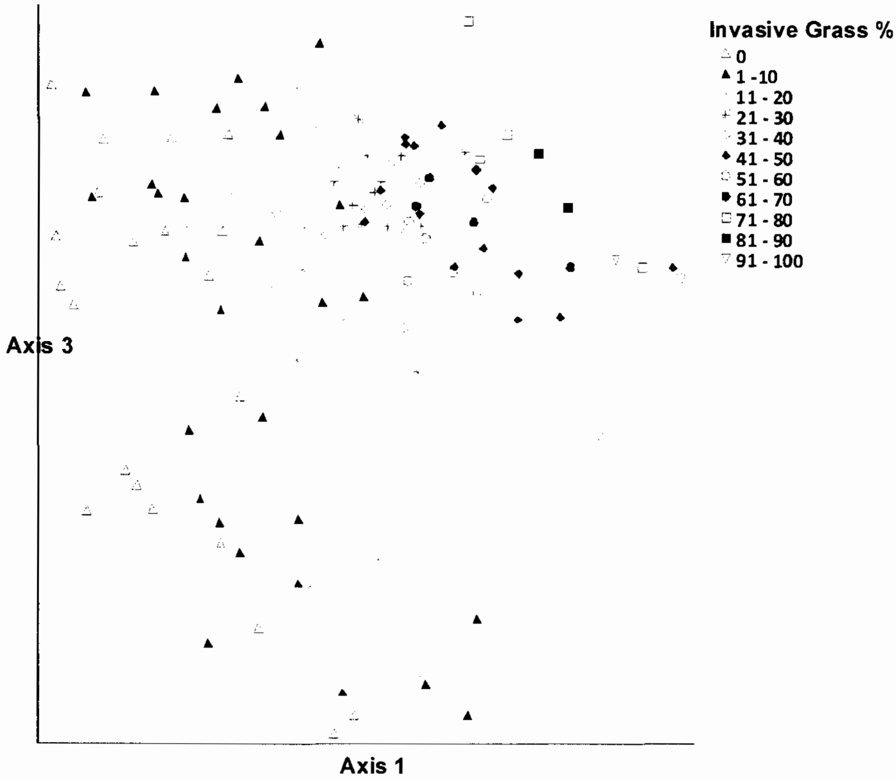

Forb % in Seed Mix
0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
Axis 3
Axis 1

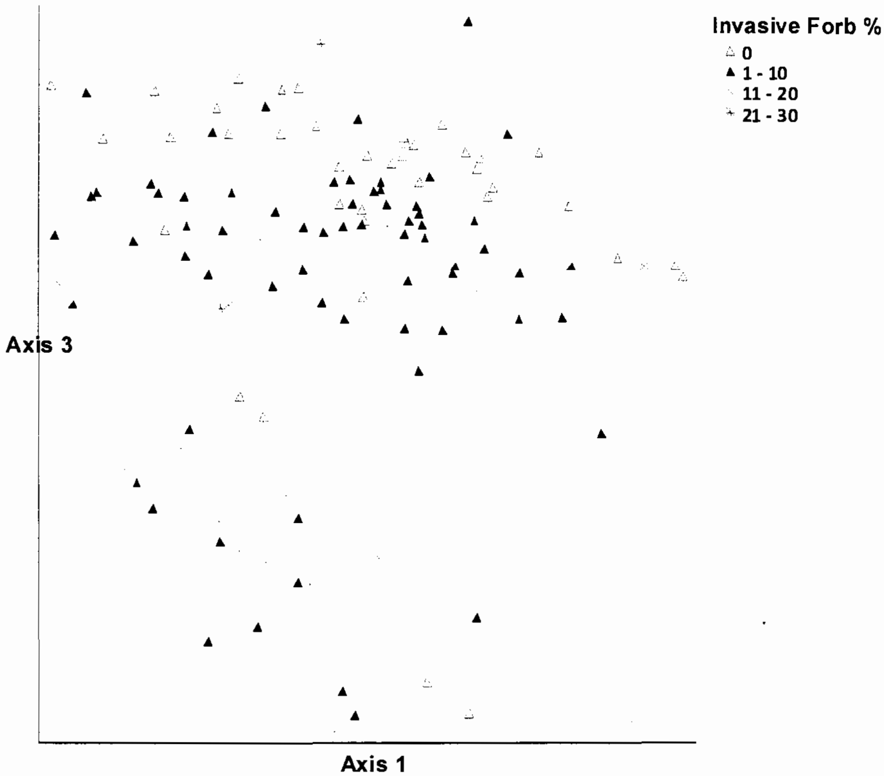

Grass Species in Seed Mix
1 - 3
4 - 6
7 - 9
10 - 12
13+
Axis 3
Axis 1

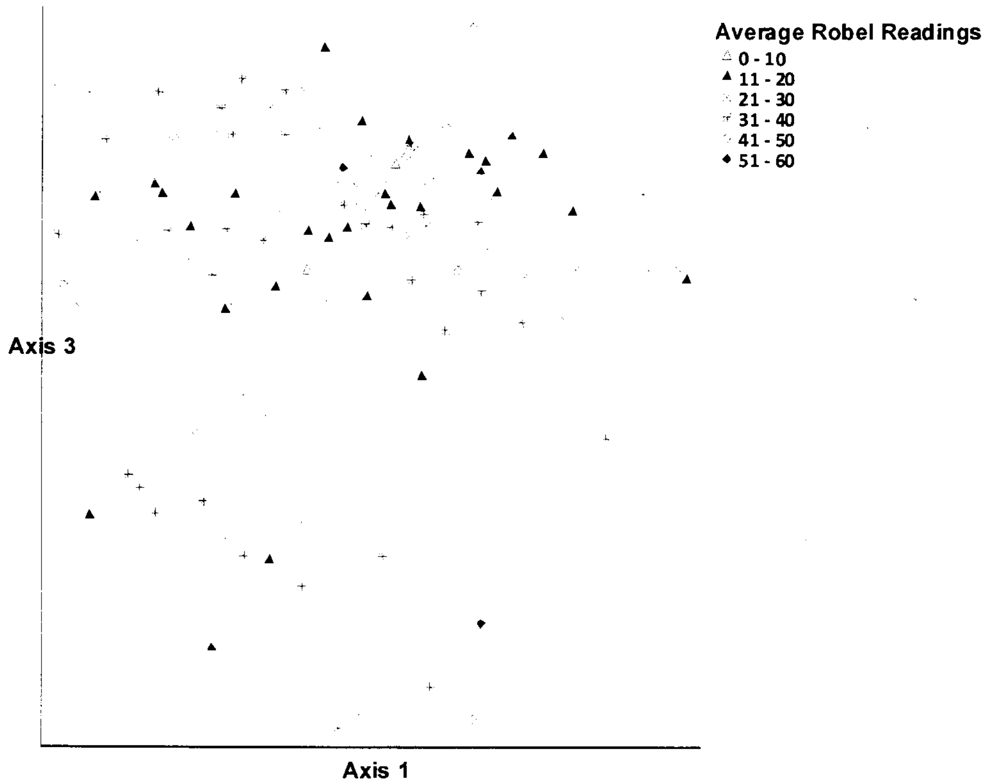

Forb Species in Seed Mix
1 - 4
5 - 8
9 - 12
13 - 16
21 - 24
Axis 3
Axis 1

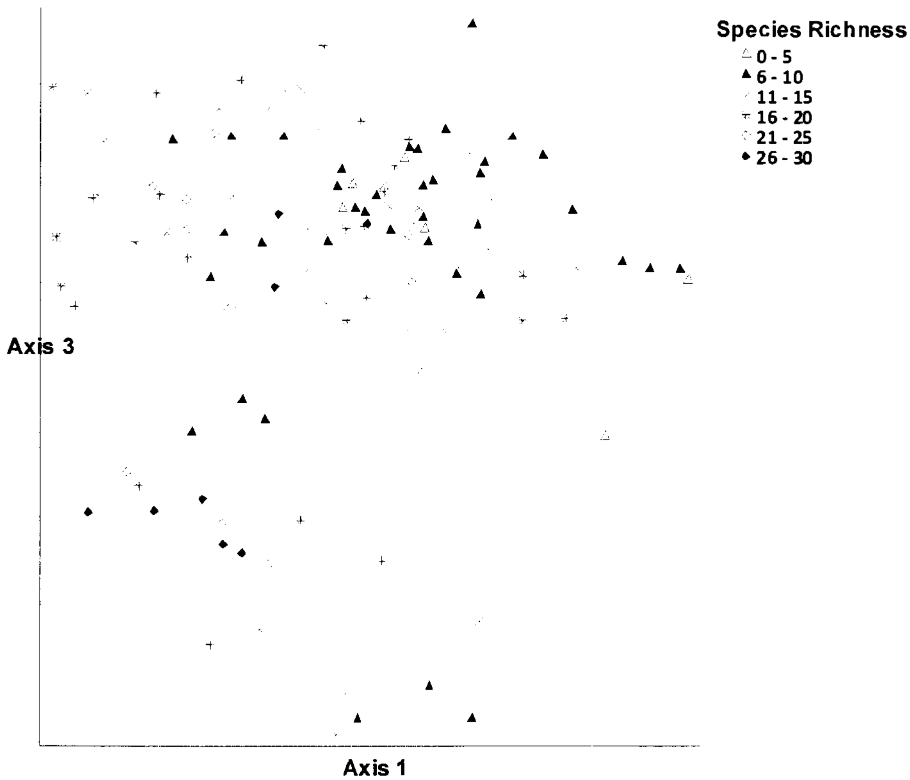

Planting Method
Drill
Broadcast
Drill and Broadcast
Axis 3
Axis 1

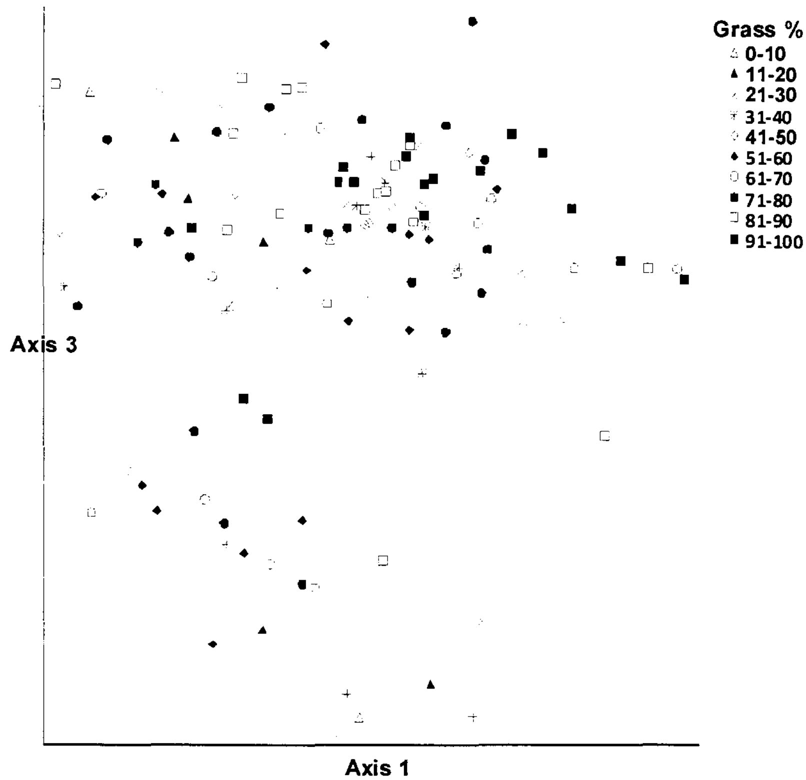

Geographic Location
NE
SE
SW
NW
Axis 3
Axis 1

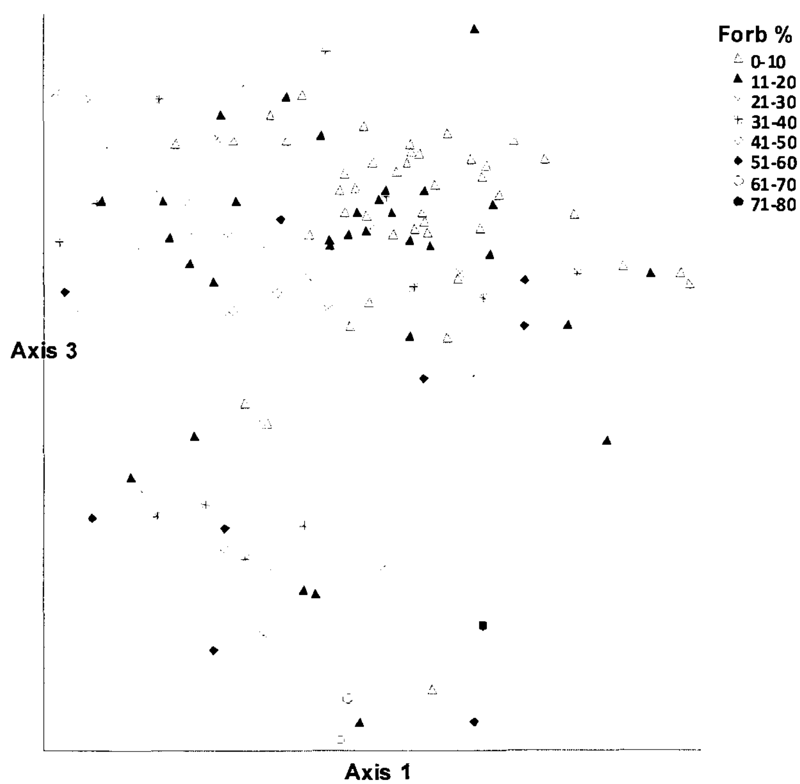

Invasive Grass %
0
1 -10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
Axis 3
Axis 1

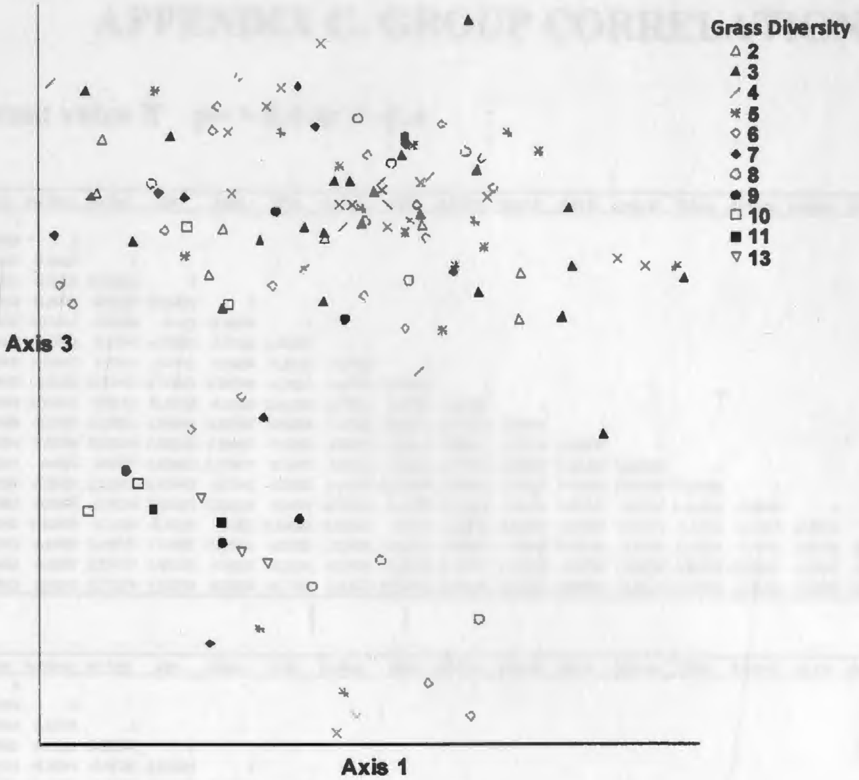

Invasive Forb %
0
1 - 10
11 - 20
21 - 30
Axis 3
Axis 1

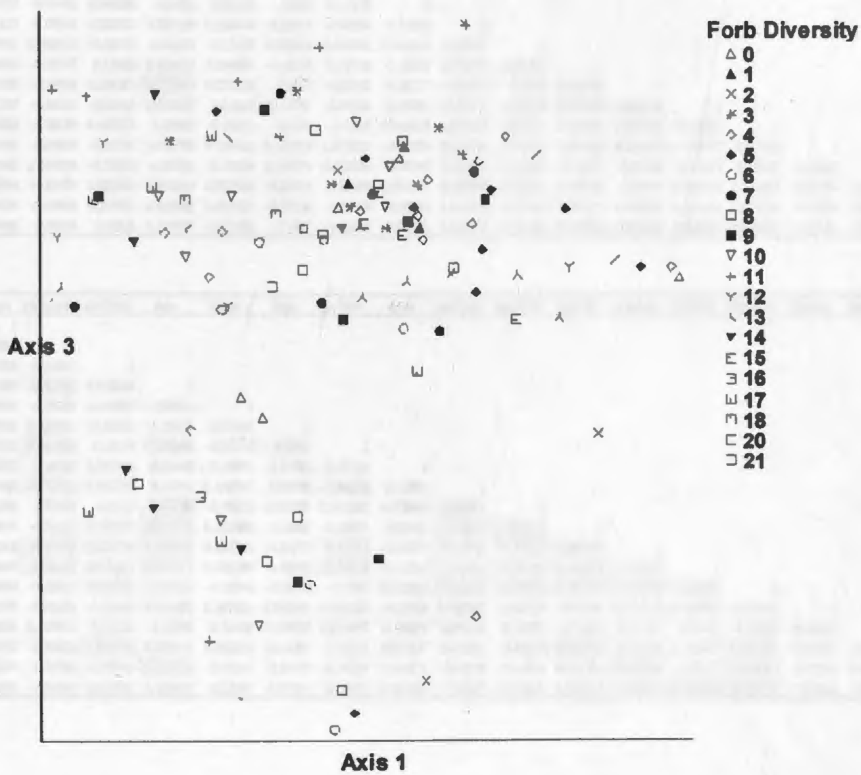

Average Robel Readings
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
Axis 3
Axis 1


Species Richness
0 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
Axis 3
Axis 1


Grass %
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
Axis 3
Axis 1


Forb %
0-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
Axis 3
Axis 1


Grass Diversity
2
3
4
5
6
7
8
9
10
11
13
Axis 3
Axis 1


Forb Diversity
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
20
21
Axis 3
Axis 1

APPENDIX C. GROUP CORRELATIONS

Significant value if p= > 0.4 or < -0.4

Group 1

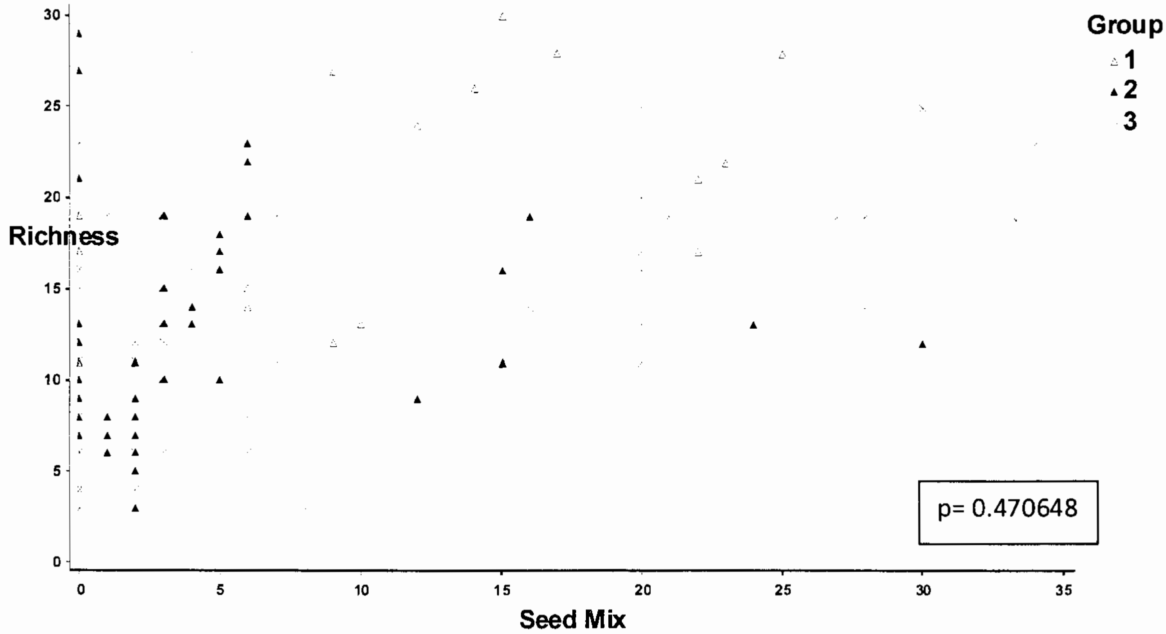
	Groups	Inv Grass	Inv Forb	Age	Robel	litter	bp litter	bare	seed mix	grass %	forb %	grass sp	forb sp	Richness	robel cv	Grasses	Forbes	N Grasses	N Forbes
Groups	1																		
Inv Grass	-0.18003	1																	
Inv Forb	-0.26517	-0.16417	1																
Age	-0.12263	-0.61988	0.113808	1															
Robel	-0.12678	-0.25437	-0.08433	0.188819	1														
litter	0.225695	0.125717	-0.26789	-0.162	-0.19005	1													
bp litter	-0.14184	0.80651	-0.19349	-0.58005	-0.27328	0.429587	1												
bare	0.079948	-0.10032	0.25114	-0.0411	-0.24256	-0.26121	-0.17719	1											
seed mix	0.079525	-0.51104	0.052442	0.712092	0.189348	-0.26252	-0.47628	-0.08442	1										
grass %	0.098608	0.276542	-0.05704	-0.49326	-0.14829	0.212536	0.270801	0.03724	-0.54137	1									
forb %	-0.07449	-0.33679	0.159012	0.509543	0.266181	-0.34748	-0.33733	0.005751	0.588672	-0.86541	1								
grass sp	-0.00924	-0.55724	0.129424	0.722139	0.184457	-0.32831	-0.53482	-0.04024	0.924941	-0.43814	0.520377	1							
forb sp	0.125011	-0.4504	0.00487	0.658692	0.179477	-0.20729	-0.41111	-0.10406	0.976046	-0.56424	0.588505	0.820087	1						
Richness	-0.19534	-0.30132	0.323212	0.328442	-0.21341	-0.29331	-0.24329	0.103004	0.470648	-0.39585	0.452547	0.502824	0.420739	1					
robel cv	0.160607	-0.05476	-0.24108	0.002603	0.261829	0.24032	0.024723	-0.15753	0.012257	-0.02196	0.037896	0.01126	0.012001	-0.26996	1				
Grasses	0.073945	0.381649	-0.21266	-0.15203	-0.1955	0.144286	0.323881	-0.0714	-0.23744	0.264353	-0.20589	-0.23901	-0.22066	-0.17866	-0.01315	1			
Forbes	-0.32915	-0.33405	0.437872	0.274902	0.199381	-0.32913	-0.23664	0.081843	0.234015	-0.29862	0.435505	0.22552	0.223219	0.56531	-0.05009	-0.37313	1		
N Grasses	-0.34626	-0.21387	0.217137	0.431209	-0.03112	-0.28792	-0.27705	-0.01646	0.362547	-0.29333	0.36788	0.486509	0.267335	0.629487	-0.24043	0.02006	0.23329	1	
N Forbes	-0.08322	-0.24042	0.277076	0.193716	-0.23718	-0.17932	-0.13527	0.101179	0.421022	-0.35573	0.380079	0.38227	0.415029	0.91662	-0.18731	-0.22576	0.576928	0.282809	1

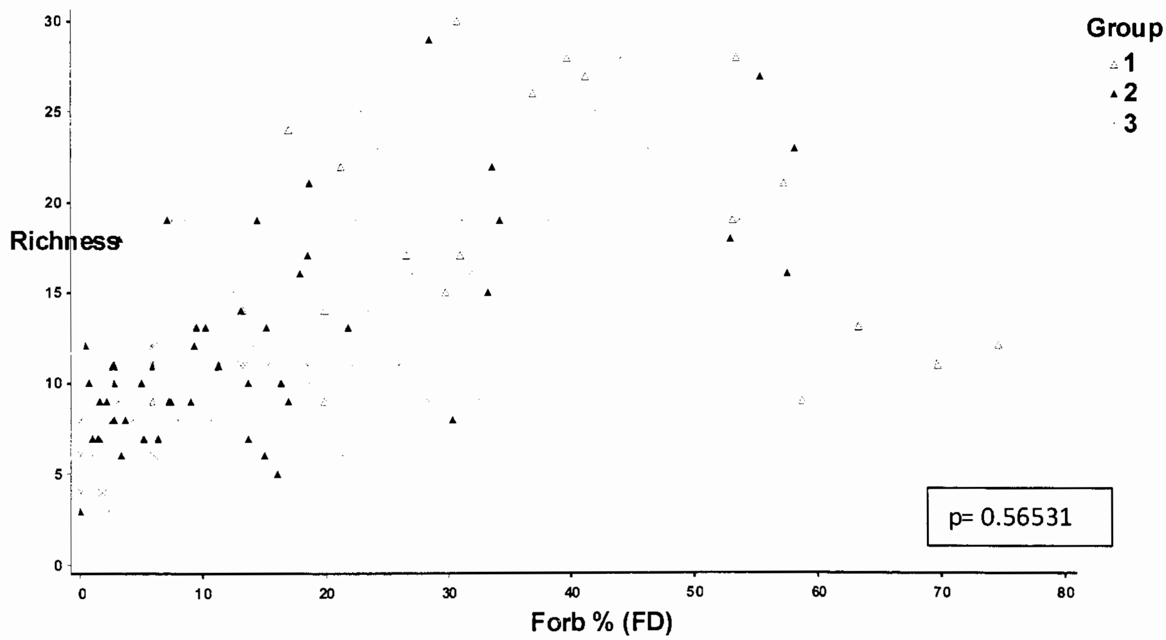
Group2

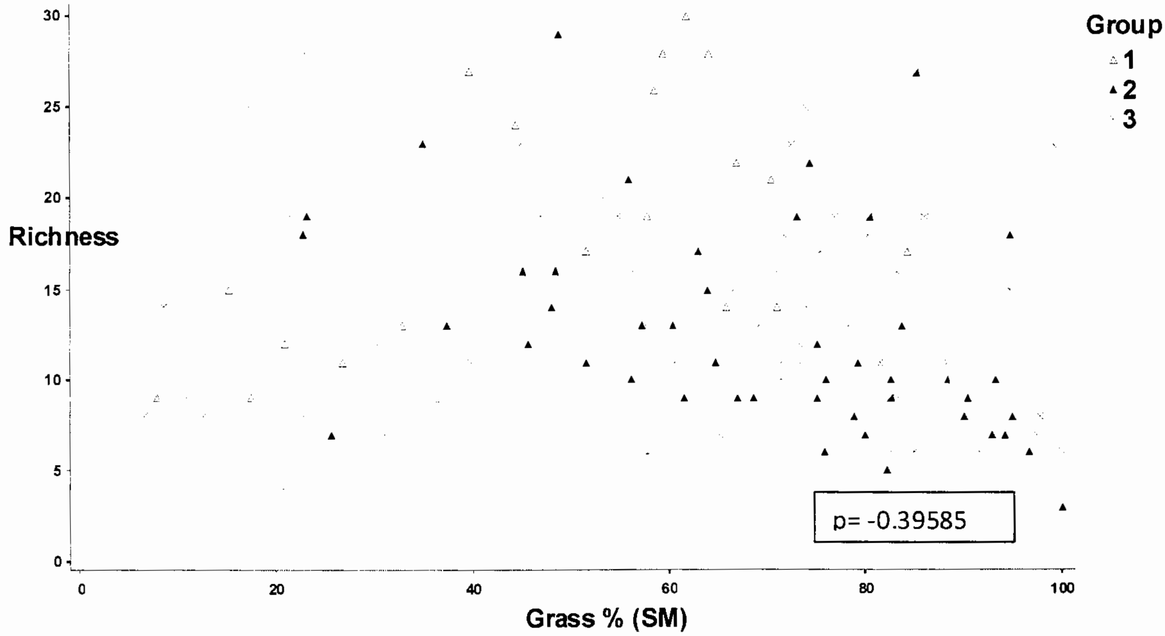
	Groups	Inv Grass	Inv Forb	Age	Robel	litter	bp litter	bare	seed mix	grass %	forb %	grass sp	forb sp	Richness	robel cv	Grasses	Forbes	N Grasses	N Forbes
Groups	1																		
Inv Grass	-0.21434	1																	
Inv Forb	-0.24714	-0.15192	1																
Age	-0.09022	-0.61321	0.098242	1															
Robel	-0.17594	-0.28344	-0.06128	0.223904	1														
litter	0.202356	0.111358	-0.25517	-0.14425	-0.22112	1													
bp litter	-0.17085	0.804181	-0.18301	-0.57419	-0.29941	0.421621	1												
bare	0.094797	-0.09445	0.243189	-0.0496	-0.23567	-0.256	-0.17243	1											
seed mix	0.11622	-0.50261	0.023315	0.707166	0.228148	-0.24331	-0.46764	-0.13215	1										
grass %	0.079991	0.268137	-0.03722	-0.48662	-0.17179	0.199318	0.261868	0.066324	-0.53412	1									
forb %	-0.04882	-0.32677	0.13566	0.501013	0.299988	-0.33275	-0.32768	-0.03049	0.579044	-0.86389	1								
grass sp	0.022669	-0.54994	0.104061	0.717417	0.221125	-0.3117	-0.52756	-0.08357	0.922831	-0.4291	0.509545	1							
forb sp	0.161787	-0.44092	-0.02452	0.652637	0.21647	-0.18741	-0.40134	-0.15088	0.975374	-0.55754	0.579156	0.815146	1						
Richness	-0.15893	-0.28599	0.302571	0.30979	-0.18215	-0.2742	-0.2285	0.089832	0.449915	-0.38382	0.436191	0.484798	0.398983	1					
robel cv	0.140916	-0.06826	-0.23291	0.019763	0.248414	0.229729	0.013923	-0.15376	0.027956	-0.03163	0.050938	0.026115	0.027071	-0.25748	1				
Grasses	0.075542	0.384399	-0.21623	-0.15352	-0.19874	0.145771	0.325679	-0.07248	-0.24281	0.266661	-0.20899	-0.24394	-0.22545	-0.18405	-0.01369	1			
Forbes	-0.28864	-0.31639	0.425986	0.246237	0.257808	-0.30814	-0.21884	0.070961	0.204909	-0.28311	0.418356	0.19772	0.194926	0.546236	-0.02439	-0.38506	1		
N Grasses	-0.3239	-0.19893	0.196955	0.418941	0.000222	-0.27191	-0.26534	-0.02982	0.341427	-0.27987	0.351213	0.470505	0.244028	0.615632	-0.22924	0.019388	0.203401	1	
N Forbes	-0.0498	-0.22618	0.25863	0.174798	-0.21295	-0.1607	-0.12046	0.09011	0.402394	-0.34365	0.363498	0.363478	0.396987	0.91422	-0.17502	-0.23024	0.564085	0.260398	1

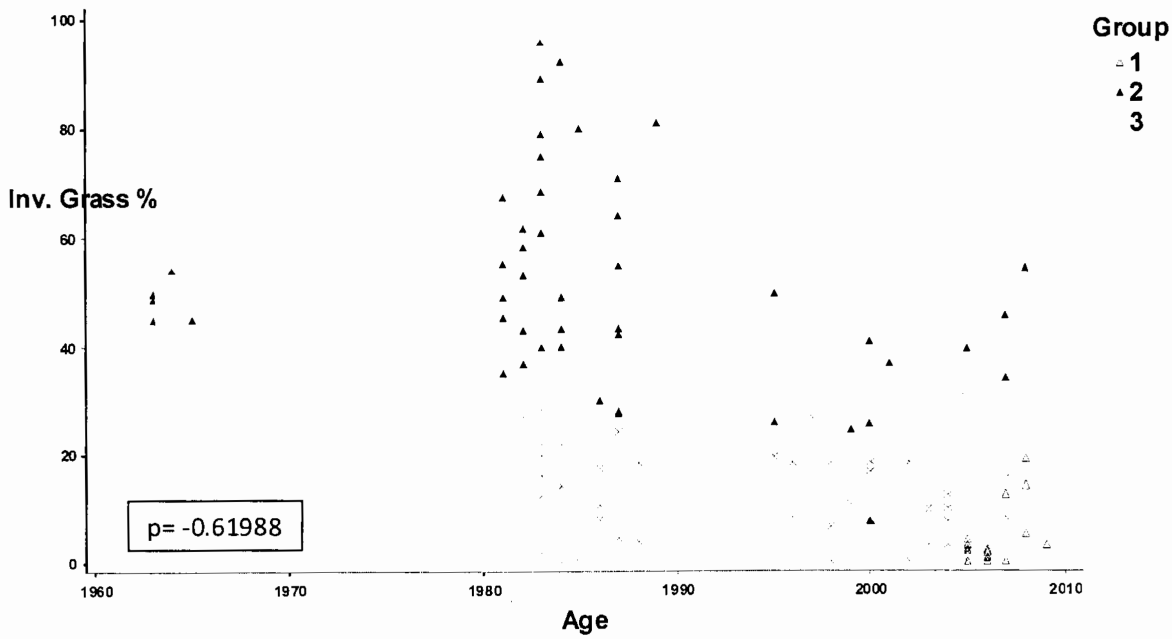
Group 3

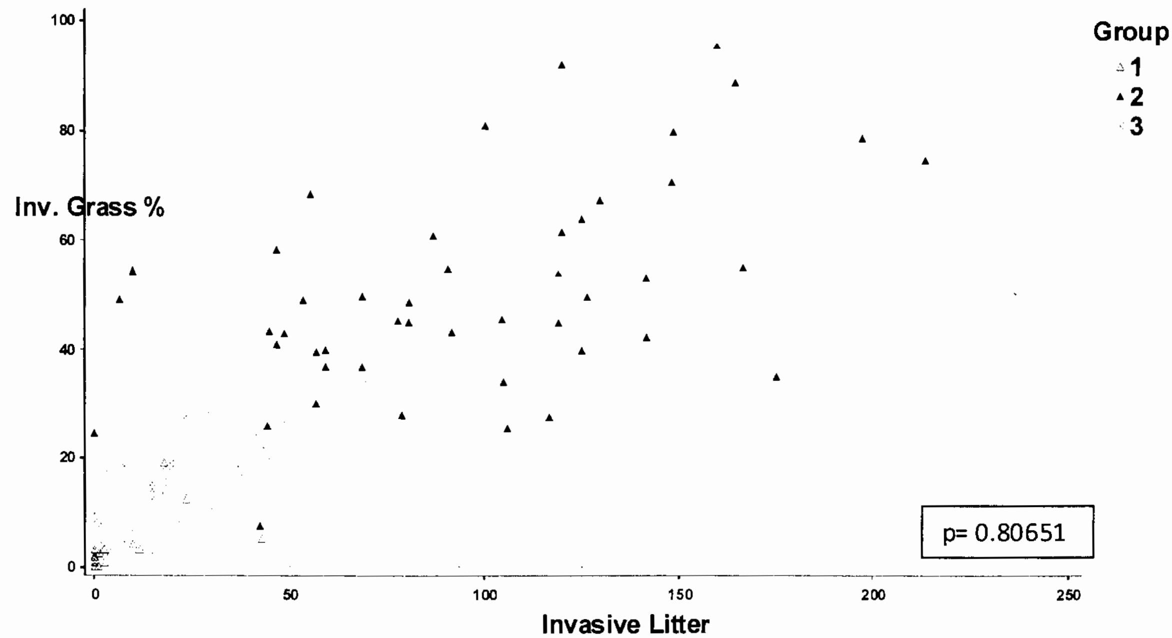
	Groups	Inv Grass	Inv Forb	Age	Robel	litter	bp litter	bare	seed mix	grass %	forb %	grass sp	forb sp	Richness	robel cv	Grasses	Forbes	N Grasses	N Forbes
Groups	1																		
Inv Grass	-0.18281	1																	
Inv Forb	-0.26333	-0.16347	1																
Age	-0.12085	-0.61705	0.118284	1															
Robel	-0.13397	-0.25015	-0.07867	0.193726	1														
litter	0.205791	0.129021	-0.26191	-0.15677	-0.17486	1													
bp litter	-0.15112	0.805803	-0.19066	-0.57397	-0.26275	0.4361	1												
bare	0.094317	-0.10289	0.233914	-0.05448	-0.25855	-0.27692	-0.18764	1											
seed mix	0.066883	-0.50443	0.059108	0.71347	0.199797	-0.24089	-0.46091	-0.12791	1										
grass %	0.106284	0.27336	-0.0621	-0.49689	-0.15615	0.195752	0.261182	0.073494	-0.54499	1									
forb %	-0.08244	-0.33337	0.163547	0.513071	0.272865	-0.32825	-0.32713	-0.03801	0.59189	-0.86622	1								
grass sp	-0.02263	-0.54878	0.136336	0.723154	0.196618	-0.30229	-0.51617	-0.09983	0.925784	-0.44312	0.524478	1							
forb sp	0.113847	-0.44542	0.010821	0.660472	0.188339	-0.18961	-0.39872	-0.13554	0.97614	-0.56733	0.591438	0.821604	1						
Richness	-0.19934	-0.29924	0.321963	0.325821	-0.20946	-0.28475	-0.2382	0.095868	0.472281	-0.39755	0.454032	0.504039	0.42264	1					
robel cv	0.147979	-0.05159	-0.23943	0.002289	0.265405	0.248183	0.032089	-0.16454	0.020567	-0.02798	0.043856	0.020832	0.019036	-0.26471	1				
Grasses	0.080806	0.378624	-0.21224	-0.15099	-0.19836	0.134857	0.316649	-0.06131	-0.24131	0.26712	-0.20892	-0.24327	-0.22415	-0.18093	-0.01818	1			
Forbes	-0.33504	-0.33005	0.437698	0.275121	0.205216	-0.31407	-0.22757	0.064564	0.242197	-0.30394	0.439763	0.235018	0.230217	0.566065	-0.04321	-0.37585	1		
N Grasses	-0.35637	-0.20781	0.215768	0.425879	-0.02184	-0.26704	-0.26264	-0.03278	0.368893	-0.29878	0.372763	0.492245	0.273517	0.629641	-0.22702	0.012324	0.240215	1	
N Forbes	-0.08231	-0.24034	0.276582	0.192981	-0.23598	-0.17794	-0.13499	0.099028	0.4207	-0.35575	0.380011	0.381788	0.415079	0.915504	-0.1868	-0.22522	0.574861	0.280362	1


Group
1
2
3
Richness
p= 0.470648
Seed Mix

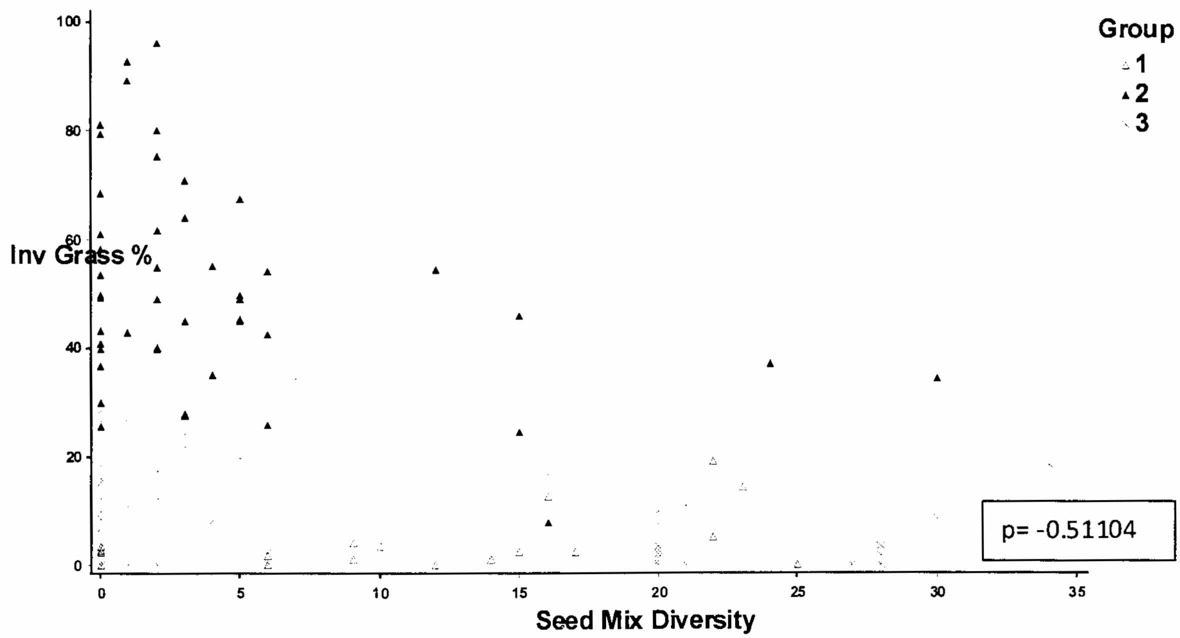

Group
1
2
3
Richness
p= 0.56531
Forb % (FD)


Group
1
2
3
Richness
p= -0.39585
Grass % (SM)
0
5
10
15
20
25
30
0
20
40
60
80
100

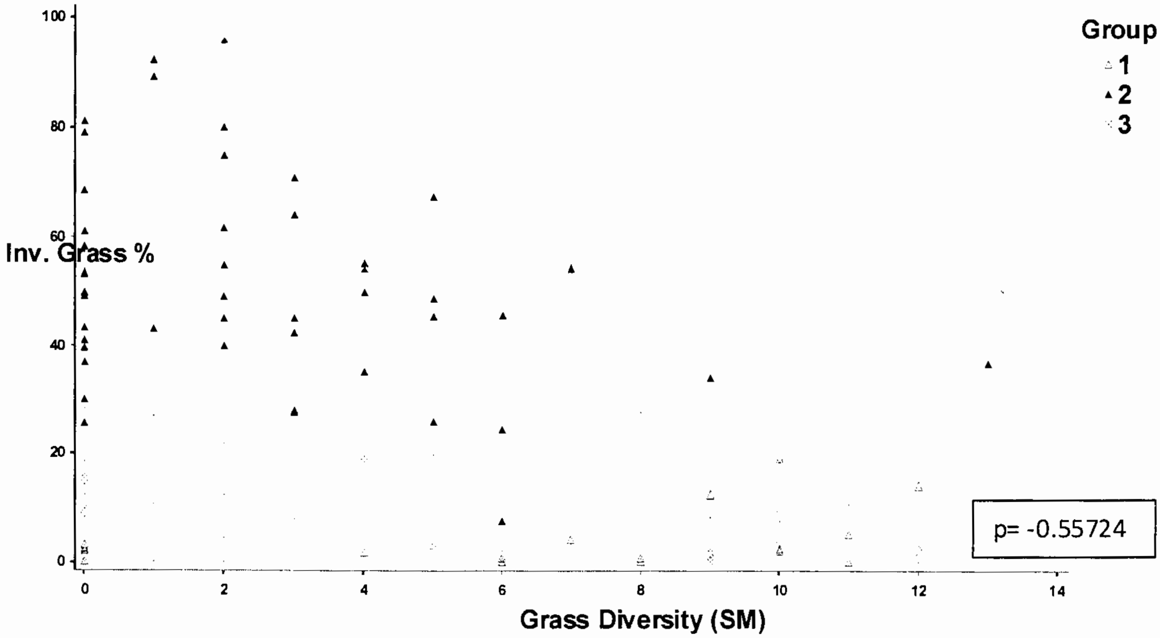

Group
1
2
3
Inv. Grass %
p= -0.61988
Age
0
20
40
60
80
100
1960
1970
1980
1990
2000
2010

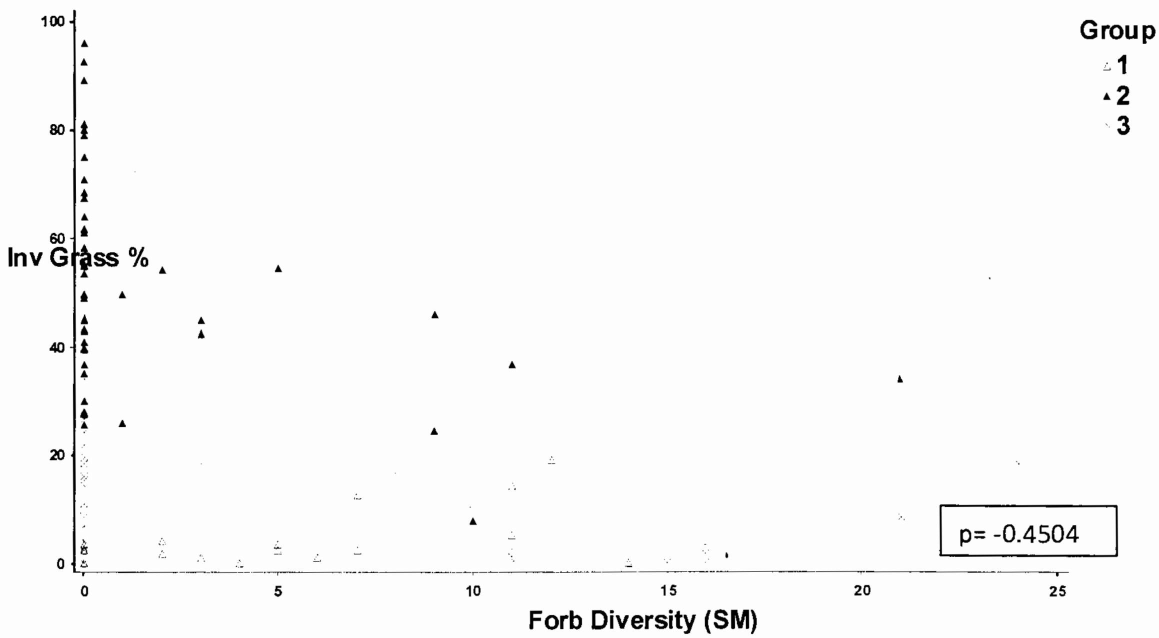


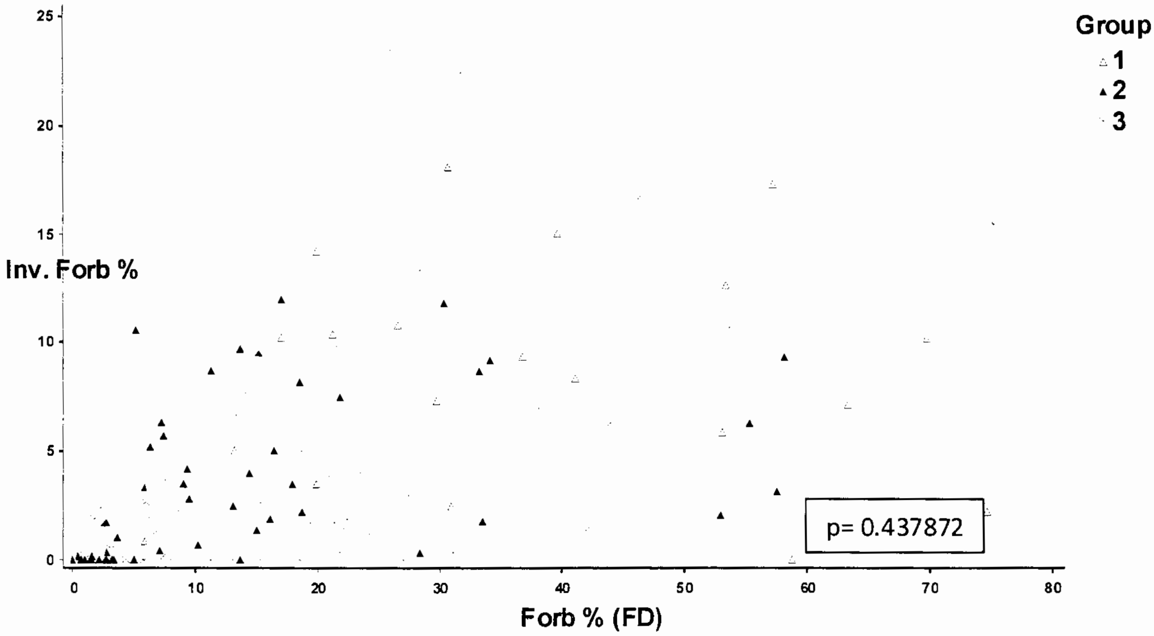
Group
1
2
3
Inv. Grass %
100
80
60
40
20
0
0
50
100
150
200
250
Invasive Litter
p= 0.80651

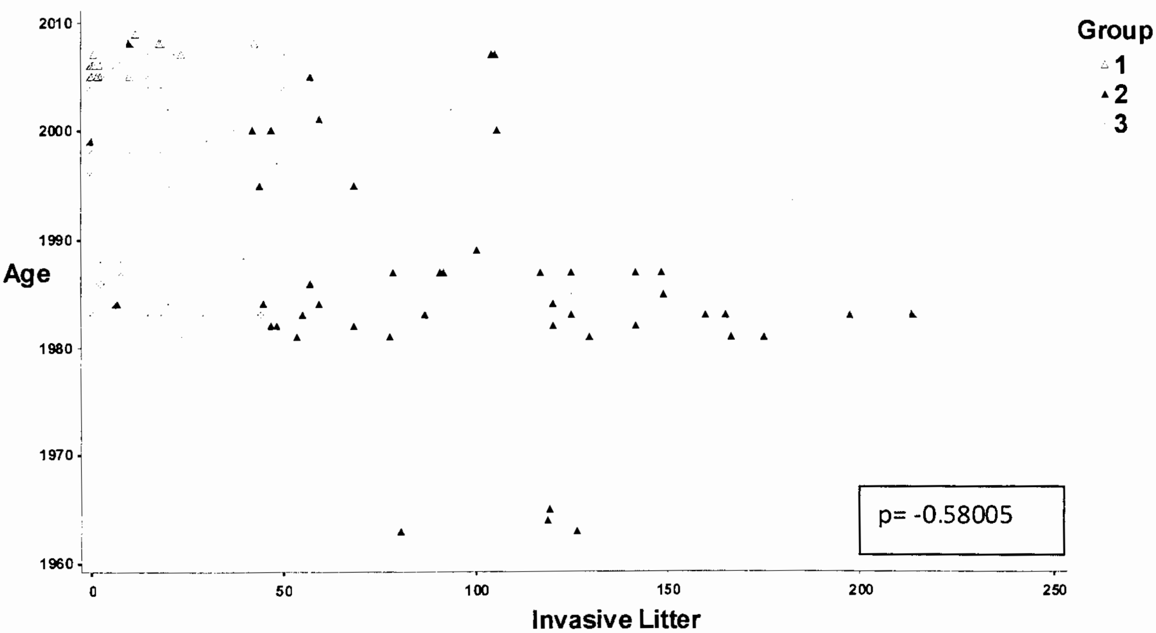


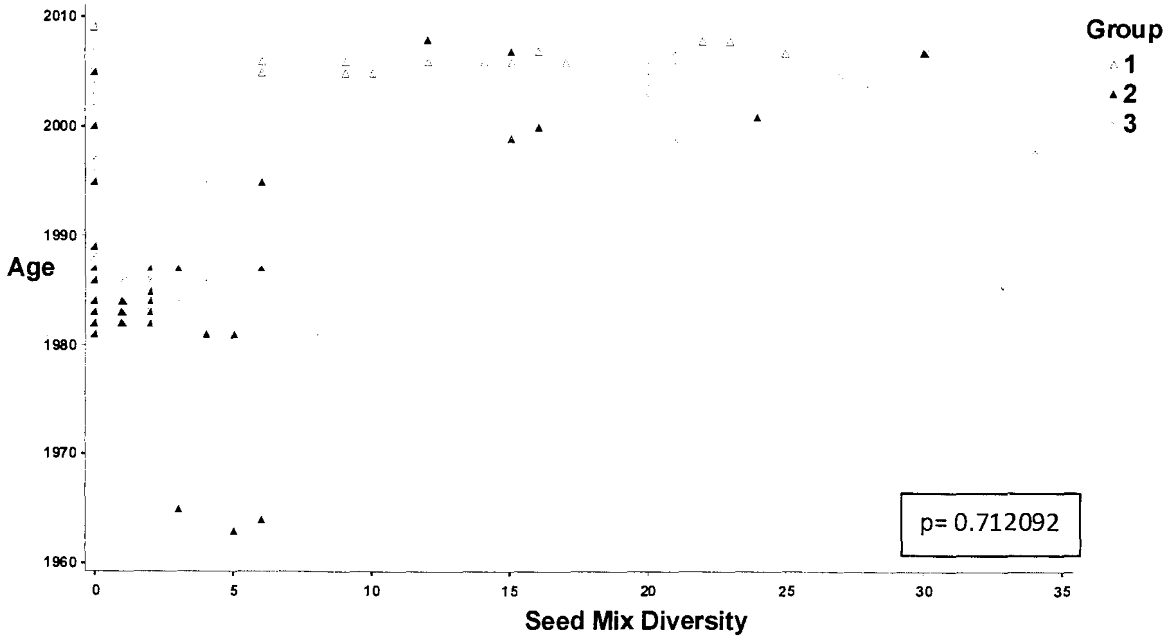
Group
1
2
3
Inv Grass %
100
80
60
40
20
0
0
5
10
15
20
25
30
35
Seed Mix Diversity
p= -0.51104

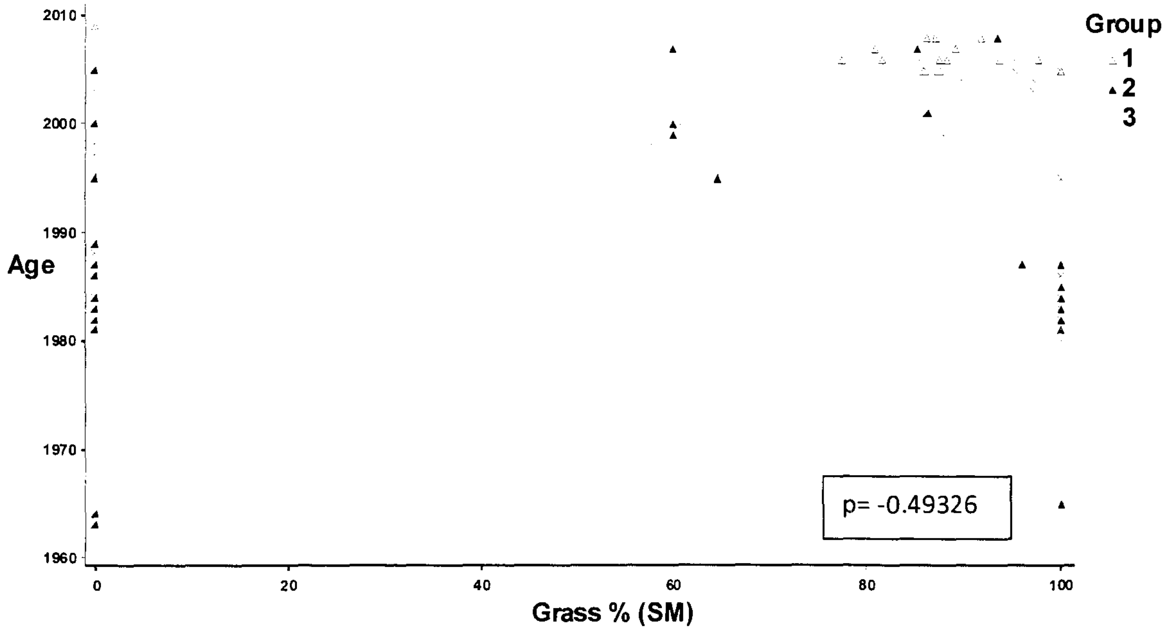

Group
1
2
3
Inv. Grass %
Grass Diversity (SM)
p= -0.55724
0
20
40
60
80
100
0
2
4
6
8
10
12
14

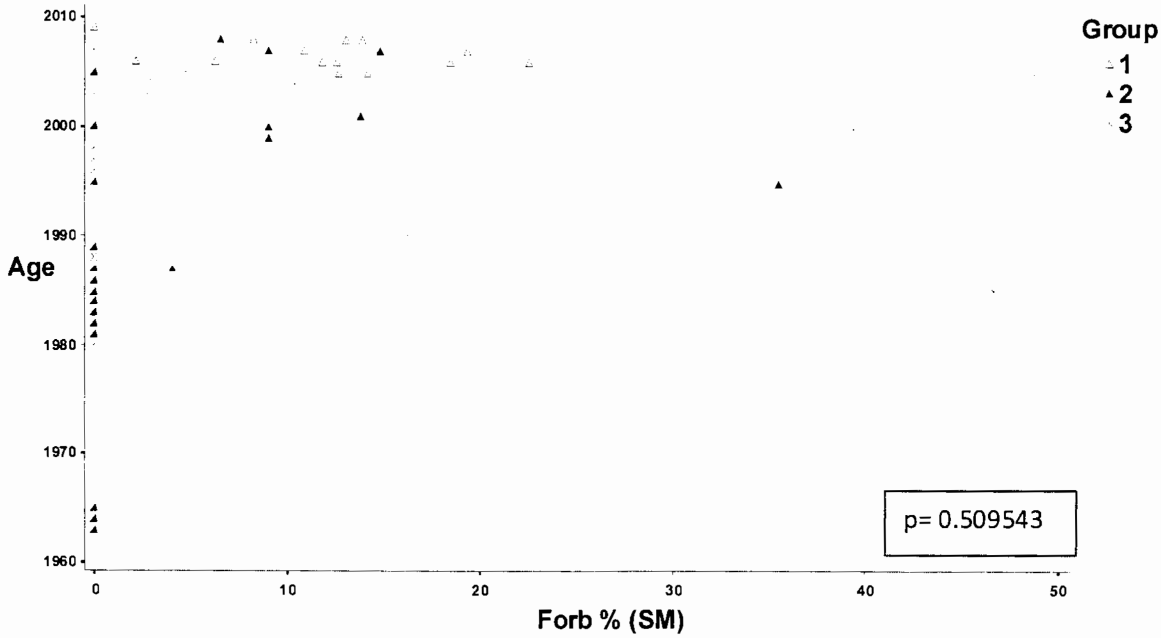

Group
1
2
3
Inv Grass %
Forb Diversity (SM)
p= -0.4504
0
20
40
60
80
100
0
5
10
15
20
25

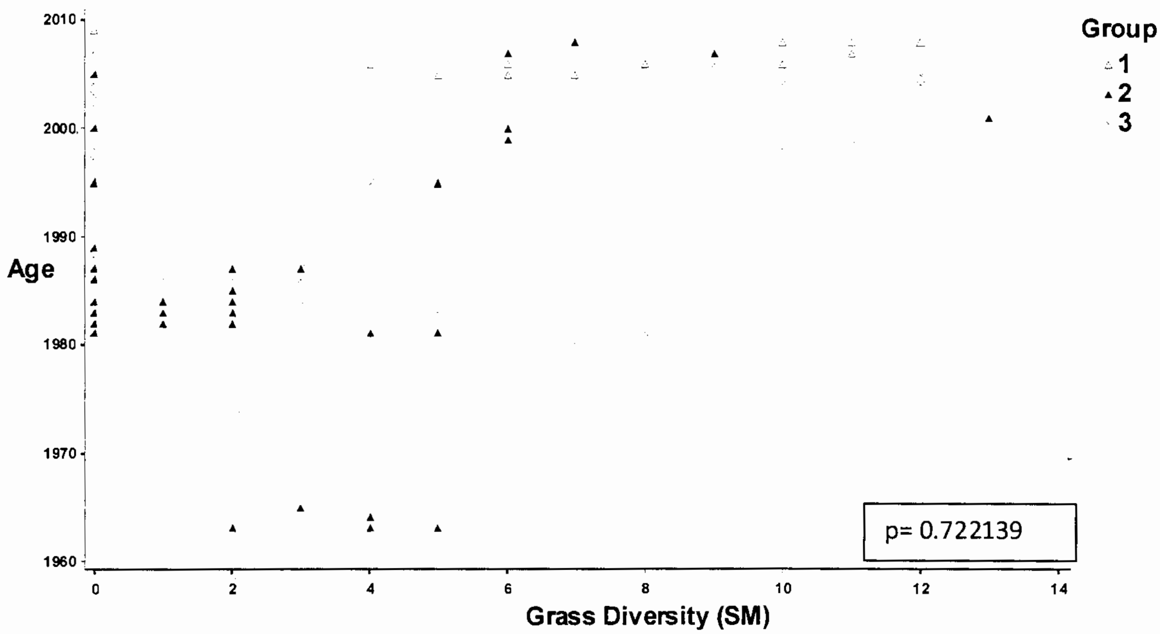

Group
1
2
3
Inv. Forb %
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
Forb % (FD)
p= 0.437872

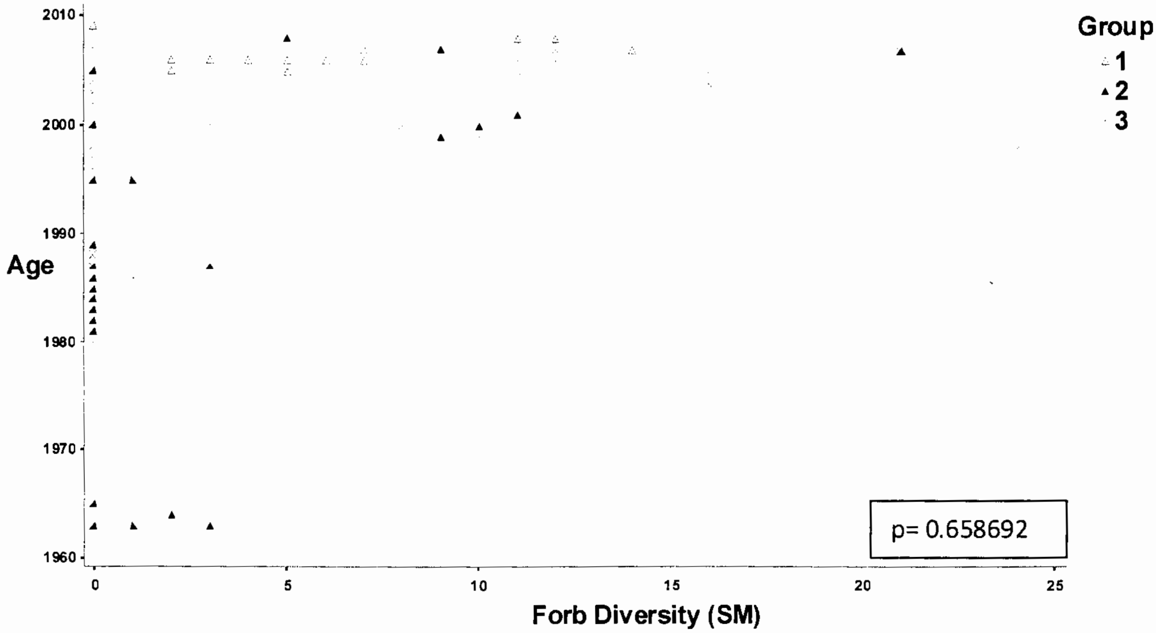

Group
1
2
3
Age
2010
2000
1990
1980
1970
1960
0
50
100
150
200
250
Invasive Litter
p= -0.58005


Group
1
2
3
Age
Seed Mix Diversity
p= 0.712092

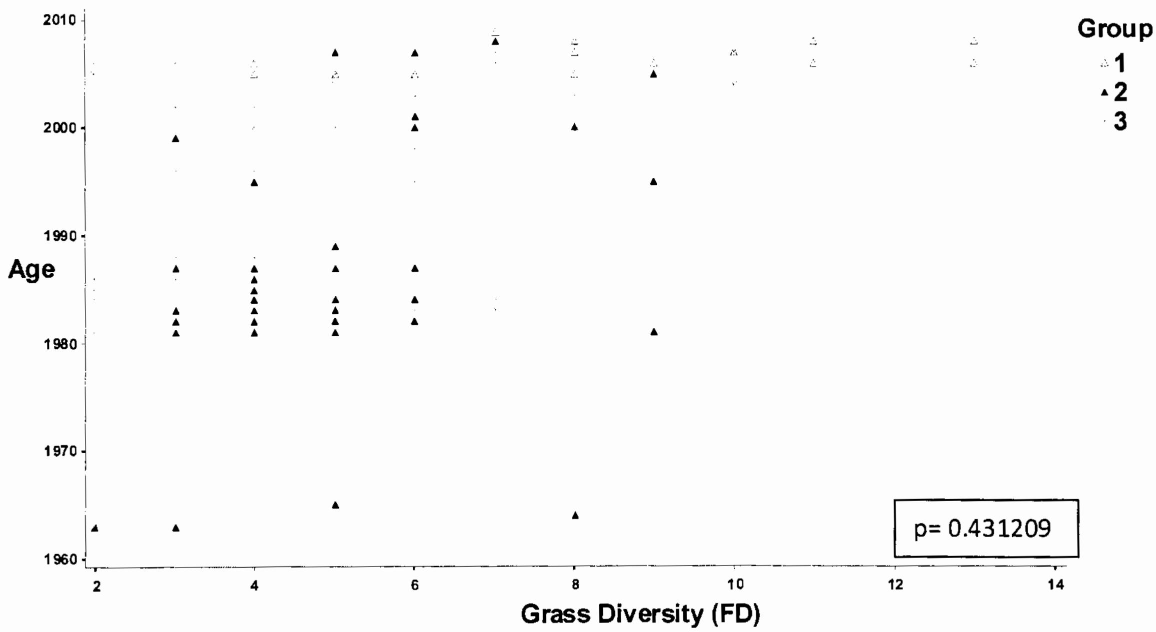

Group
1
2
3
Age
Grass % (SM)
p= -0.49326


Group
1
2
3
Age
2010
2000
1990
1980
1970
1960
0
10
20
30
40
50
Forb % (SM)
p= 0.509543

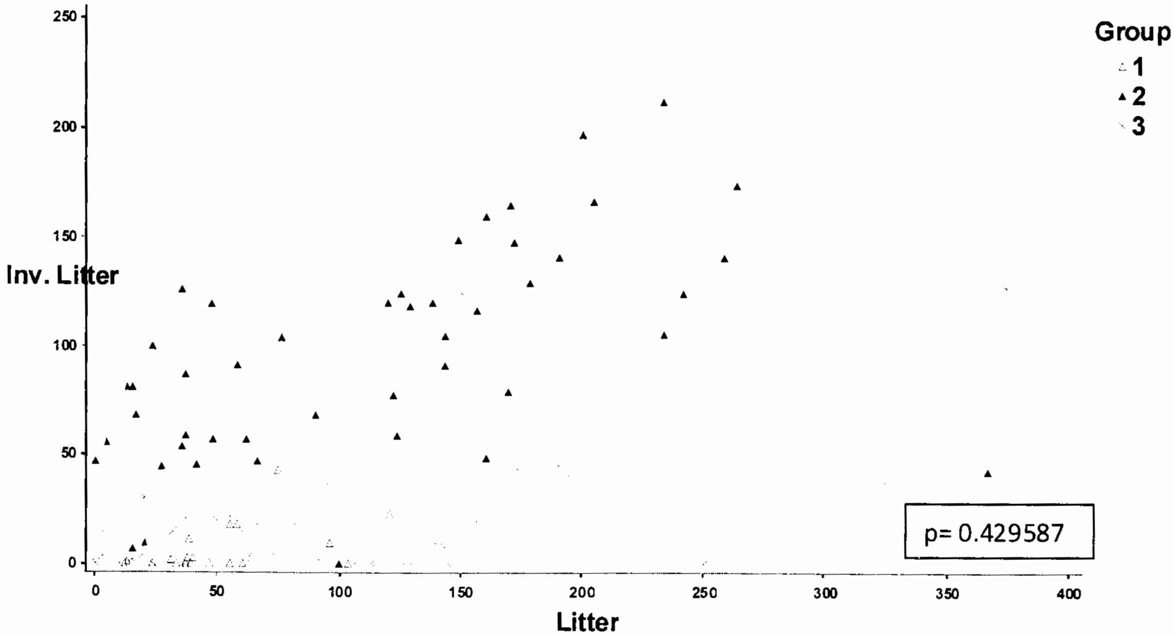

Group
1
2
3
Age
2010
2000
1990
1980
1970
1960
0
2
4
6
8
10
12
14
Grass Diversity (SM)
p= 0.722139

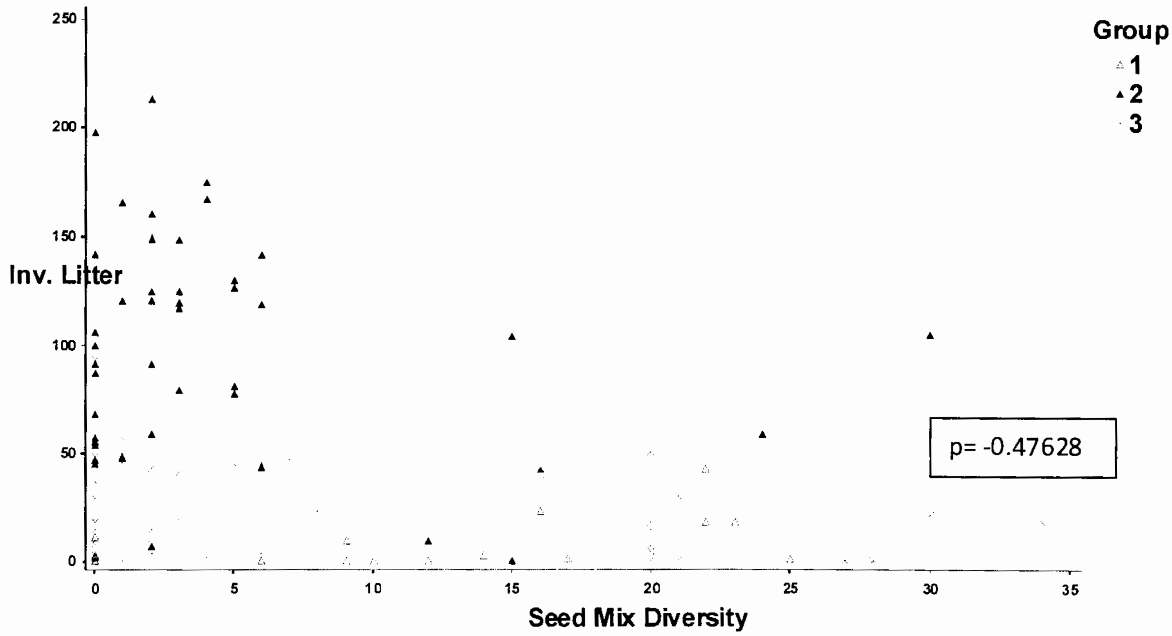


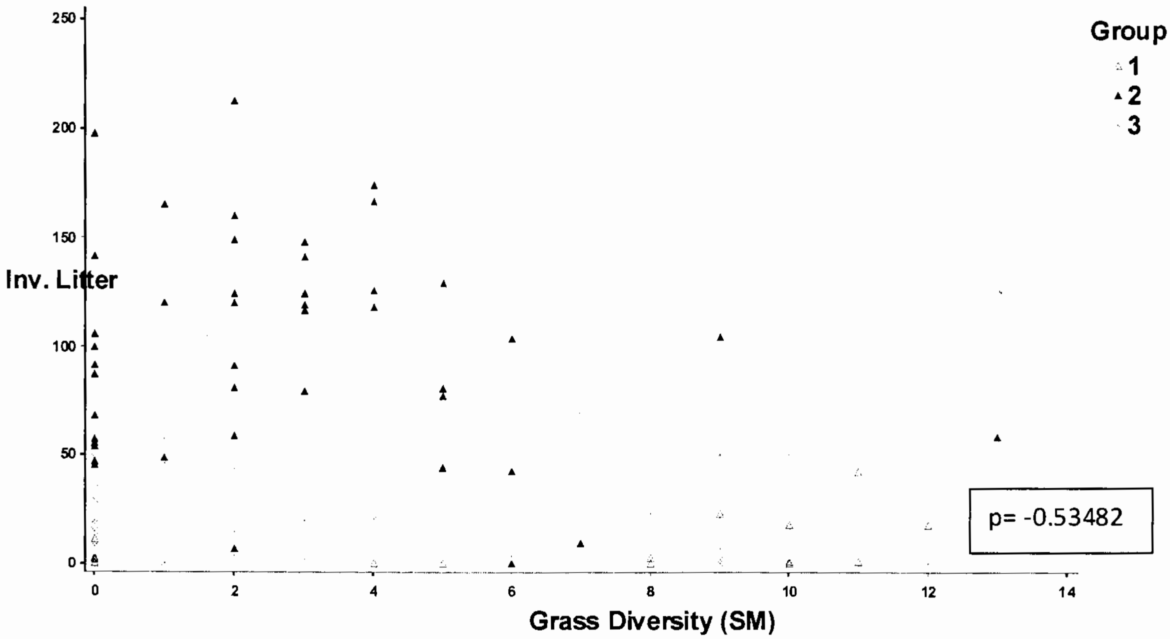
Group
1
2
3
Age
2010
2000
1990
1980
1970
1960
0
5
10
15
20
25
Forb Diversity (SM)
p= 0.658692

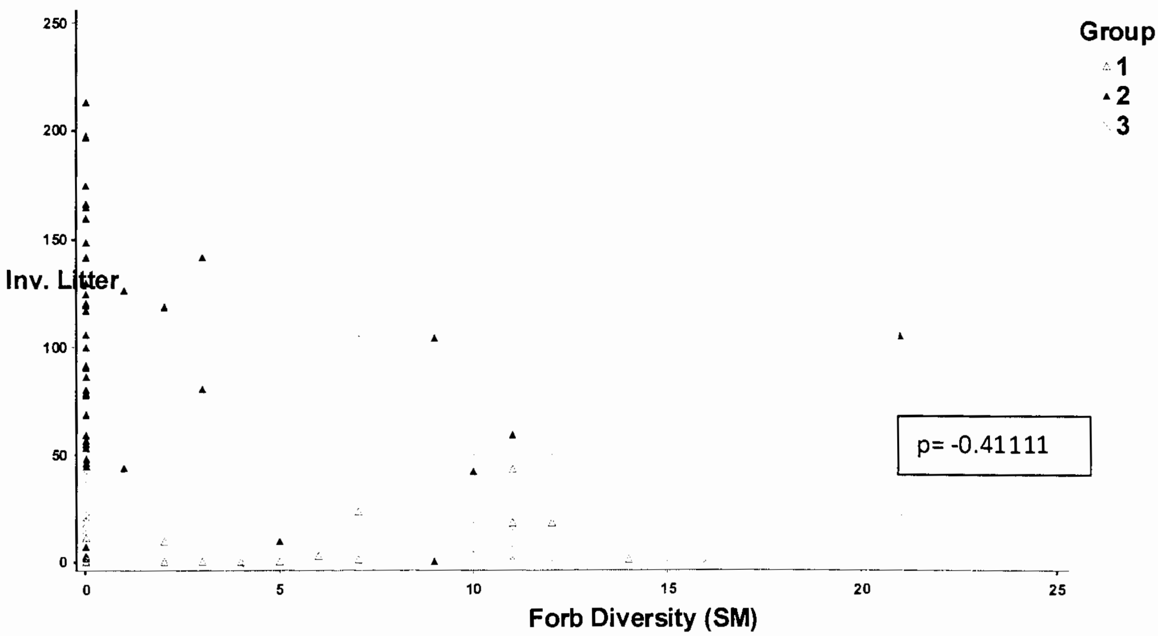


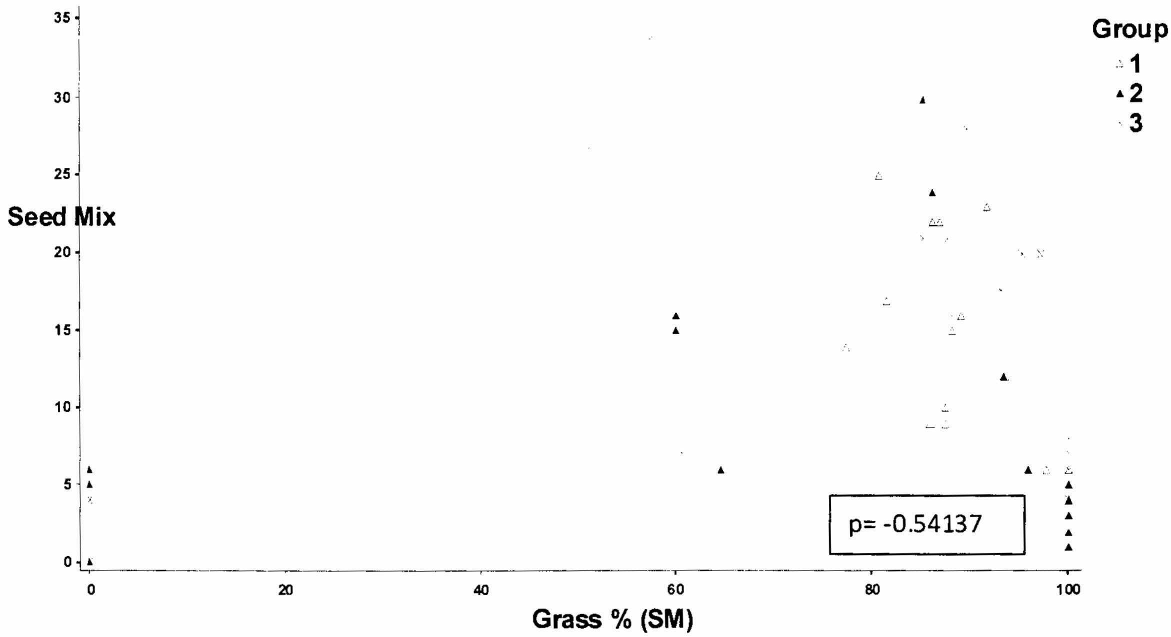
Group
1
2
3
Age
2010
2000
1990
1980
1970
1960
2
4
6
8
10
12
14
Grass Diversity (FD)
p= 0.431209

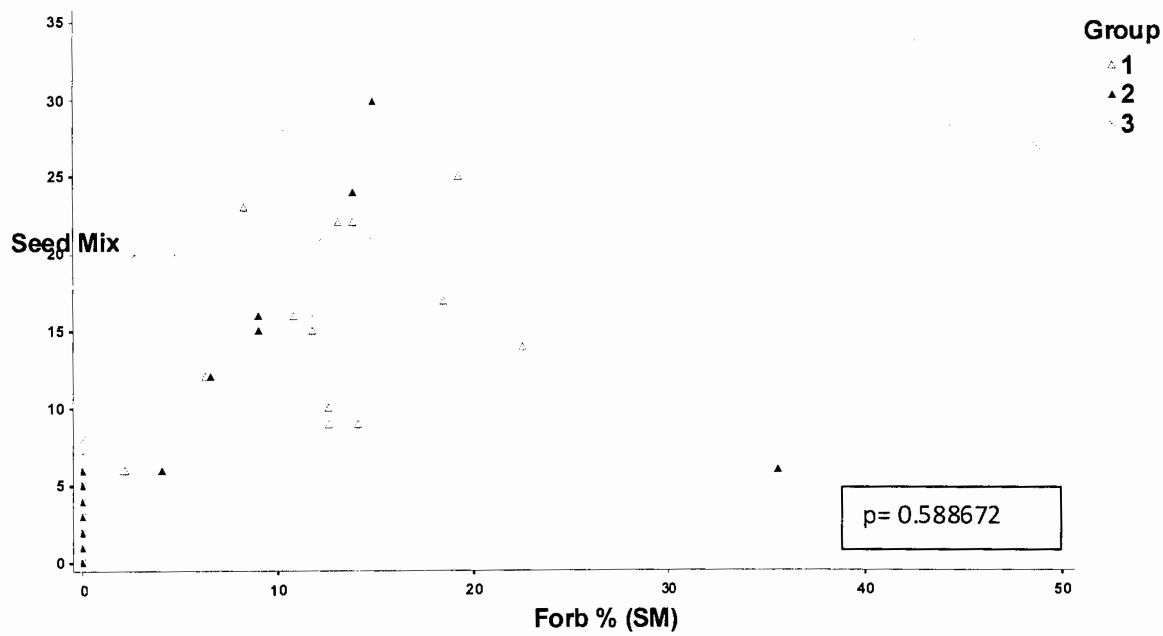

Group
1
2
3
Inv. Litter
Litter
p= 0.429587
0
50
100
150
200
250
300
350
400

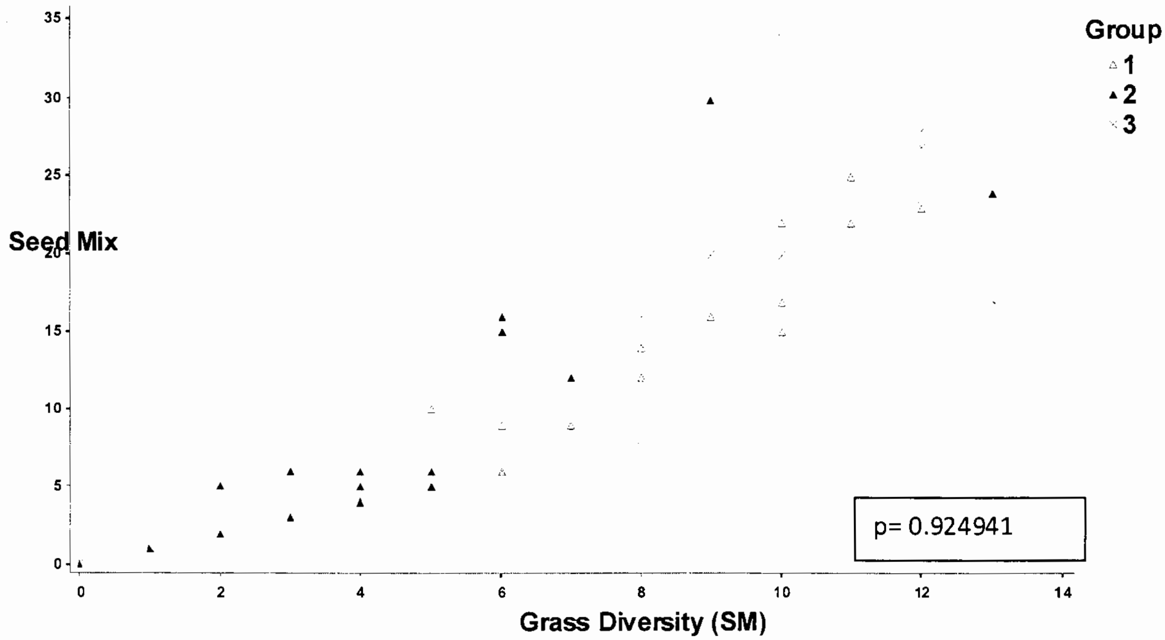

Group
1
2
3
Inv. Litter
Seed Mix Diversity
p= -0.47628
0
5
10
15
20
25
30
35

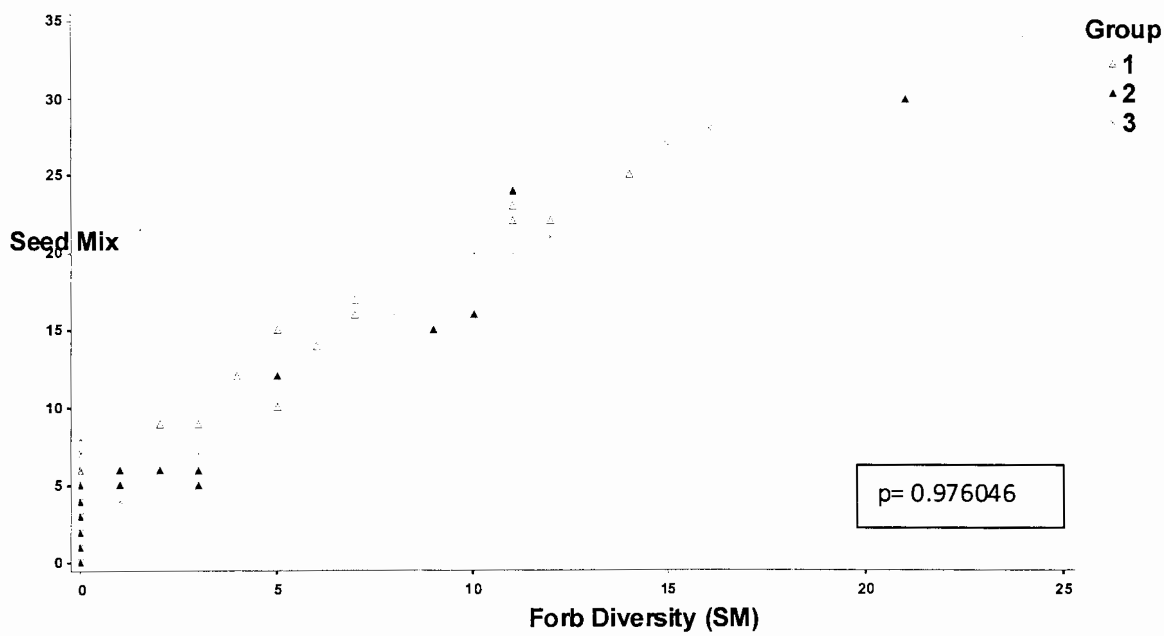

Group
1
2
3
Inv. Litter
250
200
150
100
50
0
0
2
4
6
8
10
12
14
Grass Diversity (SM)
p= -0.53482

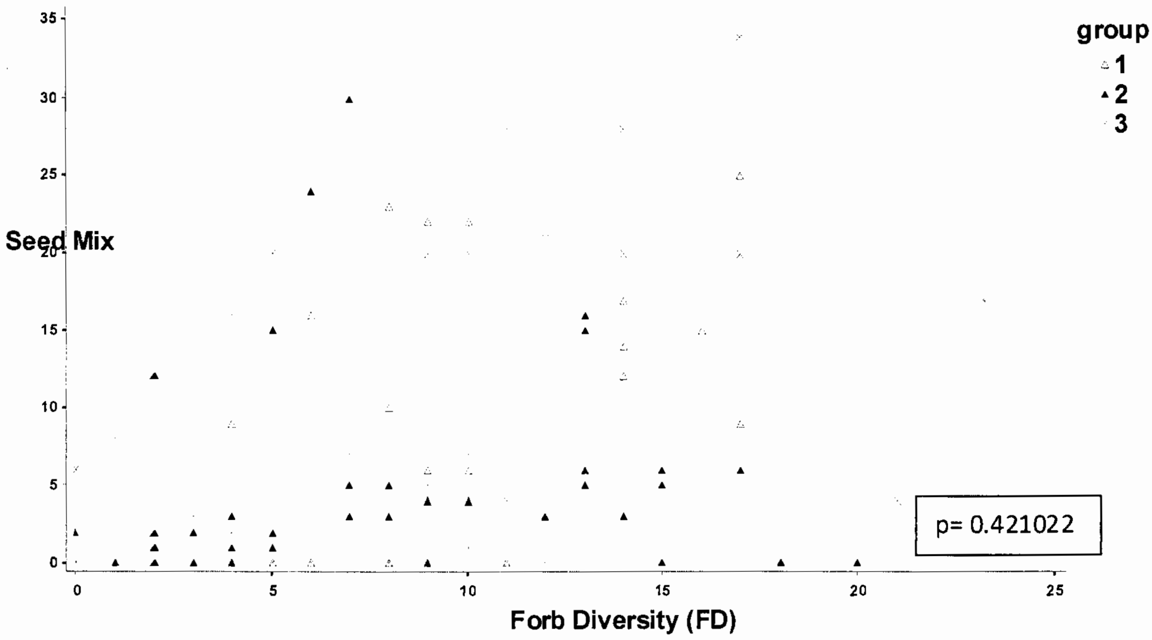

Group
1
2
3
Inv. Litter
250
200
150
100
50
0
0
5
10
15
20
25
Forb Diversity (SM)
p= -0.41111

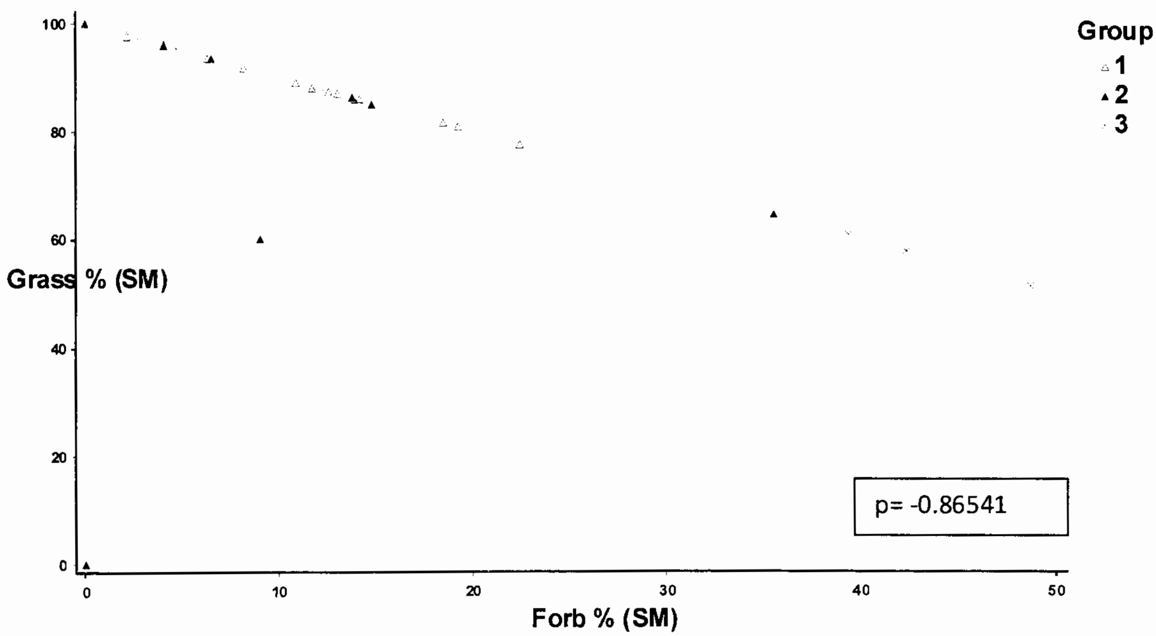

Group
1
2
3
Seed Mix
35
30
25
20
15
10
5
0
0
20
40
60
80
100
Grass % (SM)
p= -0.54137

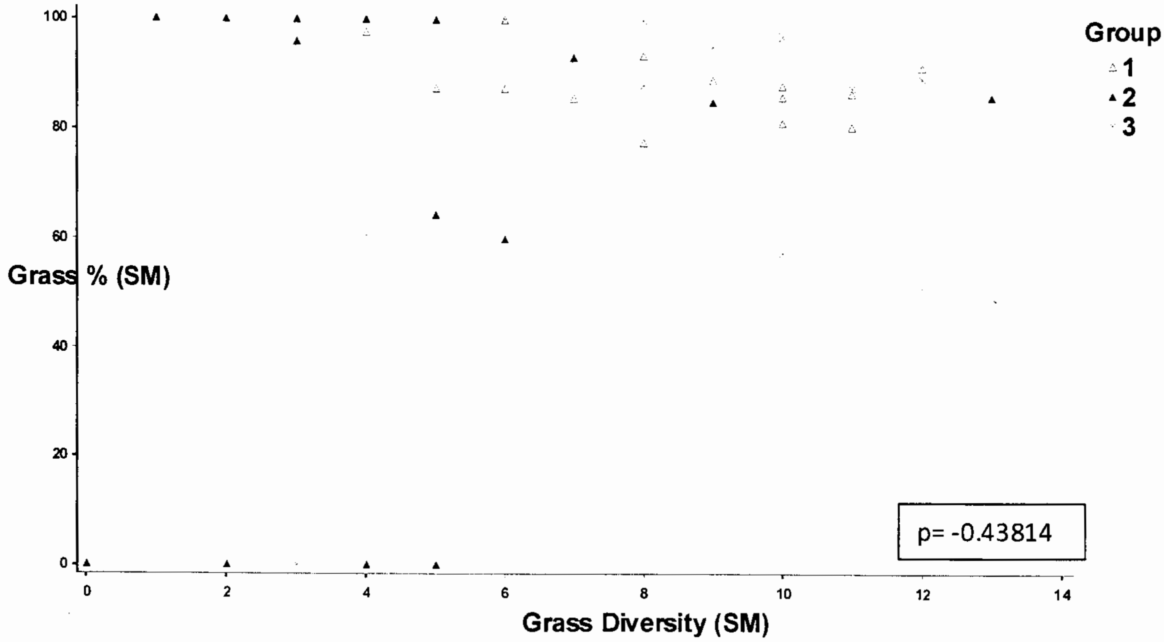

Group
1
2
3
Seed Mix
35
30
25
20
15
10
5
0
0
10
20
30
40
50
Forb % (SM)
p= 0.588672

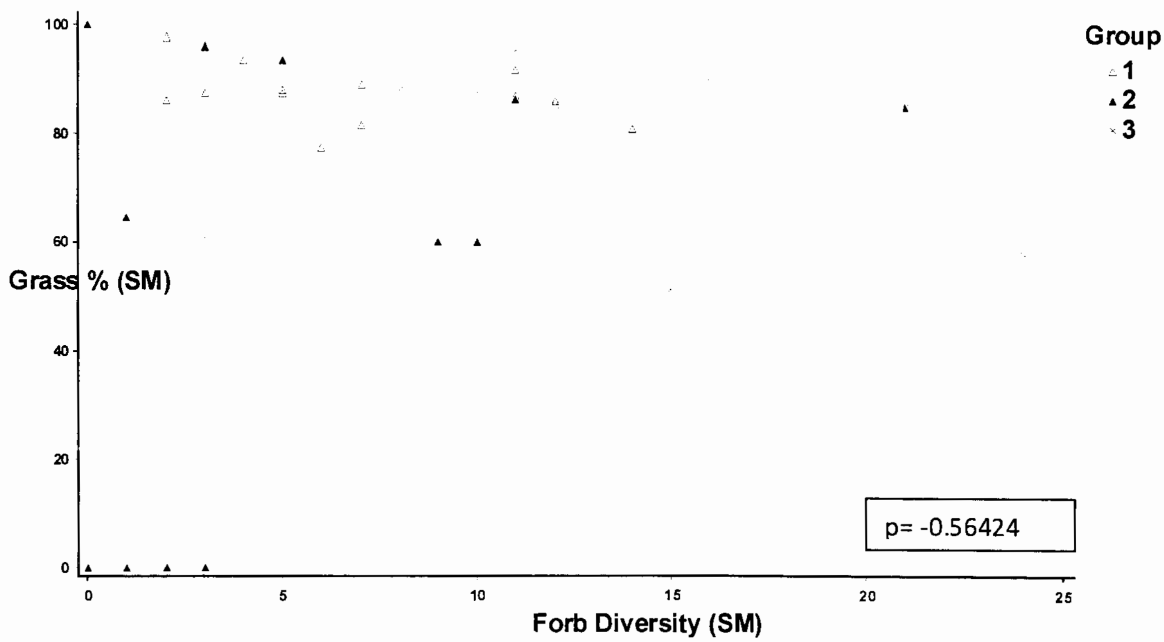

Group
1
2
3
Seed Mix
p= 0.924941
Grass Diversity (SM)

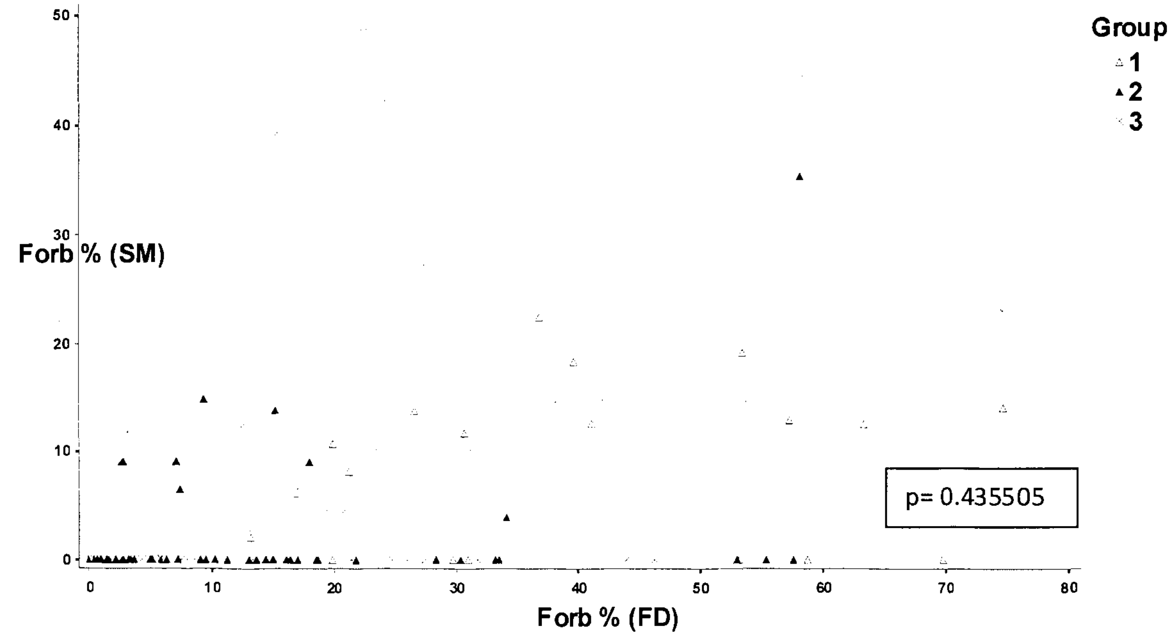

Group
1
2
3
Seed Mix
p= 0.976046
Forb Diversity (SM)

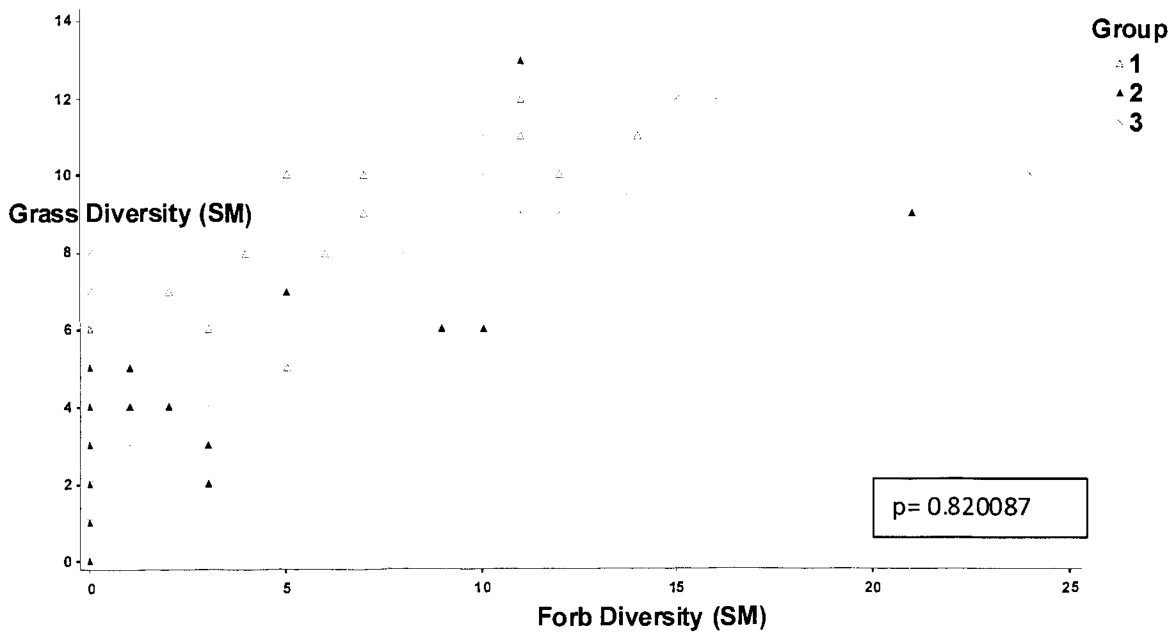

group
1
2
3
Seed Mix
Forb Diversity (FD)
p= 0.421022

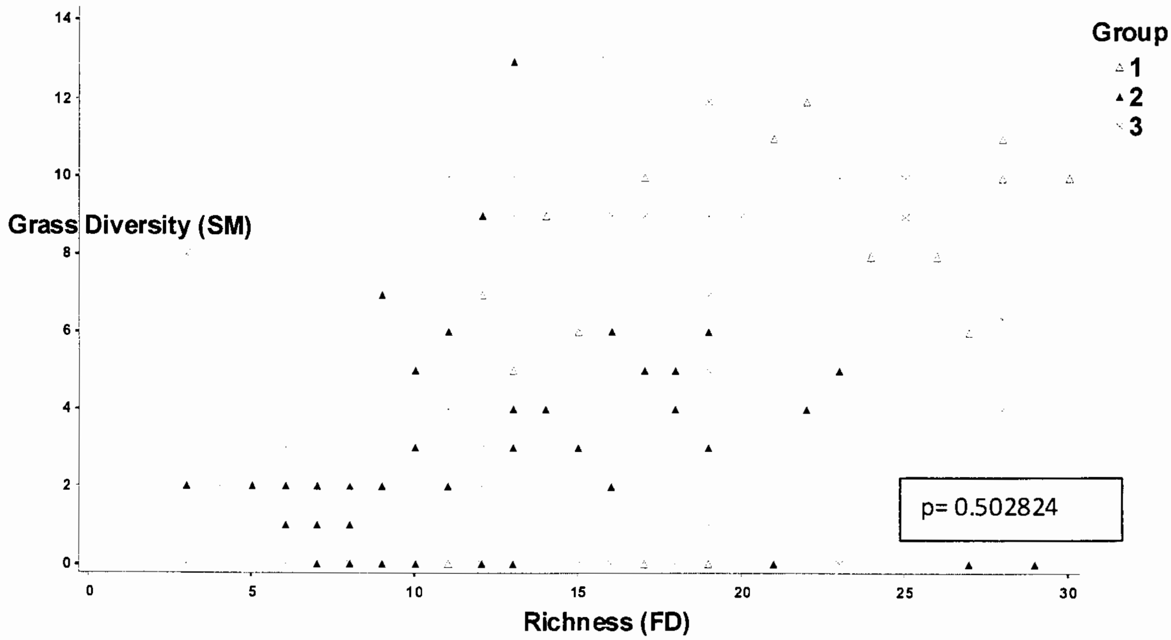

Group
1
2
3
Grass % (SM)
Forb % (SM)
p= -0.86541


100
80
60
40
20
0
Grass % (SM)
0
2
4
6
8
10
12
14
Grass Diversity (SM)
Group
1
2
3
p= -0.43814


100
80
60
40
20
0
Grass % (SM)
0
5
10
15
20
25
Forb Diversity (SM)
Group
1
2
3
p= -0.56424


Group
1
2
3
Forb % (SM)
Forb % (FD)
p= 0.435505
0
10
20
30
40
50
60
70
80


Group
1
2
3
Grass Diversity (SM)
Forb Diversity (SM)
p= 0.820087
0
5
10
15
20
25
2
4
6
8
12
14


Group
1
2
3
Grass Diversity (SM)
Richness (FD)
p= 0.502824
0
2
4
6
8
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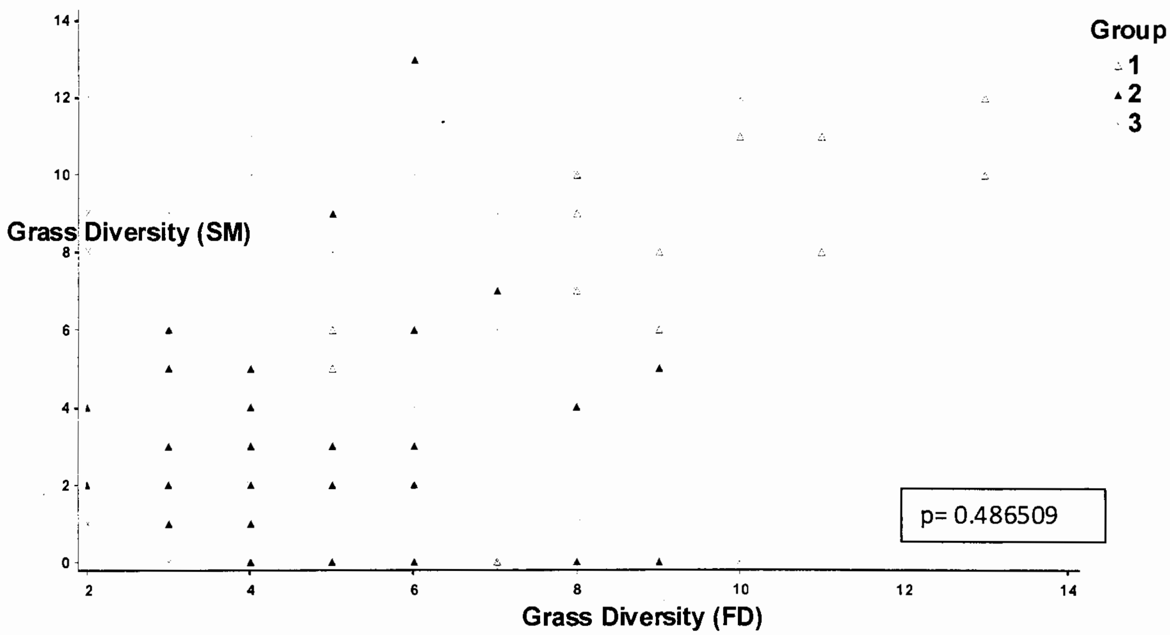
14
0
5
10
15
20
25
30


Group
1
2
3
Grass Diversity (SM)
Grass Diversity (FD)
p= 0.486509
0
2
4
6
8
10
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2
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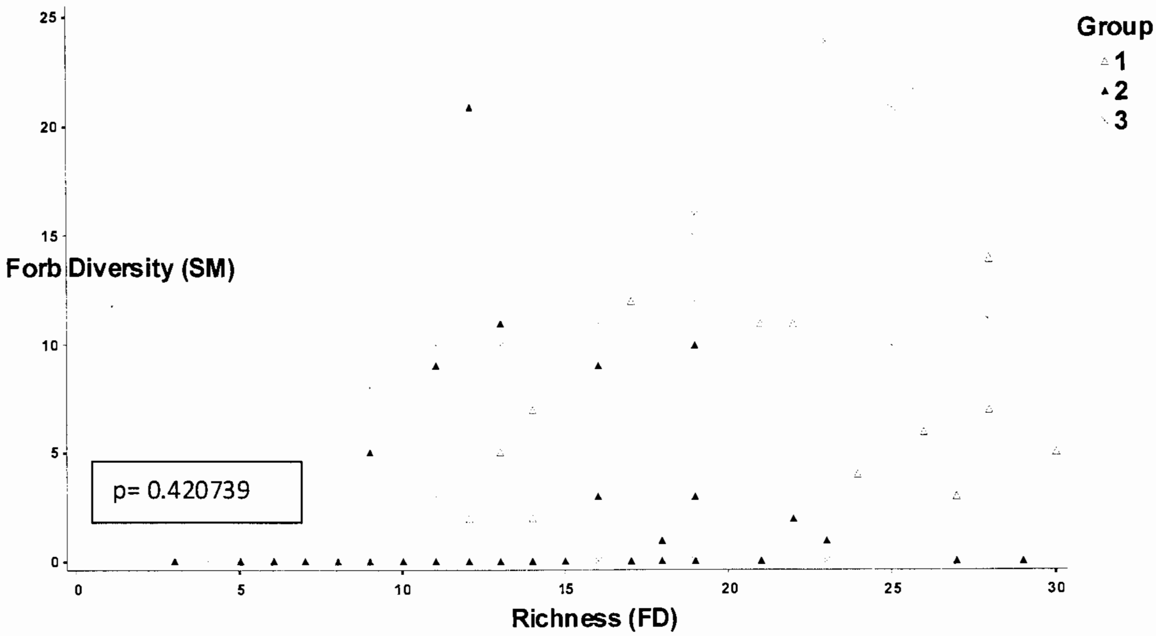
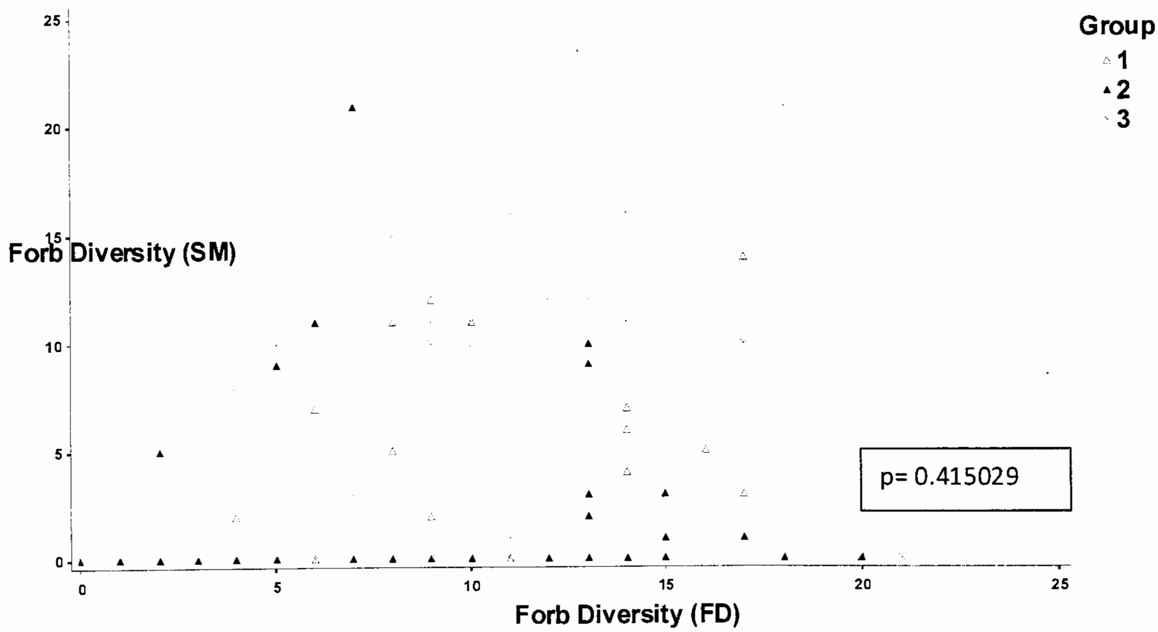
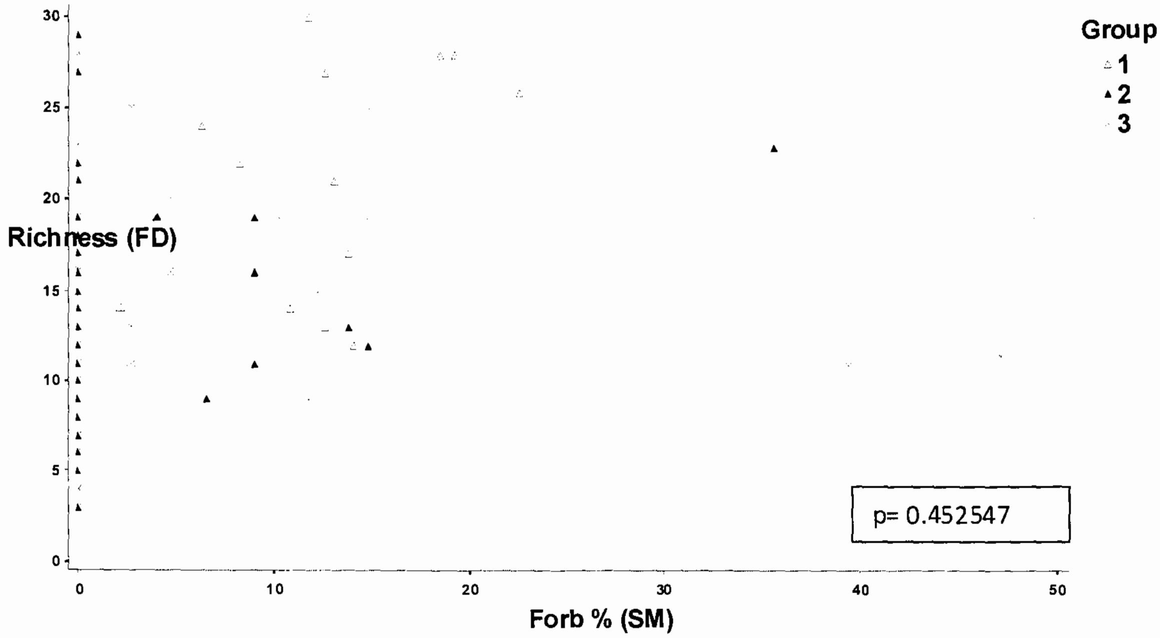
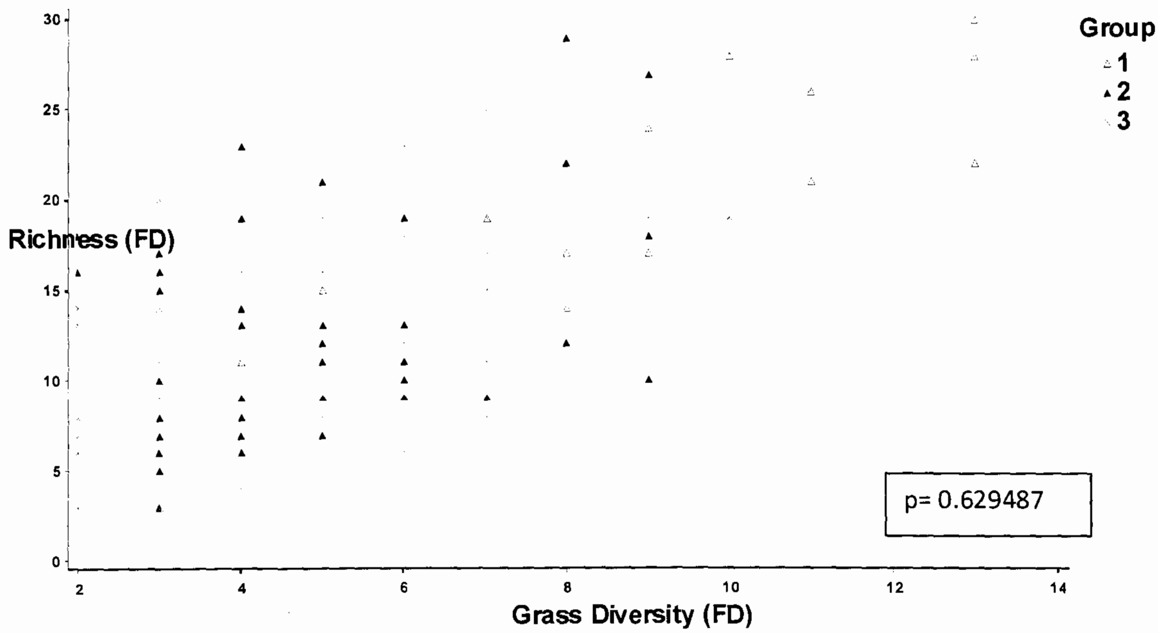
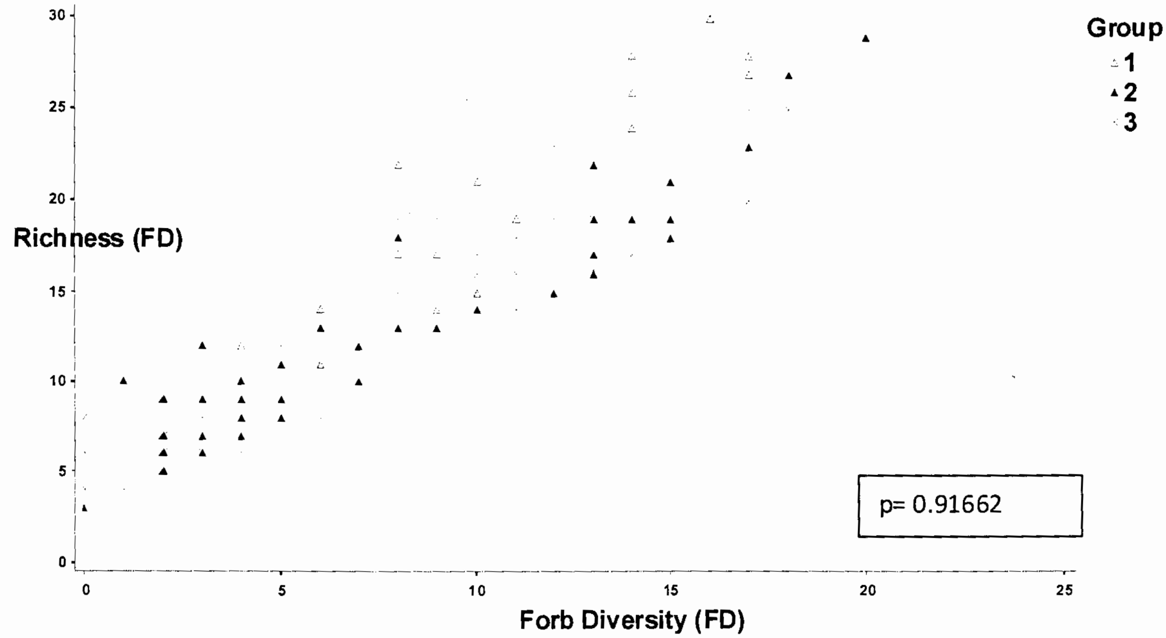
6
8
10
12
14

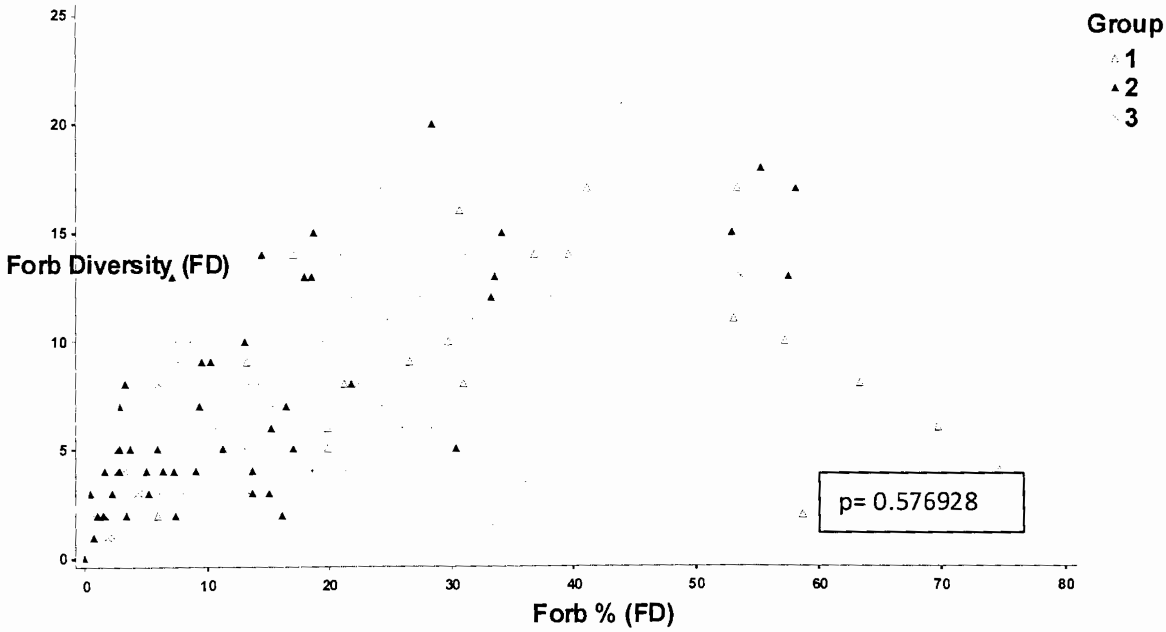

Group
1
2
3
Forb Diversity (SM)
p= 0.420739
Richness (FD)


Group
1
2
3
Forb Diversity (SM)
p= 0.415029
Forb Diversity (FD)


Richness (FD)
Forb % (SM)
Group
1
2
3
p= 0.452547
0
5
10
15
20
25
30
0
10
20
30
40
50


Richness (FD)
Grass Diversity (FD)
Group
1
2
3
p= 0.629487
0
5
10
15
20
25
30
2
4
6
8
10
12
14


Group
1
2
3
Richness (FD)
Forb Diversity (FD)
p= 0.91662
0
5
10
15
20
25
30


Group
1
2
3
Forb Diversity (FD)
Forb % (FD)
p= 0.576928
0
10
20
30
40
50
60
70
80

Oats	avesat	*Avena sativa*
Hoary Alyssum	berinc	*Berteroa incana*
Kittentail	besbul	*Besseya bullii*
Sideoats	boucur	*Bouteloua curtipendula*
Blue grama	bougra	*Bouteloua gracilis*
Japanese Brome/Oats	broarv	*Bromus arvensis*
Smooth Brome	broine	*Bromus inermis*
Kalms Brome	brokal	*Bromus kalmii*
Bindweed	calspi	*Calystegia spithamaea*
Harebell	camrot	*Campanula rotundifolia*
Plumeless Thistle	caraca	*Carduus acanthoides*
Musk Thistle	carnut	*Carduus nutans*
Tall Sedge	carext	*Carex sp.*
Wet Sedge	carexw	*Carex sp.*
Unknown	sedge	*Carex sp.*
Lambsquarter	chealb	*Chenopodium album*
Canada Thistle	cirarv	*Cirsium arvense*
Prairie Thistle	cirhil	*Cirsium hillii*
Wavy-leafed Thistle	cirund	*Cirsium undulatum*
Bull Thistle	cirvul	*Cirsium vulgare*
Marestail	concan	*Conyza canadensis*
Redoiser dogwood	corser	*Cornus sericea*
Crown Vetch	corvar	*Coronilla varia*
Orchard Grass	dacglo	*Dactylis glomerata*
White Prairie Clover	dalcan	*Dalea candida*
Purple Prairie Clover	dalpur	*Dalea purpurea*
Showy Tick Trefoil	descan	*Desmodium canadense*
Purple Coneflower	echang	*Echinacea angustifolia*
Pale Purple Coneflower	echpal	*Echinacea pallida*
Barnyard Grass	echcru	*Echinochloa crus-galli*
Russian Olive	elaang	*Elaeagnus angustifolia*
Canada Wild Rye	elycan	*Elymus canadensis*
Bearded Wheat Grass	elysub	*Elymus subsecundus*
Scouring Rush	equhye	*Equisetum hyemale*
Philidelphia Fleabane	eriphi	*Erigeron philadelphicus*
Annual Buckwheat	eriann	*Eriogonum annuum*
Leafy Spurge	eupesu	*Euphorbia esula*
Grass Leaved Goldenrod	eutgym	*Euthamia gymnospermoides*
Wild Strawberry	fravir	*Fragaria virginiana*
Green Ash	frapen	*Fraxinus pennsylvanica*

Oats	avesat	*Avena sativa*
Hoary Alyssum	berinc	*Berteroa incana*
Kittentail	besbul	*Besseya bullii*
Sideoats	boucur	*Bouteloua curtipendula*
Blue grama	bougra	*Bouteloua gracilis*
Japanese Brome/Oats	broarv	*Bromus arvensis*
Smooth Brome	broine	*Bromus inermis*
Kalms Brome	brokal	*Bromus kalmii*
Bindweed	calspi	*Calystegia spithamaea*
Harebell	camrot	*Campanula rotundifolia*
Plumeless Thistle	caraca	*Carduus acanthoides*
Musk Thistle	carnut	*Carduus nutans*
Tall Sedge	carext	*Carex sp.*
Wet Sedge	carexw	*Carex sp.*
Unknown	sedge	*Carex sp.*
Lambsquarter	chealb	*Chenopodium album*
Canada Thistle	cirarv	*Cirsium arvense*
Prairie Thistle	cirhil	*Cirsium hillii*
Wavy-leafed Thistle	cirund	*Cirsium undulatum*
Bull Thistle	cirvul	*Cirsium vulgare*
Marestail	concan	*Conyza canadensis*
Redoiser dogwood	corser	*Cornus sericea*
Crown Vetch	corvar	*Coronilla varia*
Orchard Grass	dacglo	*Dactylis glomerata*
White Prairie Clover	dalcan	*Dalea candida*
Purple Prairie Clover	dalpur	*Dalea purpurea*
Showy Tick Trefoil	descan	*Desmodium canadense*
Purple Coneflower	echang	*Echinacea angustifolia*
Pale Purple Coneflower	echpal	*Echinacea pallida*
Barnyard Grass	echcru	*Echinochloa crus-galli*
Russian Olive	elaang	*Elaeagnus angustifolia*
Canada Wild Rye	elycan	*Elymus canadensis*
Bearded Wheat Grass	elysub	*Elymus subsecundus*
Scouring Rush	equhye	*Equisetum hyemale*
Philidelphia Fleabane	eriphi	*Erigeron philadelphicus*
Annual Buckwheat	eriann	*Eriogonum annuum*
Leafy Spurge	eupesu	*Euphorbia esula*
Grass Leaved Goldenrod	eutgym	*Euthamia gymnospermoides*
Wild Strawberry	fravir	*Fragaria virginiana*
Green Ash	frapen	*Fraxinus pennsylvanica*

Blanket Flower	gaiari	*Gaillardia aristata*
Northern Bedstraw	galbor	*Galium boreale*
American Licorice	glylep	*Glycyrrhiza lepidota*
Maximillus Sunflower	helmax	*Helianthus maximiliani*
Nuttles Sunflower	helnut	*Helianthus nuttallii*
Rigid Sunflower	helrig	*Helianthus rigida*
False Sunflower	helhel	*Heliopsis helianthoides*
Needle and Thread	sticom	*Hesperostipa comata*
Porcupine Grass	stispa	*Hesperostipa spartea*
Hairy False Goldenaster	hetvil	*Heterotheca villosa*
Foxtail Barley	horjub	*Hordeum jubatum*
Rush	juncus	*Juncus sp.*
Poverty Rush	junten	*Juncus sp.*
Kochia	kochia	*Kochia*
Junegrass	koegra	*Koeleria macrantha*
Wild Lettuce	laccan	*Lactuca canadensis*
Blue Lettuce	lacobl	*Lactuca oblongifolia*
Marsh Vetchling	latpal	*Lathyrus palustris*
Rough Blazing Star	liaasp	*Liatris aspera*
Dotted Blazing Star	liapun	*Liatris punctata*
Prairie Blazing Star	liapyc	*Liatris pycnostachya*
Marsh Blazing Star	liaspi	*Liatris spicata*
Prairie Lily	lilphi	*Lilium philadelphicum*
Toadflax Butter and Eggs	linvul	*Linaria vulgaris*
Blue Flax	linper	*Linum perenne*
Hoary Puccoon	litcan	*Lithospermum canescens*
Blue Lobelia	lobspi	*Lobelia siphilitica*
Birdsfoot Trefoil	lotcor	*Lotus corniculatus*
Skeletonweed	lygjun	*Lygodesmia juncea*
Black Medic	medlup	*Medicago lupulina*
Alfalfa	medsat	*Medicago sativa*
Sweet Clover	meloff	*Melilotus officinalis*
Heart Leafed Four o Clock	mirnyc	*Mirabilis nyctaginea*
Wild Bergamot	monfis	*Monarda fistulosa*
Plains Muhly	mulcus	*Muhlenbergia cuspidata*
Marsh Muhly	muhrac	*Muhlenbergia racemosa*
Green Needle Grass	stivir	*Nassella viridula*
Common Evening Primrose	oenbie	*Oenothera biennis*
Stiff Goldenrod	solrig	*Oligoneuron rigidum*
False Gromwell	onomol	*Onosmodium molle*
Switch Grass	panvir	*Panicum virgatum*

Silvery Scurf Pea	pedarg	*Pediomelum argophyllum*
Pale Beard Tongue	penpal	*Penstemon pallidus*
Reed Canary	phaaru	*Phalaris arundinacea*
Timothy	phlpra	*Phleum pratense*
Ground Cherry	phylon	*Physalis longifolia*
Canada Bluegrass	poacom	*Poa compressa*
Fowl Bluegrass	poapal	*Poa palustris*
Kentucky Bluegrass	poapra	*Poa pratensis*
Smartweed	polspp	*Polygonum sp.*
Eastern Cottonwood	popdel	*Populus deltoides*
Prairie Cinquefoil	potarg	*Potentilla arguta*
Norweigen Cinquefoil	potnor	*Potentilla norvegica*
Slender Mountain Mint	pycten	*Pycnanthemum tenuifolium*
Prairie Coneflower	ratcol	*Ratibida columnifera*
Prairie Rose	rosark	*Rosa arkansana*
Black Eyed Susan	rudhir	*Rudbeckia hirta*
Curly Dock	rumcri	*Rumex crispus*
Sandbar Willow	salint	*Salix interior*
Willow	salix	*Salix sp.*
Little Bluestem	schsco	*Schizachyrium scoparium*
Annual Grass	setaria	*Setaria sp.*
Green Foxtail	setvir	*Setaria viridus*
Bladder Campion	sillat	*Silene latifolia*
Prairie Blue-Eyed Grass	siscam	*Sisyrinchium campestre*
Tall Goldenrod	solalt	*Solidago altissima*
Canada Goldenrod	solcan	*Solidago canadensis*
Gigantic Goldenrod	solgig	*Solidago gigantea*
Old-Field Goldenrod	solnem	*Solidago nemoralis*
Sowthistle	sonarv	*Sonchus arvensis*
Indian Grass	sornut	*Sorghastrum nutans*
Prairie Cordgrass	spapec	*Spartina pectinata*
Prairie Dropseed	spohet	*Sporobolus heterolepis*
Woundwort	stapal	*Stachys palustris*
Western Snowberry	symocc	*Symphoricarpos occidentalis*
Smooth Blue Aster	astlae	*Symphyotrichum laeve*
Panicled Aster	astlan	*Symphyotrichum lanceolatum*
Skyblue Aster	symool	*Symphyotrichum oolentangiense*
Common Tansy	tanvul	*Tanacetum vulgare*
Common Dandelion	taroff	*Taraxacum officinale*
Meadow Rue	thadas	*Thalictrum dasycarpum*
Field Pennycress	thlarv	*Thlaspi arvense*
Goatsbeard	tradub	*Tragopogon dubius*

Red Clover	tripra	*Trifolium pratense*
Siberian Elm	ulmpum	*Ulmus pumila*
Cut-leaf weed	aster	*Unknown*
Bushy Vetch	bvetch	*Unknown*
Yellow Flax Weed	mustard	*Unknown*
Yellow Mustard Weed	mustard	*Unknown*
Unknown	saplings	*Unknown*
Weedy Little Sunflower	weedsun	*Unknown*
Stinging Nettle	urtdio	*Urtica dioica*
Hoary Vervain	verstr	*Verbena stricta*
Culvers Root	vervir	*Veronicastrum virginicum*
American Vetch	vicame	*Vicia americana*
Heart-leafed Golden Alexander	zizapt	*Zizia aptera*
Golden Alexander	zizaur	*Zizia aurea*

*Species names are from The PLANTS Database: USDA, NRCS. 2010. The PLANTS Database (http://plants.usda.gov, August 2010). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.