Restoring Industrial Disturbances with Native Hay in Mixedgrass Prairie in Alberta

Authors

Peggy A. Desserud, Chris H. Hugenholtz

Abstract

Native grassland restorations are often unsuccessful as a consequence of unreliable seed sources and competition from weeds and agronomic species. To improve on conventional approaches, we tested whether native hay can be used as a seed source for restoring native mixedgrass prairie disturbances. We also assessed the recovery of grassland which had been cut to harvest native hay. Three wellsites seeded with native hay seven years earlier were assessed to evaluate longer term recovery and they showed significant similarity to controls in adjacent grassland. Five wellsites and an access road were seeded with native hay cut from grassland close to the sites. Grassland cut for native hay recovered within one year, showing similar species composition. In the second year, native hay-treated wellsites had significant weedy annuals cover; nevertheless, native grasses and forbs germinated particularly needle grasses, wheatgrasses and bluegrasses. Three of the native hay sites were sprayed with a non-selective herbicide in the third year; however, the remaining sites showed good recovery in the third year, with native grasses replacing most of the original weedy species. Collectively, results from this research suggest native hay is a successful and sustainable technique for restoring native vegetation cover and diversity on industrial disturbances in native grasslands.

Keywords: native grassland restoration, native hay, needle and thread grass, mixedgrass prairie

Restoration Recap

- Native hay appears to be a viable source of seeds for wellsite reclamation. Good recovery was observed by the third year, hosting many species found in the adjacent grassland, and respective cover. In addition, native grasses appeared on all sites by the second year, despite initial cover of weedy species. Sites treated with native hay over seven years ago showed very good recovery.

- To harvest sufficient native hay for the treatment, the area of adjacent undisturbed grassland to be harvested, must be approximately 3 times the area of the disturbance in mixedgrass prairie.

- Cutting hay from native grassland has little effect on species composition and range condition, even if large areas (> 3 ha) are cut.

- Much of the chopped hay blew away over the first summer, and although not tested, we suggest improved results for native species germination could be achieved by roughing up the disturbance topsoil to create microsites and harrowing in the chopped hay.

Native grasslands are an important resource for livestock farming, providing self-sustaining, high quality forage (Holechek et al. 2004), but they are also among the least protected and globally the most altered habitats (Samson and Knopf 1996). For example, in Alberta, Canada, it is estimated that less than half (43%) the original 11.8 million acres of prairie classified as Dry Mixedgrass remains intact (Adams et al. 2013). Moreover, instead of large intact expanses, the native grassland that remains in places like Alberta is highly fragmented owing to anthropogenic modifications such as urban and rural development, cultivation, and livestock over-grazing (Adams et al. 2013). Compounding these effects is the continued expansion of oil and gas development, wind energy and other industries in native grassland, which adds additional fragmentation to this valued resource. Consequently, methods to restore native grassland are an ongoing focus of sustainable resource management.

The most commonly used method to restore native grassland vegetation at oil and gas disturbances involves the application of seed mixes, either from commercial cultivars or from native harvesting. However, seed mixes are often unsuccessful for grassland restoration, particularly those derived from cultivars, as a consequence of unreliable seed sources and competition from weeds and agronomic species (Wilson et al. 2002, Desserud et al. 2010). For example, Elsinger (2009) and Desserud et al. (2010) found gas wellsites and pipelines in central and southern Alberta have had fair to poor establishment of native species from seed mixes. Fast growing species, such as wheat grasses, including western wheatgrass (*Pascopyron smithii*), northern wheatgrass (*Elymus lanceolatus*) or slender wheatgrass (*Elymus trachycaulus*) are generally included in native seed mixes to prevent wind and water erosion on newly disturbed sites with the expectation that slower growing bunch grasses will eventually establish (Hammermeister et al. 2003). However, agronomic cultivars of these species may aggressively ultimately out-compete native grasses, persisting for many years following reclamation seeding, and resulting in a lack of genetic and species diversity (Hammermeister et al. 2003, Elsinger 2009, Desserud and Naeth 2014).

Wild-harvested native seed may alleviate problems with seeding cultivars on disturbances. Nonetheless, harvesting native seed presents particular difficulties including uncertainty of the seed maturity dates, variable field conditions, location of the seed source being incompatible with the reclamation site, knowledge of the collector, hand-collection methods, and storage methods (Morgan et al. 1995, Smreciu et al. 2003). A possible solution is to reclaim industrial disturbances with hay cut from native grassland in close proximity to, or directly on the disturbance prior to construction. The rationale would be to provide a seed source of species originally populating the disturbance or the surrounding undisturbed area, as well as protective straw mulch from chopped-up grasses.

Freshly mown hay has been successfully used in Europe and England (Jones et al. 1995, Hölzele and Otte 2003, Kiehl and Wagner 2006, Donath et al. 2007, Edwards et al. 2007, Kiehl and Pfadenhauer 2007), and to some extent in United States northern grasslands (McGinnies 1987). Factors that affect the viability of native hay include the variability of native seed production from year to year (e.g., some species do not seed every year); the timing of harvesting, which will result in the dominance of whichever species have seeded at that time; and methods, such as tackifying or harrowing to keep the mulch in place (Romo and Lawrence 1990).

Issues that might preclude using native hay for disturbance reclamation include limited access to or extent of adjacent grassland. There may be resistance from landowners to harvesting their rangeland, since the cut grassland may not be available to cattle grazing for at least two years, and currently there is no known guarantee that the grassland would return to pre-harvesting state. In addition, the state of native grassland in close proximity to a disturbance is crucial in determining if native hay is a suitable seed source. If non-native species, such as crested wheatgrass (*Agropyron cristatum*) are present, such species may eventually dominate the disturbance if included in the native hay seed source (Wilson and Pärtel 2003).

We found little research involving native hay for mixedgrass prairie restoration. For example, Bakker et al. (2003) and Wilson et al. (2004) found no seedling emergence from native hay application in mixedgrass prairie restoration in Saskatchewan. On the other hand, in a native hay experiment in south-central Alberta, on a narrow disturbance (e.g. 15 m), Desserud and Naeth (2011) presented preliminary evidence suggesting native hay is a good seed source for native species in close proximity to a grassland disturbance, if desired species are present. In their experiment, within 3 years, all species that emerged from the native hay application were found in adjacent undisturbed grassland (Desserud and Naeth 2011).

The objective of this research was to build on the initial results of Desserud and Naeth (2011) by testing whether freshly cut native hay can be used as a seed source for restoring large grassland disturbances (e.g. > 1 ha) associated with fully-built wellsites in mixedgrass prairie. Harvesting hay from native grassland at a time when desirable species have seeded may result in a viable native seed mix. Chopping native grass straw should provide protective mulch. Our hypothesis is that native hay will provide propagules of native grassland species for disturbance restoration and, that native grassland species will emerge and result in a trend towards pre-disturbance conditions.

Methods

Study Sites

The study areas are located in the Dry Mixedgrass and Mixedgrass natural sub-regions of the Grassland natural region in southeastern Alberta, identified as Brooks, Gem, the Eastern Irrigation District (EID), and Pinhorn (Figure 1). The majority of soils in the areas are Orthic Brown Chernozems on medium to coarse-textured till, with occasional Dark Brown Solod and

Solozenic Brown Chernozems. The climate of the study area is continental with low precipitation, very cold winters, and short but warm summers. During the study, mean annual precipitation was 330 mm with an average of 1,380 effective growing degree days (GDD) at Brooks and Gem; 296 mm and 1,406 GDD at the EID; and 336 mm and 1,335 GDD at Pinhorn. Mean summer temperature (May to August) was 16°C at Brooks and mean winter temperature (November to March) was -7°C; 16 and -6°C at the EID; and, 15 and -4°C at Pinhorn (Alberta Agriculture and Rural Development 2012). Vegetation in the study area is dominated by needle and thread (*Hesperostipa comata*), shortbristle needle and thread (*H. curtiseta*), and June grass (*Koeleria macrantha*).

Native Hay Application

Five wellsites were reclaimed in May and June 2012: two in the Brooks area (B 10-16 and B 16-08), one in the EID (E 6-24), two at Pinhorn (P 7-21, P 7-21L) and a 300 m access road (P 7-21A; Table 1). Each wellsite was originally a natural gas well, constructed 15 to 20 years previously, situated on an area cleared of topsoil, with accompanying piping and infrastructure. All structures and piping were removed and fresh topsoil, from areas within 10 km of the sites, was applied. Topsoil was also applied to the access road. To act as controls for the native hay-treated wellsites and to evaluate grassland recovery after mowing, 100 m transects were randomly placed in undisturbed grassland allocated for hay mowing and marked with GPS locations and metal pins.

In July 2012, a modified combine (1.5 m width) with more durable and sharper blades than traditional crop blades and attached to a tractor, was used to mow fresh hay in grassland less than 0.5 km away from each disturbance. To provide seed rain for infill of the cut area, cutting rows were separated by approximately 0.5 m of uncut grasses. Stubble of approximately 6 cm was left. The cut areas were measured by length with a GPS (global positioning system) and width with a tape measure. The hay was immediately coarsely chopped with mechanical blades attached to the modified combine and sprayed on the disturbance to a depth of 2-5 cm. After spraying, the mulch was lightly crimped into the soil, with a harrow attached to the tractor.

Seven-year old Native Hay Sites

To evaluate longer term results of native hay applications, we assessed three wellsites in the Gem area, each active wells surrounded by metal exclosures, and which had been treated with native hay in 2005 seven years previously (Table 1). An area 25 m^2 around the wells was cleared of vegetation and topsoil during well construction. Topsoil was replaced within three months, and the area, except for an access road and the 1 m^2 well) was seeded with native hay as described above. Adjacent undisturbed grassland served as controls.

In June 2013, all sites treated in 2012 were mown to remove a heavy cover of annual weedy species. In June 2014, B 10-16, B 16-08 and E 6-24 were sprayed to eliminate invasive species such as crested wheatgrass (*Agropyron cristatum*) with a non-selective herbicide; which eliminated all growth and reduced the third-year native hay experiment to three sites at Pinhorn.

Vegetation Sampling

The control areas of the 1 ha wellsites were assessed in July 2012 immediately prior to mowing and again in July 2013 after mowing. Along each 100 m transect, Daubenmire frames were placed every 10 m. Within every Daubenmire frame all vegetation species were identified and percent cover of vegetation, litter and bare ground was estimated. Within 25 m of the seven-year old wellsites, a 100 m transect was randomly placed in the control areas.

The sites at Brooks, EID and Pinhorn, treated with native hay in 2012, were assessed in August 2013 (second-year sites), and the Pinhorn sites again in July 2014 (third-year sites). The three wellsites in the Gem area (G 2-06, G 4-06, G 16-09) were assessed in July 2012. The 25 m^2 seven-year old wellsites were divided into 16 quadrats, each 6.25 m^2, and a Daubenmire frame was placed in the center of each of the outer 12 quadrats. Wellsites of 1 ha in area were divided in to 16 quadrats, each 25 m^2, and three 20 × 50 cm Daubenmire frames (Daubenmire 1959) were randomly placed in each quadrat. A 100 m transect was randomly placed along the center of the access road.

Data analysis

Comparisons between native hay sites and controls for selected species and ground cover was analyzed by t-tests. Vegetation data from native hay sites and controls were classified with two-way cluster analyses (Ward's method) and ordinated with detrended correspondence analyses (DCA). Indicator species analysis (ISA) validated the dominant species of the resulting plant communities. Indicator values ranged from 0 to 100, where 100 indicated a species is exclusively found in a particular plant community (Dufrene and Legendre 1997). Statistical analyses were performed with IBM® SPSS® Statistics (21, SPSS, Chicago IL). PC-ORD (5.31, MjM Software, Gleneden Beach OR) was used for classification, DCA and ISA. Nomenclature follows USDA NRCS (2016).

Results

Grassland Recovery after Harvesting

The cut areas varied in size from between 2.5 and 3 times the reclaimed area. Comparison of control areas prior to and after cutting with t-tests indicated little effect of hay harvesting on mixedgrass prairie. No significant differences were found for percent cover of dominant mixedgrass species: shortbristle needle and thread (p = 0.060), needle and thread (p = 0.187), blue grama (p = 0.278), western wheatgrass (p = 0.619), June grass (p = 0.652) and bluegrasses (p = 0.672; Figure 2a). Similarly, no significant differences were found for litter (p = 0.942), moss and lichens (p = 0.558), native grasses (p = 0.260), forbs (p = 0.318) and shrubs (p = 0.208; Figure 2b).

Native Hay Application

Comparison of second-year native hay sites after mowing with controls by t-tests indicated controls had significantly less bare ground ($p < 0.001$) and non-native species (p = 0.002), and significantly greater abundance of native grasses ($p < 0.001$), needle grasses ($p < 0.001$), and wheatgrasses (p = 0.040; Figure 3a).

Undisturbed controls had significantly greater abundance of needle and thread, shortbristle needle and thread, and blue grama than second-year sites, although needle and thread grass had started to appear in the second-year native hay sites (Table 2). Second-year sites showed dominance of ground covers: pigweeds and kochia. Foxtail barley (*Hordeum jubatum*) was found on second-year sites and none in the controls. June grass, green needle grass, and bluegrasses had similar cover between controls and second-year sites (Table 2). A count of all native species found on second-year native hay sites indicated 71% of the native grasses and forbs found in controls had germinated on second-year native hay sites.

Classification of native hay sites with controls with two-way cluster analysis resulted in a chaining factor of 8.0 and three major plant communities (Figure 4). Species dominance was confirmed by ISA analyses (Table 3).The first plant community was dominated by foxtail barley and comprised of P 7-21, P 7-21L and P 7-21A in the second year, as well as third-year P 7-21A3 (Figure4; Table 3). The second community was dominated by crested wheatgrass and northern wheatgrass, comprised of the remaining second-year native hay sites after ground cover species were removed. The third plant community was dominated by shortbristle needle and thread and needle and thread grass and included third-year 7-12 sites (P 7-213 and P 7-21L3) and all controls (Figure 4; Table 3).

DCA ordination of second and third-year (P 7-21, P7-21L and P 7-21A) native hay sites with controls indicated second-year sites were dissimilar to controls; whereas, third-year sites trended towards controls in terms of overall species cover (Figure 5). A t-test comparison of second and third year species and ground cover at P 7-21, P 7-21L and P 7-21A indicated significant increase of green needle grass ($p = 0.001$), Idaho fescue (*F. idahoensis*; $p < 0.001$), bluegrasses ($p = 0.036$) and litter ($p < 0.001$) by year three (Figure 6a). Bluegrasses include Sandberg bluegrass (*Poa secunda*) and fowl bluegrass (*Poa palustris*). Increases also occurred in total cover ($p = 694$), total native grasses ($p = 0.260$) and forbs ($p = 0.318$), although they were not statistically significant (Figure 6b). Bare soil ($p = 0.016$) and flixweed ($p < 0.001$) significantly decreased from the second to third year, and foxtail barley ($p = 0.387$) also decreased although not significantly (Figure 6)

Seven-year old Native Hay Sites

The seven-year old sites, showed similarity to adjacent undisturbed grassland (Figure3b). Species not significantly different to control areas included total forbs ($p = 0.247$), total native grasses (p = 0.102), needle grasses (needle and thread, shortbristle needle and thread, and green needle grass; p = 0.853), blue grama (p = 0.857) and sedges (*Carex* spp.; (p = 0.204). Controls had significantly greater abundance of western wheatgrass (p = 0.007) and wellsites had greater cover of pasture sagewort (*Artemisia frigida*; p < 0.001; Figure 3b).

Regulatory Requirement Results

The Seven-year old sites complied with reclamation regulatory requirements for Alberta, Canada, and received the required Reclamation Certificates. After three years it was too early to apply for a Reclamation Certificate for the Pinhorn site. Nevertheless, it met several restoration criteria. The undisturbed control had a total percent community cover of over 70%. The disturbance had 72% cover of infill species and 99% cover of total acceptable vegetation, well within the tolerances of 15% and 50% respectively. Bare areas were 40%, less than the allowable 50% for the Dry Mixedgrass area (Alberta Environment 2011).

Discussion

Our hypothesis that native hay will provide grassland species for disturbances and that native grassland species will emerge was confirmed. In addition, we observed potential trends towards per-disturbance vascular plant species diversity and cover. Restoration was successful at the seven-year old sites, where much of the vegetative cover resembled adjacent grassland, and included many mixedgrass species. After three years, the sites at the newly native-hay reclaimed Pinhorn also showed a trajectory towards resembling adjacent grassland plant community composition and cover.

One species found in abundance on the seven-year old sites and not in adjacent grassland was pasture sagewort. Its presence was likely caused by cattle, possibly attracted to the metal cattle guard surrounding the well equipment for rubbing, as cattle grazing pressure may result in an increase of pasture sagewort (Dormaar and Willms 1990, Willms et al. 1990, Slogan 1997). Also, given the age (7 years) and small size (25 m^2) of the seven-year old sites, natural recovery may have also played a part in species composition (Desserud and Naeth 2013a).

Native grassland appears resilient to native hay harvesting, as all species found prior to cutting remained post-cutting, and ground cover, e.g. litter, moss and lichens, remained similar. In particular, one previously cut grassland had been grazed by cattle the following year and still showed close resemblance to pre-cutting conditions. We may surmise that cutting hay simulates cattle grazing; thus this evidence can assist industry practitioners to obtain permission from landowners to harvest native hay from their rangelands, proving they need not be exempt from cattle grazing for several years.

Second year results of native hay applications initially showed dominance of weedy colonizers: pigweeds, kochia and flixweed (*Descurainia sophia*). Such annuals commonly appear in the first year following ground disturbance (Desserud and Naeth 2013b); however, the high cover of weedy species may have developed due to wind blowing away the hay mulch. Had the mulch remained, it might have reduced the amount of bare ground, which attracts weedy annuals, and might have lowered the amount of ground cover. To lower the susceptibility to wind erosion, suggestions from Polster (2014) might be in order. He suggested looking at how natural systems solve disturbance problems, solutions for industrial sites can be found. One technique involves purposely making sites rough and loose to provide micro-sites where seeds of native species can be trapped, germinate and young plants can grow (Polster 2014). In our study, roughening up the wellsites prior to applying native mulch, may have assisted seed trapping and promoted germination. In addition, harrowing in the native mulch, instead of simply crimping it, might have provided protection from wind (M. Neville, Gramineae Services Ltd., pers. comm.).

After mowing the weedy species, crested wheatgrass and northern wheatgrass became the most abundant grasses on the newly treated native hay sites, dominating the second-year plant community. Crested wheatgrass was commonly used in oil and gas reclamation prior to the 1900’s (Hammermeister et al. 2003) and is found in the area surrounding native hay sites at Brooks and the EID. Crested wheatgrass may have existed in the pre-reclamation seed bank, or it may have invaded the sites from seed rain due to high winds in the area.

Third year results at the Pinhorn sites indicated that applying native hay is a promising reclamation technique. Native species started to emerge in the second year and increased significantly by the third year. Overall the Pinhorn sites showed a trajectory towards restoration. In addition, cover met current reclamation regulatory requirements, unusual after only 3 years (Alberta Environment 2011) Since the majority of species which had germinated by the second year (71%) on all sites were those found in controls, extrapolating Pinhorn results to the sites that had been sprayed with herbicide in the third year suggests they may have been positioned for a recovery trajectory towards undisturbed conditions. In particular, if allowed to develop, they might have experienced increased cover of native species such as blue grama, needle and thread, June grass, green needle grass, bluegrasses, and numerous forbs, all found in their adjacent grassland. Nevertheless, crested wheatgrass occurs in close proximity to these sites and would have needed aggressive management to prevent its dominance.

In summary, native hay appears to be a viable source of seeds for wellsite reclamation. Good recovery was observed by the third year, hosting many species found in the adjacent grassland, and respective cover. Collectively, results from this research suggest native hay is a successful and sustainable technique for restoring native vegetation cover and diversity on industrial disturbances in native grasslands.

Acknowledgements

This research was funded by Cenovus Energy and the Cenovus Chair – Canadian Plains Mitigation. We would like to thank Joel Heese and Mark Grant from Cenovus, Adam LeClair and Tania Bravo Garcia for their assistance. We especially acknowledge the foresight of Marshall Gillespie and Tim Wilk for inventing the native hay harvester used in our experiment.

Peggy A. Desserud (corresponding author), Department of Geography, University of Calgary, 2500 University Drive NW, Calgary, AB, T2N 1N4, Canada, desserud@ualberta.ca,

Chris H. Hugenholtz, Department of Geography, University of Calgary, 2500 University Drive NW, Calgary, AB, T2N 1N4, Canada, chhugenh@ucalgary.ca

Tables and Figures

Table 1. Study sites showing site name, site type (wellsite or pipeline), year treated, and study area as shown in Figure 1.

Site Name	Site Type	Year Treated	Size	Area
P 7-21	wellsite	2012	0.7 ha	Pinhorn
P 7-21L	lower area	2012	25 m^2	Pinhorn
P 7-21A	access road	2012	7.5 km x 7 m	Pinhorn
E 6-24[†]	wellsite	2012	1 ha	EID
B 10-16[†]	wellsite	2012	1 ha	Brooks
B 16-08[†]	wellsite	2012	1 ha	Brooks
G 2-06	wellsite	2005	25 m^2	Gem
G 4-06	wellsite	2005	25 m^2	Gem
G 16-09	wellsite	2005	25 m^2	Gem

[†] Sprayed with herbicide in June 2014.

Table 2. Mean cover and standard error (SE) of selected species found on undisturbed controls and second-year wellsites, compared by t-tests.

Species	Controls	SE	2nd-year sites	SE	*p*-value
Grasses					
blue grama	8.2	8.3	0.2	0.2	0.026
bluegrass	5.1	9.2	2.5	3	0.592
crested wheatgrass†	0.1	0.3	1.5	2.6	0.121
foxtail barley	0		8.8	6.9	0.006
green needle grass	1	1.3	1.6	2	0.318
June grass	2.4	1	1.1	1.3	0.518
needle and thread	10.5	11	0.4	1	0.042
northern wheatgrass	0.5	1.3	0.3	0.4	0.044
Sandberg bluegrass	0.7	1.9	1.4	3.5	0.050
sedges	4.3	4	0		0.002
shortbristle needle and thread	15.3	13	0		0.002
slender wheatgrass	0		0.3	0.4	0.007
western wheatgrass	5.8	4.2	0.4	0.3	0.007
Forbs					
dandelion	0.1	0.2	2	3	<0.001
kochia†	0		2.1	3.3	<0.001
pasture sagewort	4.5	4	1.1	1	0.016
pigweed†	0		8.8	4.4	0.009
prairie sagewort	0		0.2	0.2	0.069
yarrow	0.2	0.3	0.6	0.4	0.091

† Non-native species

Table 3. **S**elected species of plant communities of second- and third-year native hay sites, seeded sites and controls, derived from two-way cluster analysis (Figure 6) and named for the dominant species identified by ISA analysis.

	Plant Community								
	Foxtail barley			**Shortbristle needle & thread / needle & thread**			**Crested wheatgrass / northern wheatgrass**		
Species	Mean	SE	ISA	Mean	SE	ISA	Mean	SE	ISA
Grasses									
blue grama	0.2	0.3	2	7.2	9.0	67	0.2	0.3	2
bluegrasses	5.9	4.5	29	10.3	14.4	22	0.9	0.7	15
crested wheatgrass[†]	0	0	0	0	0	0	3.0	3.2	100
foxtail barley	13.3	4.2	72	1.9	5.0	1	3.4	2.6	18
green needle grass	5.1	4.6	43	6.5	8.7	39	0.3	0.4	1
June grass	0.9	0.9	14	2.3	1.7	43	1.4	1.7	30
needle & thread	1.5	1.7	6	10.1	11.1	62	0.1	0.1	0
northern wheatgrass	0	0.1	2	0	0	0	0.5	0.4	91
Sandberg bluegrass	2.6	4.0	46	0.2	0.6	1.0	0	0	0
sedges	0.1	0.2	1	2.5	2.1	68	0	0	0
shortbristle needle & thread	0	0.1	0	10.9	11.7	71	0	0	0
slender wheatgrass	0.2	0.4	8	0.2	0.5	8	0.3	0.3	27
western wheatgrass	0.6	0.4		5.6	4.4	63	0.3	0.2	4
Forbs									
dandelion	5.6	4.4	63	0.9	1.4	6	0.2	0.2	2

pasture sagewort	2.4	3.3	28	2.8	3.3	37	1.4	1.3	21
prairie sagewort	0.7	0.9	34	1.4	3.8	9	0	0	0
yarrow	0.7	0.5	45	0.3	0.5	8	0.6	0.5	37
kochia†	0	0	0	0	0	0	4.2	3.8	100
pigweeds†	1.3	1.5	1	0	0	0	12.1	4.2	96

† Non-native species

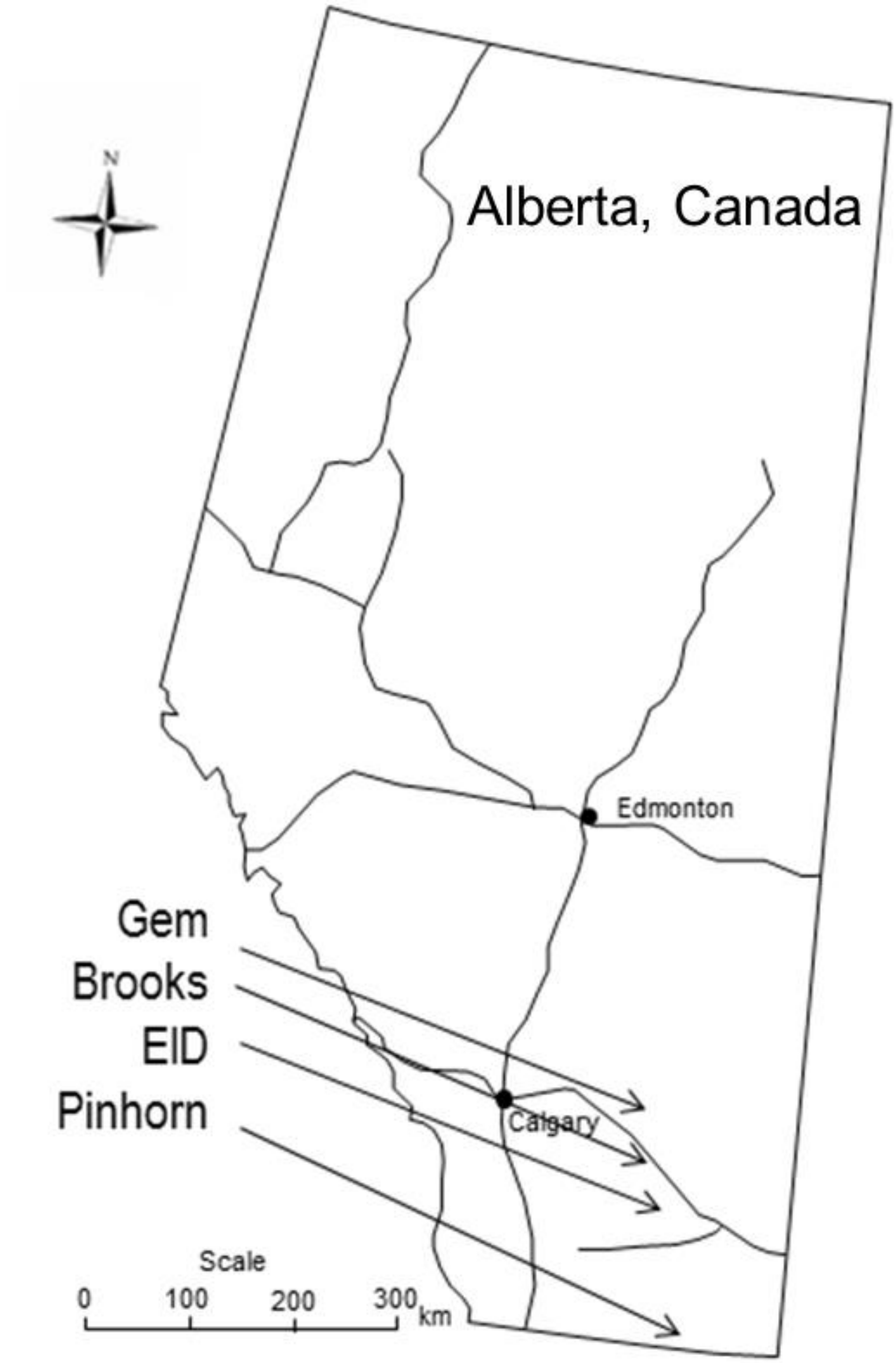

Figure 1**.** Locations of the research sites in southeastern Alberta.

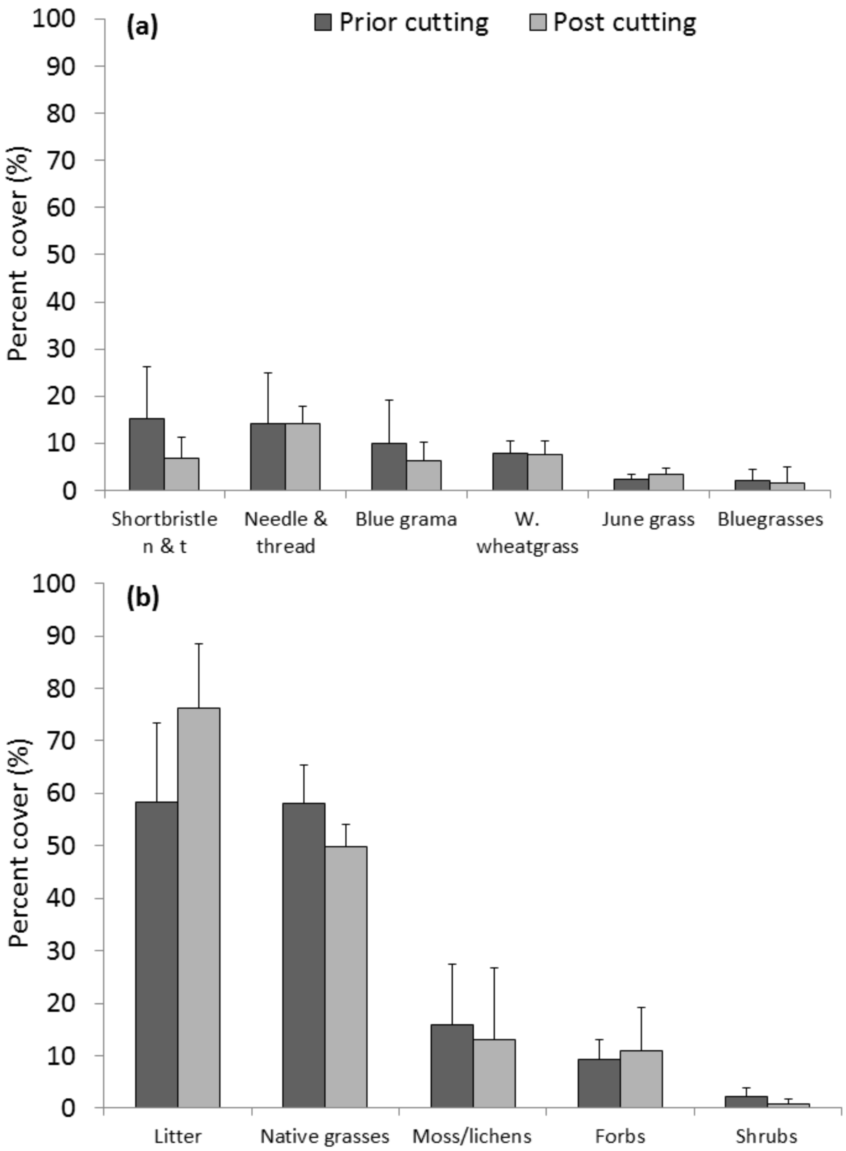

Figure 2. Comparison of control areas prior to native hay cutting and one year later (post cutting) showing: a) dominant species and b) ground cover. When analyzed by t-tests, no significant differences were found between species and ground cover prior cutting and one year later.

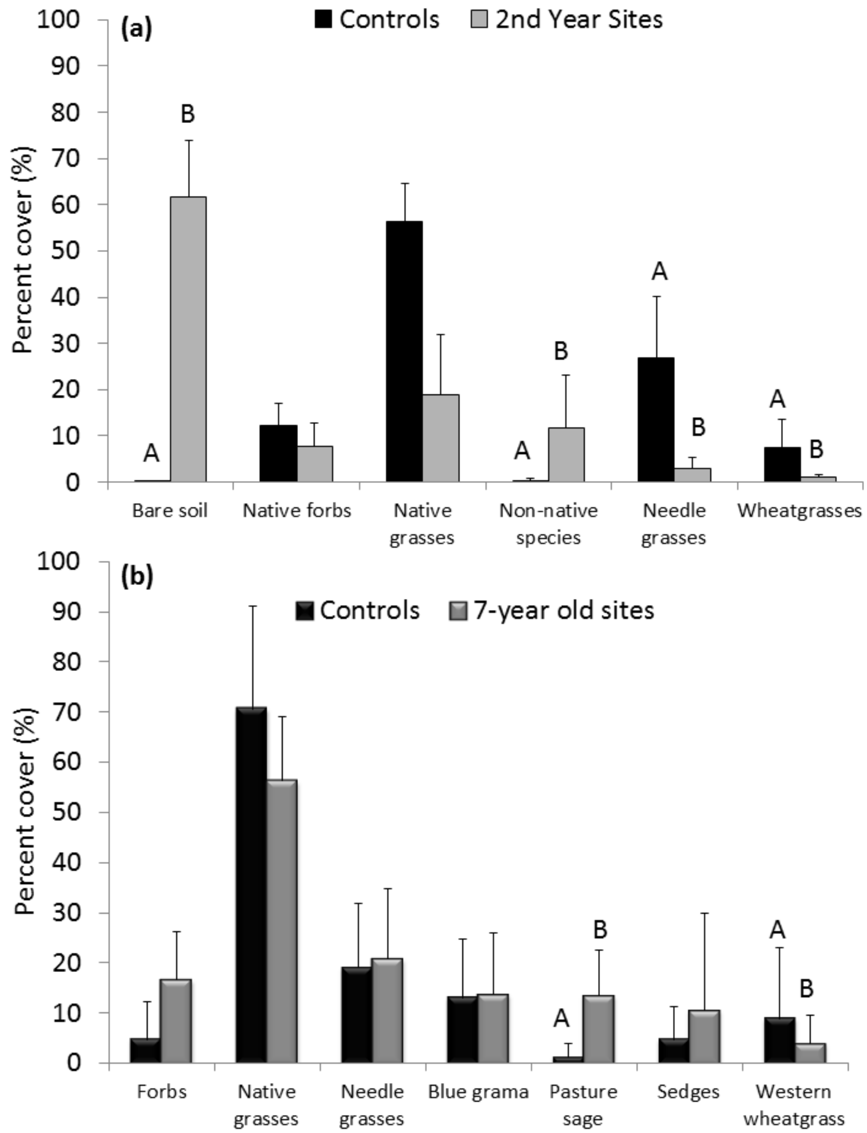

Figure 3. Comparison of controls and second-year native hay sites (a) showing significant differences for bare ground, native grasses, non-native species, needle grasses (needle and thread, shortbristle needle and thread, green needle grass) and wheatgrasses (western, northern and slender wheatgrass) as tested by t-tests. Comparison of native hay and control sites seven years after treatment in the Gem area (b) showing no significant differences for forbs, native grasses, needle grasses, blue grama and sedge as tested by t-tests. Mean cover values with letters were different at $p < 0.05$. Error bars are standard deviation.

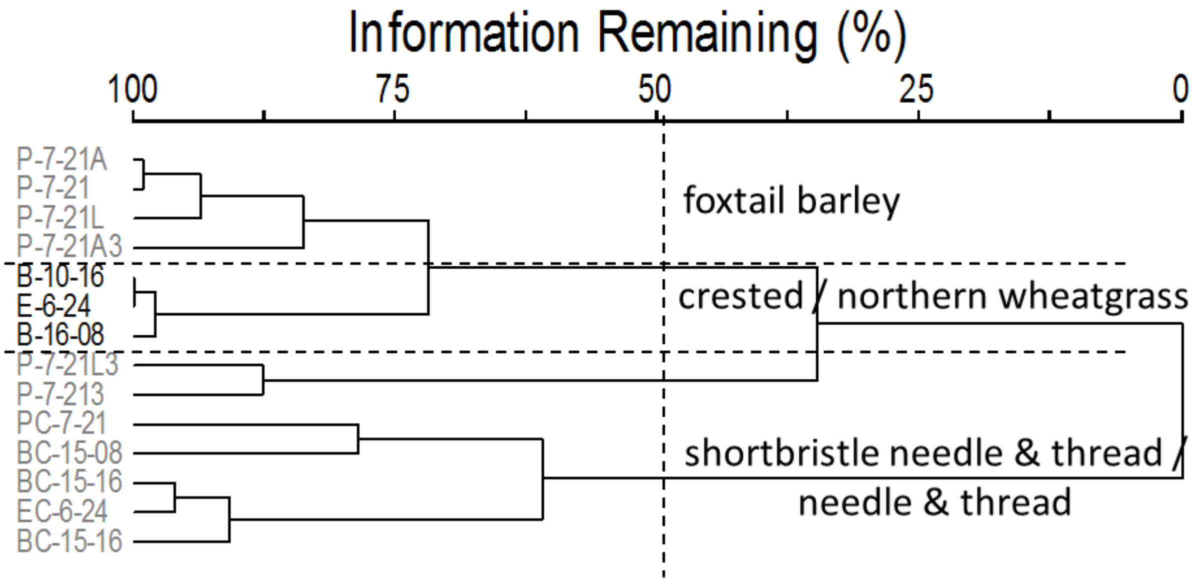

Figure 4. Classification of second- and third-year native hay sites and controls by two-way cluster analyses, showing resulting plant communities with a 50% cut-off of information remaining.

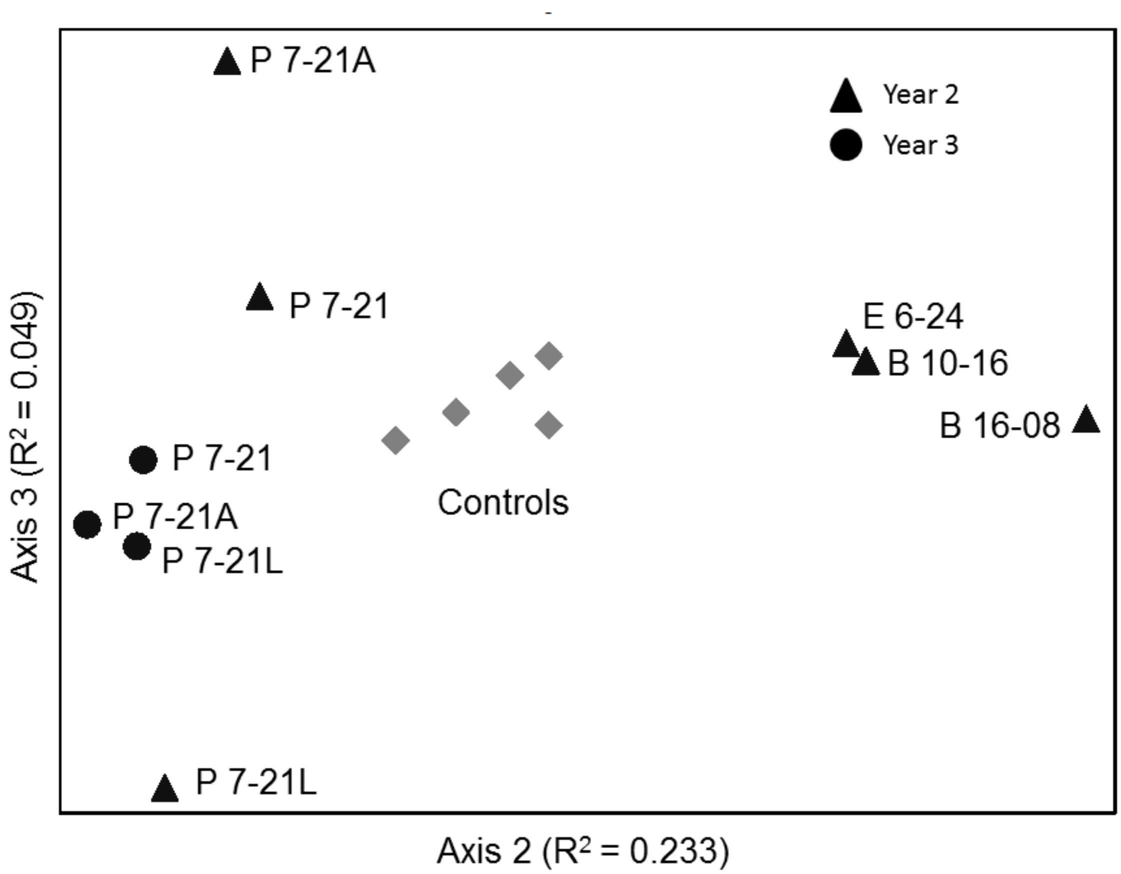

Figure 5. DCA Ordination of native hay wellsites and their controls, showing second year results of all sites, third year results for P 07-21 three sites, and controls.

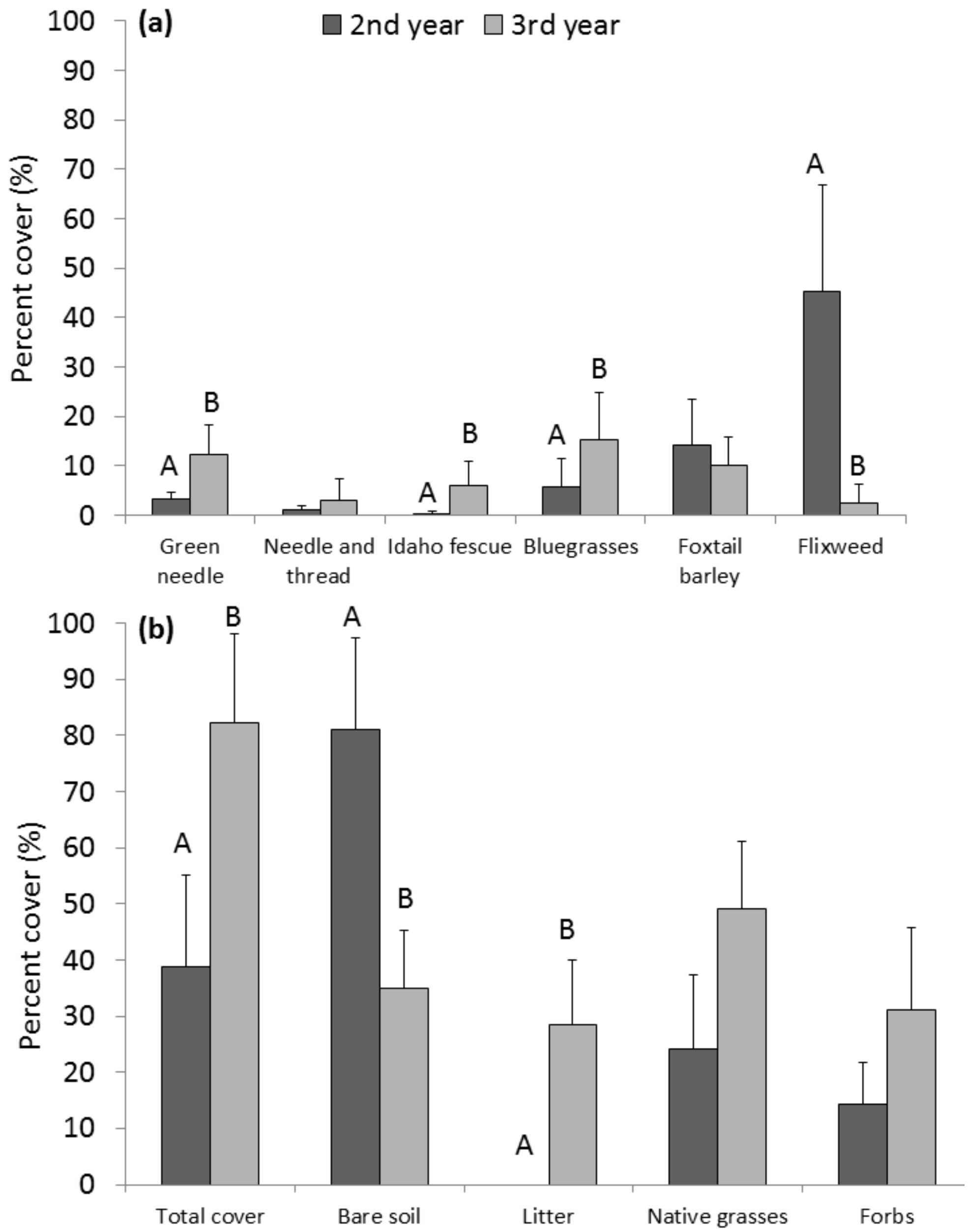

Figure 6. Comparison of second and third year percent cover at the Pinhorn sites (P 7-21, P7-21L and P 7-21A) by t-tests showing a) selected species and b) total cover, litter, native grasses and forbs. Letters indicate significant differences between years two and three. Error bars are standard deviation.

References

Adams, B. W., J. Richman, L. Poulin-Klein, K. France, D. Moisey, and R. McNeil. 2013. Range plant communities and range health assessment guidelines for the Dry Mixedgrass natural subregion of Alberta, Second approximation (Pub. No. T/040). Lethbridge, AB: Alberta Environment and Sustainable Resource Development.

Alberta Agriculture and Rural Development. 2012. Current and Historical Alberta Weather Station Data Viewer. http://www.agric.gov.ab.ca/acis/alberta-weather-data-viewer.jsp. [Accessed January 4].

Alberta Environment. 2011. 2010 Reclamation criteria for wellsites and associated facilities for native grasslands. http://www.environment.alberta.ca/documents/2010-Reclamation-Criteria-for-Wellsites-and-Associated-Facilities-for-Forested-Lands.pdf. [Accessed January 16].

Bakker, J. D., S. D. Wilson, J. M. Christian, X. Li, L. G. Ambrose, and J. Waddington. 2003. Contingency of grassland restoration on year, site, and competition from introduced grasses. *Ecological Applications* 13: 137-153.

Daubenmire, R. F. 1959. A canopy-cover method of vegetational analysis. *Northwest Science* 33: 43-46.

Desserud, P., C. C. Gates, B. Adams, and R. D. Revel. 2010. Restoration of Foothills rough fescue grassland following pipeline disturbance in southwestern Alberta. *Journal of Environmental Management* 91: 2763-2770.

Desserud, P., and M. A. Naeth. 2011. Promising results restoring grassland disturbances with native hay (Alberta). *Ecological Restoration* 29: 215-219.

Desserud, P., and M. A. Naeth. 2013a. Natural recovery of rough fescue (*Festuca hallii* (Vasey) Piper) grassland after disturbance by pipeline construction in Central Alberta, Canada. *Natural Areas Journal* 33: 91-98.

Desserud, P., and M. A. Naeth. 2013b. Promising results with rough fescue (*Festuca hallii*) seeding following disturbance, in Central Alberta. *Native Plants Journal* 14: 25-31.

Desserud, P., and M. A. Naeth. 2014. Predicting grassland recovery with a state and transition model in a natural area, Central Alberta, Canada. *Natural Areas Journal* 34: 429-442.

Donath, T. W., S. Bissels, N. Hölzele, and A. Otte. 2007. Large scale application of diaspore transfer with plant material in restoration practice – Impact of seed and microsite limitation. *Biological Conservation* 138: 224-234.

Dormaar, J. F., and W. D. Willms. 1990. Sustainable production from the rough fescue prairie. *Journal of Soil and Water Conservation* 45: 137-140.

Dufrene, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* 67: 345-366.

Edwards, A. R., S. R. Mortimer, C. S. Lawson, D. B. Westbury, S. J. Harris, B. A. Woodcock, and V. K. Brown. 2007. Hay strewing, brush harvesting of seed and soil disturbance as tools for the enhancement of botanical diversity in grasslands. *Biological Conservation* 134: 372-382.

Elsinger, M. 2009. Reclamation status of plains rough fescue grasslands at Rumsey Block in Central Alberta after oil and gas well site and pipeline disturbance. Thesis. Edmonton, AB: University of Alberta.

Hammermeister, A. M., M. A. Naeth, J. J. Schoenau, and V. O. Biederbeck. 2003. Soil and plant response to wellsite rehabilitation on native prairie in southeastern Alberta, Canada. *Canadian Journal of Soil Science* 83: 507–519.

Holechek, J. L., R. D. Piper, and C. H. Herbel. 2004. Range management: principles and practices (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Hölzele, N., and A. Otte. 2003. Restoration of a species-rich flood meadow by topsoil removal and diaspore transfer with plant material. *Applied Vegetation Science* 6: 131-140.

Jones, G. H., I. C. Trueman, and P. Millett. 1995. The use of hay strewing to create species-rich grasslands (i) general principles and hay strewing versus seed mixes. *Land Contamination and Reclamation* 3: 104-107.

Kiehl, K., and J. Pfadenhauer. 2007. Establishment and persistence of target species in newly created calcareous grasslands on former arable fields. *Plant Ecology* 189: 31-48.

Kiehl, K. K., and C. Wagner. 2006. Effect of hay transfer on long-term establishment of vegetation and grasshoppers on former arable fields. *Restoration Ecology* 14: 157-166.

McGinnies, W. J. 1987. Effects of hay and straw mulches on the establishment of seeded grasses and legumes on rangeland and a coal strip mine. *Journal of Range Management* 40: 119-121.

Morgan, J. P., D. R. Collicutt, and J. D. Thompson. 1995. Restoring Canada's native prairies. A practical manual. http://www.npss.sk.ca. [Accessed January 16].

Polster, D. F. 2014. Effective reclamation – lessons learned from 35+ years of work in field. *In:* F. Desrosiers [ed]. Proceedings from the CLRA 2014 Annual General Meeting and Conference; Red Deer, AB. Canadian Land Reclamation Association.

Romo, J., and D. Lawrence. 1990. A review of vegetation management techniques applicable to Grasslands National Park. Canadian Parks Service technical Report 90-1/GDS. Saskatoon, SK: Environment Canada.

Samson, F. B., and F. L. Knopf. 1996. Prairie conservation: preserving North America's most endangered ecosystem. Washington, DC: Island Press.

Slogan, J. R. 1997. Long-term vegetation dynamics of plains rough fescue (*Festuca hallii*) grasslands in Riding Mountain National Park, Manitoba. Thesis. Winnipeg, MB: University of Manitoba.

Smreciu, E. A., H. M. Sinton, D. G. Walker, and J. K. Bietz. 2003. Establishing Native Plant Communities. Edmonton, AB: Alberta Agriculture, Food and Rural Development, Alberta Environment and Alberta Sustainable Resource Development.

USDA NRCS. 2016. The PLANTS Database. http://plants.usda.gov. [Accessed 30 December, 2016].

Willms, W. D., S. Smoliak, and J. F. Dormaar. 1990. Vegetation response to time-controlled grazing on Mixed and Fescue prairie. *Journal of Range Management* 43: 513-517.

Wilson, S. C., F. M. Mitlöhner, J. Morrow-Tesch, J. W. Dailey, and J. J. McGlone. 2002. An assessment of several potential enrichment devices for feedlot cattle. *Applied Animal Behaviour Science* 76: 259-265.

Wilson, S. C., and M. Pärtel. 2003. Extirpation or coexistence? Management of a prsistent inroduced gass in a pairie rstoration. *Restoration Ecology* 11: 410-416.

Wilson, S. D., J. D. Bakker, J. M. Christian, X. Li, L. G. Ambrose, and J. Waddington. 2004. Semiarid old-field restoration: Is neighbor control needed? *Ecological Applications* 14: 476-484.