Effects of Fire Severity on Herbaceous Vegetation Recovery, Following a Southwest Ponderosa Pine Wildfire

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INTRODUCTION

This poster presents research on the effectiveness of aerial seeding conducted on private lands by the Natural Resources Conservation Service (NRCS) following the Trigo Wildfire of April 2008, which burned 13,709 acres of ponderosa pine and mixed conifer in the Manzano Mountains of central New Mexico.

The general objectives of this research were to:

- **determine the effects of fire severity on the recovery of forest understory vegetative communities and determine how different plant species respond to fire severity;**
- **determine the response of intentionally seeded grass species used in restoration efforts by the NRCS (annual rye grass, *Lolium multiflorum*, and tall wheat grass, *Thinopyrum ponticum*) to high and low fire severity; and**
- **evaluate the relative recovery responses of native and exotic plant species to fire severity.**

METHODS

Study Area

The Trigo fire was one of three fires (also Ojo Peak and Big Springs) that burned in late 2007 and early 2008 on the eastern slopes of the Manzano Mountains, New Mexico. The fire was started by human ignition on April 15, 2008 and burned 5,548 hectares (13,709 acres) of the Estancia Basin Watershed. The burned area ranged in elevation from 2,076 to 2,827 meters (6,811–9,275 feet) and comprised of piñon/juniper woodland to ponderosa pine and mixed conifer forest. The fire burned at a mosaic of severities as shown by the Burned Area Emergency Response (BAER) map (**Figure 1**). All the monitoring plots in this study were located within the ponderosa pine vegetation type.

The climate within the project area is mild and characterized by relatively light annual precipitation, a wide range of diurnal and annual temperatures, abundant sunshine, and low relative humidity, factors that combine to create semi-arid climatic conditions (**Figures 3 and 4**).

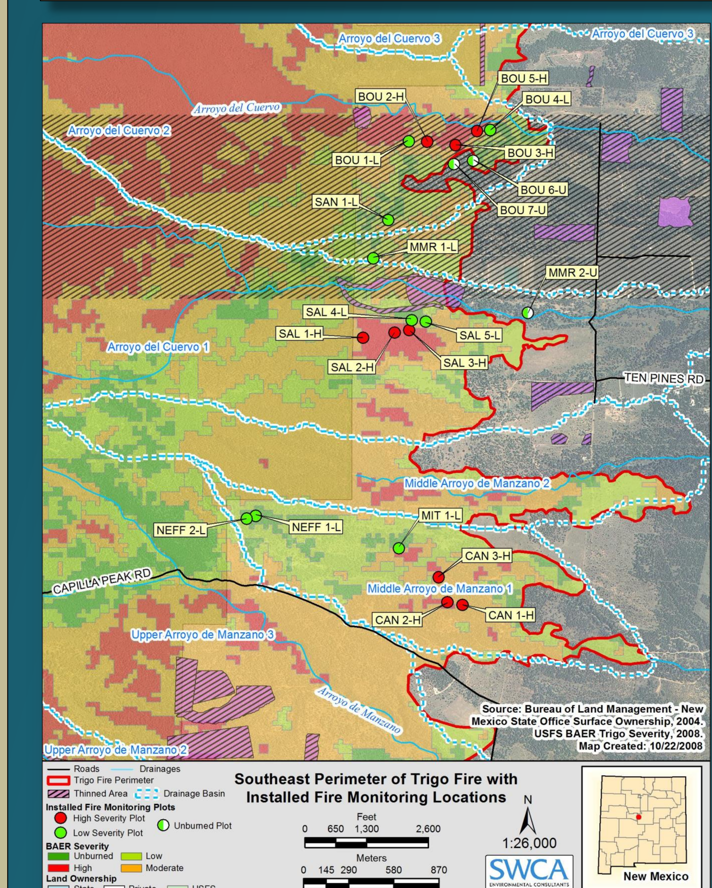


Figure 1. Fire Monitoring Plot Locations with BAER severity.

Tree densities in the study area ranged from 84 to 3,188 trees per hectare. **Overall, canopy closure was greater than 60%. Stands were primarily even-aged, lacking structural diversity (SWCA Environmental Consultants [SWCA] 2012).** The NRCS conducted post wildfire seeding on private lands approximately 1 month after the fire to help alleviate the detrimental effects wildfires have on ecosystem resources. The species used in this effort were a mixture of annual rye grass (*Lolium multiflorum*) and tall wheat grass (*Thinopyrum ponticum*).

Plots were distributed randomly in three adjacent watersheds located in ponderosa pine stands and stratified by burn severity as determined by the BAER map (**Figure 1**).

Study Design

Twenty-one plots (Figure 1) were established in August 2008 on private lands within the Trigo fire perimeter and were measured over a 3–year period beginning in the fall of 2008 and ending in the fall of 2011.

Eight mini-meteorological stations were operated around the study area to measure ambient temperature and precipitation over the duration of this study.

Plots were distributed randomly in three adjacent watersheds located within ponderosa pine stands and stratified by burn severity as determined by the BAER map (**Figure 1**).

Nine plots were established in areas burned at a high severity and nine plots were established in areas burned at a low severity. Due to a lack of unburned area within the fire perimeter just three plots were established in unburned areas to serve as reference sites.

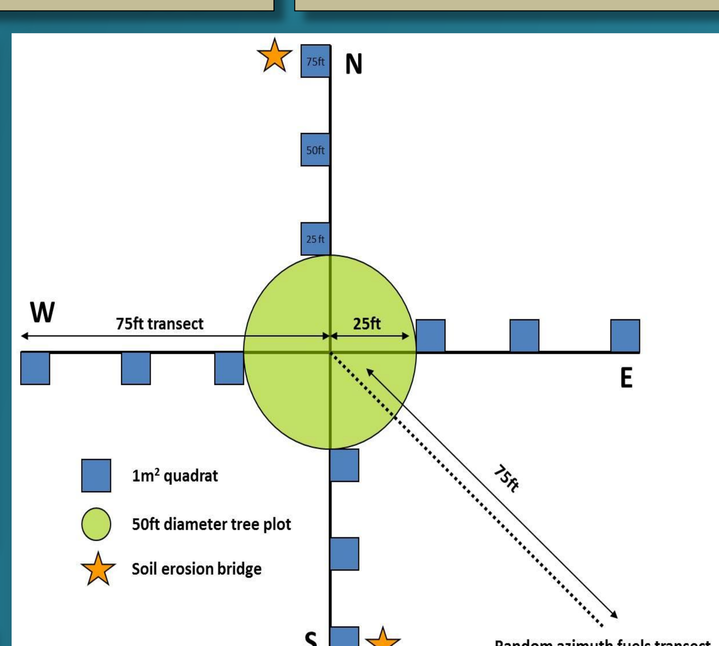


Figure 2. Plot design.

Measurements

Quadrats measuring 1-m² were used to characterize the plant species composition and foliage canopy profile up to 1 m (3 feet) above the ground surface. Three quadrats were systematically placed on each of four 75-m (246-foot) transect lines (**Figure 2**). All plant species and ground surface features were measured from each quadrat in the fall (September) of each year, 2008–2011. All cover values were averaged over all 12 quads per site for analysis. An alpha level of 0.05 was used for all statistical testing. All analyses were performed for each year (**Table 1**).

Analyses

Table 1. Analytical methods used.

Method	Description
Hierarchical cluster analysis	Group-average cluster analysis was used to examine how similar the plant species compositions of the various sites representing different burn severities and unburned conditions were to each other.
Non-parametric MRPP (parametric MANOVA equivalent) & Indicator Species analysis (MjM Software 2010)	A non-parametric multivariate Multi-response Permutation Procedure (MRPP) was used to test for differences between high and low severity and unburned sites based on all plant species compositions and species indicator analysis was used to determine which plant species were significantly associated with either burn severity or unburned sites(McCune and Mefford 2008).
Wilcoxon	Non-parametric Wilcoxon tests were used to test for differences in the measured cover values of ground surface variables including some plant species, plant growth-forms, bare soil, and leaf litter, between high and low fire severity sites.
Mean cover	Calculated for the quadrat data by severity, season, and year. The means were graphed in order to see any trends in the data that may be explained by fire severity.

ACKNOWLEDGEMENTS

We thank the **New Mexico Water Trust Board** for providing the majority of funding for this project. We also thank the **Estancia Basin Water Planning Committee**, **New Mexico Forest and Watershed Restoration Institute**, **New Mexico State Forestry**, the **Bouton, Candelaria, Kelly, Mitchell, Neff, Salazar, Sanchez landowners, and the Manzano Mountain Retreat** for allowing post-fire monitoring research to be conducted on their lands.

A big thanks also goes to **Dierdre Tarr** of the **Claunch-Pinto Soil and Water Conservation District** who has been critical to the implementation and success of this project and other projects within the Estancia Basin.

RESULTS

Plant Species Composition

Year	Test	T	A	P Value
2008	Overall	-2.04	0.04	0.04
	Low vs. High	-1.05	0.02	0.14
	Low vs. Unburned	-0.44	0.01	0.28
	High vs. Unburned	-3.44	0.09	0.006
2009	Overall	-5.56	0.10	<0.0001
	Low vs. High	-4.29	0.06	0.002
	Low vs. Unburned	-3.01	0.09	0.01
	High vs. Unburned	-4.03	0.09	0.002
2010	Overall	-5.37	0.12	0.0002
	Low vs. High	-4.30	0.08	0.002
	Low vs. Unburned	-2.19	0.07	0.03
	High vs. Unburned	-4.42	0.13	0.002
2011	Overall	-5.34	0.27	0.0001
	Low vs. High	-2.96	0.37	0.02
	Low vs. Unburned	-3.46	0.19	0.005
	High vs. Unburned	-3.16	0.17	0.01

Table 2. Results of MRPP analysis testing for differences in composition of plant species among fire severity levels 2008–2011. 'T' denotes the statistic measuring group separation, 'A' the statistic measuring within-group agreement, and 'P' the probability of finding a higher value of T in all permutations of the data. Significant p-values (<0.05).

MRPP analysis revealed overall significant differences in plant species composition between the unburned, low severity and high severity sites in 2008, 3 years following the fire (Table 2). We observed both native species and non-native seeded species throughout the 3 years of measurement; however, the timing of dominance of these species is related to time since fire.

Year	Growth Form	Species	Severity Association	Indicator Value	p Value
2008	Herb	White sagebrush	Unburned	98.6	0.001
	Forb	Unknown forbs	Unburned	62.2	0.04
	Fob	Fremont's geranium	Unburned	64.2	0.02
	Shrub	Broom snakeweed	Unburned	100.00	<0.0001
	Forb	Copper globemallow	Unburned	66.7	0.02
2009	Forb	Ragleaf bahia	High	64.2	0.05
	Grass	Blue grama	Unburned	97.2	0.001
	Forb	Wright's deervetch	High	94.5	0.0002
	Forb	Fremont's geranium	Unburned	66.7	0.01
	Shrub	Broom snakeweed	Unburned	61.5	0.03
	Forb	Copper globemallow	High	66.7	0.02
	Grass	Prairie junegrass	Unburned	74.9	0.002
	Grass	*Tall wheatgrass*	*High*	*72.7*	*0.001*
	Tree	Gray oak	Unburned	59.2	0.03
	Forb	Carruth's sagewort	Unburned	47.9	0.04
	Forb	Wright's goldenrod	Unburned	66.7	0.01
2010	Grass	Blue grama	Unburned	90.2	0.001
	Forb	Spreading fleabane	High	63.2	0.04
	Forb	Wright's deervetch	High	88.0	0.0002
	Forb	Perkey sue	Unburned	66.7	0.01
	Forb	Copper globemallow	High	66.7	0.01
	Grass	Prairie junegrass	Unburned	87.0	0.001
	Grass	Littleseed ricegrass	Unburned	68.3	0.02
	Grass	*Tall wheatgrass*	*High*	*71.2*	*0.0004*
	Forb	Narrowleaf goosefoot	High	72.4	0.03
	Tree	Gray oak	Unburned	55.8	0.05
	Forb	Carruth's sagewort	Unburned	63.8	0.04
	Forb	Canadian horseweed	High	59.4	0.03
2011	Grass	Blue grama	Unburned	86.3	0.01
	Forb	Fremont's goosefoot	Low	76.0	0.05
	Forb	Wright's deervetch	High	100.0	0.01
	Grass	Littleseed ricegrass	Unburned	64.2	0.05
	Grass	*Tall wheatgrass*	*High*	*79.7*	*0.003*
	Grass	Mexican lovegrass	High	100.0	0.01

Table 3. Results of indicator species analysis to determine associations of species with severity levels based on the composition of all plant species measured from study plots. Only those species significantly associated with a severity level are presented. All other species were not significantly associated (present more than expected by random chance alone) within any severity levels. The exotic seeded annual grass, tall wheatgrass, is represented in italics. All other plant species were native. Common names are from USDA Plants Database 2014.

Cluster Analysis

Dendrograms resulting from cluster analysis of study site groupings based on similarities in plant species composition relative to fire severity history and geographic locations for each year of the study are presented in Figure 8:a-d.

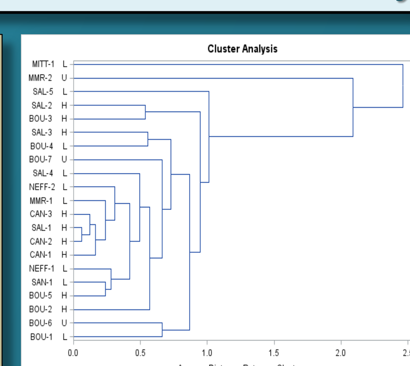


Figure 8-a. 2008 cluster analysis.

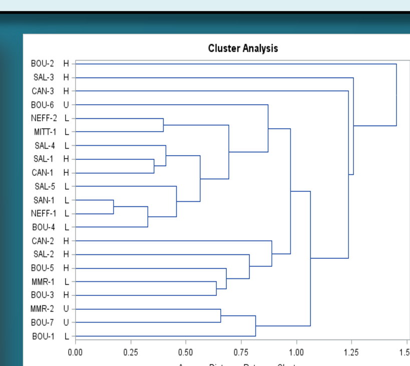
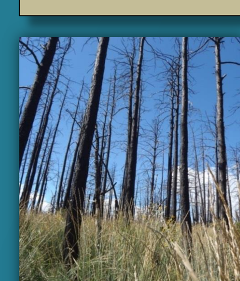


Figure 8-b. 2009 cluster analysis.



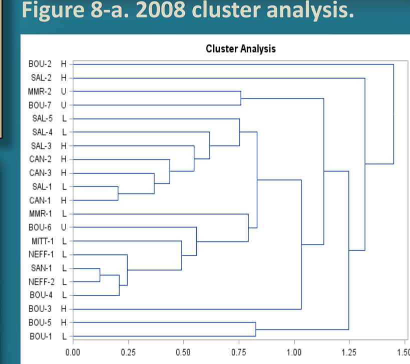


Figure 8-c. 2009 cluster analysis.

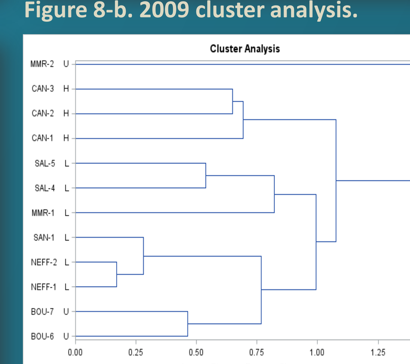


Figure 8-d. 2011 cluster analysis.

- **Most significant results can be seen on the high-severity plots where bare ground has decreased, while grasses increased (see Figure 9). Forbs increased in 2009 over 2008 levels, but then remained relatively constant in 2010 and 2011.** The low severity plots did not change as significantly. The cover of grasses increased between 2008 and 2009, and then remained relatively constant in 2010 and 2011.
- MRPP analysis revealed overall significant differences in plant species composition between the unburned, low severity and high severity sites in 2008, three years following the fire (see **Table 2**).
- Among pair-wise comparisons of severity levels , plant species compositions differed significantly only between the high severity and unburned sites in 2008 (see **Table 2**). **From 2009 through 2011, plant species compositions differed significantly in overall comparisons of all severity levels, and among all pair-wise comparisons** (see **Table 2**).
- Dominant species specific to the high severity plots included Wright's deervetch (*Lotus wrightii*), narrowleaf goosefoot (*Chenopodium leptophyllum*), Fremont's goosefoot (*Chenopodium fremontii*), and spreading fleabane (*Erigeron divergens*). These species are typical of early colonizers following disturbance (Wolfson et al. 2005) (see **Table 3**).
- The seeded grasses annual rye grass and tall wheat grass were the only non-native species found on the plots. **Tall wheat grass was consistently associated with high severity sites from 2009–2011, with peak cover of the species occurring in the fall of 2010 on both low and high severity plots** (see **Figures 5 and 7**).
- Native grass cover was low in all years on both low and high severity plots (see **Figure 6**) with no significant difference between high and low severity sites.
- **High severity sites recorded the greatest cover of seeded grasses, with cover amounts increasing from 15% in 2009 to over 45% in 2011** (see **Figure 7**). Cover of seeded grasses on low severity sites peaked in 2010 with over 10% cover then dropped back to just over 5% in 2011 (see **Figure 6**).
- Cluster analysis (see **Figures 8a:d**) revealed that three years following the fire in 2008, there were some groupings of sites based on fire history and location, but many sites were unique and overall grouping distances were low. **From 2009 through 2011, fire history groupings and geographic location groupings became more pronounced and such groupings were most pronounced in 2011.**
- Results of Wilcoxon tests for differences in ground cover features and vegetation growth forms between high and low severity sites revealed that **bare soil cover was significantly greater at high severity sites than low severity sites** (see **Figure 10a**).
- Ground surface leaf litter accumulations had the opposite pattern, being significantly greater on low severity sites, but the differences declining over time (see **Figure 10b**).
- **From 2009 through 2011, grass cover was significantly greater across high severity sites than low severity sites** (see **Figure 10c**). Forb cover also was significantly higher on high severity sites in 2010, but not any other years (see **Figure 10d**).

Rainfall and Temperature

In the study area, average annual temperatures increased and total yearly precipitation decreased from 2008 through 2011 (**Figures 3 and 4**).

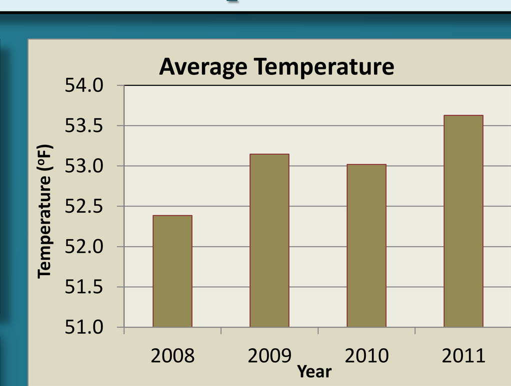


Figure 3. Average monthly temperature in study area for 2008—2011.

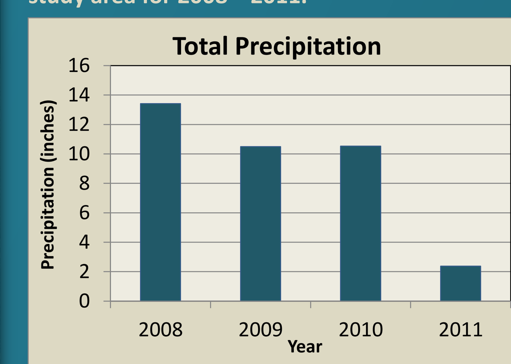


Figure 4. Annual total precipitation in study area for 2008–2011.

Seeded Species

The seeded grasses were the only non-native species found on the plots (**Figure 5**).

Figure 5. Dominance of tall wheat grass (*Thinopyrum ponticum*) occurring on a high severity plot in fall 2010.

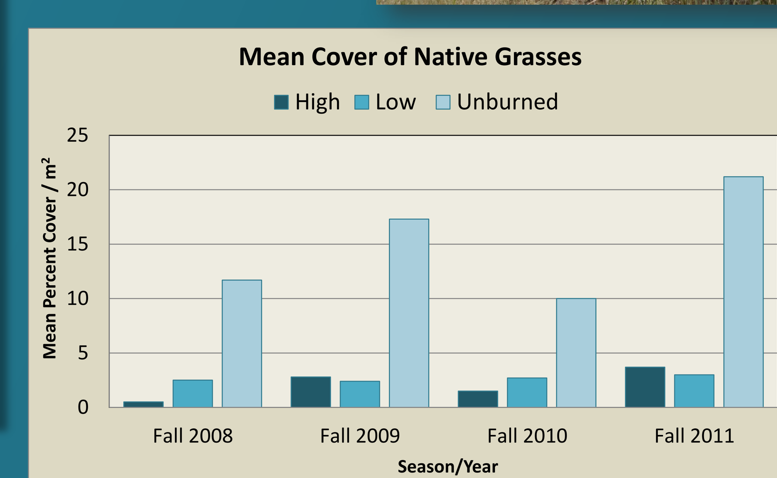


Figure 6. Mean cover of native grasses across all severity classics and fall monitoring periods. Unburned sites are included for reference.

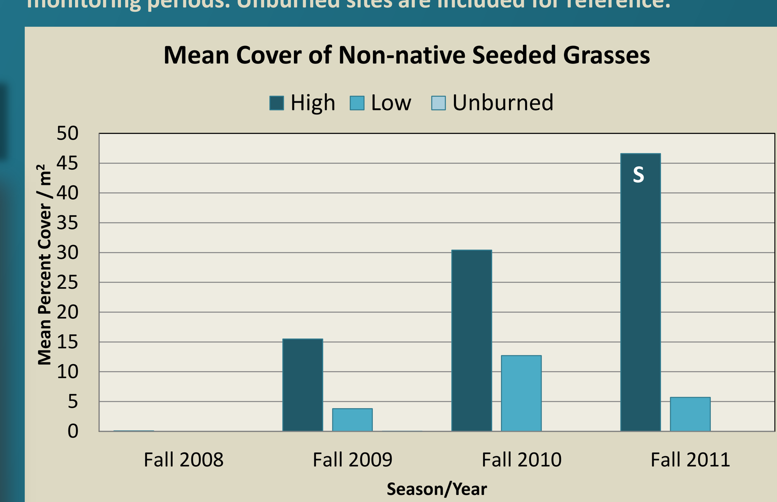


Figure 7. Mean cover of non-native seeded grasses across all severity classes and fall monitoring periods. Unburned sites are included for reference. 'S' denotes significant difference (p<0.05) between high and low severity.

Ground Cover

Dramatic changes in ground cover were observed over the monitoring period, particularly for the high-severity plots, as seen in the photo series below (**Figure 9-a:d**).

Figure 9-a. Fall 2008; little vegetation cover.

Figure 9-b. Fall 2009; dominance by fetid goosefoot (*Chenopodium graveolens*).

Figure 9-c. Fall 2010; dominance by tall wheat grass (*Thinopyrum ponticum).*

Figure 8-d. Fall 2011; nearly 80% dead and downed trees.

Average percent cover by type across all plots and all monitoring years are shown in **Figure 10-a:d**. 'S' denotes significant difference between high and low severity sites.

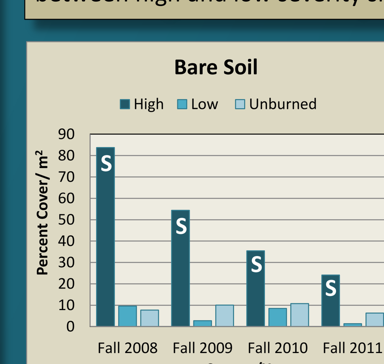


Figure 10-a

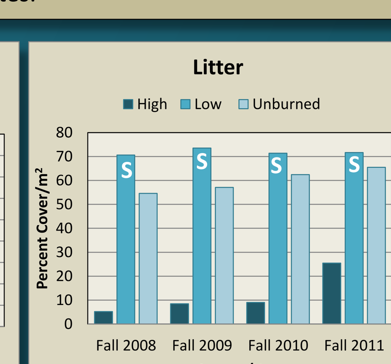


Figure 10-b

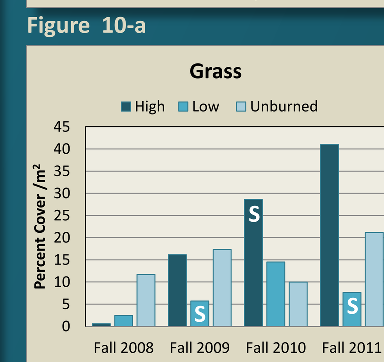


Figure 10-c

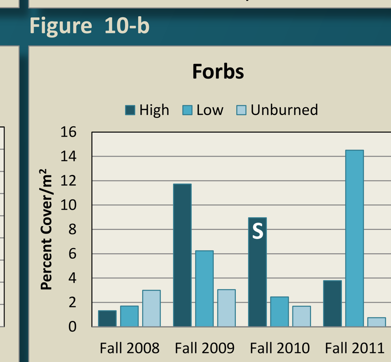


Figure 10-d

DISCUSSION

- Data from our study supported the hypothesis that **post-fire vegetation composition is related to burn severity.** From 2009 through 2011, a number of native grass and forb species, and the exotic seeded grass, tall wheat grass, were associated with high severity sites, and a number of native grasses, forbs, and trees were associated with the unburned sites. Only one plant species, the forb Fremont's goosefoot was associated with low severity sites.
- **Seeded grasses proliferated throughout the study area.** Tall wheat grass persisted on all high severity sites throughout the study years, but began to decline in fall 2011.
- Our findings demonstrate that **native herbaceous species were important colonizers of the high severity sites, along with the seeded tall wheat grass.** While species associations did change from year to year, the seeded tall wheat grass was consistently associated with high severity sites from 2009 through 2011.
- The greatest number of plant species associated with high severity sites were seven species in 2010 (see **Table 3**), indicating that **two years following the fire is when high severity sites had the most unique plant species assemblages compared to unburned and low severity sites.**
- The severity levels all differed significantly from each other in terms of plant species composition.
- Contrary to other studies (Crawford et al. 2001; Fornwalt et al. 2003; Hunter et al. 2006, Freeman et al. 2007), **we did not find any relationship between burn severity and presence of non-native species, other than aerial seeded non-native grasses.**
- Climate and precipitation data (see **Figures 3 and 4**) reveal **this area was recovering during a time of warming and drying that can be associated with global climate change (Gutzler 2013), which likely attributed to the dominance of the seeded species.** If the climate was wetter and cooler like historic climate patterns then it would have been expected that more native forbs and grasses would persist.