Research Article

Effects of managed fire on a swale grassland in the Chihuahuan Desert

By Brandon T. Bestelmeyer, Laura M. Burkett and Leticia Lister

On the Ground

• Fire is considered a critical process for limiting shrub encroachment and maintaining grassland structure and functions.
• Fire can be detrimental to grasses in upland settings of arid desert grasslands, but no studies have been performed in more productive swale grasslands.
• Monitoring of a prescribed fire treatment in a swale grassland in southern New Mexico indicated that perennial grasses had not recovered after 5 years, even with above-average rainfall. Furthermore, indicators of erosion susceptibility increased, and shrubs resprouted rapidly.

Keywords: prescribed fire, ecological site descriptions, state and transition models, vegetation monitoring.

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Introduction

It is widely believed that fire has helped to shape grassland ecosystems in the Southwestern United States and fire is considered a critical process maintaining grassland ecosystem structure and function.[1] Fire limits the dominance of woody plants[2] and can have favorable effects on nutrient availability to grasses and photosynthesis by grasses.[3,4] For these reasons, restoring natural fire frequencies is often a priority for management of Southwestern grasslands.[5]

There is concern, however, that fire may be detrimental to perennial grasses in less productive arid to semiarid grasslands.[6] Especially in the context of drought, the cover of dominant perennial grasses can be reduced for prolonged periods[7,8] and small grass clones can be killed.[9] Prolonged post-fire recovery can increase susceptibility to erosion and soil degradation that compounds grass mortality.[10] Furthermore, fire may only partially damage or top-kill some shrubs,[11] and older individuals are especially resistant to fire.[12] Consequently, shrubs can recover more quickly than perennial grasses after fire, potentially lending a competitive advantage to shrubs for soil water resources.[13]

Grasslands in the Chihuahuan Desert of southern New Mexico circumscribe a wide range of climates (ca. 200-400 mm [8-16 inches] mean annual rainfall) and soils (deep clayey to shallow gravelly) that influence the prevalence of fire.[14] It is reasonable to expect that fire effects on vegetation should also vary with climate and soils. For example, although successful use of prescribed (managed) fire is common in areas such as the Major Land Resource Area (MLRA) 41.1 (Madrean oak savanna, 300-400 mm [12-16 inches] precipitation zone) in the boot-heel of southwest New Mexico,[15] areas with lower elevation and rainfall in the adjacent MLRA 42.2 (Chihuahuan Desert shrub, 200-300mm [7-12 inches]) are not usually considered as candidates for successful fire use. Although fire may have been an important process in desert grasslands with lower rainfall before European settlement,[16] current production and continuity of fine fuels is seldom adequate to support fire, with fire return intervals estimated from 35 to >200 years.[i] Furthermore, fire is known to harm some grasses, especially black grama (*Bouteloua eriopoda*).[9] Grassy swales that receive overland water flow from adjacent uplands may be an exception to these generalizations. Swale ecosystems, known as Chihuahuan-Sonoran Desert Bottomland and Swale Grasslands following the NatureServe Ecological Systems classification[17] or Draw ecological sites (R042XB016NM) in the US ecological site classification system,[ii] feature relatively high production and fuel loads. Grasses associated with this site, including *Pleuraphis mutica* and *Sporobolus airoides*, are known to be fire resistant and tolerant, respectively.[18,19] For these reasons, swales have been targeted for prescribed fire treatments to reduce the cover of woody plants and stimulate grass growth. To date, however, there are no documented observations of fire effects in swale ecosystems.

We took advantage of a unique fire treatment applied by the United States Department of Interior Bureau of Land Management Las Cruces District Office in February of 2014 to an area within T16S R01E in Sierra County, New Mexico. Fires were ignited using a drip torch in cool, dry, relatively

i https://www.landfire.gov/geoareasmaps/2012/CONUS_FRG_c12.pdf.
ii https://edit.jornada.nmsu.edu/catalogs/esd/042X/R042XB016NM.

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calm conditions (16-22°C [61-71°F], 24-40% humidity, 3-11 kph [2-7 mph] winds, 0-3°C [32-38°F] dew point). The planned burn area was 1,416 ha [3,500 acres] including both swale and adjacent upland landforms. We placed two monitoring plots within swales of the planned burn area and conducted pre-fire and post-fire (1 and 5 years) measurements to examine the effects of fire on vegetation.

Methods

We installed two plots located 5,800 m (3.6 miles) apart and collected baseline data the week before the prescribed fire (21-25 February 2014). Plots were located in portions of shrub-invaded swale grasslands that had sufficient fuel continuity to carry fire and were 50 to 100 m (164-328 feet) from roads. Plots were revisited for data collection one year post burn (19 February 2015) and five years post burn (30 September 2019). We used different, but complementary, methodologies in the plots.

Plot A consisted of two, 50-m (164-feet) transects separated by 20 m (66 feet) with rebar marking the transect ends. Line-point intercept (25 cm [9.8 inches] intervals), belt transects for shrub density (2 m [6.6 feet] belt; collected only at baseline), and photos (one from each transect end) were collected.[20] Line-point intercept observers were calibrated to an absolute range of 5% from one another and this method emphasized precise estimates of cover change over time.

Plot B was 20 m x 20 m (66 feet x 66 feet) centered on a 0.9 m × 0.9 m (3 feet × 3 feet trend photo plot [3 × 3 grid]) marked with rebar in three locations.[21] Photos were taken of the 3 × 3 grid and four landscape photos (azimuths recorded). A sketch of the 3 × 3 grid was made and species identified. Domin-Krajina (DK) cover classes were recorded by species within the 20 m × 20 m (66 feet × 66 feet) plot.[iii] DK observers were calibrated against line-point intercept. If a species was recorded at baseline, extra effort was spent trying to locate it in following years.

In contrast to the precision emphasized with line-point intercept (plot A), DK methodology (plot B) emphasized a complete species inventory for the area. Pedoderm and Pattern Classes were recorded for both plots, including the Resource Retention Class (RRC) that characterized the connectivity of bare ground and the potential for wind and water erosion and the Soil Redistribution Class (SRC) that characterized the magnitude of soil loss and/or soil deposition.[22] Both indicators were recorded on ordinal scales.

Results

Modelled precipitation data[23] indicated that the study site experienced a drought for the 4 years preceding the fire and in the treatment year (Fig. 1). Precipitation was normal or above average in 4 of the 5 years after the fire.

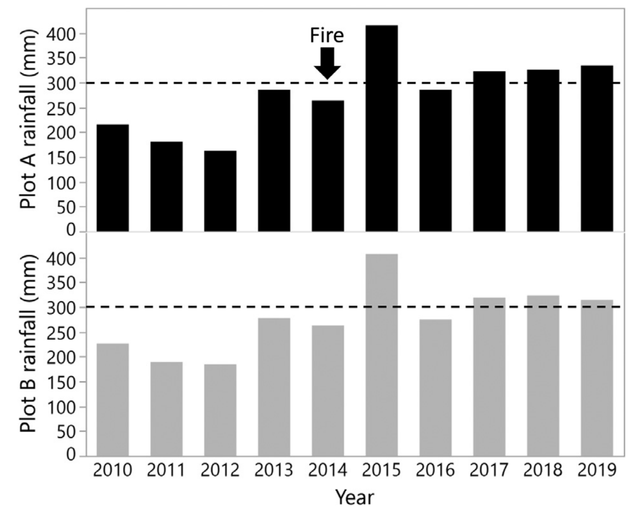

Figure 1. Annual modelled precipitation data obtained for each plot. The year of the fire is indicated and the dashed horizontal line is the 30-year (1981-2010) climate normal.

We recorded a marked decrease in plant cover one year post-fire on both plots (Tables 1 and 2; Figs. S1 and S2). Decreases in cover were consistent across all species and life forms except for perennial forbs in Plot A, which experienced a slight increase in silverleaf nightshade (*Solanum elaeagnifolium*). Five years post-fire, Plot A, dominated by *S. airoides*, had partial recovery of perennial grasses, but perennial grasses on Plot B, dominated by *P. mutica*, had not recovered. Additionally, shrubs had resprouted on both plots less than 2 months post-fire (9 April 2014), and persisted as of 2019.

Both plots had interconnected persistent plant patches with scattered bare areas (>30 cm [11.8 inches] across) pre-fire (RRC 2), and fragmented persistent plant patches with elongated bare areas five years post-fire (RRC 4, Table 3). The soil redistribution class for Plot A did not change. Soil redistribution increased on Plot B five years post-fire, with evidence of increased soil redistribution and soil loss (SRC from 2 to 3a).

Discussion

All species of shrubs resprouted within a few months of the prescribed fire. Although vegetation structure was temporarily altered, shrubs were not removed from the plant community and the area remained in the same state, similar to results in uplands of MLRA 42.2.[7] Reduced perennial grass cover, on the other hand, has persisted five years post-fire. In flood prone swale landforms, reduced ground cover indicates an increased risk of water erosion. Thus, fire appears to have shifted this swale site to a less stable, more at-risk plant community phase,[24] indicated by persistent reduction in perennial grass cover and increased soil redistribution.

The lack of grass recovery could be due to a combination of factors. Drought preceding and following a prescribed burn can negatively affect perennial grass response to fire,[25] although in the present case rainfall was mostly above average

iii https://jornada.nmsu.edu/esd/development-resources.

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Table 1
Line-point intercept percent cover pre- and post-fire treatment for plot A

	All annual forbs	All annual grasses	All perennial forbs	All perennial grasses	All shrubs	*Flourensia cernua* (SH)	*Pleuraphis mutica* (PG)	*Prosopis glandulosa* (SH)	*Setaria leucopila*(PG)	*Sporobolus airoides*(PG)
Baseline	34.25	5.25	4.75	75	21.25	15	5	7.75	16.75	60
1 year post fire	3.25	0.25	5.25	51	8	5	3	3.5	3.25	40.25
5 year post fire	4.75	0.25	1.25	60.25	9.5	6.75	3.75	2.75	0.5	52.75

Note: See Appendix 1 for all species. The lifeform of species is noted. PG indicates perennial grass; and SH, shrub.

Table 2
Domin-Krajina percent cover pre- and post-fire treatment for plot B

	All annual forbs	*Flourensia cernua*(SH)	*Panicum obtusum* (PG)	*Pleuraphis mutica* (PG)	*Prosopis glandulosa* (SH)	*Rhus microphylla* (SH)	*Setaria leucopila* (PG)	*Sporobolus airoides* (PG)	All perennial grasses
Baseline	7.5	10	17.5	30	3	1	3	25	78.1[†]
1 year post fire	0.05	3	5	4	3	0.5	0	7.5	17.5[†]
5 year post fire	0	1	8	*	0.05	0.05	0	*	17.5*

* High utilization prevented observers from identifying perennial grass species so species were combined and assigned one cover class.
† The sum of all perennial grasses (Domin-Krajina midpoint) for the year. See Appendix 1 for all species. PG indicates perennial grass; and SH, shrub.

Table 3
Pedoderm and pattern classes pre and post fire

Plot	Year	RRC	SRC
A	2014	2	3a
A	2015	3	3a
A	2019	4	3a
B	2014	2	2
B	2015	4	3a
B	2019	4	3a

RRC indicates Resource Retention Class, which scales from 1 (highest retention) to 6 (lowest retention); and SRC, Soil Redistribution Class, which scales from 0 (no evidence of erosion) to 4 (extensive, severe erosion).

following the fire event (Fig. 1). Pedestalling of grass plants before the fire may have prevented sufficient insulation from the heat of the fire causing individual plant mortality.[26] Mortality may have been exacerbated in species such as *S. airoides* by standing dead material and litter within the tussock, causing high burn temperatures. Livestock grazing following the fire treatment may also have limited grass recovery.[26] Cattle grazing was observed in the treatment in the months immediately after the treatment, and moderate to high utilization of grasses was observed in 2015 and 2019, which may be due to both cattle and introduced oryx (*Oryx gazella*).[27]

Conclusions

Our observations indicate that the prescribed fire treatment we studied did not cause shrub mortality nor benefit perennial grasses over 5 years, even in the context of above-average rainfall after the treatment. Based upon existing literature summarized for *P. mutica* and *S. airoides*, 5 years is ample time to see a positive response in the context of above-average rainfall.[18,19] In contrast, indicators suggest the plant community is at increased risk of accelerated soil erosion. Our results echo those of earlier authors who urge caution or avoidance in considering prescribed fire in more arid grasslands of the Chihuahuan Desert.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.rala.2021.05.001.

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